CQ REVIEWS:

The Yaesu FL-7000 Solid-State HF Automatic Linear Amplifier

BY JOHN J. SCHULTZ*, W4FA

Remember the old FL-7000 linear amplifier? The *old* FL-7000? Probably not too many readers will really remember the FL-7000 amplifier which Yaesu introduced in the late 1980s. At the time of its introduction it probably was both ahead of its time technically and considered too "pricey." However, times surely change, and it is fortunate that Yaesu continues to produce the FL-7000 at what is now a very competitive price. The FL-7000 seems to have been "rediscovered" both by amateurs and dealers.

The FL-7000 is a solid-state, HF, no-tune linear amplifier that runs 1200 watts input with less than 100 watts of drive. Several solid-state amplifiers currently available can do the same. So what is special about the FL-7000? I guess the one-word answer would be "packaging." The FL-7000 incorporates in one desk-top enclosure not only a linear amplifier, but also a 110/220 volt power supply, a completely automatic antenna tuner, SWR and power output monitoring, and remote antenna selection switching (using an option). If you use the FL-7000 together with a modern transceiver providing a nominal 100 watts output, you can achieve a completely "no-tune" station operating at a very competitive power level in a very compact overall configuration.

The operating ease and frequency agility of such a setup is tremendous compared to a setup involving an amplifier and an antenna tuner requiring manual tuning adjustments. Of course, there are some trade-offs. The manually tuned amplifier/tuner combination can provide more power output per dollar if you demand a maximum legal power output setup, especially for modes requiring long key-down periods. It depends on what you want for an HF operating setup. I would suggest a careful look at the FL-7000 if you are content to run a desk-top CW/SSB station at the 1.2 kW input level with pretty much the ultimate in operating convenience and with a minimum of station setup problems.

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The FL-7000's front panel consists only of various fields of pushbutton controls, LEDs, and two analog meters. If the amplifier is fully set up for automatic operation, only the power on/off switch and the operate/standby switch have to be used.

Specifications

The overall specifications of the FL-7000 are shown in Table I. The amplifier covers all of the currently available HF bands, including 12/10 meters with a slight modification. It can be bandswitched by toggling "up/down" switches on its front panel, or it can be bandswitched remotely by transceivers which provide the ne-

SPECIFICATIONS

General
Frequency coverage (MHz): 1.8–2, 3.5–4, 7–7.5, 10–10.5, 14–14.5, 18–18.5, 21–21.5 and 24.5–25, 28–30 except USA version.
Collector input power (final transistors): (SSB) 1200 W PEP, (CW/FSK) 1200 W DC.
Continuous full power transmission period: SSB 100% for 30 min., Full Carrier 100% for 1 min.
Case size: 390 W × 130 H × 400 D mm.
Weight: 30 kg (66 lb.).
Supply voltage: 100/110/117/200/220/234 VAC (±10%).
Power consumption: 1900 VA maximum (at 500 W RF output).

Linear Amplifier Section
Excitation power: less than 100 W for 1200 W input.
ALC voltage range: 0 to −9 V.
Spurious radiation: less than −50 dB.
Third-order intermodulation distortion: less than −25 dB.
Input/Output impedance: 50 ohms, unbalanced.

Automatic Antenna Tuner Section
Impedance matching range: 1.8–2 MHz—25 to 100 ohms, unbalanced; other amateur bands—16 to 150 ohms, unbalanced.
Maximum feedthrough power: 600 watts.
Insertion loss: less than 0.5 dB when tuned to match.
VSWR after matching: 1:1 to 1.2:1.

Table I– Specifications of the Yaesu FL-7000.

FL-7000
BLOCK DIAGRAM

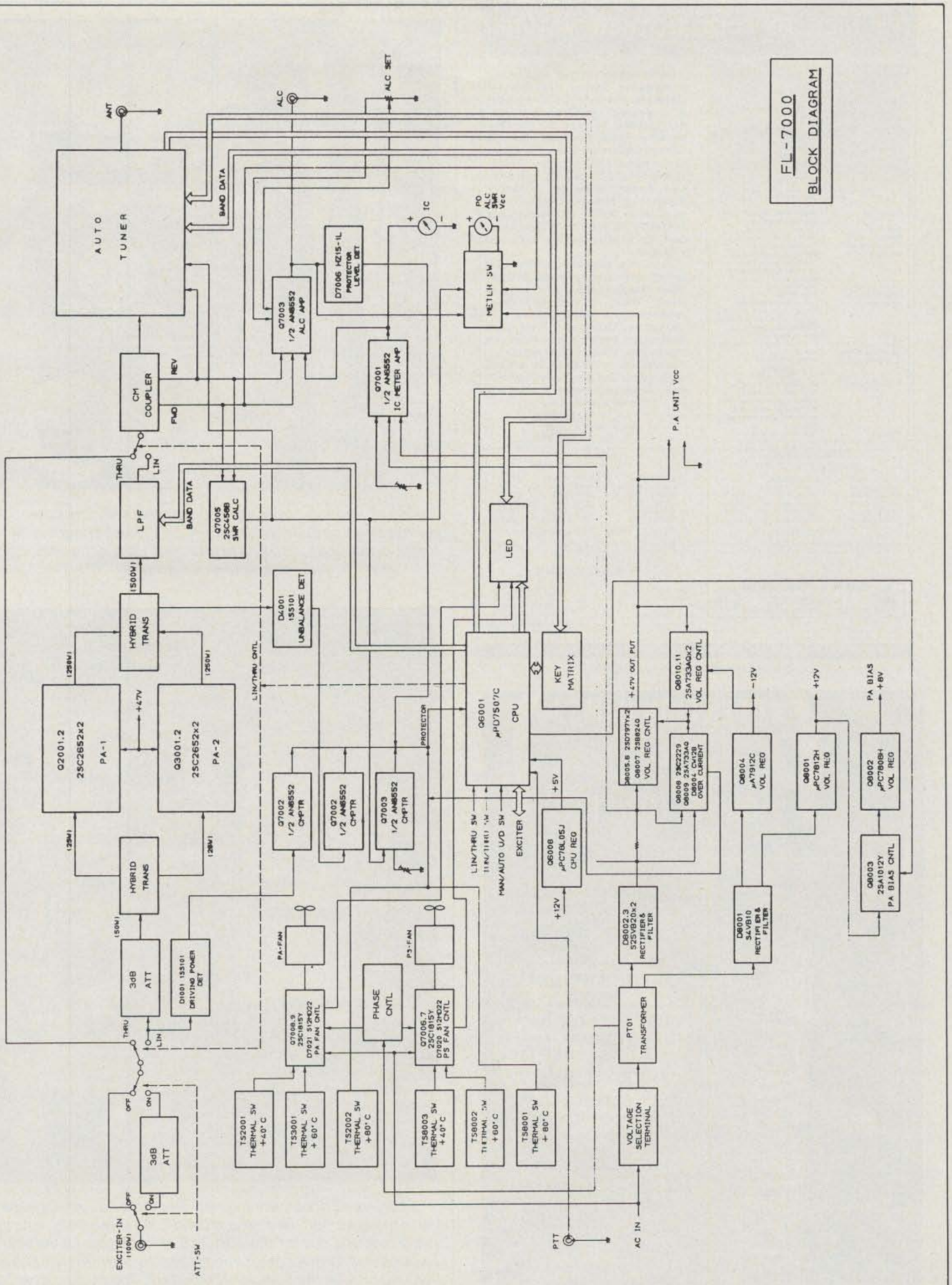
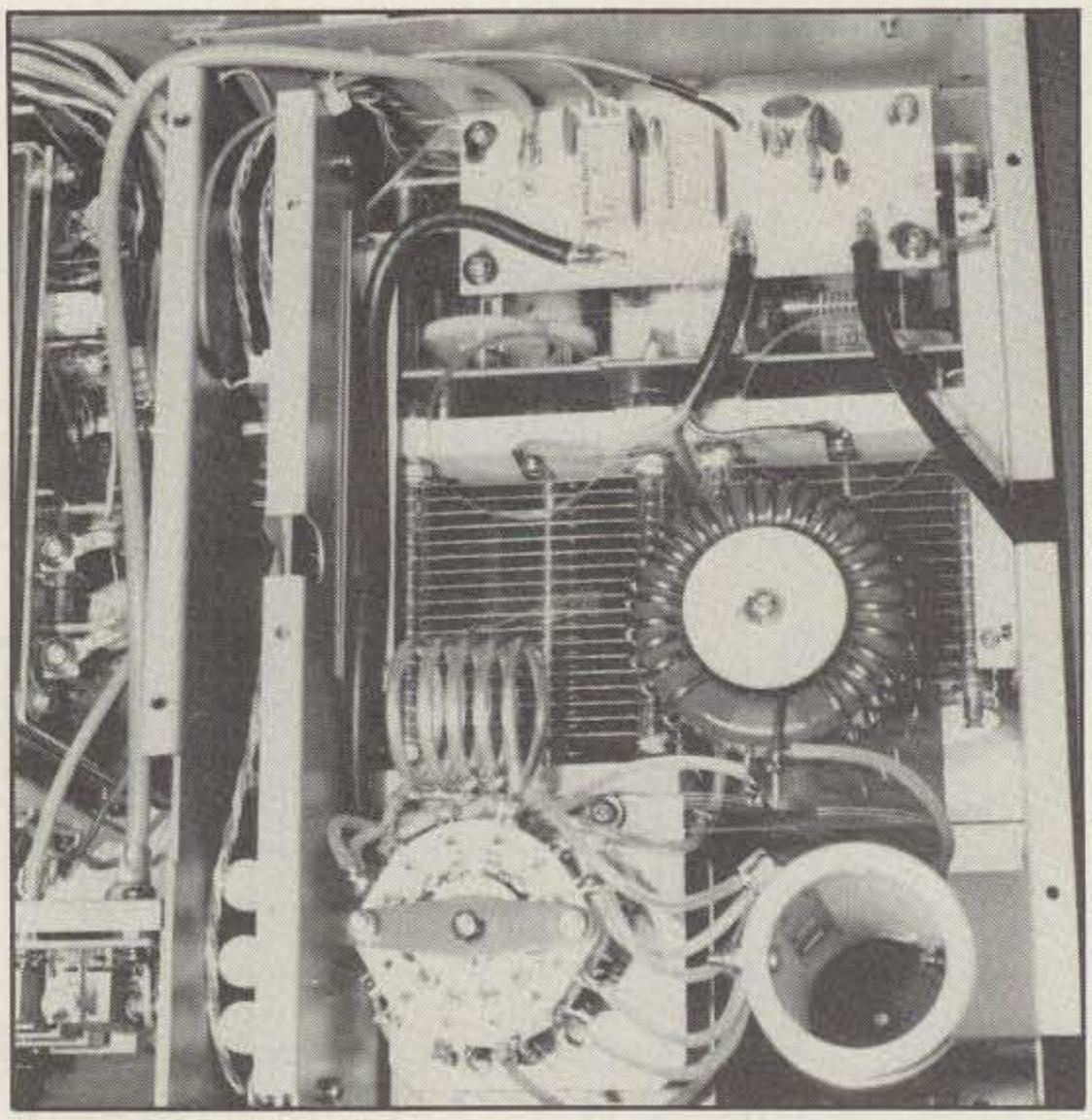
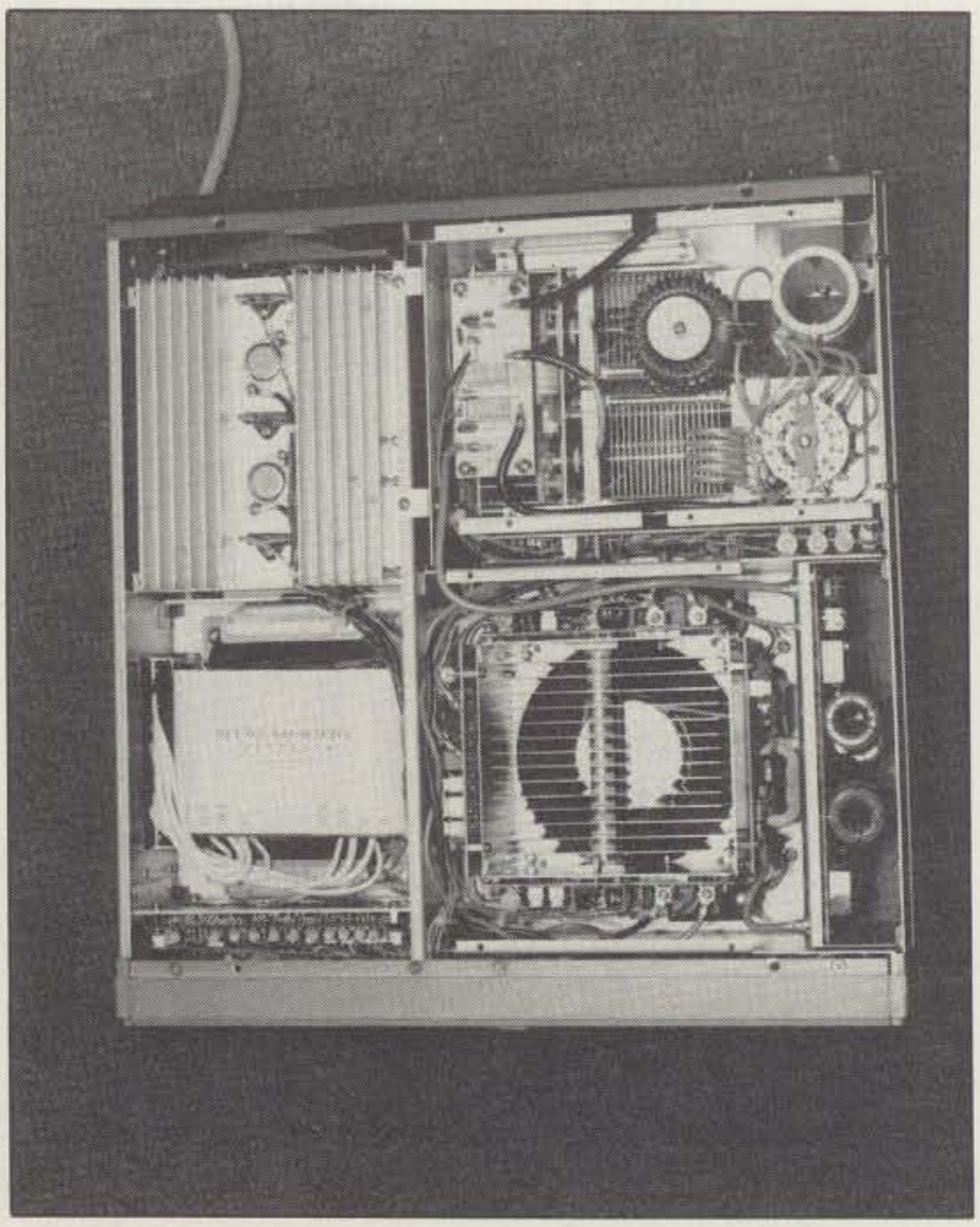


Fig. 1– Block diagram of the FL-7000 excluding the power supply.



Taking off the top cover, this is what you see. The power-supply/regulator circuitry is to the left. To the upper right is the automatic antenna tuner, and to the lower right is the unique power-amplifier assembly.



A close-up of the antenna tuner. The motor-driven bandswitch is to the lower left. Grouped around it are three coils: a horizontal air-wound coil for the 10/12/15 meter bands, a vertical coil wound on a form for other bands (except 160 meters), and a coil wound on a ferrite core for 160 meters. The two variable capacitors can be seen below the latter and are driven by motors and gearing hidden from view.

cessary band-change information. Yaesu FT-747GX, FT-757GXII, FT-767GX, and FT-1000 transceivers provide the necessary data, but many other transceivers can be adapted to also do so by suitable interface circuitry.

The linear is microprocessor controlled and has a wide variety of memory functions with lithium-battery-backed memories. Even if band-change information information from a transceiver is not available, the linear will still remember the tuner settings for each band and the antenna selected for a given band. If the tuner has to rematch a new or changed antenna load, the power amplifier is automatically shut down until an antenna match is achieved. The linear has very fast transmit/receive turn-around time and is suitable for QSK CW, packet, and AMTOR. Its key-down period, however, is limited (see Table I) unless a lower power RTTY mode is selected. The linear is really most suited for operators who enjoy casual SSB/CW operation with perhaps occasional excursions into key-down modes.

The unit has an extremely extensive array of protective circuitry which monitors parameters in the amplifier, power supply, and tuner sections. The parameters monitored range from the driving power to various temperatures to output SWR. Eight LEDs indicate various conditions. The amplifier will shut down if various parameters are exceeded. It will also not shut off if certain temperature conditions are exceeded, even if you turn off the AC power switch! The internal fans will continue to operate until internal temperature conditions have been stabilized. I'm sure you can do harm to a unit such as the FL-7000 if you are very careless, but its range of protective circuits is very impressive.

If you would like to do a little math using the figures shown in Table I, you'll notice something interesting. The FL-7000 has a volume of less than ¾ cubic foot, but weighs a very hefty 66 lbs. Considering all that it contains in one enclosure, it has to rate as one of the most compact, modern linears on the market. Again, I refer back to one of my opening comments about the FL-7000 being "rediscovered."

Circuitry

A block diagram of the FL-7000, excluding the power supply section, is shown in fig. 1. Just a few highlights may be of interest. The 3 dB attenuator (upper left) accommodates driving transceivers having more than a nominal 100 watts output (e.g., the FT-1000). The drive power is split in a hybrid transformer to drive two identical power amplifiers, each of which contains two 2SC2656 transistors having a collector dissipation of 300 watts *each*. Therefore, a total of 1200 watts of heatsinked power dissipation is available. The output of both power-amplifier units is combined, passed through a relay-switched low-pass filter unit, directive coupler, and then on to the automatic antenna tuner.

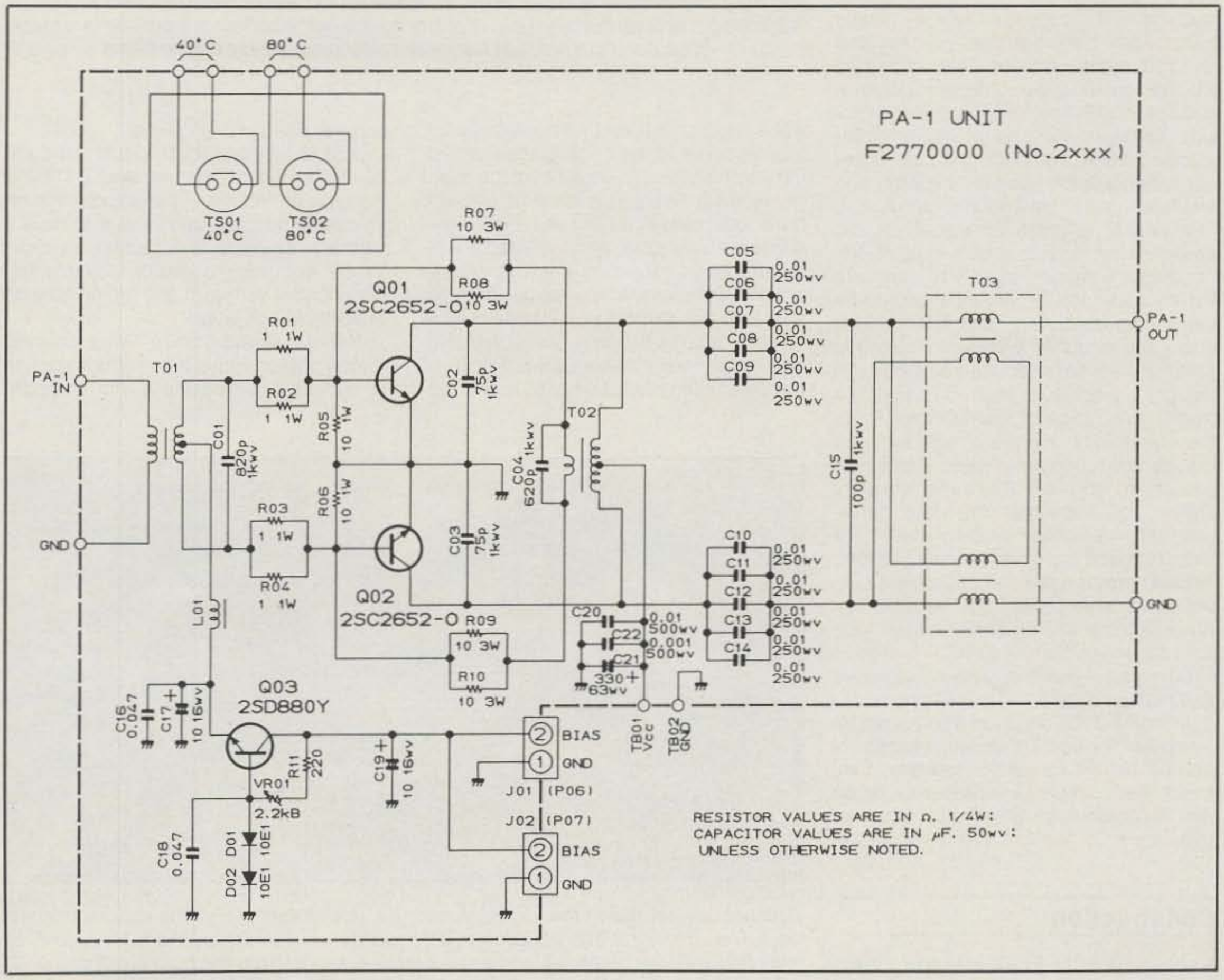


Fig. 2– One of the two power amplifier units in the FL-7000. Each 2SC2652 transistor as heatsinked can dissipate up to 300 watts.

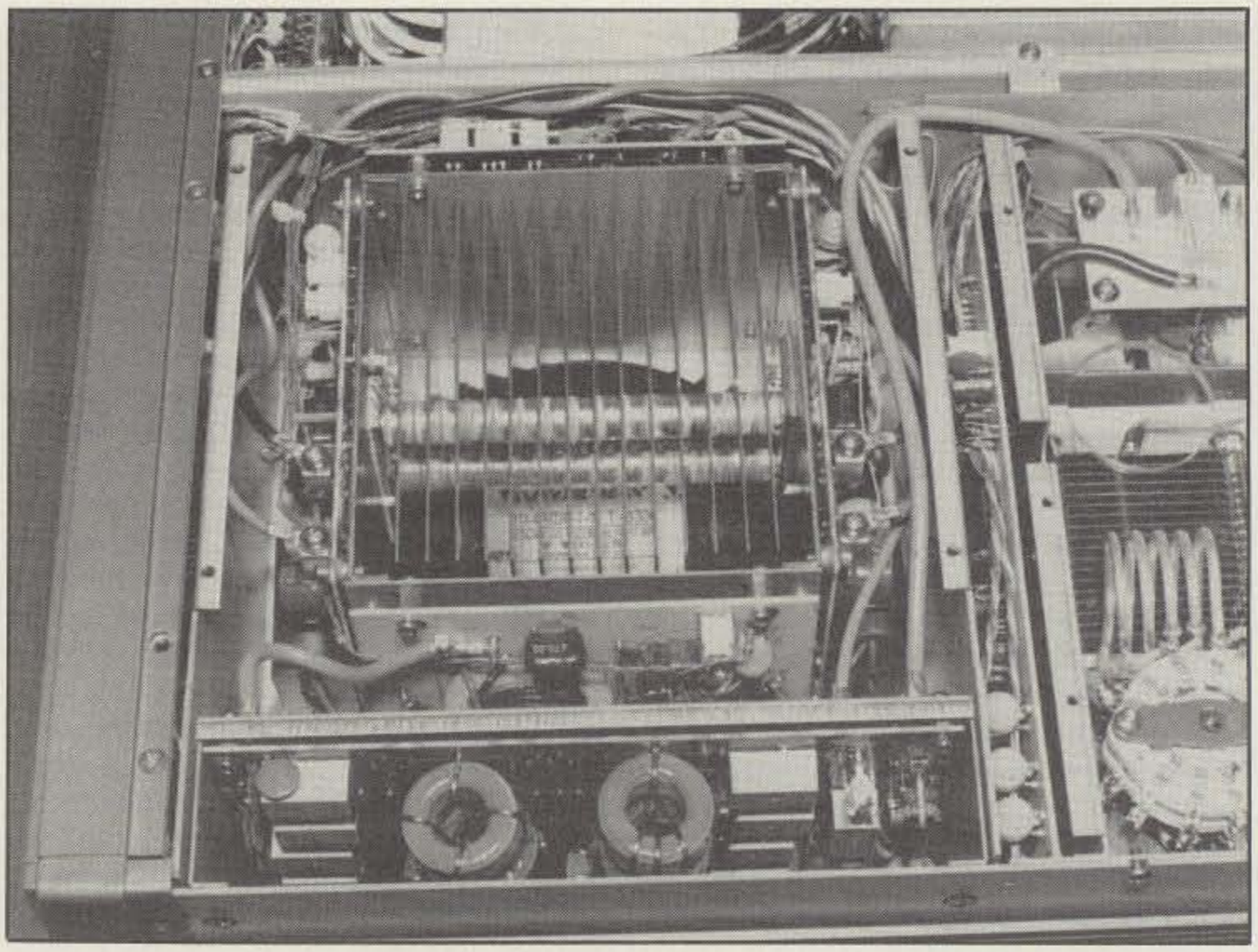
Most of the rest of the blocks shown in fig. 1 have to be referenced to the CPU unit shown roughly in the middle. It processes data from the various sensory components, translates key commands, drives indicators, stores data, etc. A sophisticated solid-state linear certainly needs sophisticated control circuitry, and the FL-7000 has it.

Fig. 2 is a closer look at one of the two identical power-amplifier units. The circuitry is clean and basically straightforward. Th 2SC2652 transistors are Toshiba units that are rated to develop 220 watts output at 28 MHz. Therefore, they certainly are not being stressed under the conditions under which they are being used. The overall IMD specification for the FL-7000 at −25 dB was found to be conservative, and the actual third-order distortion was closer to −30 dB. That is still not on the cutting edge of technology, but is certainly acceptable.

The two power-amplifier units are powered by a single 47 volt, 25 ampere power supply. The power-supply circuitry, although not shown, is rather massive. It consists of a single transformer having a dual primary and four secondary windings. Two secondary windings provide low voltages for control circuits, and the other two windings provide voltages for the power-amplifier stages. Here 30,000 mF of filter capacitance is involved for the latter and an elaborate series regulator circuit.

A partial diagram of the automatic antenna-tuner unit is shown in fig. 3. It's not that any reader is likely to duplicate the circuitry, but I think most amateurs can relate to tuners and are curious about the circuitry involved. Automatic tuners present a particular challenge to a designer, since it is desired to match a reasonable range of impedances, keep the component count low, use a circuit that can be tuned rapidly, etc. Anyway, if you try to sort out the basic circuitry shown, you'll see that one motor simultaneously steps switch taps on the series inductors and chooses input capacitors. Another motor tunes the 290 pF parallel-output variable capacitor. The third motor drives the 430 pF series-output variable capacitor. Similar circuitry has been used over the years in various automatic and manual tuners and is well-proven.

In the FL-7000 there are many other interesting circuits which involve control and protective circuitry. However, they are spread out over various PC boards, so it's impossible to present a succinct overview.



A closer look at the unique power-divider/dual-power-amplifier/power combiner assembly grouped around a very large, finned heatsink. The power amplifiers are to the left and right around the heatsink. The dark outline in the bottom is a cooling fan. In the foreground are some of the relay-switched low-pass output filters.

Construction

Mechanically, the FL-7000 is an amazing piece of equipment. To say that it is built like a battleship is an understatement. A look at some of the photographs providing internal views gives a hint of the quality involved. The unit is densely packed, but almost every corner seems to be reasonably accessible. And included are all those nice little touches, such as lacquer around the main screwheads to make sure they don't work loose in spite of lockwashers also being used. Component ratings appear very conservative. It's one of the finest examples of amplifier construction I've seen in a long time.

Just to balance those deserved compliments a bit, let me say the FL-7000 is the type of amplifier you would place on an operating table and expect to have it sit there for years of dependable usage. You're not going to readily tuck this amplifier under your arm and run off for a bit of portable operation!

Various shield covers were removed for the photographs, but the construction is broken down basically into compart-

The back panel shows the cooling fan for the power supply plus the various connectors. The terminal strip in the lower middle supplies an operating voltage for up to three external antenna relays which can be switch-selected from the front panel of the FL-7000. Separate ALC-level adjustments are provided for SSB and RTTY (upper left).

ments for the main blocks shown in fig. 1 plus a compartment for the power supply. Two independently controlled cooling fans are used—one mounted on the rear panel for the power supply and one mounted on the underside for the power-amplifier/power-divider/power-combiner units. Both are low-noise "muffin" (axial) types.

Metering, Controls, and Indicators

Two back-lighted front-panel meters are provided. One is dedicated to total collector current measurement. The other multimeter can be switched to measure power output, SWR, collector voltage, or ALC range. The SWR "compute" function is automatic, and both the power-output and SWR readings are active even if the amplifier is in a standby mode. Thus, you can easily evaluate the SWR of a potential antenna load to see if it is in a range likely to be accommodated by the automatic tuner in the FL-7000 before placing the FL-7000 into operation.

There are no rotary controls on the front panel. There are only various pushbutton controls. You may ask why an "automatic" unit should have any controls at all. Actually, if the FL-7000 is set up to take advantage of all of its features, you don't have to use any of them except the on/off rocker switch and operate/standby pushbutton. The FL-7000 will memorize tuner settings, antenna selection, etc., for each band as band-change data is received from a driving transceiver. Only initial antenna-selection data has to be given to the FL-7000.

In the real world most of us like to vary our operating habits a bit with regard to the band segments we use, antenna parameters, etc. The FL-7000 incorporates a nice combination of automatic features with manual overrides for when you want to do the antenna-coupler tuning, band selection, antenna selection, and so forth manually.

Interconnections

Basic interconnections between a transceiver and the FL-7000 are quite simple—the usual antenna line, a PTT line, and an ALC connection. An ALC adjustment potentiometer on the back panel of the unit allows an SSB ALC adjustment range of from 0 to −9 VDC. A separate interconnection line is provided if the transceiver can provide bandswitching data to the FL-7000. Full details are contained in the FL-7000 manual.

The antenna-selection feature of the FL-7000 was mentioned a few times, and it should be explained a bit. The FL-7000 has only one antenna output connector.

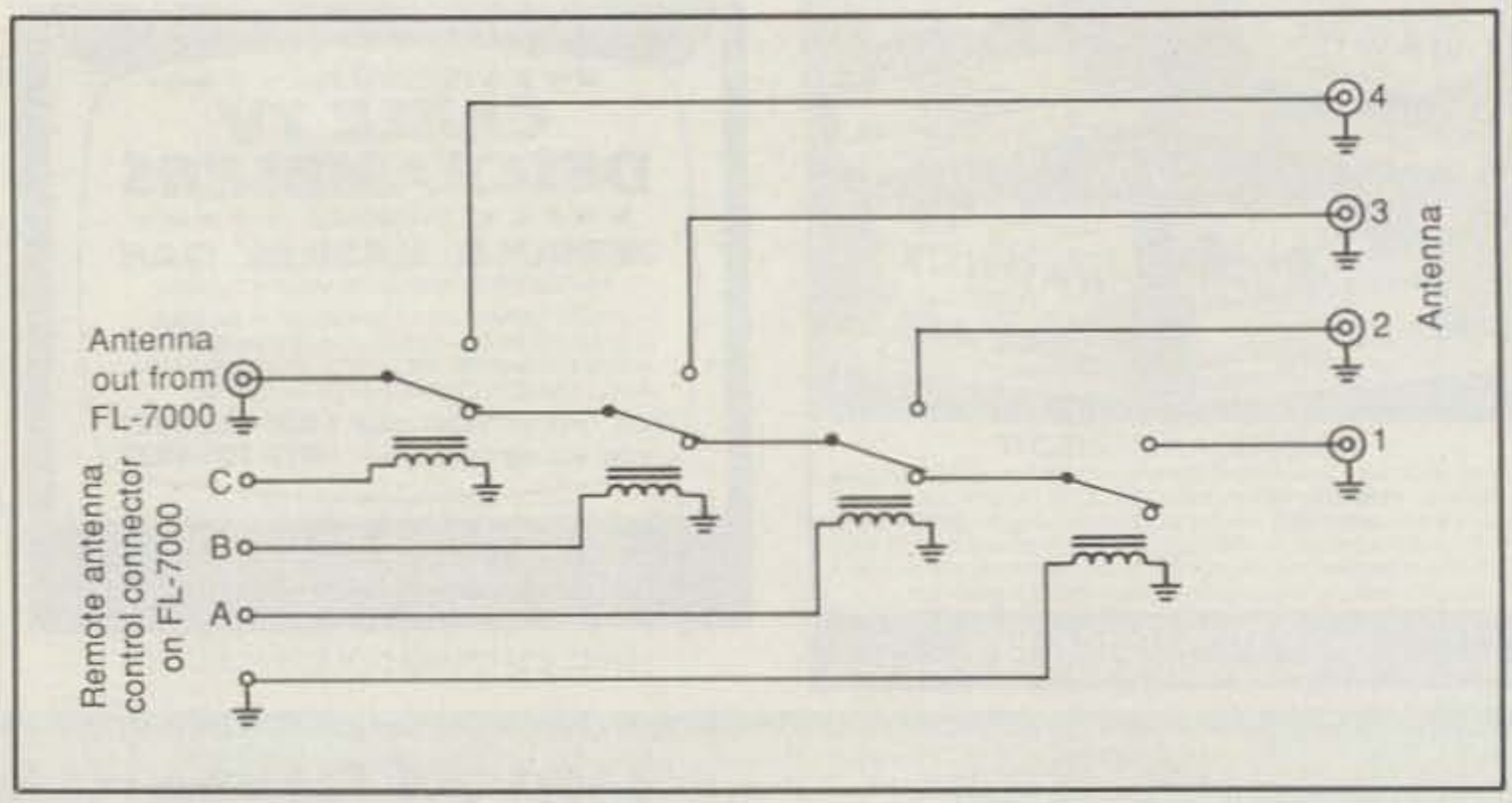


Fig. 4– Schematic of a remote antenna switching unit you might build to mate with the FL-7000. Any 12 VDC relay type having suitable RF insulation and a coil resistance of less than a few hundred ohms would be suitable (e.g., Radio Shack 275-218).

However, it does have three 13.5 VDC output terminals which are energized in turn by the Antenna 2, 3, and 4 pushbuttons and which can be used to switch three *external* 12 VDC antenna switching relays. The relays can be mounted at any reasonable distance from the amplifier depending upon the voltage drop in the interconnecting cable. Fig. 4 shows the idea involved. You can easily construct a homebrew antenna-relay selector "box," or the FAS-1-4R option can be purchased from Yaesu. You should not underestimate the versatility involved here if the basic idea involved is understood. There is no need to have all of the three relays shown in fig. 5 in one enclosure. They can be split up as desired to select, for instance, an in-shack dummy load, either of two dipoles, or a multiband beam.

Test and Operating Results

The FL-7000 I tested required less than 60 watts of drive to easily produce 500–550 watts of output. I never did talk long enough continuously on SSB to exceed the specified 30 minute time limitation. Testing the amplifier at full power output key-down, the fans switched to high speed after about a minute, but full power output continued for 2 minutes when, I guess, temperature sensors shut down the unit (actually, the power-amplifier units were bypassed and operation could still continue with a transceiver working through the FL-7000). Placing the unit in the RTTY mode produces about 200 watts output, but it would appear to have a continuous duty cycle. The fans will cycle into a high-speed mode every 90 seconds or so, remain in a high speed for 90 seconds, and then revert to their low-speed mode.

The fans, when operating normally, are the quietest I have ever encountered. They are quieter than those found in most transceivers. During normal SSB contacts the fans never did switch to a high-speed mode. I suppose part of the quietness is due to the very robust construction of the unit. There are certainly no thin metal surfaces that are possibly going to vibrate as the fans operate.

Third-order IMD products measured close to −30 dB, and fifth-order products were about −45 dB. These figures are not outstanding, but are acceptable. In reality, I don't think you would notice any difference between the FL-7000 and an amplifier having a few more dB of better distortion figures unless two amateurs were neighbors on the same street.

The CW QSK operated perfectly, at least up to the 20-plus WPM speeds I can operate. The only problem with a long CW contact at full power output is that the fans will switch to high speed. That in itself is no problem, but you would probably prefer to be using headphones if you are working a weak DX station. Of course, licensed amateurs can obtain information on how to enable the 24 and 28 MHz bands on the amplifier. In fact, it amounts to nothing more than moving a slide switch. However, you do have to know where it is located and to which position to slide the switch!

The input SWR on all bands measured no more than 1:1.3. The automatic antenna tuner is rated to match SWRs of roughly 1:3 on all bands except 160 meters, where the matching range is 1:2. The matching range is limited because only one coil tap position is available per band, as can be seen in fig. 3. The matching range is sufficient to load into antennas such as triband beams, where the SWR may rise toward the edges of a band or a dipole where the same effect takes place. The tuner can be used with any antenna,

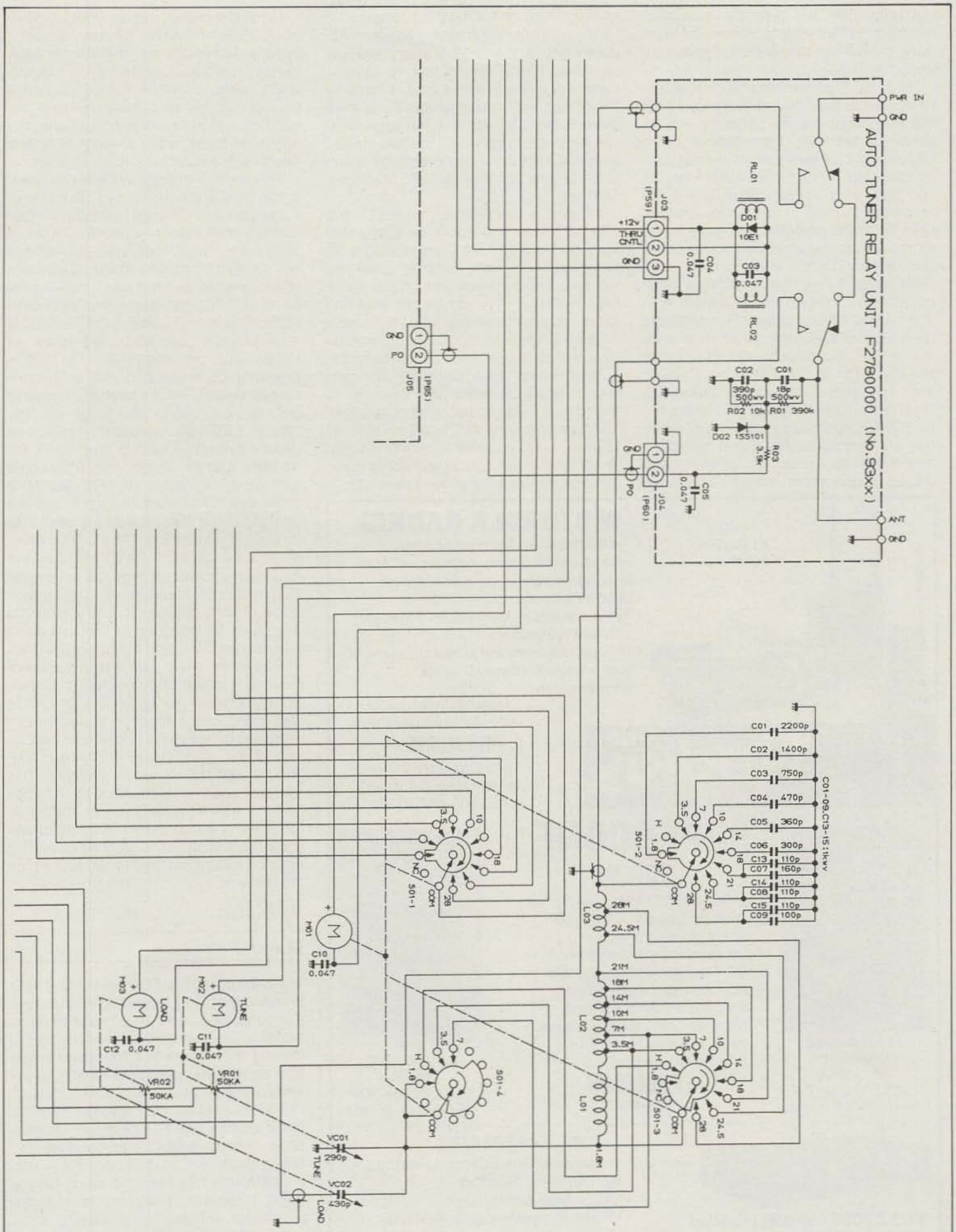


Fig. 3– A partial diagram of the automatic antenna tuner which covers 160–10 meters.

but only after the antenna has been trimmed or otherwise compensated to reduce the SWR to the range the tuner can accommodate.

In reality, the matching range is somewhat greater than stated, but I would not push the point. You can get away with various little operating discrepancies at the 100 watt output level using a manual tuner, but that is very inadvisable at the 500-plus watt output level using an automatic tuner. It's not that you are likely to harm the amplifier, because it has extensive protective circuitry. The more likely scenario is that an arc-over will take place in the tuner, thus creating a weak point that is even more likely to arc over in the future. Yaesu suggests measuring the antenna SWR using the SWR circuitry in the FL-7000 but with the FL-7000 in standby. Then if the SWR is much more than 1:3, correct the antenna before using the FL-7000. I agree, and using the FL-7000 in such a manner I have never had any problems. The automatic tuner memorizes its last setting for each band and takes only about 15 seconds to reset when going over the extreme range of 10 to 160 minutes. When going between adjacent bands, the reset time is just a few seconds. If the tuning has to seek a match for a new antenna load, it can take 30–45 seconds, but that setting is then memorized. I found the tuner to be very responsive and only very seldom could I obtain a slightly better match by using manual override to "tweak" the tuner settings.

I tried the amplifier on both 117 and 230 VAC lines. It will operate quite satisfactorily on a 117 VAC line having a 20 ampere capacity and will even allow you to use a small transceiver on the same line. However, you could not load the same line with other equipment. It's easy enough to see if the FL-7000 is going to be "happy" on a given line. If the collector voltage (as monitored on the panel meter) loses regulation when the amplifier is keyed, full power output is not obtainable. The use of a 230 VAC line provides, of course, a lot of extra capacity so you don't have to be concerned about operating on the fringe of a line's capacity.

Once it is initially set up, operating the FL-7000 is extremely simple. Once a band is chosen, the automatic tuner goes to its memorized position and the memorized antenna selection. If you go back to a band previously used, the amplifier is "instant on." If you go to another band, the only time delay is the amount of time it takes for the automatic tuner to reset.

The meters are always easy to read, since they are back-lighted. The operational-status LEDs are easy to discern because of their colors—green for "ready," yellow for "wait," and red for various warnings. The green "band" LEDs are readily visible, but the band marking for each LED is unreadable in a semi-dark room. This is no problem if the FL-7000 is automatically bandswitched from a transceiver. However, if the FL-7000 is manually bandswitched, the only way I found to readily tell the band in use was to put vertical, white markings on the "band" LED field to separate it into three groups of three—1.8, 3.5, 7 MHz; 10, 14, 18 MHz; and 21, 24, 28 MHz. Although it still wasn't possible to read the MHz markings, it was easy enough to see the position of the illuminated LED relative to its position in a group. The FL-7000 delivers a solid signal. If driven with only the necessary power to produce full power output, it provides almost a 10 dB power boost. That's quite a bit, and as the ads say, you'll be less than an "S" unit down from stations running the full legal limit.

Everyone has to define the equipment needed for his own operating preferences. I found the FL-7000 a delight to use along with a modern transceiver. It was sort of like years ago when I was on top of the world using a Collins KWM-2/30L1 combo. However, that time has passed, and I'm not the least bit unhappy about it as I hit a band key on the transceiver and watch the FL-7000 automatically reset itself from a bit of DX operating time on 15 to a net time I want to meet on 40 meters.

Manual

The manual for the FL-7000 (circa 1986) is well written. The operating instructions are quite clear, and a multitude of interconnection diagrams for various transceivers is presented. A four-page large-size set of separate diagrams which cover all of the basic circuitry is included.

The manual is not a service manual, but it comes close to being so. A four-page section contains some quite detailed alignment procedures which can be performed in the field using only a good multimeter, a dummy load, and a wattmeter. Photographs clearly show which internal adjustments are involved during alignment. Be careful, however, that attempting an adjustment on a new

FL-7000 does not invalidate the warranty. If a problem should develop, though, the manufacturer does present enough alignment data so that you probably could communicate intelligently back and forth to Yaesu to possibly avoid shipping out the FL-7000 for service. I really can't quite believe that a unit such as the FL-7000 is ever going to require service if operated properly, but . . . .

Newer models of the FL-7000 incorporate a separate front-panel switch, next to the "operate/standby" switch for "SSB/RTTY" modes. Switching to the RTTY mode reduces the collector voltage from 47 to 36 volts to allow longer key-down periods, but no specific data is given in the manual. The models that have this switch also have a separate RTTY ALC level control on the rear panel.

Overall, the manual is quite adequate, but the hardware (the FL-7000) has progressed forward while the manual has not been updated. Yaesu should consider bringing the manual up to the standard that the hardware has now reached.

Summary

Why did I want to review the FL-7000? No one asked me to do so. I noticed the FL-7000 several years ago when it first came on the market, and I was quite impressed by its specifications and its price! The latter, of course, kept it out of my mind for a long time—until now.

Why now? Well, if you really look closely at the FL-7000, you will note that price-wise it is now very competitive with other solid-state amplifiers of the same general power level. You must remember that it is a "complete" package, including power supply and automatic antenna tuner. Compared to manually tuned, tube-type linears it is of course expensive. However, until you get into enjoying the convenience of solid-state automatic-tuned equipment, you don't know what you are missing—as long as you can comfortably afford it. I suspect the FL-7000 is going to become a classic as linear amplifiers progress more and more into the no-tube era.

The power boost provided by an amplifier such as the FL-7000 is significant. In most cases the FL-7000 can be operated along with a small transceiver from a regular 117 VAC line. And there are all those automatic, no-tune features! Yaesu apparently intends to keep the FL-7000 on the market, since their very latest production run of the unit included the new RTTY modifications previously mentioned. Otherwise they certainly would not have retooled for new front-panel, back-panel, and PC-board modifications.

FL-7000 sells for $2,279.00, while the FAS-1-4R Remote Antenna Selector is $120.00. They are available from Yaesu U.S.A., 17210 Edwards Road, Cerritos, CA 90701. CQ