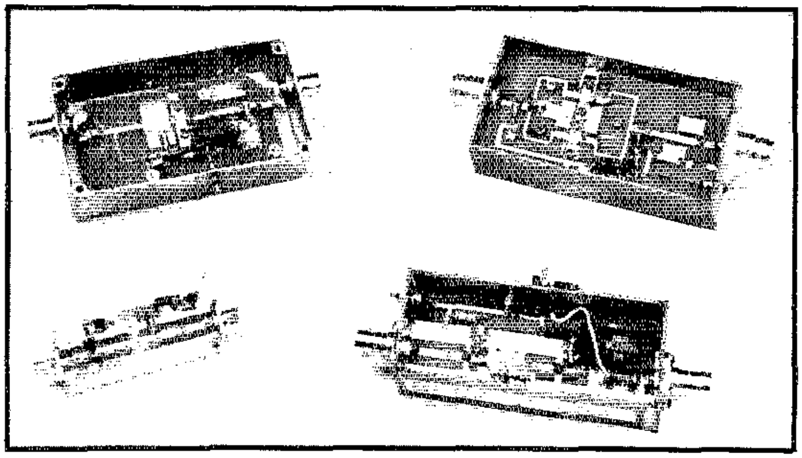
903-MHz Linear Amplifiers —*Part 1*



Looking for a gain block or two for your 903-MHz station? Here are *eleven* of them to cover just about any need you may have, from a simple receiving preamplifier to one with 23 dB gain and over 4 W output!

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The 33-cm Amateur Radio band (902-928 MHz) is becoming well populated in many areas of the country. Propagation on 33 cm has traits similar to both 432 MHz and 1296 MHz, but has characteristics all its own at times, making it a very interesting band. It's pleasantly surprising what you can do with a few watts on 903 MHz with high-gain loop-Yagi antennas.

Articles have been published on transverters, amplifiers and receivers for 33 cm. I described a 759-MHz local oscillator[1] intended to be used with a 144-MHz IF for operation on 903 MHz. If you've built the transmit section of a transverter that gets you to the 10-mW level, or if you've purchased a commercial transverter such as Down East Microwave's low-power, no-tune unit,[2] you'll need to bring your transmitter power up to a usable level. Instead of showing a typical transmit-amplifier chain, many of which have been described in Amateur Radio literature, I will discuss eleven different gain blocks, for several different gains and power levels, in this two-part series.

I suggest that you build each amplifier in its own enclosure, rather than trying to build more than one amplifier in one box to eliminate connectors or reduce size. If you are building your own equipment, you probably aren't too concerned about size and compactness, and having separate enclosures makes for much easier tuning and troubleshooting. Many transistors used in 1296-MHz projects are suitable for use at 903 MHz; some even have more gain at 903.

Transistors with SD prefixes used in the following designs are manufactured by SGS-Thomson Microelectronics.[3] Some of these transistors don't operate at 12 V. Again, in building your own equipment, this shouldn't be a major problem. Gains listed are averages for several different devices tried. All of the amplifiers can be driven harder than indicated—*for CW or FM operation only*—but should be used at or below their rated power output for SSB work. All the designs can be used at lower power output; they are all linear amplifiers.

Construction

All of the amplifiers are built using similar techniques. Each design uses common 1/16-inch-thick, G-10, double-sided, fiberglass-epoxy PC board for the microstrip circuitry. The ground-plane side of each PC board is unetched.

The microstrip boards can be made using what I call the "X-ACTO®-etch" method. This involves using a piece of clear tape as the resist. (Four-inch-wide clear tape is available at stationery stores.) After

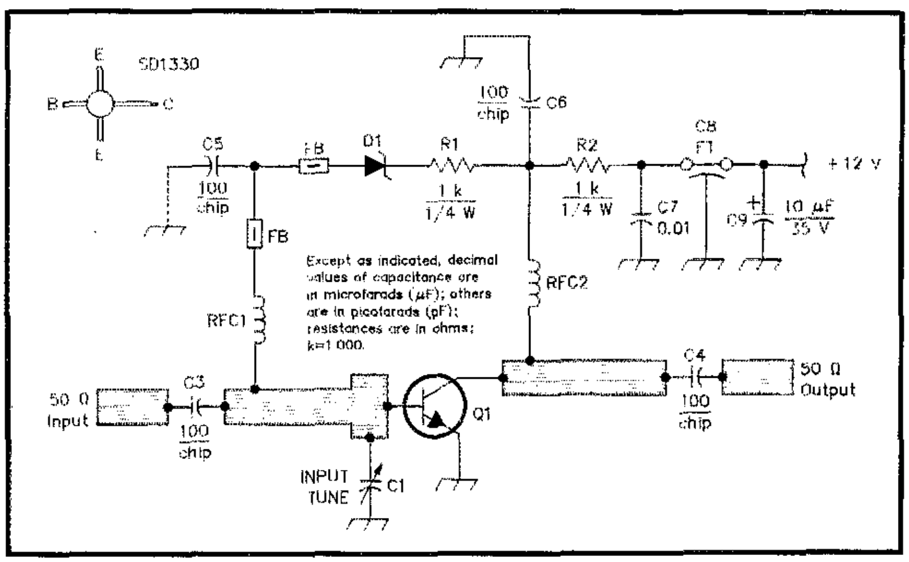


Fig 1—Schematic of the SD1330 receive preamplifier/low-level transmit stage. RFC1 and RFC2 consist of 8 turns of no. 24 enam wire closewound on a 0.1-inch-ID form (such as a 0.1-inch drill). D1 is a 9.1-V, ½-W Zener. C1, a 12.5-pF trimmer, is available from Mouser (part no. 24AA071).

[1]Notes appear on page 25.

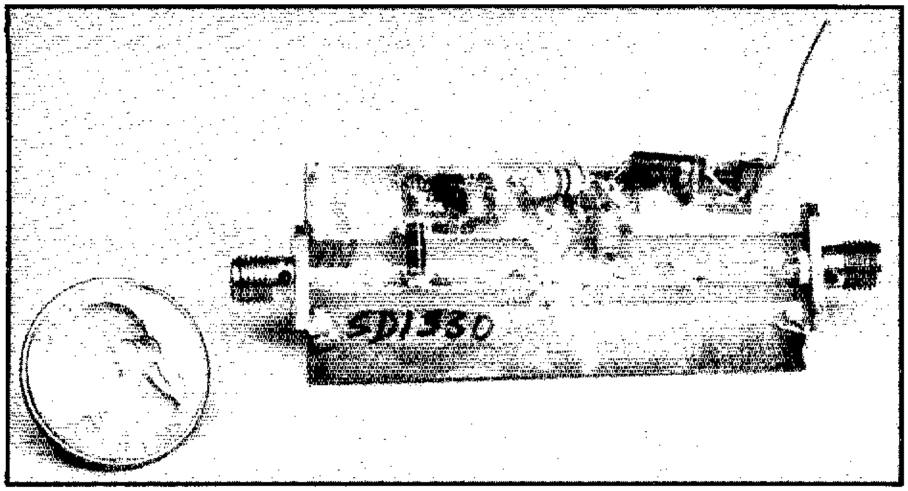


Fig 2—Amplifier No. 1, a 10-mW-output stage that's well suited to receiving applications, in prototype form.

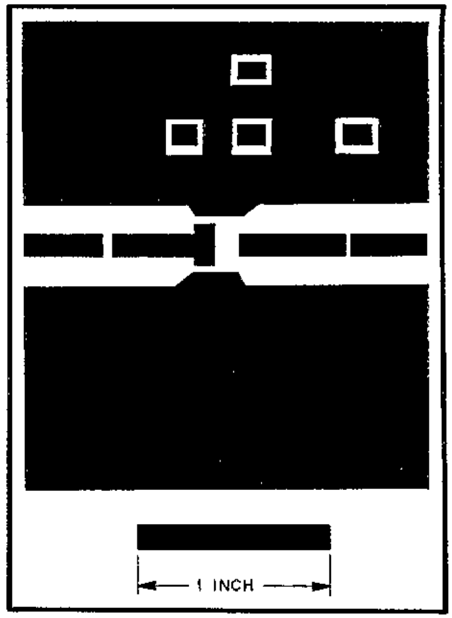


Fig 3—Full-scale PC-board artwork for the 10-mW SD1330 amplifier. Black areas represent unetched copper foil. All parts are mounted on the foil side of the board. Crop the finished boards as necessary.

drawing the pattern on the board with a pencil or fine-tipped marker, cover it on both sides with clear tape and cut the pattern in the tape with an X-ACTO knife. Then, remove the tape from the areas to be etched and etch the boards in ferric chloride in a crock pot on low heat. Do this in a well-ventilated area! Etching takes about half an hour without agitation. The crock pot is a no-mess way to etch boards. Only an inch or so of ferric-chloride solution is needed. Of course, you can also use a photographic method to make boards, as I do for multiple or complicated boards.

After the PC board is etched, clean it with steel wool and drill holes at all dc- and RF-ground points using a no. 50 drill. No holes are needed for component leads, as all components are mounted on the microstrip side of each PC board. RF grounds must be located as close to the areas to be grounded as possible, to ensure low-inductance ground paths. There are at least two ways to do this. One is to install a rivet in each hole, flare it with an awl or ice pick, then flatten it by tapping with a small hammer on an anvil or other hard surface. Then, solder the rivets on both sides of the PC board. Alternatively, pieces of bus wire can be used for grounding.

Because parts placement is quite straightforward, I haven't provided parts-placement drawings for all of the designs. The schematics and PC-board artwork should provide all the guidance you'll need to assemble the boards. I can help with any questions that you might have when building any of the amplifiers.

All of the amplifiers described, except those operating under the 300-mW level, require some heat sinking. A small brass sheet is sufficient for the studded parts, but a finned heat sink an inch or two square is needed for the flanged-device amplifiers. Thermally conductive compound is required between the devices and their heat sinks. For studless devices, a small piece of brass shim stock soldered from the bottom of the device to the ground-plane side of the PC board should work fine.

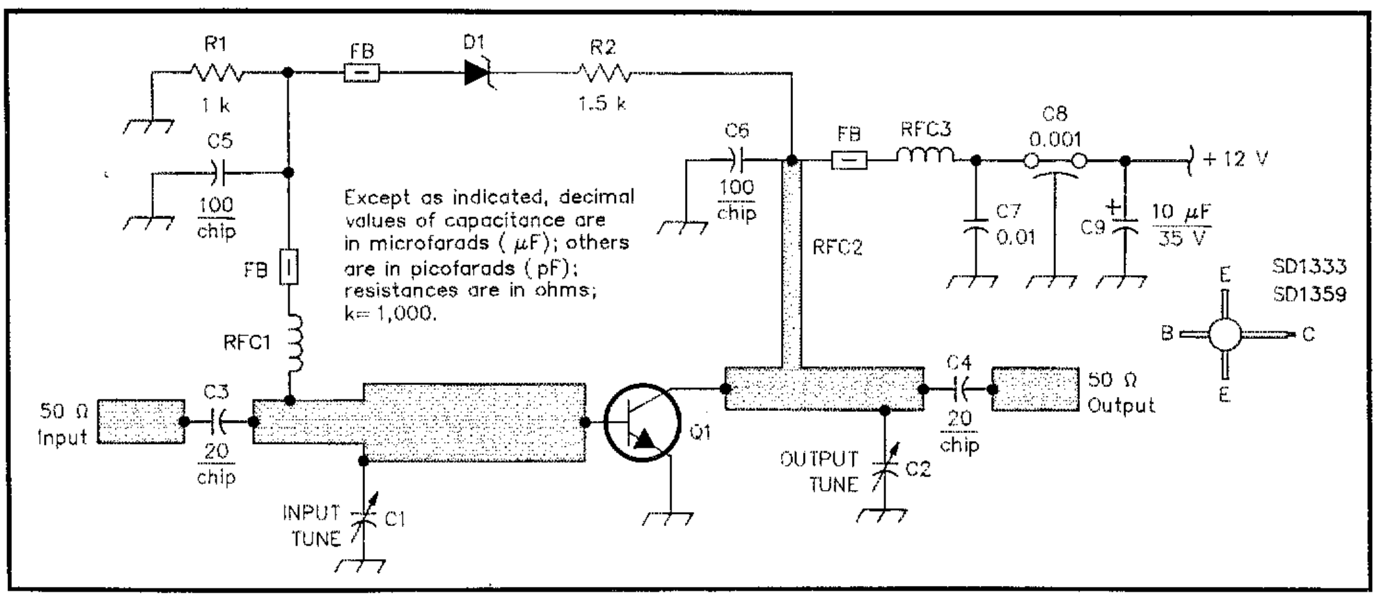


Fig 4—Schematic of the SD1333 and SD1359 amplifiers (Amplifiers No. 2 and No. 3). All components except Q1 are common to both designs (see text).

C1, C2—12.5-pF trimmer, Mouser no. 24AA071.

C7—0.01-µF disc ceramic.

D1—9.1-V, ½-W Zener.

RFC1, RFC3—8 turns of no. 24 enam wire, 0.1 inch ID, closewound.

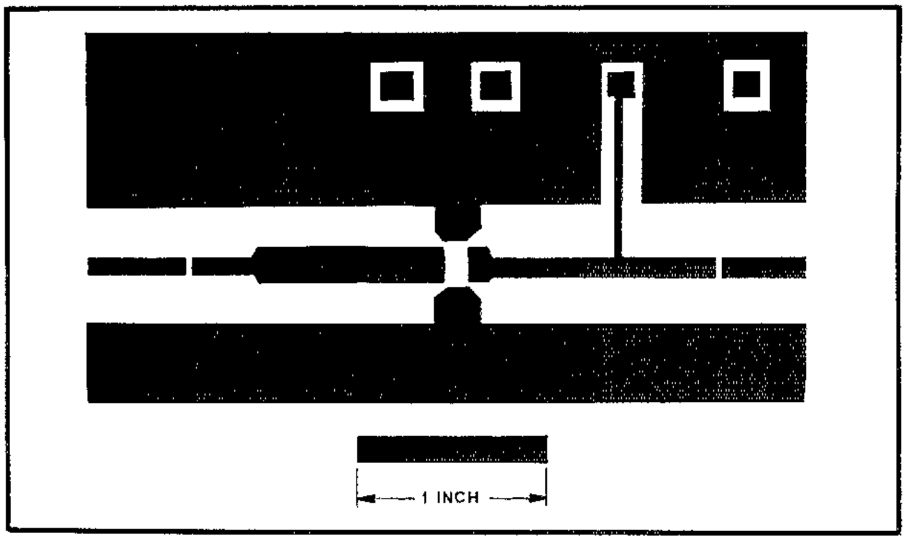


Fig 5—Full-scale PC-board artwork for the 100- and 250-mW amplifiers. Black areas represent unetched copper foil. All parts are mounted on the foil side of the board.

An easy way to enclose an amplifier like those described is to make a housing using double-sided PC board or brass sheet for the four walls and bottom cover. The amplifier PC board makes the top cover. Input and output connectors (N, BNC or SMA) can be bolted or soldered to the end walls with their center pins soldered directly to the microstrip input/output lines in an end-launch configuration. When using PC-board material for housings, mount the side walls in such a way that the grounding is continuous from the connectors to the ground-plane side of the amplifier board.

Various die-cast aluminum boxes, such as Bud CU-123 and CU-124 and the Hammond 1590 series, also work great for enclosing these designs. Die-cast boxes usually provide sufficient heat sinking for amplifiers operating at less than 2 W output. Device studs or flanges should be attached directly to the boxes in these cases.

All component leads must be kept as short as possible. This also applies to trimmer caps. Mount them flush to the PC board so that they act as capacitors—*not* as inductor/capacitor combinations. Use multiple rivets (or bus wires) to ground the trimmers.

Components

Use ceramic chip capacitors for the dc blocks and high-frequency bypassing. Some of the larger-value bypass capacitors, like 0.001 µF and 0.01 µF, are available in chip form also. These epoxy types are good for all the designs described here. I use inexpensive chip caps from Mouser Electronics.[4] Chip caps and Johanson piston trimmers are available from Microwave Components of Michigan.[5] Transistors are available from RF Parts[6] and RF Gain, Ltd.[7] Components, rivets and PC boards are available from Frontier Microwave.[8]

Tune-Up

In most of these amplifiers, the quiescent collector current (I_{cq}) initially will have to be checked and set with no drive applied. To check bias current, disconnect the cold end of the collector choke and insert a milliammeter in series with the choke. Adjust I_{cq} by changing the value of the collector-bias resistor or by changing the collector voltage. All amplifiers requiring 12 V can be powered directly from low-current, 12-V dc sources (a three-terminal, 12-V regulator, for example). Amplifiers running on 14-18 V dc or 21-23 V dc can be powered by an LM317T (or LM317K) adjustable regulator. Set the regulated voltage to a minimum, and adjust it upward from minimum while monitoring I_{cq}. Idling collector current can be adjusted to suit your gain and power-output requirements.

Amplifier No. 1: A Receive Preamplifier or 10-mW-Output, 13-dB-Gain Transmit Stage

The amplifier shown in Figs 1 and 2 is a low-power stage using an SD1330, Motorola MRF901 or NEC NE64535. This stage is best suited to the receiving side of a transverter. With a noise figure (NF) of 2 dB, it makes a fine front end by itself. With a good, low-noise GaAsFET preamplifier in front of it, you'll have all the sensitivity you need in front of the receive mixer. For transmitting applications, where a low noise figure isn't important, an MMIC amplifier would be better because it is a lot easier to build for the same results.

The SD1330 amplifier is built on G-10 double sided board; the artwork appears in Fig 3. After etching the board, install rivets at the RF and dc grounds. To mount the device, drill a hole in the PC board the size of Q1's macro-X case. This allows all

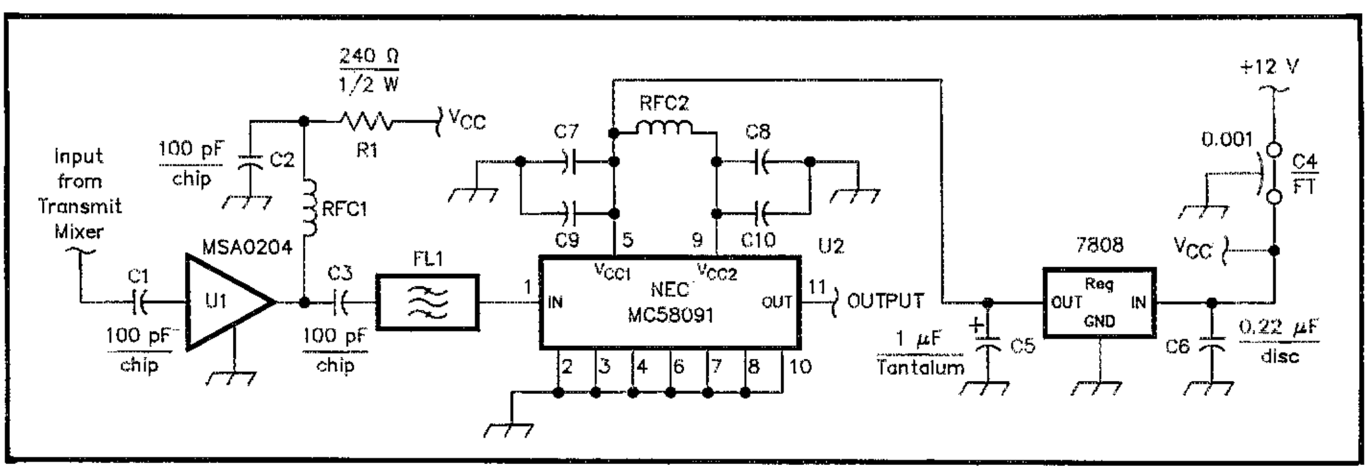


Fig 6—Schematic of the MSA 0204/MC5809L amplifier.

C7, C9—100-pF chip.
C8, C10—0.01-µF ceramic disc.

FL1—Two-stage Toko helical filter (Digi-Key no. TK23313).

RFC1—8 turns of no. 24 enam wire, 0.1 inch ID, closewound.
RFC2—1-µH molded choke.

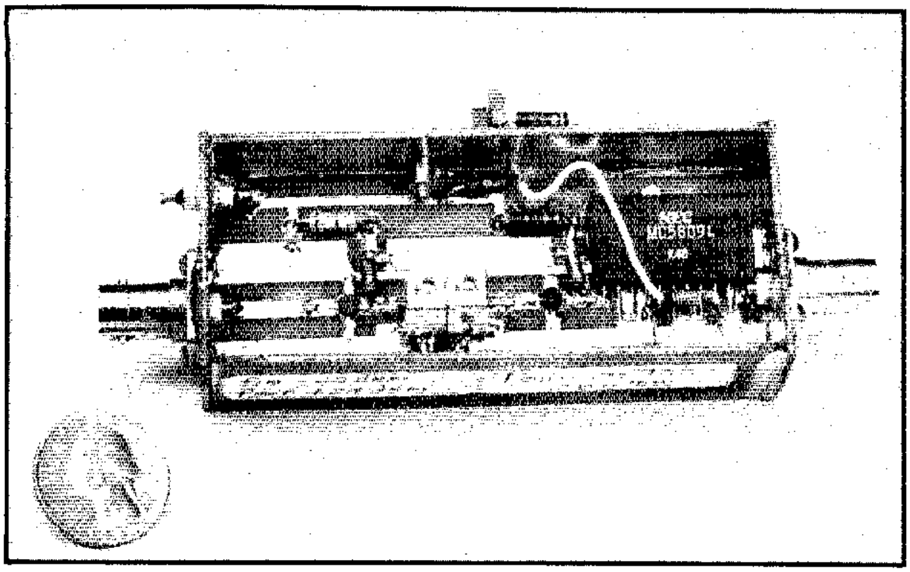


Fig 7—The 200-mW-output MSA 0204/MC5809L amplifier. In this prototype, I used MSA 0204 stages before and after the helical filter to provide additional gain. The biasing components (the 7808 and associated parts) are mounted on the outside of the enclosure for convenience.

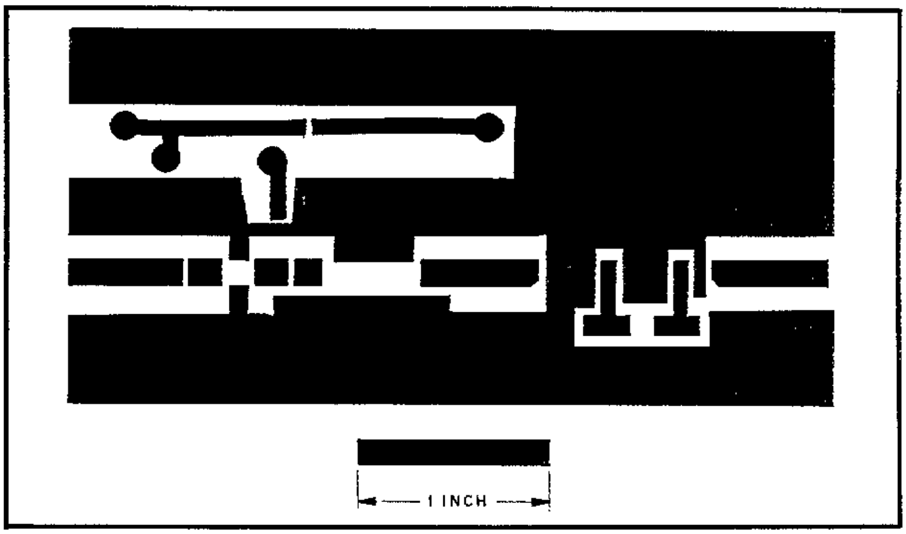


Fig 8—Full-scale PC-board artwork for the 200-mW amplifier. Black areas represent unetched copper foil.

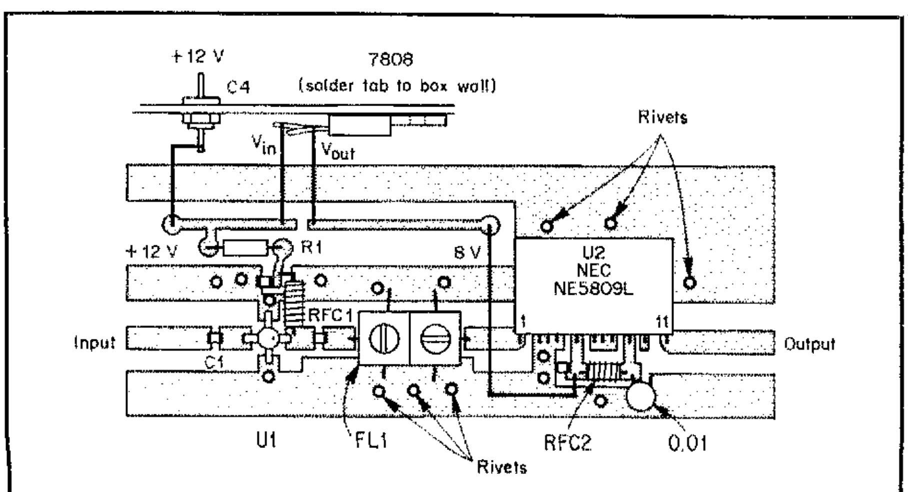


Fig 9—Parts-placement diagram for the 200-mW amplifier. All parts are mounted on the foil side of the board. Note the locations of rivets. At each V_{cc} lead on the MC5809L (pins 5 and 9), install a 100-pF chip capacitor and a 0.01-μF disc to ensure proper bypassing.

four leads to be soldered to the microstrip without bending them.

The idling current for this amplifier should be set to 5 mA or less for good noise figure. The idling current is kept constant for different transistors and over different voltages and temperatures by current-limiting resistors R1 and R2 and Zener diode D1. Tune the input trimmer for best NF or maximum gain if an NF-measurement setup isn't available.

Amplifier No. 2: 10 mW In, 100 mW Out

The SD1333 transistor, a macro-X plastic-packaged device used in this design, delivers 100-125 mW. This device is capable of a reasonable noise figure (2-3 dB) and good dynamic range, which allows it to be used as a second stage (following a GaAsFET preamplifier) in a receiving system. (Motorola's BFR96/MRF961/MRF962 also work well in this circuit; the BFR96 has slightly less gain.) Fig 4 shows the amplifier schematic and Fig 5 shows the full-scale artwork.

Zener-diode bias is used for simplicity and some temperature compensation. Set the quiescent current to 40-50 mA (not critical) by varying R1. A pot can be used initially, then the pot can be replaced by a fixed-value resistor. Or the collector voltage can be varied slightly.

After the rivets are installed in the PC board, drill a hole the diameter of Q1's molded package in the PC board. Mount the device in the board so its unbent leads are soldered directly to the microstrip board. Use the small variable capacitors to tune for maximum gain.

Amplifier No. 3: 9 dB Gain, 250 mW Out

This unit is a slightly higher-power version of the previous amplifier, using an SD1359 or Motorola TRF559 plastic-packaged device. The artwork and schematic are identical to that of Amplifier No. 2. Idling current, 40-50 mA, can be optimized by adjusting the collector supply between 10 and 13 V to set the stage gain.

After the PC-board rivets are installed, drill a hole in the PC board to accept Q1. Mount the device in the board so its unbent leads are soldered directly to the microstrip board. Tuning is as discussed with Amplifier No. 2.

Amplifier No. 4: 0.8 mW In, 200 mW Out

The amplifier shown in Figs 6 and 7 is a high-gain unit that can be used to follow the output of your 903-MHz transmit mixer. An Avantek MSA 0204 or Mini-Circuits MAR-2 MMIC is used for the first

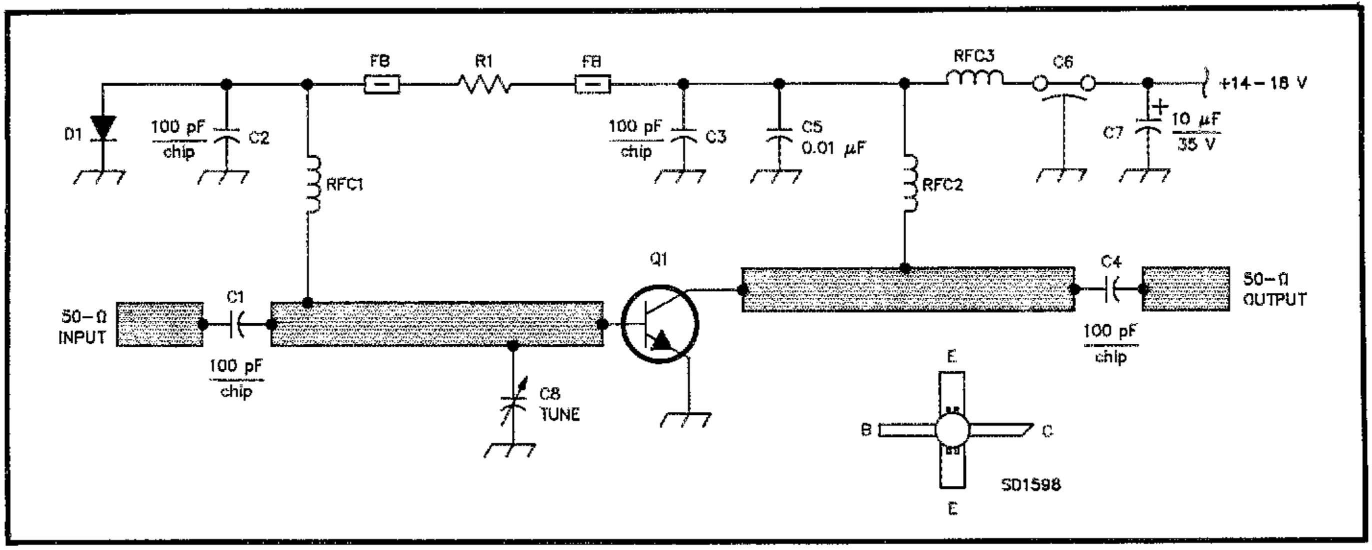


Fig 10—The 350-mW amplifier. Glue D1 to Q1's ceramic body for thermal compensation.

C6—0.001-µF feedthrough.
C8—0.6- to 8-pF Johanson piston trimmer.
D1—1N4001.
Q1—SD1598.
R1—1.5-1.6 kΩ, ½ W.
RFC1, RFC2—8 turns of no. 26 enam wire, closewound, 0.1 inch ID.

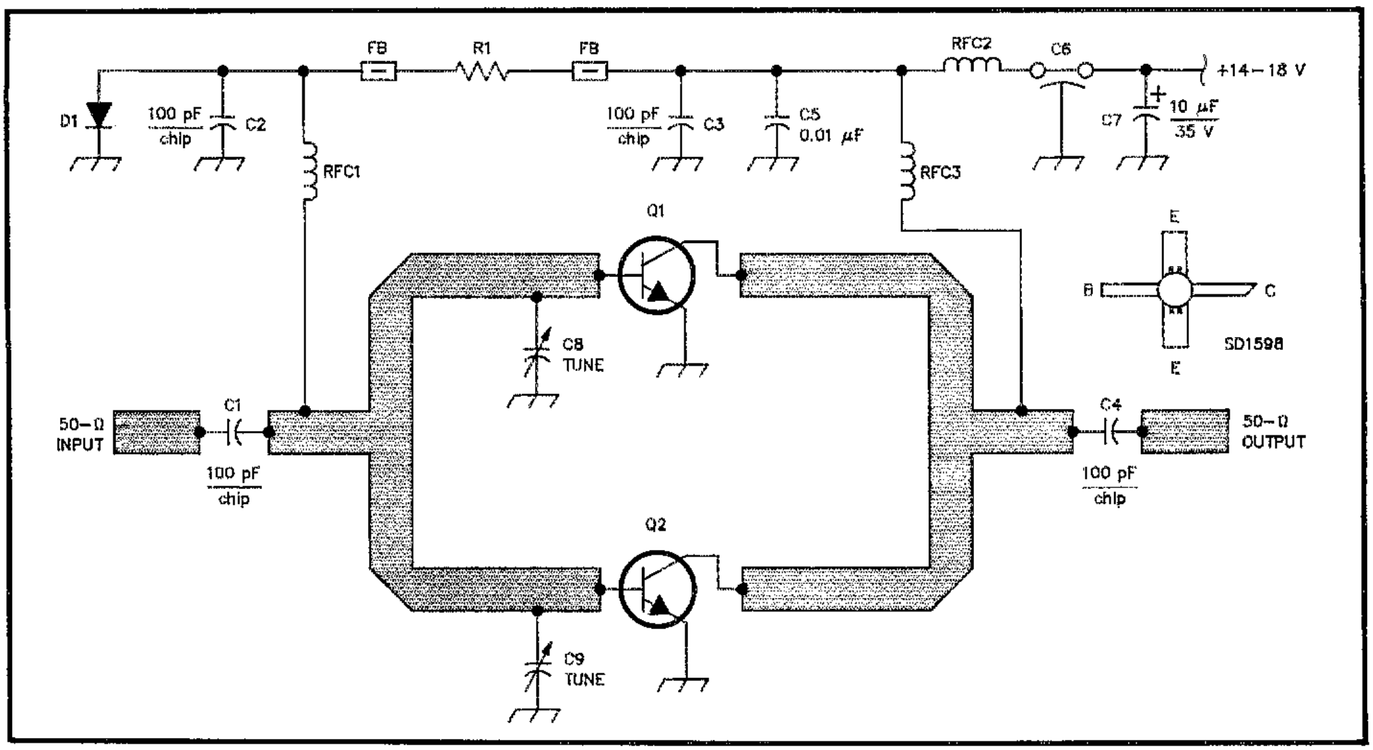


Fig 11—The 2 × SD1598 amplifier. Glue D1 to Q2's ceramic body for thermal compensation.

C8, C9—0.6- to 8-pF Johanson piston trimmer.
D1—1N4001.
Q1, Q2—SD1598.
R1—1.5-1.6 kΩ, ½ W.
RFC1-RFC3—8 turns of no. 26 enam wire, closewound, 0.1 inch ID.

stage, followed by a Toko two-stage helical filter.[10] (In the prototype amplifier shown in Fig 7, I used two MMIC stages, in addition to the helical filter, before the final stage.) The output stage is an NEC MC5809L thick-film hybrid module. This NEC hybrid module is one of four such units intended for hand-held cellular telephones operating in the 800- to 960-MHz range. The MC5809-series amplifiers are rated at 150 mW minimum power output at 7.5 V dc. Using a more readily available power source (a 7808 regulator), the NE5809s I tried were linear at over 200 mW output. These hybrid amps are easy to use and are stable into any load.

The full-scale PC-board artwork is shown in Fig 8. The helical filter is used between stages to clean up the transmitter signal by filtering out the local-oscillator and image frequencies, but isn't required for applications where such filtering is done in other stages. A three-stage Toko filter[11] will also fit on the board, and could be used for better filtering. The filter leads are bent to the side to allow soldering to the PC-board traces. See Fig 9 for parts placement.

This amplifier is easy to build and get working. Because both active stages and the filter are designed for 50 Ω in and out, the amplifier uses 50-Ω microstrip throughout. No trimmer capacitors are needed and no bias adjustments are necessary—just apply the dc voltages and the drive signal, and peak the helical filter for maximum power output at 903 MHz!

Because more gain is available from this design than I needed, I tried mixing two signals at the input of the first stage. Using a T connection at the input of the first stage, I used the circuit to mix a 759-MHz local oscillator with a 144-MHz IF signal. The 903-MHz output signal was about 175 mW and was fairly clean. Using MMIC amplifiers for gain blocks, almost anything can be used as a mixer!

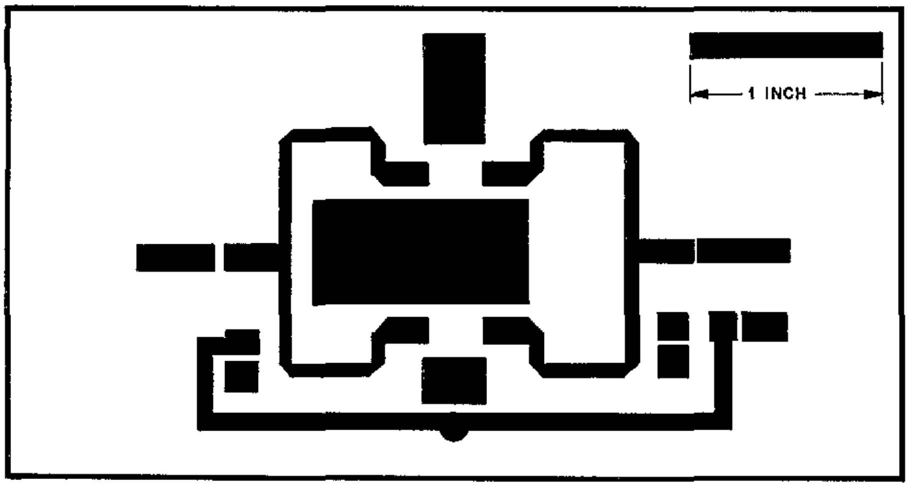
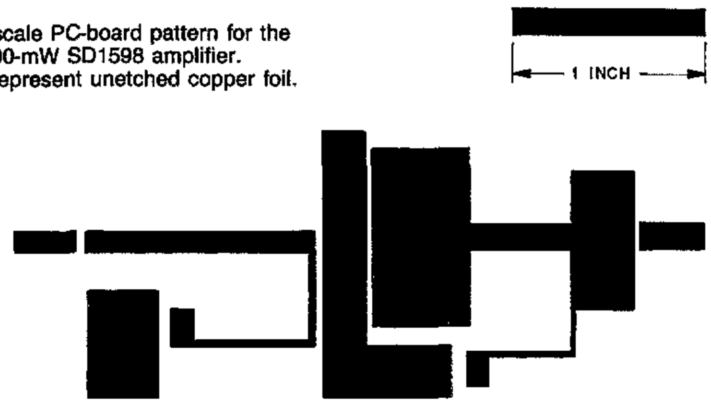


Fig 12—Full-scale PC-board artwork for the 2 × SD1598 amplifier. Black areas represent unetched copper foil.

Amplifier No. 5: 35 mW In, 350 mW Out

The amplifier shown in Fig 10 is practically as simple as an MMIC amplifier. The transistor, an SD1598, produces more than 350 mW output when mounted in a 50-Ω line. The SD1598 (originally another part number) was designed by Bill Olson, W3HQT, years ago, when he was employed by Solid State Microwave (now SGS-Thomson Microelectronics). I've used this transistor, which I refer to as a "hot 2N3866," in amplifiers and frequency multipliers at frequencies from 144 MHz to 3.3 GHz. The SD1598 is in a studded package and the SD1598-1 is a studless package; either style is suitable for use at 903 MHz. I've built two-stage SD1598 amplifiers with 50-Ω lines that work from 400-1300 MHz. Such a two-stage amplifier fits nicely into a 1.5 × 3.6 × 1-inch Bud

Fig 14—Full-scale PC-board pattern for the broadband 500-mW SD1598 amplifier. Black areas represent unetched copper foil.



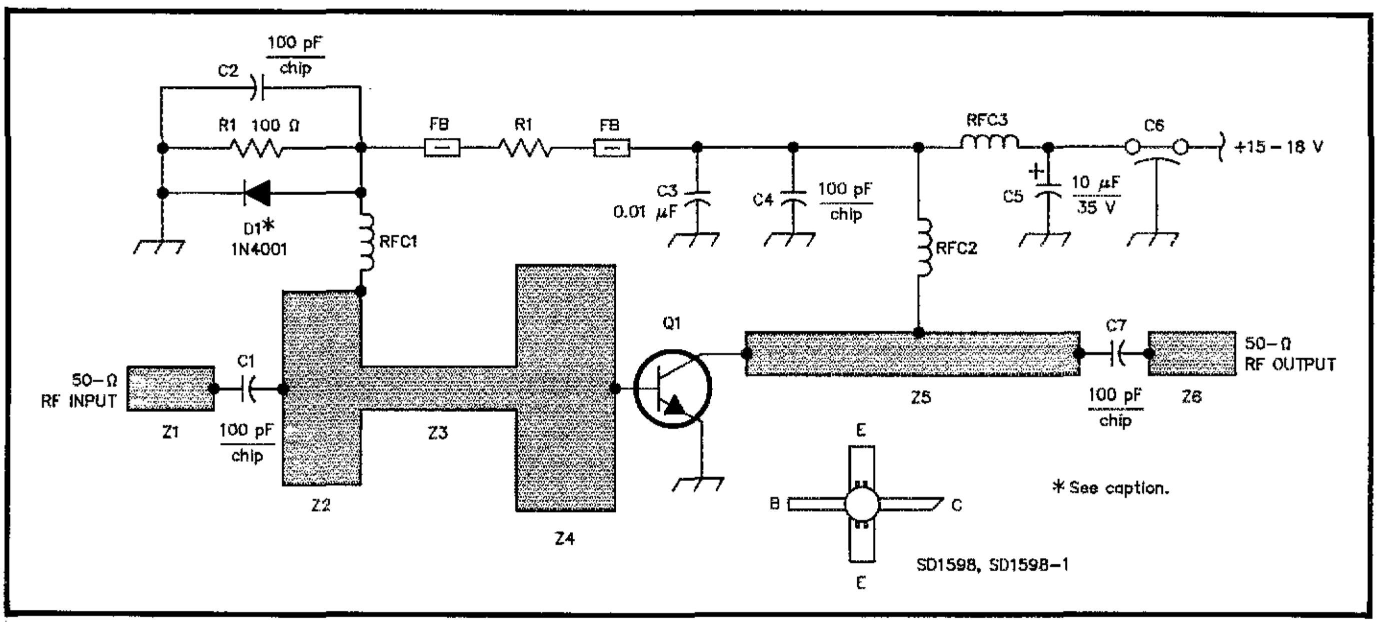


Fig 13—The 500-mW broadband amplifier. For power levels over 500 mW output, glue D1 to Q1's ceramic body for thermal compensation. RFC1 and RFC2 are implemented as PC-board traces.

Q1—SD1598 or SD1598-1.
R2—1.5-1.6 kΩ, ½ W.

RFC3—8 turns of no. 28 enam wire, closewound, 0.1 inch ID.

Z1-Z5—Microstriplines. See text and Fig 14.

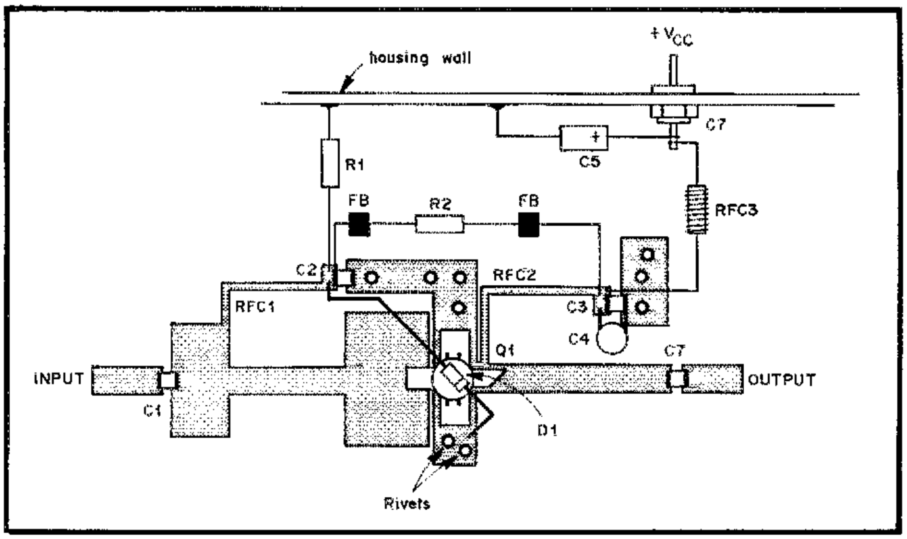


Fig 15—Parts-placement diagram for the broadband 500-mW SD1598 amplifier. The PC-board edges are not shown. All components are mounted on the foil side of the PC board (except those mounted to the enclosure).

CU-123 die-cast box. Gain is 10 dB per stage at 903 MHz and 8-9 dB per stage at 1296 MHz.

PC-board artwork isn't necessary for this amplifier, as the 50-Ω line can be easily made on a piece of G-10 PC board using an X-ACTO knife and a straight edge. A 50-Ω line on G-10 PC board is about 0.1-0.11 inches wide. After cutting the edges of the 50-Ω line, cut another line about a quarter inch from, and parallel to, the 50-Ω line on each side of the 50-Ω line. Using a soldering iron, heat the quarter-inch-wide strips between the 50-Ω line and the outer sections and remove them with the knife or a needle-nose pliers. Leave some copper near the transistor for connecting Q1's emitter leads to the microstripline.

Drill a hole in the board for the transistor such that the leads of the transistor can be soldered flush to the microstripline and ground foils. This is important: Excessive lead lengths drastically reduce the gain of this amplifier. Attach a small heat sink to the stud of the device.

The SD1598 can be powered by a 12- to 18-V supply, depending on the gain and power output required. Use an LM317T voltage regulator in the power supply, and vary the voltage to set the gain of this low-level stage. This is an easy way to match the drive levels needed by the following stages.

Set Q1's quiescent current, I_{cq}, to 30-50 mA. Vary R1 to get the correct idling current. This bias current is not critical, and depends on the device and the collector voltage used. Tune up is simple: Adjust C8 for maximum power output.

Amplifier No. 6: 100 mW In, 1 W Out

A pair of SD1598s and a Wilkinson power divider/combiner combination are used in this design. The schematic for the combined amplifier is shown in Fig 11, and the PC-board artwork is shown in Fig 12. I didn't make an effort to terminate the 75-Ω Wilkinson divider/combiner; the amplifier works fine as is. Power sharing between the two devices is excellent, and a 3-dB improvement in power output is available over a single device. Saturated power output is well over 1 W.

The supply voltage and idling currents are the same as single-device Amplifier No. 5 (Fig 10). If this amplifier is mounted in a die-cast box, no additional heat sinking is required; If not, a small heat sink should be attached to the stud of each device. Adjust C8 and C9 for maximum power output.

Amplifier No. 7: 12 dB Gain, 500 mW Out

The amplifier shown in Fig 13 is a broadband design that's been around for about 6 years. Bill Olson, W3HQT, designed it as a 1296-MHz amplifier. (The 1296-MHz version differs in that it has a small piston trimmer on the output circuit, about an inch from Q1's ceramic cap.)

This amplifier is a very versatile design; it works from 900-1300 MHz and has a power gain of 10-13 dB over this range. I built two test amplifiers for this design: one for the studded transistor and one for the flanged version. Over a dozen different devices were tried in these test circuits, both at 903 MHz and at 1296 MHz. Classes A, AB, C and pulsed-class-C operation were all tried, and all worked well.

The studded SD1598 is used in this design. Full-scale artwork appears in Fig 14; Fig 15 shows parts placement. As with the other designs, rivets are used at all dc and RF grounds. After the rivets are soldered in place, drill a hole in the board for the device. Trim Q1's leads with scissors, then solder them directly to the microstriplines and ground foils. If the amplifier is to be mounted in a die-cast box, the box will provide sufficient heat sinking. If you use another mounting method, attach a small heat sink to Q1's stud.

Power output for SSB is 500 mW, and up to 1 W for CW and FM, depending on the device. In applications where the device will deliver over 500 mW, a 1N4001 (D1) diode can be glued to Q1 for thermal stabilization, as shown pictorially in Fig 15. Power gain at 1 W output is 7 dB or so. By varying R2, set Q1's I_{cq} for 30-50 mA for power levels up to 500 mW, and 15-20 mA for higher levels.

For low-level stages (up to 200 mW out), you can use the SD1598-1 studless part in this circuit. Solder the studless device to the microstrip, then solder a piece of hobby brass to the device's gold-plated bottom area and to the ground plane. This provides enough heat sinking to dissipate a few hundred milliwatts.

At 903 MHz, no output trimmer capacitor is required. Some improvement in the output match can be achieved by trimming the width of the output line by a few thousandths of an inch with an X-ACTO knife.

Amplifier No. 8: 10 mW In, 1 W Out

A second 1-watt amplifier, this one using a pair of SD1598's driven by a single SD1598, is shown in Fig 16. This design is similar to that of Amplifier No. 6, with the addition of a driver stage. The artwork appears in Fig 17.

For the driver transistor, you can use an SD1598-1 studless device, as Q1 must provide only a hundred milliwatts or so. The driver is mounted in a hole in the PC board. A small piece of brass shim stock is soldered to the bottom of the device and to the ground-plane side of the PC board for heat sinking.

This amplifier runs on 14-18 V dc. The idling current for each device is around 30-50 mA. Again, the supply voltage can be provided by an LM317T regulator. Adjust R2 and R3 to individually set each device's idling current. Then, tune the amplifier by adjusting C11, C12 and C13 for maximum output. Vary the supply voltage to optimize the required power output or gain.

The 2.4 × 4.4 × 1-inch Bud CU-124, or an equivalent die-cast box, is a suitable enclosure for this amplifier. Mount the connectors on the ends of the box, and place the amplifier PC board inside the box body, instead of on the inside of the cover. The box provides sufficient heat sinking for this amplifier.

Next month, I'll describe three more 903-MHz linear amplifiers, including two 4-W units.

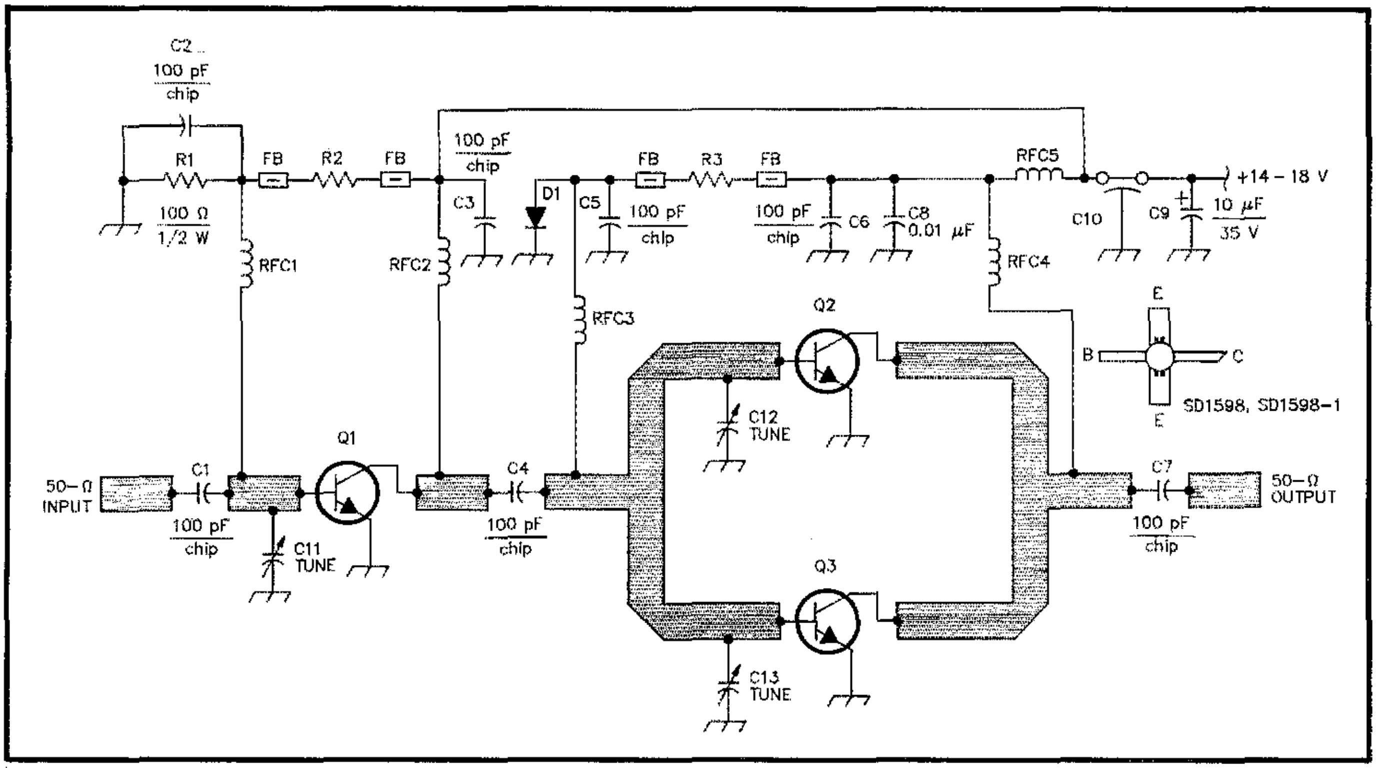


Fig 16—The two-stage, 1-W SD1598 amplifier. Glue D1 to Q2's ceramic body for thermal compensation.

C10—0.001-µF feedthrough.
C11-C13—0.6- to 8-pF Johanson piston trimmer.
Q1—SD1598 or SD-1598-1.
Q2, Q3—SD1598.
R2, R3—1.5-1.6 kΩ, ½ W.
RFC1-RFC5—8 turns of no. 24 enam wire, closewound, 0.1 inch ID.

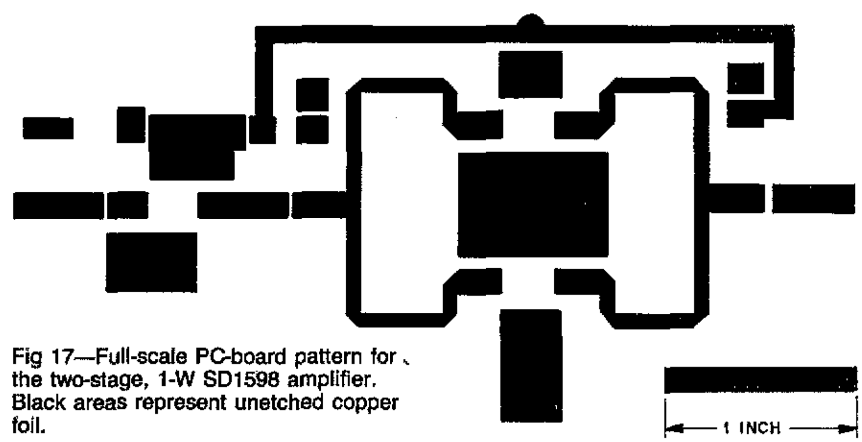


Fig 17—Full-scale PC-board pattern for the two-stage, 1-W SD1598 amplifier. Black areas represent unetched copper foil.

Dave Mascaro, first licensed in 1966 as WN3FTO, presently holds an Advanced class ticket. While serving in the US Army Signal Corps in Kwangju, Korea, Dave was also licensed as HL9KK, and operated mostly on 20-meter CW. He worked for many years in radio, TV and appliance repair, and joined the Engineering Department at Solid State Microwave (now SGS-Thomson Microelectronics) in Montgomeryville, Pennsylvania, in 1981. Dave's job at Thomson involves the design, building and testing of fixtures used to test RF power transistors.

Notes

[1]D. Mascaro,"A 759-MHz Local Oscillator," *QEX*, May 1988, pp 12-15.

[2]No-tune transverters, as well as antennas and microwave components, are available from Down East Microwave, Box 2310, RR 1, Troy, ME 04987, tel 207-948-3741. Catalog available.

[3]The amplifiers in this article use transistors manufactured by SGS-Thomson Microelectronics, 211 Commerce Dr, Montgomeryville, PA 18936, tel 215-362-8500.

[4]Mouser Electronics, 2401 Hwy 287 N, Mansfield, TX 76063, tel 817-483-4422. Catalog available.

[5]Microwave Components of Michigan, 17141 Merriman, Romulus, MI 48174, evening tel 313-753-4581. Parts list available.

[6]RF Parts, 1320 Grand Ave, San Marcos, CA 92069, tel 619-744-0728.

[7]SGS-Thomson Microelectronics transistors are available through RF Gain Ltd, 100 Merrick Rd, Rockville Center, NY 11570, tel 800-645-2322. $50 minimum order.

[8]Frontier Microwave, RD 1, Box 467, Mink Rd, Ottsville, PA 18942, evening tel 215-795-2648.

[9]D. Mascaro, "A Transverter Band-Switching Display and Universal Power Supply," *QEX*, Aug 1987, pp 8-14.

[10]Available from Digi-Key® Corp, 701 Brooks Ave South, PO Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4539. Catalog available.

[11]Toko filters and other components are available from Steve Kostro, N2CEI, Box 341A, RD 1, Frenchtown, NJ 08825, evening tel 201-996-3584. Parts list available.

Feedback

☐ The address for Quorum Communications in Table 4, p 23 of "A Weather-Facsimile Package for the IBM PC—*Part 1*," *QST*, April 1990, is incorrect. Quorum's address is PO Box 277, Grapevine, TX 76051.

Strays

SAW BATTALION REUNION

The 574th-565th SAW Battalion's reunion will be held in Moline, Illinois, this July. Contact Angel M. Zaragoza, W6ZPR, 1581 9th St, San Bernardino, CA 92411.

I would like to get in touch with...

☐ anyone who has a manual for and/or paper used with a Stewart Warner Data Fax recorder Model FR-1824. The paper is a special electrolyte type. Ted Stewart, W6NPB, 2157 Braemar Rd, Oakland, CA 94602.

903-MHz Linear Amplifiers —*Part 2*†

Did you like the projects in Part 1 last month? Here are three more amplifiers to suit your 903-MHz, 50-ohm gain-block needs.

By Dave Mascaro, WA3JUF
RD 1 Box 467
Ottsville, PA 18942

In Part 1, I covered construction methods for building the 903-MHz linear amplifiers described in this two-part series. The amplifiers described this month cover a higher power range than those in Part 1, starting with a 2-W-output design, and finishing with a pair of 4-W-output units (one with 13 dB gain, the other with 23 dB gain).

Amplifier No. 9: 100 mW In, 2 W Out

The transistor used in this amplifier, an SD1853, is a class-A device in a "strip-pac" flanged package. The PC-board artwork is shown in Fig 18, and the schematic appears in Fig 19. The parts-placement diagram is shown in Fig 20, and a photo of my prototype appears in Fig 21.

After the board is etched and rivets are installed, cut a hole and file its edges to accept Q1's flange. The SD1853 must be mounted to a heat sink. (A Bud CU-124 or equivalent die-cast box is adequate.) Use a piece of G-10 PC board between the amplifier board and the heat sink, to allow the device to be mounted flush to the microstrip. The device flange is the emitter, and a low-inductance ground connection is a must. Make this connection by using a piece of copper-foil tape soldered to the microstrip ground plane and placed between Q1's flange and the heat sink. Mount the transistor to the heat sink with no. 4-40 screws. Use heat-sink compound between Q1 and the heat sink.

An LM317T (or LM317K) adjustable

†Part 1 of this article appeared in *QST*, June 1990, pp 18-25.

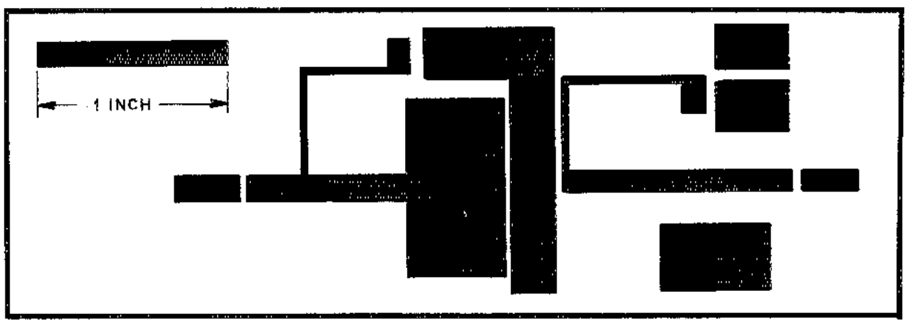


Fig 18—Full-scale PC-board pattern for the 2-W SD1853 amplifier. Black areas represent unetched copper foil.

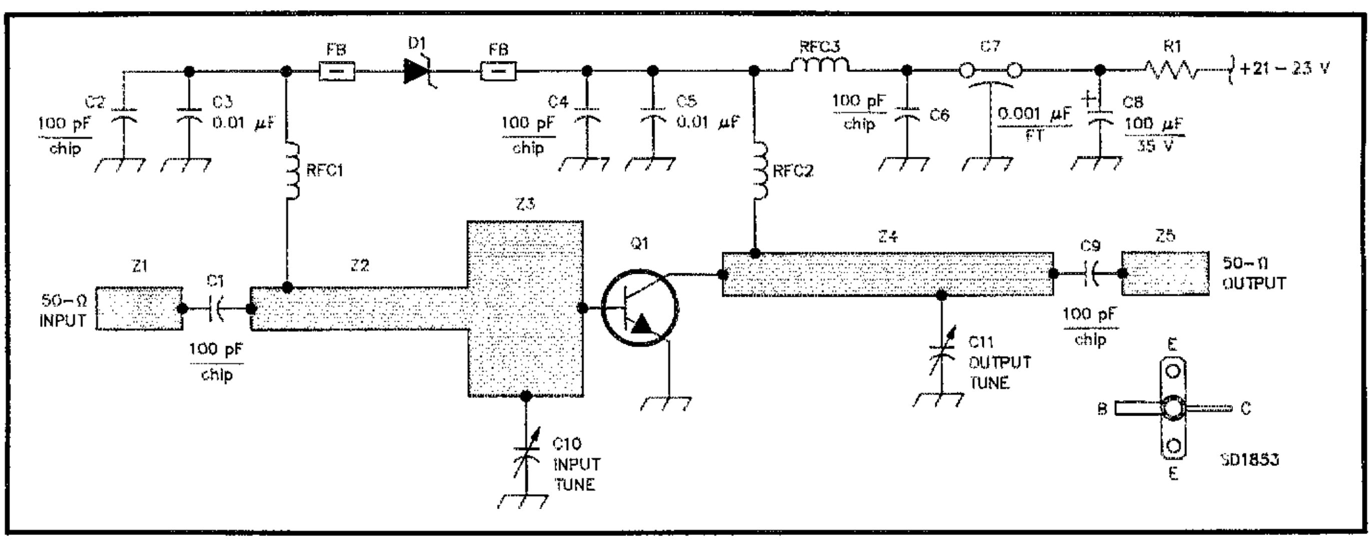


Fig 19—The 2-W SD1853 amplifier. RFC1 and RFC2 are implemented as PC-board traces.

C10, C11—0.3- to 3-pF Johanson piston trimmer.
D1—1N4747A 20-V, 1-W Zener.
Q1—SD1853.
R1—2-3 Ω, 1 W.
RFC3—8 turns of no. 26 enam wire, closewound, 0.1" ID.
Z1-Z5—Microstriplines. See text and Fig 18.

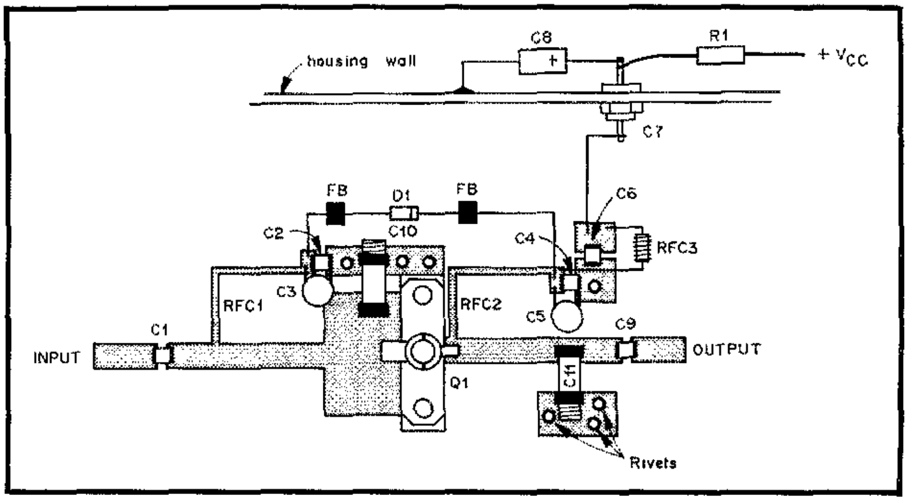


Fig 20—Parts-placement diagram for the 2-W SD1853 amplifier. The PC-board edges are not shown. All components are mounted on the trace side of the PC board (except those mounted to the enclosure).

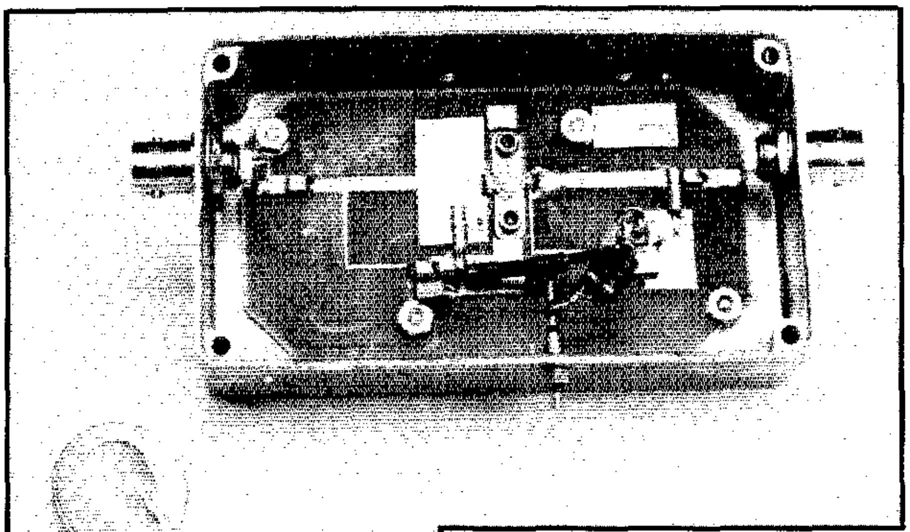


Fig 21—The prototype 2-W amplifier.

regulator can be used to supply the voltage required by this amplifier. Use a 10-turn pot for the **ADJUST** control; smooth adjustment of the supply voltage to this amplifier is a must. Insert a milliammeter in series with current-limiting resistor R1, and slowly adjust the regulator output up from minimum until the idling current is 200-225 mA without RF drive applied. The exact supply voltage depends on the beta of Q1, the value of R1, and D1's breakdown voltage. Idling current can be adjusted slightly to optimize gain and/or power output. The supply voltage must be removed during receive to minimize device heating.

Tune-up is simple. Apply drive and tune C10 and C11 alternately for maximum power output. If you have access to a return-loss bridge or network analyzer, you may want to trim the width of Z2 to improve the input return loss. Verify stability (as indicated by no output and no change in supply current) by tuning the trimmers through their ranges with no input signal applied.

Amplifier No. 10: 200 mW In, 4 W Out

This high-gain design consists of a pair of SD1853s combined in a Wilkinson power divider/combiner. As before, I made no effort to terminate the 75-Ω Wilkinson divider/combiner with balancing resistors.

Fig 22—The 4-W, 2 × SD1853 amplifier.
C4-C6—0.3- to 3-pF Johanson piston trimmer.
D1—1N4747A 20-V, 1-W Zener.
Q1, Q2—SD1853.
R1—2-3 Ω, 1 W.
RFC1, RFC2—8 turns of no. 26 enam wire, closewound, 0.1″ ID.
Z1-Z5—Microstriplines. See text and Fig 23.

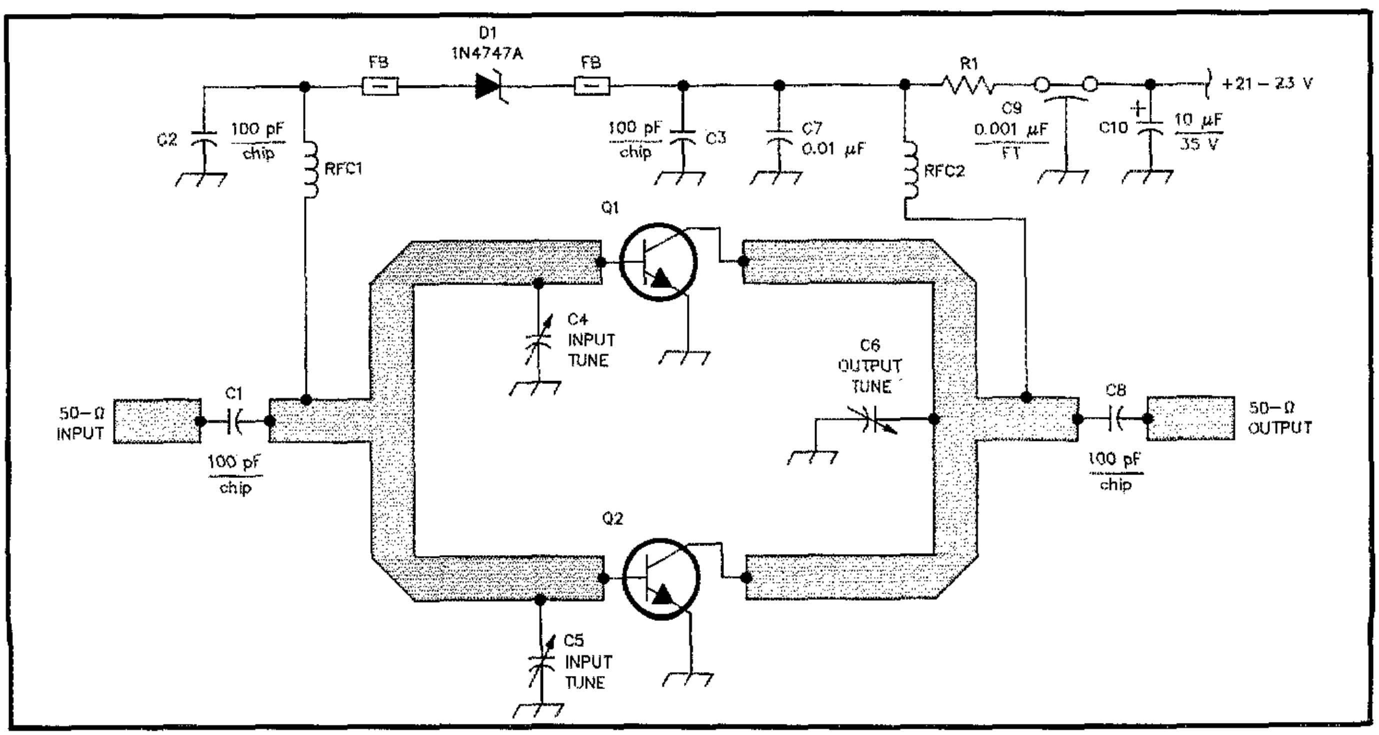
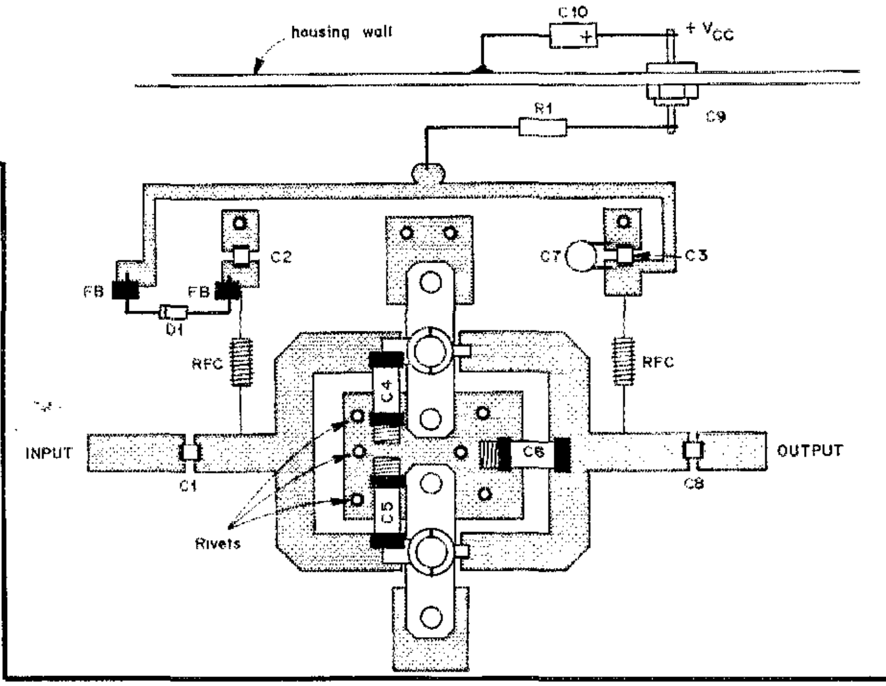


Fig 23—Parts-placement diagram for the 2 × SD1853 amplifier. The PC-board edges are not shown. All components mount to the trace side of the PC board (except those mounted to the enclosure).



It worked just fine without them. Even the 1296-MHz version, which uses the same board layout, worked well in this configuration.

Fig 22 shows the schematic of this class-A amplifier, and Fig 23 shows parts placement. The PC-board pattern, the same as that for Amplifier No. 8, is shown in Fig 17 (shown in Part 1). The board's driver-stage traces are by-passed with a brass strip in this amplifier. Fig 24 shows my prototype mounted in a PC-board enclosure. A single base-bias source, using a current-limiting resistor and Zener diode, feeds both devices. Total idling current, measured in series with R1, is 400-450 mA.

The same mounting arrangement used

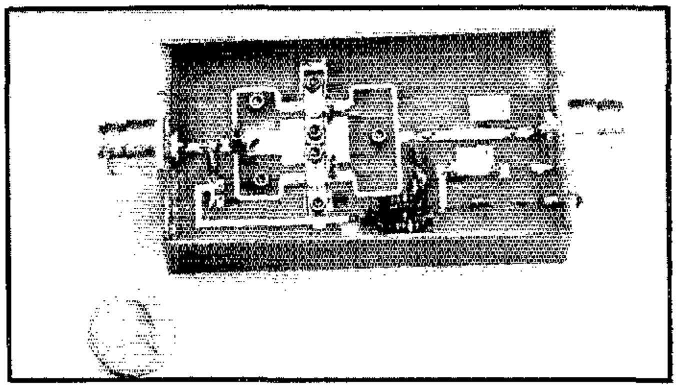


Fig 24—This prototype 4-W amplifier was built on a PC board with a spare driver stage that's bypassed with a brass strip.

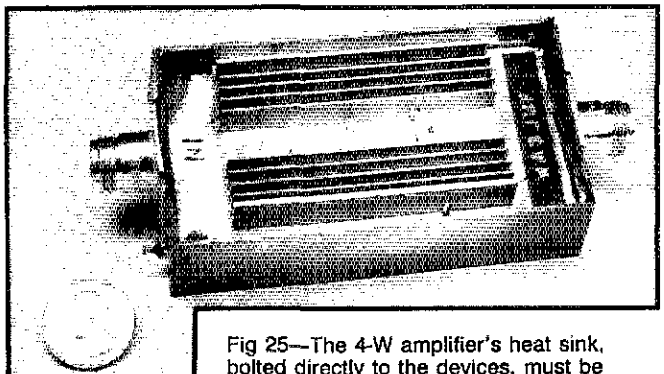


Fig 25—The 4-W amplifier's heat sink, bolted directly to the devices, must be positioned such that cooling air can flow over it during amplifier operation.

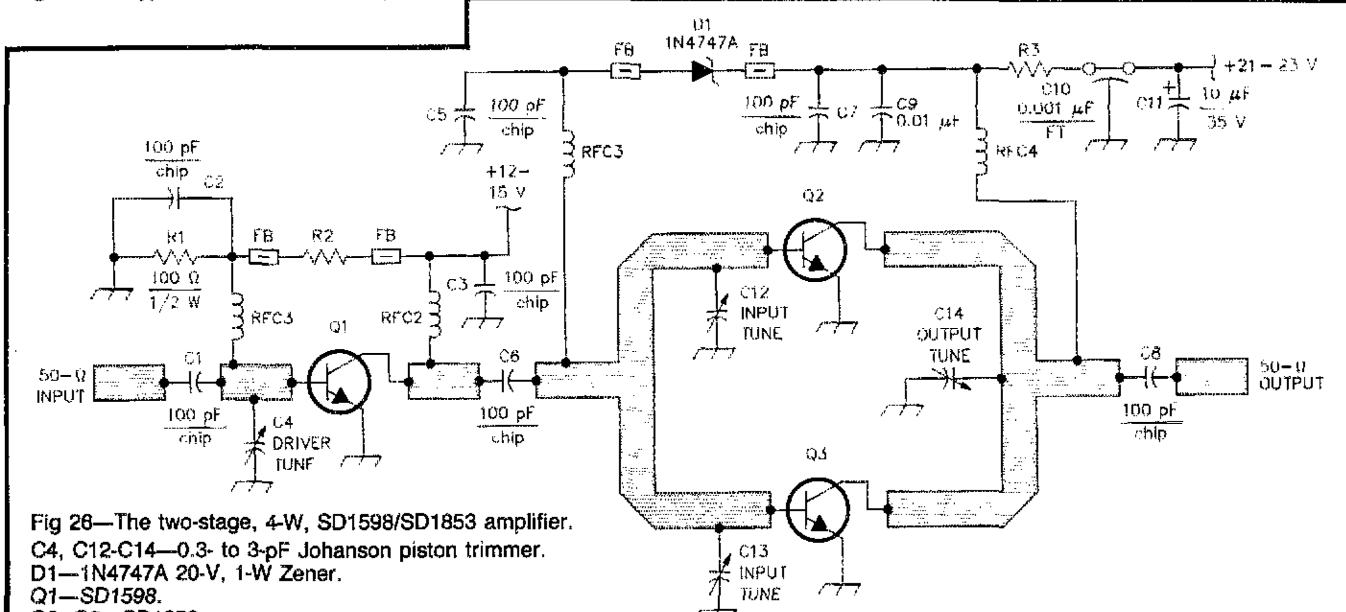


Fig 26—The two-stage, 4-W, SD1598/SD1853 amplifier.
C4, C12-C14—0.3- to 3-pF Johanson piston trimmer.
D1—1N4747A 20-V, 1-W Zener.
Q1—SD1598.
Q2, Q3—SD1853.
R2—1.5-1.7 kΩ, ½ W. See text, Part 1, June 1990 *QST*, p 24.
R3—1-2 Ω, 2 W.
RFC1-RFC4—8 turns of no. 26 enam wire, closewound, 0.1″ ID.

with the single-SD1853 amplifier (Amplifier No. 9) applies to this unit. The device flanges must have low-inductance ground connections. Mount the transistors to a heat sink about 2 × 3 inches with ½ inch or taller fins, as shown in Fig 25. Again, the supply voltage is switched on only during transmit. To tune this amplifier, adjust C4, C5 and C6 alternately for maximum output.

Amplifier No. 11: 20 mW In, 4 W Out

A second 4-W amplifier, using a pair of SD1853s driven by a single SD1598, is shown in Fig 26. The final stage is Amplifier No. 10, and the driver is the same as that used in Amplifier No. 8. The PC-board artwork is shown in Fig 17; the parts placement can be done using Figs 23 and 16 as guides.

The power-supply and bias adjustments are the same as those for the previously described amplifiers using these devices. Transistor mounting is also the same as before, but extra heat sinking is required with this unit because of the class of operation and the power output.

Higher Power Output

Higher-power devices usable at 903 MHz are available from several manufacturers. NEC's NEL1320 (2SC3542) produces 18-20 W linear output at 903 MHz. These devices also work on the 1296-MHz band. These transistors, as well as single- and dual-stage amplifiers based on them, are available from Down East Microwave (DEM). (The DEM two-stage 3318PA runs around 18 W output for about 1 W input).

SGS-Thomson Microelectronics also makes high-power devices for the 800- to 960-MHz range. For example, the SD1423 is a 4-W-in, 30-W-out class AB device, and the SD1660 is a class-AB transistor that runs a whopping 120 W output for about 35 W drive. Both of these devices run on 28 V dc.

Summary

As I've shown in this two-part series, there's really nothing difficult about building your own 903-MHz equipment—from the local oscillator to the final amplifier. This ease of construction is a vast improvement over what it was just a few years ago—and the 903-MHz band's population has grown as a reflection of that. See you on the microwaves!

New Books

GENIUS AT RIVERHEAD: A PROFILE OF HAROLD H. BEVERAGE

By Alberta I. Wallen. First edition, 1988. Published by the North Haven Historical Society, PO Box 858, North Haven, ME 04853. Hardcover, 6 × 9 inches, 130 pages. $15.95 (plus $1 postage/handling; Maine residents must include 5% sales tax).

Reviewed by Rus Healy, NJ2L

Harold Beverage is a remarkable man. At 97, he has far outlived almost all of his contemporaries, some of whom Beverage considered close friends. Among them were Edwin H. Armstrong (inventor of the regenerative detector and FM), David Sarnoff (president of RCA in the 1930s and '40s) and Albert Einstein.

Genius at Riverhead, Alberta I. Wallen's biography of Harold H. "Bev" Beverage, ex W2BML, gets its title from Bev's time with RCA in Riverhead, New York, during the earliest days of transoceanic radio communications. Bev's assignment at Riverhead was as an engineer in RCA's first "laboratory" there: a tent! Riverhead also was the location of the first full-scale wave antenna, which was named for Beverage by Paul Godley, 2XE, who, sent by ARRL to Britain to listen for American signals during the transatlantic tests of late 1921, used a wave antenna for his reception of those signals. One of the stations Godley heard was Beverage's 2BML.

Wallen has the unique perspective of a summertime resident of Bev's childhood home of North Haven Island, Maine, and that of a family friend who's keenly interested in the lives of North Haven's noteworthy natives. Thus, a substantial part of *Genius at Riverhead* relates Bev's lineage and his activities as a youngster, before he left North Haven, destined to find great success in radio engineering.

Alberta Wallen portrays Harold Beverage in a most endearing way. Beverage, personally, is far more than the man who invented the wave antenna, and who established the first radio station in South America, and so on: He is also a talented and flexible musician; in fact, his first employment offer after graduating from the University of Maine in 1915 was a $22-per-week job playing trombone at a local theater—an offer he decided to forego in lieu of General Electric's $11-a-week radio engineering offer!

Genius at Riverhead is filled with interesting historical vignettes that reveal Bev's humble nature and his fond memories of his career in radio. The book profiles the likable, pleasant *person* behind this engineer who changed radio history in several tangible ways. Beverage's many inventions and patents are enumerated in an appendix in *Genius at Riverhead.* In addition to the wave antenna, these include numerous means of improving reception of radio and television signals using frequency- and space-diversity techniques, noise-reduction systems, a television AGC system, numerous control systems, a communications-secrecy technique involving switching signals among multiplexed channels, and many others. In the appendix that lists Bev's 40 patents, a section describing his recent reflections on some of those patents is included.

Other appendixes in the book include a reprint of Beverage's famous November 1922 *QST* article, "The Wave Antenna for 200-Meter Reception," as well as Graduation Exercises Program: North Haven High School, 1910; Chronology of Events in the Life of a Radio Engineer; and Awards and Honors. Five more appendixes explore Beverage's family tree, and another involves Beverage's parents' courtship. As I said, Wallen has extensively documented the Beverage family lineage.

Alberta Wallen handled the technical aspects of this book extremely well, especially considering the fact that her education is in psychology and history. One of the book's few technical flaws is a statement made during the introduction of Bev's friendship with Edwin Armstrong, in which Wallen claims that Armstrong's regenerative detector is "used today in practically every transmitter and receiver throughout the world." This isn't true, but it's a minor slip that doesn't detract from the book's enjoyability.

Genius at Riverhead is printed on high quality stock and has excellent photographic reproduction. Thirty-five photographs help to set the book's warm tone and document Beverage's first 85 or so years in more than his professional life, from which most hams know of a few of Beverage's accomplishments. If you have a nostalgic or historic interest in radio, or if you're just interested in reading about the fascinating life of a true radio pioneer, this book will please you.

Feedback

☐ Refer to D. Mascaro, "903-MHz Linear Amplifiers—*Part 1,*" *QST,* Jun 1990, p 23, Fig 13. In the upper left part of the schematic diagram, two resistors are labeled R1. The left-most resistor is R1; the resistor between the two ferrite beads is R2.