Solid-State Linear Amplifiers for 33 cm

By David Hallidy, KD5RO
2118 W Jefferson Rd
Pittsford, NY 14534

Since the 33-cm band (902 to 928 MHz) became available for amateur use several years ago, a number of articles have described construction of 33-cm transmitters, receiving converters and transverters. Most of these projects, however, feature low-power (1 W or less) linear transmitting amplifiers, or else they use class-C amplifier modules to generate higher RF-output levels (typically 5 to 10 W). These approaches generally preclude the use of SSB because the effective communications range of low-power SSB is minimal at UHF, and the nonlinearity of a class-C amplifier causes objectionable distortion of an SSB signal.

I tried low-power and class-C transmitters, and I wanted to find something better—an amplifier capable of delivering 10 to 20 W of linear 33-cm power. My goal was an amplifier that could be used for portable "grid-peditions," and it had to provide an output level sufficient to drive a 2C39 cavity amp to a couple hundred watts output for long-haul tropo or EME work.

This article describes construction of a pair of solid-state 33-cm power amplifiers that meet my requirements:

• They are linear and can be used with any emission mode.

• They are compact and run from a 13.8-V dc supply—ideal for portable use.

• When the modules are cascaded and driven with about 1.5 W, the output level is about 18 W—more than enough to drive a 2C39 amplifier to full output.

• They are stable.

• They are easy to duplicate.

My amplifiers are based on a design presented several years ago in *QST* by Al Ward, WB5LUA.[1] (These amplifiers are also described in Chapter 32 of *The ARRL Handbook* from 1986 to the present edition.) Al described the use of the NEL1306 and NEL1320 transistors at 1296 MHz. Manufactured by NEC, these NPN bipolar transistors are specified for operation from 1.0 to 1.5 GHz. The '1306 is rated at 6.5 dB gain and 7 W output,
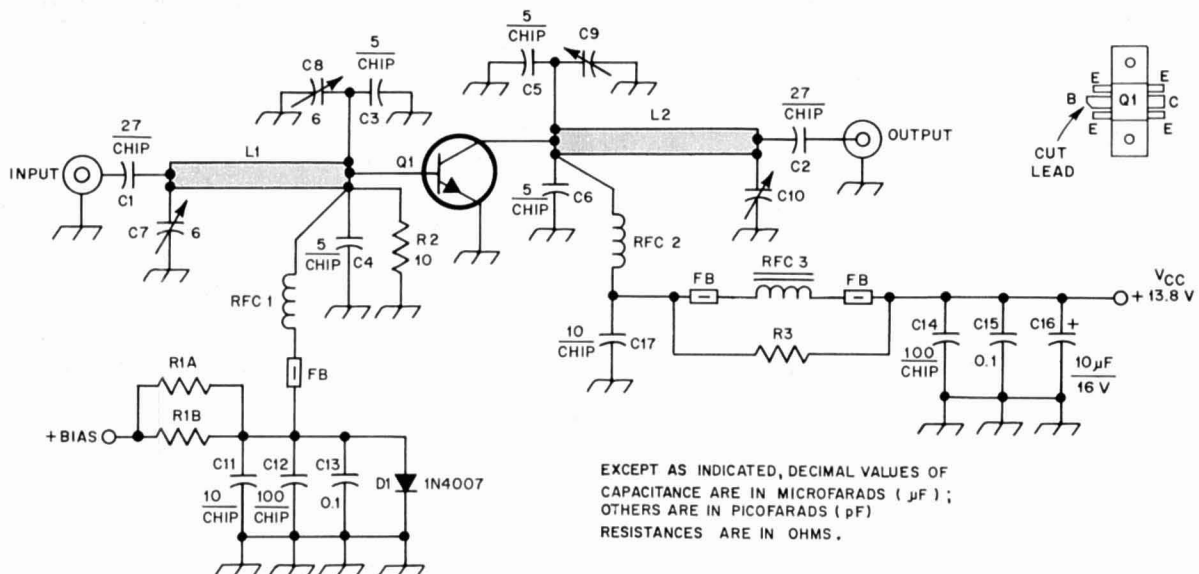
[1]Notes appear on page 7.

Fig 1—Schematic diagram of the 33-cm solid-state power amplifiers. The schematic is identical for both versions. Component values are the same except as noted.

C1, C2—27-pF chip capacitor.
C11, C17—10-pF chip capacitor.
C3, C4, C5, C6—3.6- to 5.0-pF chip capacitor.
C7, C8—1.8- to 6.0-pF miniature trimmer capacitor (Mouser 24AA070 or equiv).
C9, C10—Same as C7 and C8 for the NEL1306 amplifier. For the NEL1320 version, 0.8- to 10-pF piston trimmers are used (Johanson 5200 series or equiv.).
C12, C14—100-pF chip capacitor.

C13, C15—0.1-μF disc ceramic capacitor.
C16—10-μF electrolytic capacitor.
D1—1N4007 diode.
L1, L2—30-ohm microstrip line, ¼-wavelength long (see text).
Q1—NEC NEL130681-12 (6 W) or NEL132081-12 (18 W) transistor.
R1—82- to 100-Ω resistor, 2-W minimum. Vary for specified idling current.

R2—10-Ω, ¼-W carbon-composition resistor with "zero" lead length. See text.
R3—15-Ω, 1-W carbon-composition resistor.
RFC1—4 turns no. 24 wire, 0.125 inch ID, spaced 1 wire diam.
RFC2—2 turns no. 24 wire, 0.125 inch ID, spaced 1 wire diam.
RFC3—1-μH RF choke; 18 turns no. 24 enam. close-spaced on a T-50-10 toroid core.

and the '1320 is rated at 6.0 dB gain and 18 W output. (Power output ratings are at the 1-dB compression point.) Current prices make these devices reasonable for amateur work; as of early 1988, the '1306 is $32.50 and the '1320 is $54.00 in single quantities.[2]

Al's circuit, as originally presented, was very straightforward. He used microstrip-lines each one-quarter wavelength long to match the input and output of the amplifiers. He also used a simple bias network and clean construction techniques. It will be helpful for you to refer to Al's original article in QST or The ARRL Handbook for background information regarding construction of these amplifiers. This article concentrates on my efforts to modify Al's original design for operation at 33 cm.

Construction

Most of the components shown in the original article are retained in the 33-cm design. See Fig 1. All components mount on a pair of 0.031-inch, double-sided, glass-epoxy circuit boards.[3] No hard-to-find parts are used. If you don't have suitable chip capacitors and trimmer capacitors on hand, you should be able to find everything you need at Microwave Components of Michigan.[4]

I decided that it would be a simple matter to redesign the input and output circuits to tune to 902 MHz. The most important change is lengthening the 30-Ω, quarter-wave lines used in the base and collector circuits. These lines (L1 and L2 of Fig 1) are etched on the PC board.

As originally laid out, these lines are each 1.125 inches long, representing a quarter wavelength in microstrip at 1296 MHz. Calculations show that the new lines must be 1.63 inches long to resonate at 902 MHz.[5] To preserve the general layout of the original circuit, I extended the lines toward the input- and output-connector ends of the boards. To maintain the overall symmetry, I also increased the size of the ground areas extending to the board edges. This resulted in an overall increase of about ½ inch in the length of each board. Fig 2 shows a full-size etching pattern and parts-placement diagram.

A couple of component changes must be noted. In the original article, RFC1 and RFC2 were selected for "the lowest possible reactance that will not affect power gain or output power." At 902 MHz, these values are a little small. The amplifiers work well enough without changing these chokes, but increasing the size of each by one turn resulted in about 0.5 dB more gain at the new frequency. In addition, coupling capacitors C1 and C2 are increased to 27 pF from the 10-pF units used at 1296 MHz.
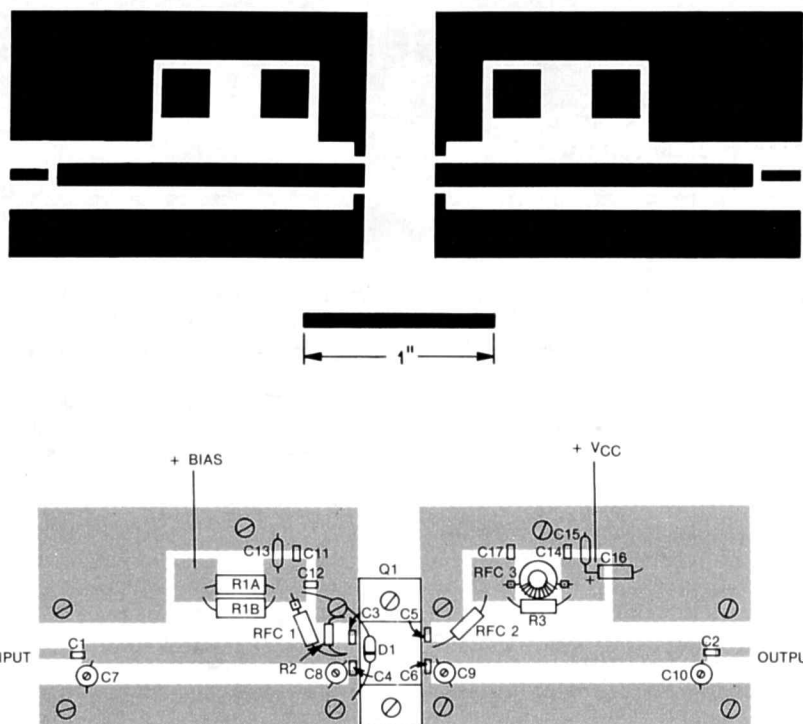
Al's 1296-MHz design included a 10-Ω,

Fig 2—Etching pattern (A) and parts-placement diagram for the solid-state 33-cm power amplifiers. PC board material is double-sided 0.031-inch glass-epoxy. One side is left unetched to act as a ground plane. Wrap the board edges with conductive foil and solder it on both sides of the board to make a good connection between the top and bottom ground planes. All components mount on the etched side of the board. The same PC boards are used for each version.

¼-W resistor (R2) in the base circuit to ensure stability. I found I could remove this resistor without causing any noticeable instability, and removing this resistor further increased the gain. I suggest first trying the circuit with the 10-Ω resistor in place. If gain and power output are sufficient, leave R2 in. If you need a little more gain, remove R2 or increase its value. Remember that if you do this, you will need to check the idling current and readjust the value of R1 to bring it back to the specified level (50 mA for the '1306 and 150 mA for the '1320).

I strongly recommend following the construction tips given in the original article—particularly those pertaining to grounding of the boards and minimizing lead lengths. I found that the output capacitor, C10, was not required in my version of the '1306 amplifier, but it was necessary in the '1320. C10 is shown on the schematic and parts placement diagram for both units, however. There is enough variation among devices and substrate characteristics that C10 may be necessary to provide optimal matching to the load.

The body of D1, in the bias network, should be placed against the case of the power transistor to ensure best thermal stability. I recommend the use of a small amount of thermal compound here to reduce the thermal resistance of this joint and maximize heat transfer to the diode. Also be sure to use thermal compound underneath the transistor before bolting it to the heat sink. Fig 3 shows the finished amplifiers. The heat sinks may look large, but the devices do dissipate quite a bit of heat, so I felt that a lot of heat sink would only aid reliability.

Tune-Up

You are again urged to refer to the original article for details of amplifier tune-up. Initially set all trimmer capacitors to minimum capacitance. You'll need a 13.8-V power supply, a 902-MHz signal source (1.5 W maximum), an appropriate wattmeter and a dummy load. It may be helpful to insert an ammeter capable of reading about twice the expected operating current of the device in the collector supply lead. This allows you to keep an eye on idling current, power dissipation and efficiency, and it also helps you to see if there is any "funny stuff" (for example, oscillations) happening.

Apply drive gradually, peaking the input and output circuits as the level is increased. With the '1306, start with
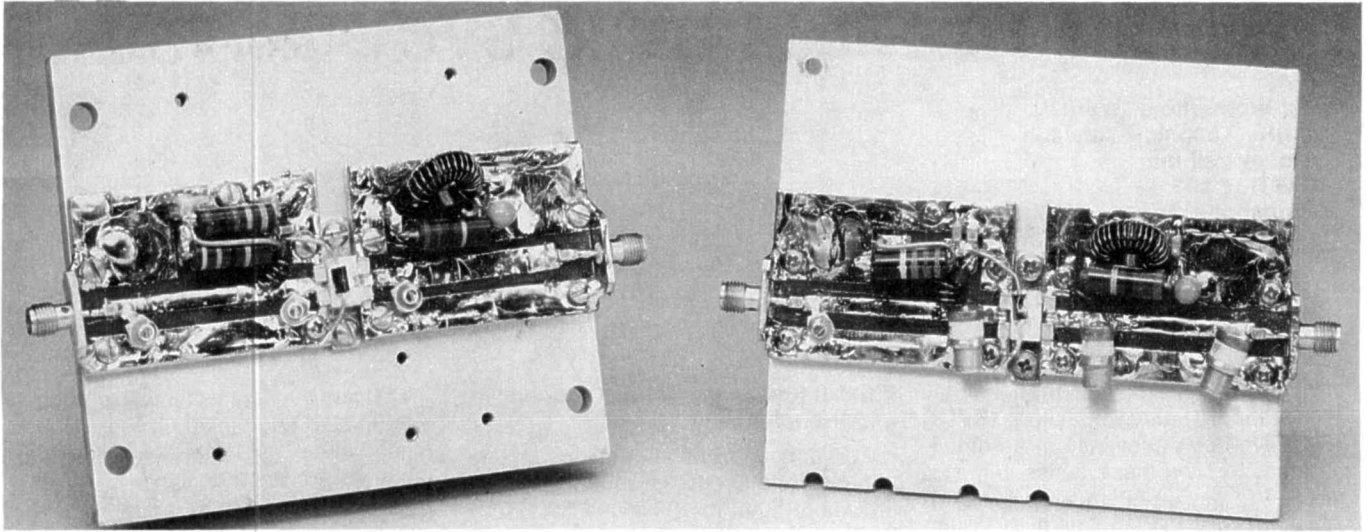
Fig 3—The 6-W (left) and 18-W (right) 33-cm amplifiers are virtually identical.

about 100 mW and end up at the 1- to 1.5-W level. With the '1320, start with about 1 W and finish with about 6 W. Table 1 lists the measured output level, gain and collector current for each device at various drive levels.

Summary

These amplifiers are a solution to the problem of developing moderate linear RF power for the 33-cm amateur band. The modules are easy to build and make operational. On-the-air reports have been gratifying—my signal has been reported to be comparable in quality to a popular commercially made 33-cm transverter. I now feel confident that I can provide enough drive to a 2C39 amplifier to maximize its potential.

**Table 1
Amplifier Performance
Characteristics**

Drive	Drive	Gain	I_c	Power Output
	(W)	(dB)	(A)	(W)
NEL130681-12	0.1	7.5	0.28	0.6
	0.2	7.0	0.40	1.0
	0.5	7.0	0.60	2.5
	1.0	7.0	0.88	5.0
	1.5	6.5	1.20	6.8
NEL132082-12	0.6	5.0	1.0	1.8
	1.0	5.0	1.3	3.1
	2.5	5.0	2.1	7.9
	5.0	4.5	2.8	14.1
	6.8	4.2	3.0	17.8

Bits

The PC-BANDIT

PRISM Electronics has developed a low-cost accelerator board for IBM® PC, PC-XT, and PC compatibles. PC-BANDIT™ resides in the computer's current 8284 clock chip position to provide additional clocks with its own clock IC. No expansion slot is required.

The 0.8-in × 3.1-in board uses software to toggle between speeds, and it is compatible with certain BIOS hot-key sequences. The board does not interfere with the computer's real-time clock, which continues to operate at its correct rate. Two versions of the PC-BANDIT are available: the high-speed 7.4 MHz for 150-ns memory chips, and the 6.7 MHz for machines using 200-ns chips. Price: $69.95. Contact PRISM Electronics, Inc, 14682 NE 95th St, Redmond, WA 98052, tel 206-881-1088.

Notes

[1]Al Ward, "1296-MHz Solid-State Power Amplifiers," QST, Dec 1985, pp 41-44.
[2]NEC transistors are available from California Eastern Laboratories, 3260 Jay St, Santa Clara, CA 95050. Contact CEL for ordering information or for the address of the closest CEL sales office.
[3]If you have trouble locating 0.031-inch PC board material, the author can provide suitable unetched pieces for a nominal charge.
[4]Microwave Components of Michigan, 11216 Cape Cod, Taylor, MI 48180, tel 313-941-8469 (eves).
[5]Calculating the length of a quarter-wavelength line in microstrip is fairly simple. In this case, a very close (and usable) approximation may be made by scaling the line length to the ratio of the two frequencies. That is, since 1296/902 equals a ratio of 1.44, the 902-MHz line will have to be 1.44 times as long as the 1296-MHz line. Therefore, 1.125 inch × 1.44 = 1.62 inches. The correct method, however, is to determine the shortening factor for the line and multiply this factor by the length of a quarter wave in air. Determining the shortening factor is fairly involved. You must first determine the *effective*

dielectric constant for the substrate material and line width being used. The shortening factor (SF) is then given by

$$SF = \frac{1}{\sqrt{\epsilon_{eff}}} \qquad \text{(Eq 1)}$$

where ϵ_{eff} is the effective dielectric constant. For 0.031-inch G-10 material with a line width of 0.121 inch (30-Ω line), this comes out to be about 0.5. This factor is then multiplied by the length of a quarter wavelength in air at the design frequency to determine the actual length. Thus,

$$L = \frac{2952 \, SF}{F} \qquad \text{(Eq 2)}$$

where
L = line length in inches
SF = shortening factor (from Eq 1)
F = frequency in MHz

In this case, L = (2952 × 0.5)/902 = 1.64 inches. This result is very close to the length determined by the scaling method, and the scaling method is simpler.
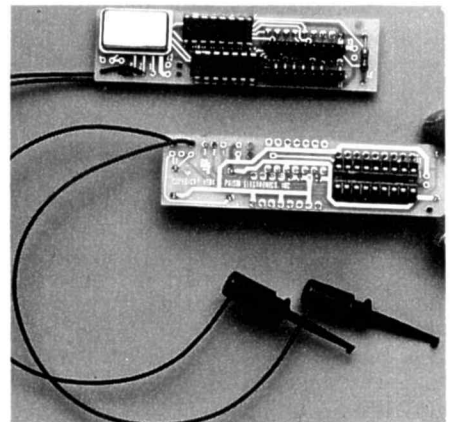
The PC-BANDIT. This small board plugs into your IBM PC (or compatible) computer to boost processing speed by as much as 60%.