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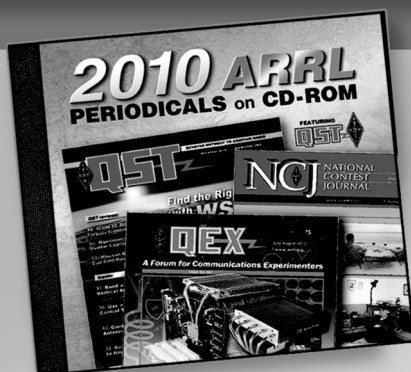
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Author: Dick Stevens, W1QWJ

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A Low-Drive, Grounded-Grid 3CX800A7 Amplifier

Here's an amplifier that many of you have been looking for! Break the "100-W exciter" barrier in style: one tube, six bands and 750 W output with less than 25 W of drive!

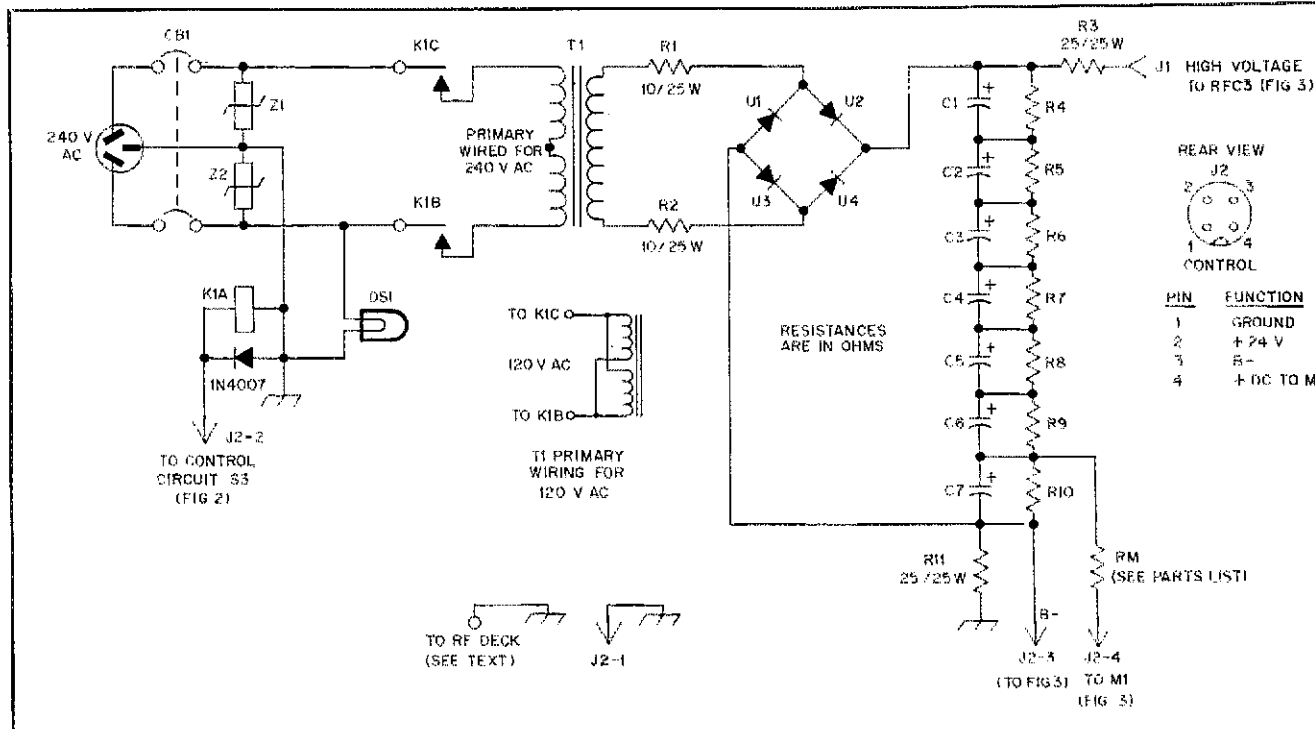
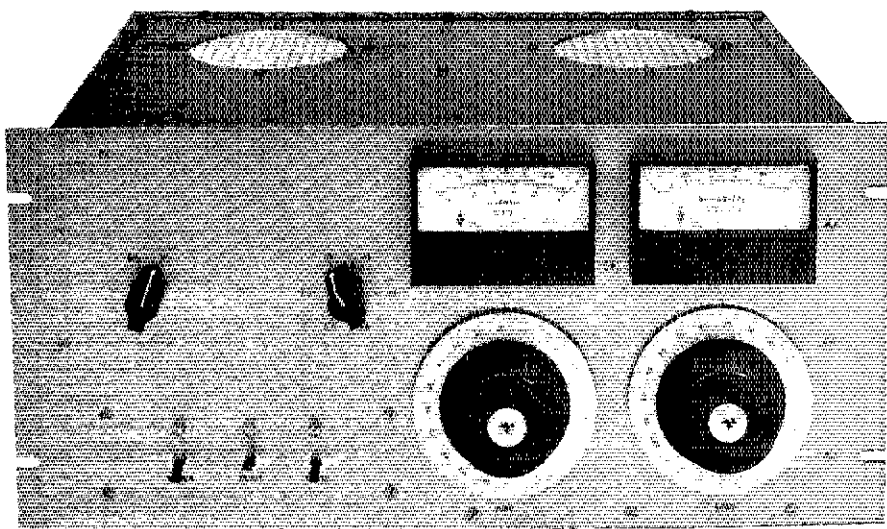
By Dick Stevens, W1QWJ
Bolton Rd, PO Box 118
Ashuelot, NH 03441

Would you like to own an amplifier that you can drive easily with a low-power exciter? Do you operate RTTY and have to settle for low power output from your transceiver

(because of RTTY's 100% duty cycle) while wishing for more? Want to boost your CW or SSB signal power? Do you find QRP operation thrilling, but today you want to (or have to) QRO and can't do it? I see a lot of heads nodding YES! Okay, here's the amplifier you've been looking for!

FCC technical standard Section 97.77(d)(6)(i) put a clamp on the marketing of commercially made 1-kW-class amplifiers that could be driven by an exciter delivering less than 50 W. Commercial (and many homemade) amplifiers today are

designed to operate with 100-W output exciters. There are a few older, low-drive amplifiers available on the used-equipment market, but most of them are roughly 30 years old. Some of those older amplifiers use tubes that are hard—or darn near impossible—to obtain today. The tubes may be quite expensive, too, costing as much as their more modern counterparts. Also, some of these amplifiers have power supplies that can be used only on 120-V lines; no 240-V primary is provided. So, what do you do if you want a low-drive



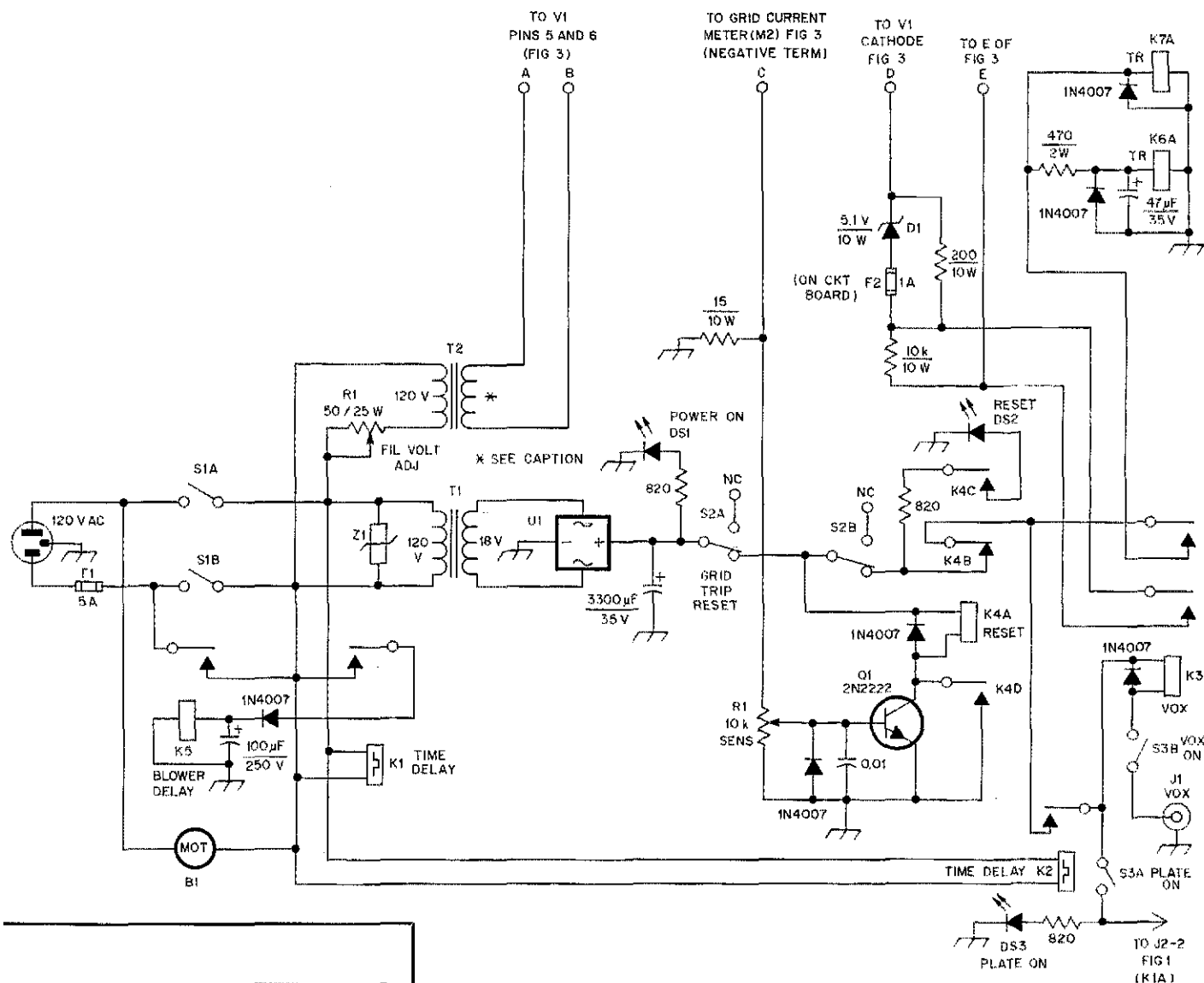


Fig 1—Schematic diagram of the high-voltage power supply. The inset shows how to wire T1's primary for operation from 120-V ac lines. (Equivalent parts can be substituted.)

C1-C7—320 μ F, 450-V electrolytic (Mallory CGS321T 450 V3C or equiv).

CB1—DPST, 125-V, 15-A contacts (Airpax
T21-8124).

DS1—Neon pilot lamp, 120 V (Radio Shack 272-704).

J1—High-voltage connector (Millen 37001 or equiv).

J2—4-pin male chassis mount socket
(Radio Shack 274-002).

K1—DPST, 25-A contacts, 120-V coil (Potter & Brumfield PR7AYO). (See text.)

R1, R2—10 Ω , 25 W.

R3, R11—25 Ω , 25 W.

R4-R10—25 k Ω , 25 W.

RM—Shunt to allow M1 (Fig 3) to read 3 kV full scale; value depends on the resistance of the basic meter movement used at M1.

T1—High-voltage transformer; 120/240-V dual primary, 1700-V, 0.6-A secondary (Avatar Magnetics AV-449).

U1-U4—K2AW HV 14-1 rectifier assembly.
Z1, Z2—MOV (Radio Shack 276-568 or SKMV130J).

EXCEPT AS INDICATED, DECIMAL
VALUES OF CAPACITANCE ARE
IN MICROFARADS (μ F); OTHERS
ARE IN PICOFARADS (pF);
RESISTANCES ARE IN OHMS;
K = 1000

Fig 2—Schematic diagram of the control board, relay and heater voltage supplies. The heater transformer is mounted in the amplifier enclosure in the sub-chassis supporting the control board and input network/amplifier tube enclosure. Adjust R1 to provide the proper heater voltage (13.5) measured at the pins of V1. (Equivalent parts can be substituted.)

B1—Blower (Dayton 4C012A).

D1—5.1-V, 10-W Zener.

DS1—Green LED (POWER).

DS2—Yellow LED (RESET).

DS3—Red LED (PLATE).

F1-5 A.

F2-1 A (mounted on circuit board).

J1—Phono jack.

J2—4-pin male chassis-mount socket

K1—Amperite 115NO69 time delay relay.

K2—Amperite 115NO180 time delay relay

K3, K4—4PDT, 24 V dc coil (P & B KH4703-2 or equiv). (Only two poles of K3 and three poles of K4 used.)

K5—DPDT, 24 V dc coil.

K6, K7—Dow Key 60-2304, 26.5 V dc coil, UHF connectors.

R1—50- Ω , 25-W adjustable resistor, slider type.

S1—DPDT (ON/OFF).

S2—DPDT (GRID TRIP RESET).

S3-DPDT (PLATE ON/VOX ON)

T1—120-V primary; secondary 18 V, 2 A.

T2—120-V primary; secondary 14 V CT,
2 A.

U1—50-PIV, 4-A bridge rectifier.

Z1—MOV (Radio Shack 276-568 or SKMV130J).

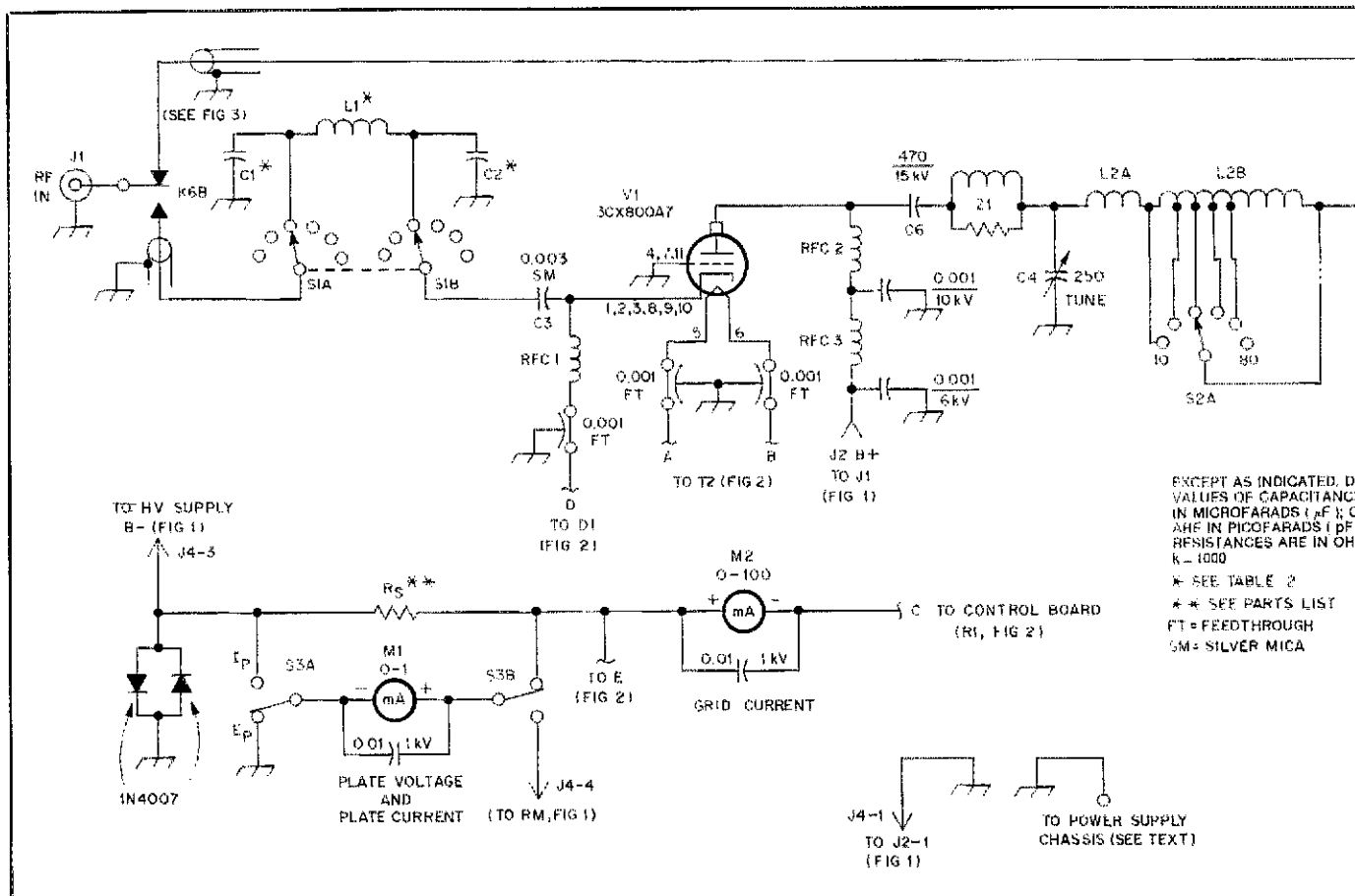


Fig 3—Schematic diagram of the low-drive 3CX800A7 amplifier. (Equivalent parts can be substituted.)

C1, C2—See Table 3.
C4—250 pF, 3500-V air variable (Cardwell 154-9-1).
C5—1000 pF, 1500-V air variable (Cardwell 154-30-1).
C6—470 pF, 15-kV (Sprague 715C-Z or equiv).
J1, J3—SO-239.
J2—High-voltage connector (Millen 37001 or equiv).
L1—See Table 3.
L2A—7 turns of 1/8-inch diam copper tubing, 1 1/2 inch ID.
L2B—15 turns of B & W 2406A coil stock. Tapped (from L2A end) at 1 turn for 12 m, 2 turns for 15 m, 4 turns for 20 m,

8 turns for 40 m, and 15 turns for 80 m.
L3—11 turns B & W 1411A coil stock. Tapped (from L2B end) at 1 1/2 turns for 10 and 12 m, 1 3/4 turns for 15 m, 2 turns for 20 m, 6 turns for 40 m, and 11 turns for 80 m.
M1—0-1 mA meter with suitable shunt resistor (RS).
M2—0-100 mA meter with suitable multiplier resistor (RM).
RFC1—100 μH (Radio Shack 273-102 or equiv).
RFC2—85 μH; 37 turns no. 22 enam wire on a 1-in. diam Delrin® form.
RFC3—Ohmite Z-50 or 14 turns no. 18 enam wire, 1/4-inch ID, air core.

RFC4—2.5 mH, 100 mA.
RS—Meter shunt to allow M1 to read 1 A full-scale. Value of RS depends on meter used for M1.
S1—Centralab 2551.
S2—Radio Switch Corp model RSC 86; 60-degree index, 2 sections, 6 positions per section.
S3—DPDT toggle switch.
V1—Eimac 3CX800A7 high-mu power triode.
Z1—2 turns of no. 14 bare wire in parallel with two paralleled 91-Ω, 2-W resistors.
Misc.—Eimac SK-1900 socket for V1, two Jackson 4-inch, 2-ball dial drives (4489/C).

amplifier, but can't buy a new one or don't want to take a chance with an older one? You *build* one, like I did.

General Description

In this amplifier, a 3CX800A7 is employed in a grounded-grid circuit. This tube and circuit arrangement offer some advantages over others. The grounded-grid circuit is simple and stable. No screen-grid power supplies are needed. The tube has low drive-power requirements; a nominal drive power of only 20 W (depending on the frequency of operation) will easily produce 750 W of RF output. See Table 1.

Such a low drive-power requirement has many benefits. For instance, 100-W output transceivers operating at a 100% duty cycle

in the continuous-duty modes (such as RTTY) may be run at a low-power level, thus ensuring component longevity. (Remember, these transceivers were designed for use primarily on SSB and CW, which have shorter duty cycles than RTTY.) Also, the amplifier can be driven by a QRP rig when the need arises. Driving powers of as little as 5 W will produce a respectable amount of RF output from this amplifier. ARRL Lab measurements show this amplifier—operating at 14.2 MHz—will produce RF power output levels of 220, 440, 575 and 700 W for driving powers of 5, 10, 15 and 20 W, respectively. Like the sound of that?

Circuit Description

This amplifier is composed of two main

sections: the high-voltage power supply and the RF deck. The RF deck houses the control circuitry for overall control of the amplifier and high-voltage power supply.

The schematic diagram of the power supply is shown in Fig 1. Figs 2 and 3 are the schematic diagrams of the heater supply and control circuits, and RF section, respectively.

Power Supply

The power supply (see Fig 1) uses a full-wave bridge circuit to develop the 2200 V at 500 mA the 3CX800A7 requires. With circuit breaker CB1 closed, DS1 illuminates when ac power is available at the power supply chassis. Z1 and Z2 are transient suppressors, used to lessen the possibility of

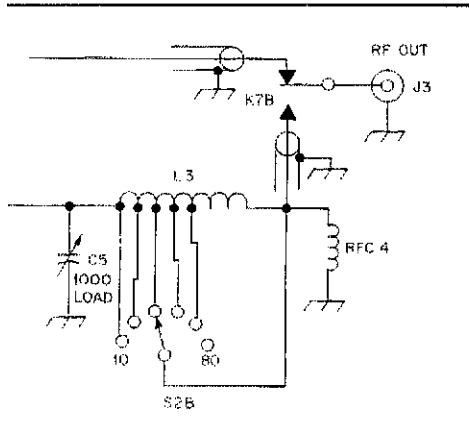


Table 1

Typical 3CX800A7 Low-Drive Amplifier Operating Characteristics for 750 W Output

<i>Band</i>	<i>Driving Power (W)</i>	<i>Input SWR</i>
80	22.6	1.46
40	18.7	1.68
20	23.1	1.3
15	20.2	1.0
12	20.2	1.78
10	22.4	1.6

Table 2

Input Coil Data

Band (Meters)	L1 (μH)	C1, C2 (pF)	J. W. Miller Part No. (L1)
80	2.07	820	4306
40	1.18	430	4305
20	0.59	210	4303
15	0.39	150	4302
12	0.35	120	4302
10	0.30	100	4302

Table 3

Parts Suppliers

Ronald C. Williams, W9JVF (aka Avatar Magnetics), 1408 W Edgewood Ave, Indianapolis, IN 46217-3618, tel 317-783-1211.

W. W. Grainger, Inc, 5959 West Howard St, Chicago, IL 60648, tel 800-323-0620; in Illinois, 800-225-7149.

**K2AW's Silicon Alley, 175 Friends Ln,
Westbury, NY 11590, tel 516-334-7024.**

RadioKit, PO Box 973-C, Pelham, NH
03076, tel 603-635-2235.

damage to power-supply components from ac-line transients. Power-supply turn-on is controlled by K1, which receives its control voltage from the control-circuit chassis located in the RF deck. (Although the relay specified has a 120 V ac coil, it works without fault from the 24 V dc supply.)

To ensure good voltage regulation, the primary of T1 is operated from a 240 V ac

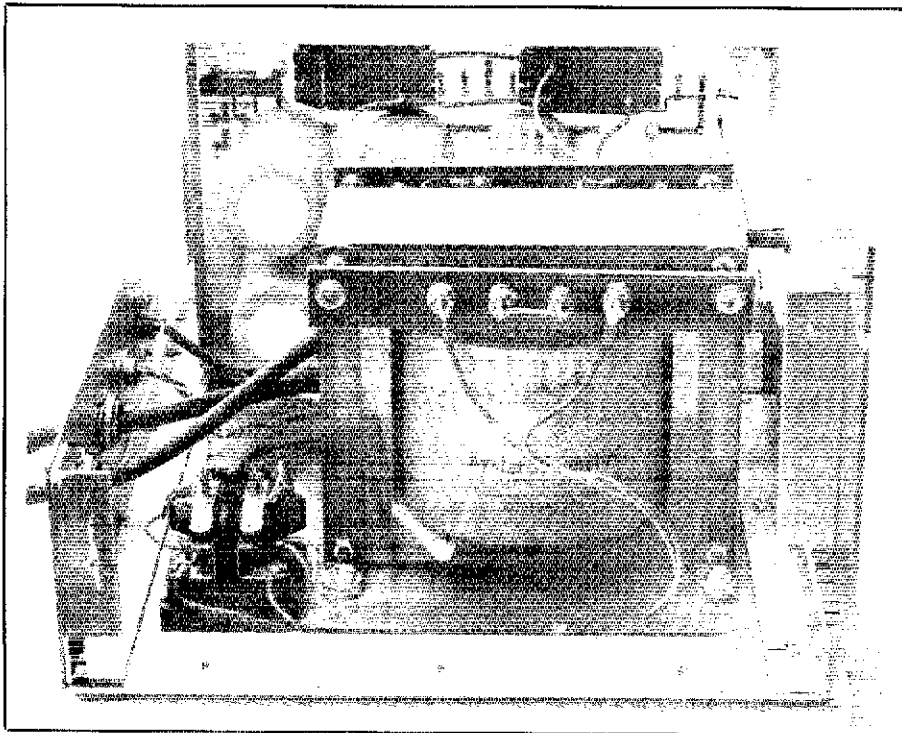


Fig 4—Inside view of the power supply. To the left is the heavy-duty relay in the high-voltage transformer primary. The circuit breaker (ON/OFF) switch is attached to the front panel (on the right in this photo) along with the power on indicator. Behind the power transformer, the filter capacitor string and rectifier assemblies (the two black modules at the top of the PC board) can be seen. The voltage-equalizing resistors across the filter capacitors are mounted on the back of the PC board. Both secondary-winding surge resistors are secured to a phenolic strip at the rear of the power transformer. This strip is similar to the one you can see mounted across the top of the power transformer primary side, to which the primary voltage lines from the relay are attached.

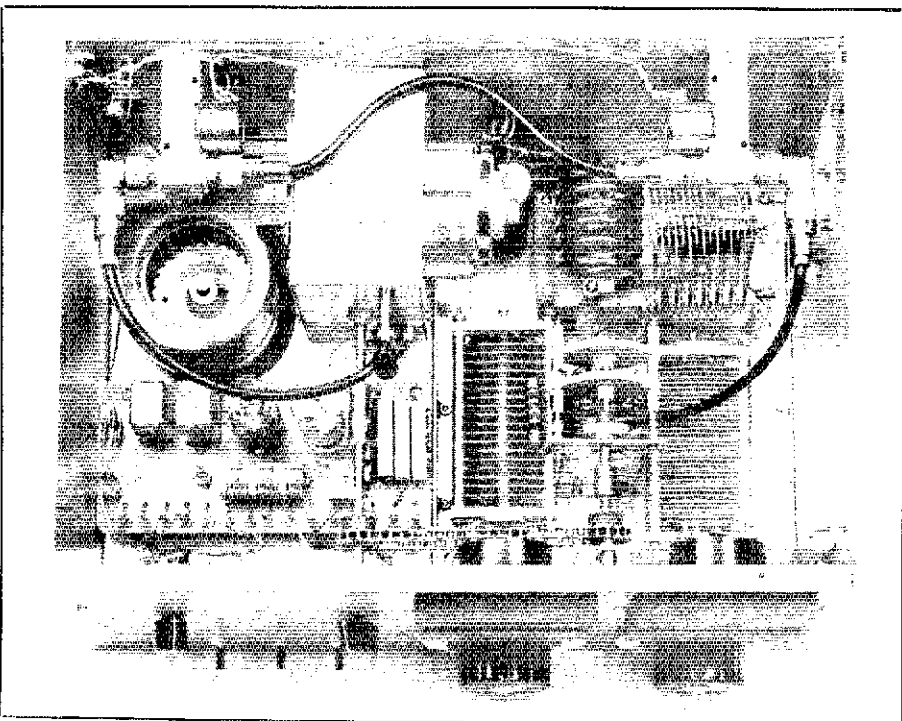


Fig 5—An inside view of the amplifier. On the chassis base, proceeding clockwise from the bottom left, are the bias and time-delay board, blower, input network enclosure and tube, pi-L output tank, LOAD capacitor, band switch and TUNE capacitor. Above the blower and output tank you can see the TR relays. The chain drive linking the band switch shaft (attached directly to the input-network switch shaft) to the output tank switch is immediately behind the left-hand (PLATE/HV) meter.

line. (The inset in Fig 1 shows how to connect T1's primary if operation from a 120-V line is necessary.) Two surge resistors (R1 and R2) are installed in T1's secondary leads. These resistors serve to protect the bridge rectifier assemblies (U1-U4) from the high initial current surge that results when ac voltage is applied to T1, and the filter capacitor string charges.

The high-voltage filter capacitor is made up of a series string of equal-value electrolytic capacitors shunted by voltage-equalizing resistors. The total filter capacitance is approximately 45 μ F. With a 3150-V dc rating for the string, there's a more-than-adequate safety margin.

Plate voltage is measured as the voltage drop across the bottommost electrolytic capacitor in the string. The value of RM, the high-voltage meter multiplier resistor, depends on the basic meter movement of M1 of Fig 3. R11 serves to keep the B-lead of the supply near ground potential and provide a means of safely monitoring the plate current.

High voltage from the power supply is made available to the RF deck at J1. J2 is a 4-pin microphone jack pressed into service as a control-cable connector. A duplicate connector exists on the RF deck. A ground connection, +24 V to operate K1 and the B- and high-voltage monitoring leads are run through a 4-conductor cable connected between the two jacks. An inside view of the high-voltage supply is shown in Fig 4.

Control Circuits

The control-circuit components of Fig 2 are mounted on a piece of fiberglass board secured to the top of a small subchassis at the left-hand side of the RF deck (see Fig 5). A 120 V ac line enters the rear of the RF deck (see Fig 6) and enters the subchassis inside which T1 and T2 are mounted. This 120-V line feeds the control-circuit power supply and the heater transformer for the final amplifier tube.

Because the 3CX800A7 has an indirectly heated cathode, it must be protected from the application of RF drive before the cathode reaches operating temperature. The time-delay circuits in this amplifier provide this insurance and also ensure that the tube cooling fan remains running for some time after the amplifier is turned off. A grid-current sensing circuit is included to shut down the amplifier if V1's grid current exceeds a preset value (50 mA, maximum). These features protect the tube from an early demise. The cost of a few relays is cheap insurance for a 3CX800A7!

S2 (GRID TRIP RESET) is normally closed and K4 deactivated. When the amplifier ON/OFF switch (S1) is closed, the start-up cycle begins. The cooling fan (B1) moves air across the base and through the anode-cooling fins of the tube, the +24-V power supply comes to life, heater voltage is fed to the final amplifier tube (V1) and K1 and

K2 begin their timing cycles. Until K2 finishes its timing cycle, plate voltage cannot be applied to V1—even with S3 closed or the transmitter's VOX relay contacts closed. The plate supply ON/OFF switch (S3) provides a path in series with the VOX control lead to prevent keying the amplifier without plate voltage applied.

Once K1 and K2 have closed, closing the PLATE ON/VOX ON switch (S3) will supply +24 V to K1 in the high-voltage power supply. That allows plate voltage to be applied to V1.

When the transmitter's VOX relay contacts close, K3 is activated through J1. One set of K3's contacts activate K6 and K7, the input and output TR relays. The other contacts remove cutoff bias from V1 and allow operating bias (supplied by D1) to be applied to V1.

K5's sole purpose is to keep the cooling fan running for a while after S1 is opened. Initially, K1 was employed to control B1. During testing, I noticed considerable arcing between the contacts of K1 as they opened. The arcing was excessive and would have destroyed the relay in time. I revised the circuit by adding an auxiliary relay (K5) to operate on dc; that cleared up the problem.

At the beginning of the start-up cycle, when K1's contacts close, operating voltage is fed to K5. As long as K1's contacts remain closed, voltage is fed to K5's coil. When S1 is opened to shut off the amplifier, that voltage is removed. However, the capacitor across K5's coil retains sufficient charge to hold K5 closed for a short period; this keeps the cooling fan running until the capacitor across K5's coil discharges sufficiently to de-energize K5.

Q1, K4 and their associated components provide protection against excessive grid current in V1. When the grid current exceeds 50 mA, Q1 conducts and energizes K4. DS2 (RESET) is lit, plate voltage is removed from V1 and the VOX line is disabled. K4 is latched until drive is removed and S2 is operated.

RF Circuits

Refer to Fig 3. RF input from the exciter is applied to J1. If K6 and K7 are de-energized, the RF is routed around the amplifier and passed directly to the amplifier output at J3. When the VOX circuit is activated, K6 and K7 are energized. K7 will close before K6 because of the capacitor connected across K6's coil (see Fig 2), which causes a short time delay. This delay ensures a load is connected to the amplifier tube before RF drive is applied. With K6 and K7 energized, RF drive is applied to V1's cathode through a pi-network input circuit tailored for each band. (See Table 2 for L and C data.) Input-network coil Q is approximately 2; this is broad enough to ensure coverage of each band without adjustment. The input and output networks

are switched simultaneously by the BAND switch.

A pi-L network is used in the output circuit of the amplifier. This network is slightly more difficult to build than a standard pi network, and requires the use of a two-section switch, but the additional 15 dB of harmonic suppression the pi-L network offers makes the effort worthwhile.

Metering

M1 can be switched to read plate voltage or plate current. A 0-1 mA meter is used at M1. Resistive shunts RS and RM are chosen to provide full scale readings of 1 A and 3 kV, respectively. M2, a 0-100 mA meter, continually monitors grid current.

Construction

Table 3 contains a list of suppliers for some of the parts used in this amplifier. Certainly, there are several ways of attacking the mechanical construction of this amplifier. There's no need to follow exactly the procedure I've chosen, but a brief description is in order.

A Bud AU-1029 utility cabinet houses the input circuit. This box also provides a mount for the tube and cooling fan. The 3CX800A7 is mounted horizontally on one of the 4 × 5-inch box covers. The blower is attached to the other cover. Input network coils are mounted on a small piece of circuit board secured to the 3 × 5-inch top surface of the box.

When wiring V1's socket, I strapped pins 4 and 7 together, then connected pin 11 to 7, finally grounding pin 7. Similarly, pins 1 and 8, 2 and 9 and 3 and 10 were joined. The RF drive is applied to the center of the three intersecting pin-pair connections.

A chain-driven band switch simultaneously switches the input and output networks. Therefore, the input and output band switches must have the same indexing. In this amplifier, switches with 60-degree indexing are used.

If you intend to use a chain-driven band-switching arrangement as I've done, be careful not to make the chain drive too tight. There must be a small amount of slack in the chain to allow the detents to operate. If the chain drive is too tight, it will be difficult to determine if the switches have sequenced properly.

Amplifier control circuits are wired "dead-bug" fashion on a piece of circuit board. An isolated-pad drill is used to make the required wiring points. This style of circuit-board construction has fallen out of favor with some constructors, but it is simple and effective.

Tune-up and Operation

Check the power supply and RF deck carefully to ensure there are no short circuits. To avoid possible component damage, the dielectric of the high-voltage supply electrolytic capacitors should be "formed" the first time the power supply

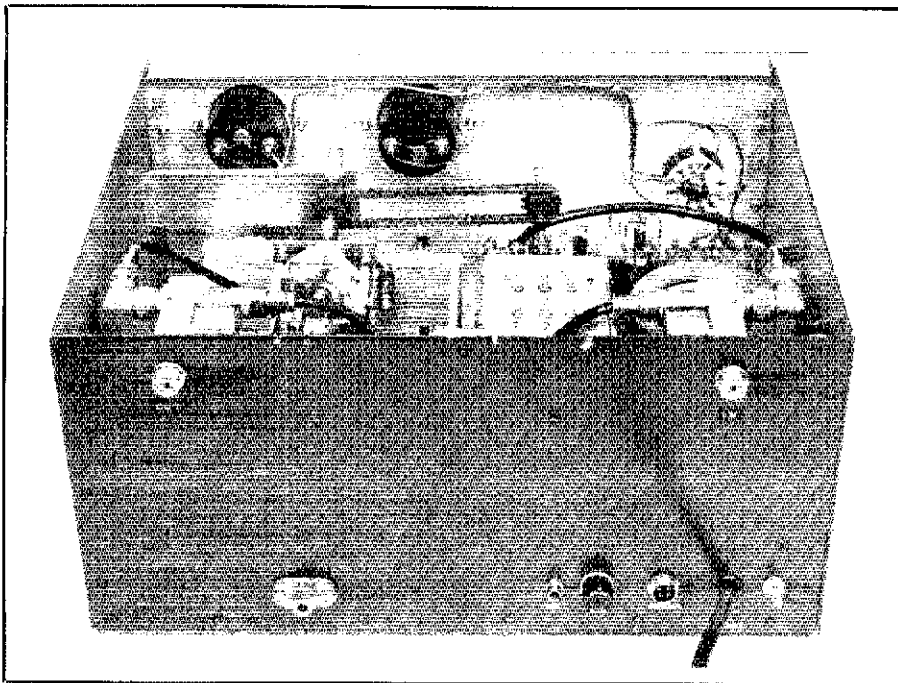


Fig 6—Rear panel of the low-drive amplifier. At the top are the two SO-239 input (IN) and output (OUT) connectors. The high voltage is connected to the amplifier through the jack at the lower-left of the panel. To the right of that jack is the vox phono jack, control/bias board fuse holder, 4-pin CONTROL jack (a commonly used microphone connector), the line cord and the ground lug. The bracket mounted to the left-hand panel behind the meter provides additional support for the output tank switch shaft and the chain drive.

is turned on. To do this, use a variable transformer (such as a Variac®) on the primary side of the power transformer. Slowly increase the voltage fed to the transformer primary. This gradual application of voltage forms the dielectric of the capacitors.

With the high voltage off and the amplifier tube out of its socket, ensure the control circuits function correctly. Next, with V1 in its socket, check for proper heater voltage at the tube socket pins, adjusting R1 as required. That done, remove power from the RF deck and connect the high-voltage supply to the RF deck. For safety, connect the chassis of the power supply and RF deck together with a length of braid or stranded wire.

Attach the output of a 40- to 50-W output exciter through a wattmeter to the amplifier input jack. (CAUTION! *Don't attempt to drive this amplifier with the full output of your 100-W [or more] exciter. Maximum drive required should not exceed 40 W.*) Place a second wattmeter in the line between the amplifier output and a suitable dummy load. Close the power-supply circuit breaker and the RF deck RESET switch and turn the POWER switch on. Heater power will be applied and the blower should start. After approximately three minutes, the high-voltage power supply will turn on. With S3 switched to allow M1 to read plate current, press the transceiver PTT switch. A resting plate current of

approximately 15 mA should be indicated by M1.

With 10 to 20 watts of drive applied, adjust the TUNE and LOAD controls until the grid-current meter indicates 50 mA. Adjust R1, the grid-trip SENSITIVITY control, until the circuit activates. Reset the circuit and check the grid current trip point.

Apply about 10 watts of drive and adjust the input-network coil slugs for lowest SWR at the center of each band. That done, gradually increase the drive while adjusting the TUNE and LOAD controls for maximum power output. ARRL Lab spectral analysis showed that tuning for maximum power output coincides with maximum spurious-signal attenuation. (You'll find the setting of the LOAD capacitor in the pi-L output circuit to be more critical than that of a conventional pi network.) Maximum power output depends on the amount of driving power available. The photos in Figs 7 and 8 show worst-case and two-tone IMD spectral displays.

Summary

This amplifier has proved itself to be a good performer. Others, including avid contesters, who've used this amplifier have commented on how much they enjoyed it. If you're looking for an easy-to-drive amplifier—one with cruise control and power steering—this one'll make you smile!

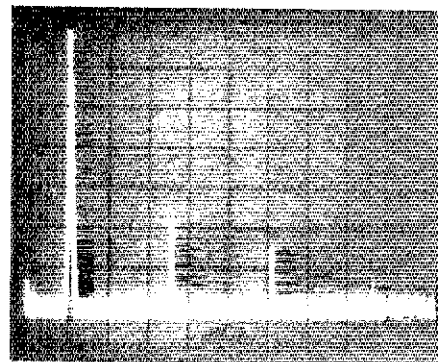


Fig 7—Worst-case spectral display of the 3CX800A7 amplifier. Horizontal divisions are each 10 MHz; vertical divisions are each 10 dB. Output power is 750 W at 24.9 MHz. All harmonics and spurious emissions are at least 47 dB below peak fundamental output.

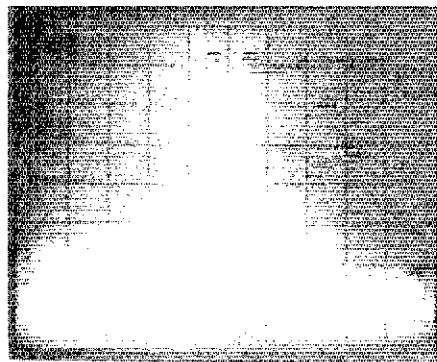


Fig 8—Spectral display of the 3CX800A7 amplifier during two-tone intermodulation distortion (IMD) testing. The amplifier is operating at 750 W PEP output at 14.2 MHz. Horizontal divisions are each 2 kHz; vertical divisions are each 10 dB. Third-order products are approximately 42 dB below PEP output, and fifth-order products are approximately 51 dB down.

Strays



I would like to get in touch with...

□ anyone with a service manual/schematic for an AM-COMM S-225 2-meter transceiver. Cary Altman, WB0OIZ, 816-254-5926 (collect) or at 64050 via packet.

□ anyone having documentation on the Mountain Computer's A/D+D/A card and/or the Apple Clock (or "The Clock") peripheral cards for an Apple® II computer. Alex Vrenios, KX9I, 507 Pleasure Dr, Mundelein, IL 60060.

□ anyone who has connected a Commodore 64 to a Radio Shack® monitor Model #1 using a Kantronics Interface and CW RTTY floppy disk program. Roland Gibson, 551 Charlemagne Blvd, Naples, FL 33926.