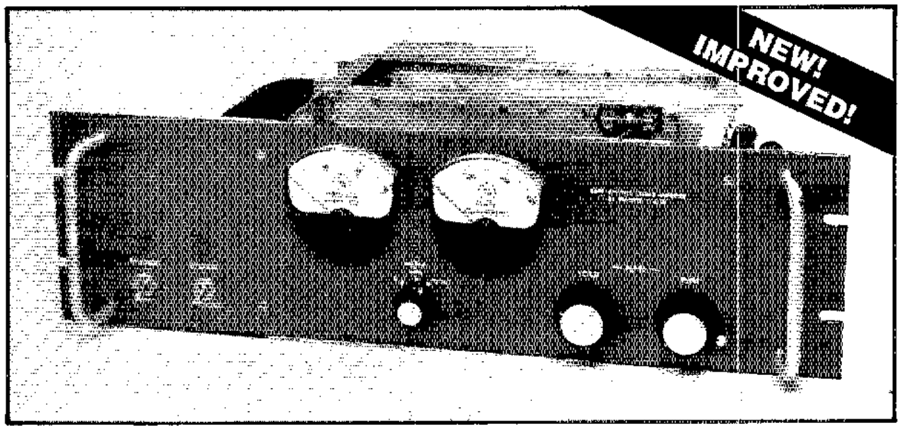
Improving the K1FO 8874 432-MHz Amplifier



The author of a *QST* classic shares some "how-to" tips on improving his design.

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More than 12 years ago I built a 432-MHz amplifier around the EIMAC 8874 triode. A write-up on this 500-W-output amplifier originally appeared in October 1979 *QST* and in several editions of *The ARRL Handbook*.[1,2] This article describes a number of changes and improvements I have made to the amplifier over the years. In addition, I will provide some important construction information to help those building copies of the amplifier. You will need a copy of the original *QST* or *ARRL Handbook* article to follow the discussion here.[3]

Operation with Newer Tubes

The most significant change to the amplifier is necessary because of a revision EIMAC made in the construction of the 8874 starting around 1974, after I had completed my amplifier. Fig 1 shows the original 8874, and Fig 2 shows the newer version. Changes to the grid ring and insulator at the tube base make it easy to distinguish between the two versions.

This physical change had an effect on the electrical characteristics of the 8874: The newer tube has greater input capacitance (20.5 pF nominal versus 19.5 pF), and the output capacitance is lower (6.0 pF versus 7.0 pF). In addition, the new grid ring made for a slightly different seating of the tube in the socket and grid collet I had used in the 432-MHz amplifier. The input and output circuits of my amplifier have enough tuning range to accommodate either tube. When I first tried a new style 8874 in the amplifier, however, I was in for a surprise.

The latest amateur power regulations (1500-W PEP output) encouraged me to try to squeeze a few more watts out of the amplifier. I had been running it with 2000 V on the plate at 500-mA plate current for 1 kW input and 530 W output. I decided to raise the plate voltage to the 2200 V maximum recommended by EIMAC. At the same time, I decided that after nine years of service I would put a new tube in the amplifier.

Operation with the new tube at 2200 V was a shock! I discovered that there was significant tuning drift—resulting in close to 100-W shift in power output from cold to hot. Also, the tuning point for maximum power output was not even close to the plate-current dip. Below 1800 V, amplifier operation with the new style tube was much more stable. Power gain with the new tube was also higher than expected. These symptoms indicated an amplifier that was not neutralized.

At 432 MHz, the 8874 is below, but close to, its self-neutralized frequency. This indicated that the simplest way to neutralize the amplifier would be to adjust the grid inductance. I insulated some of the grid-collet contact fingers with Teflon® tape in various patterns until maximum output coincided with plate current dip. Power shift was now less than 20 W at full output. Power gain dropped by about 2 dB, into the expected range. Satisfied with the operation, I broke off the unwanted fingers from the grid ring. The grid collet now has contact fingers in the pattern shown in

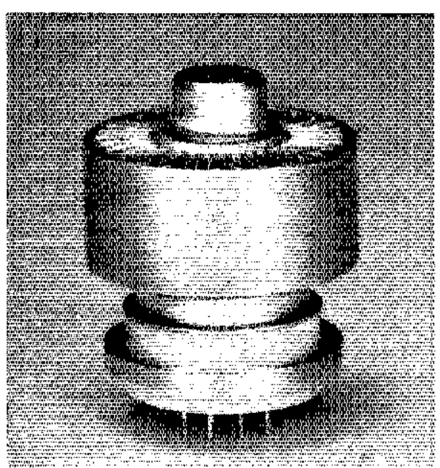

Fig 1—The K1FO 432-MHz amplifier was designed around the original 8874 tube pictured here.

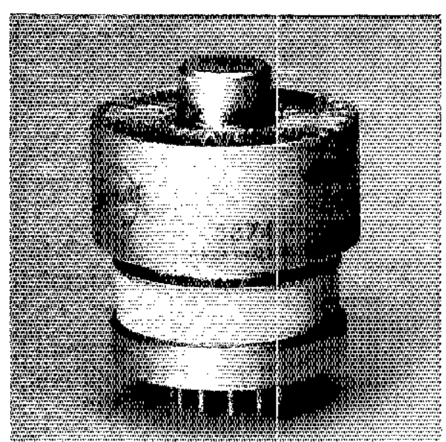

Fig 2—Newer 8874s look similar to tubes of the 4CX250 series. Changes in the physical construction necessitate changes to the 432-MHz amplifier design.

[1]Notes appear on page 23.

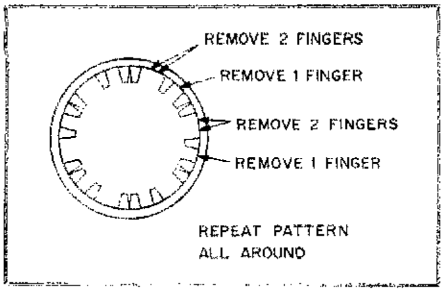

Fig 3—To neutralize the 432-MHz amplifier with a newer style 8874, you must break off fingers from the grid collet in this pattern. See text.

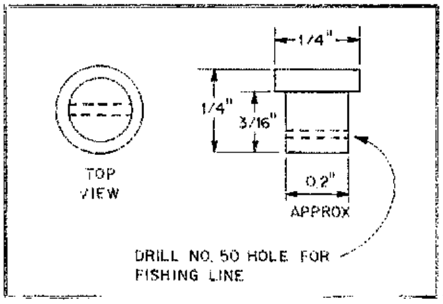

Fig 4—Details of the Teflon button insulator used to attach fishing line to the flapper capacitors.

Fig 3. To modify the collet, first break off every third contact finger. Next, break off one finger from every other remaining pair of fingers. I tried three different new style tubes, and all gave good results with the modified grid collet.

Component Values

Bias Circuit. I experimented with the cathode bias circuitry and decided on a 4.7-V, 10-W Zener diode at D1 (originally 8.2 V) for class AB operation when S4 is in the SSB position. I also changed R2, the D1 load resistor, from 400 ohms to 1000 ohms. This prevents excessive idling plate current. (If R2 is not increased to 1000 ohms, idling plate current will be over 100 mA.)

With these changes, typical amplifier SSB operating conditions at full PEP output are as shown in Table 1. With bias switch S4 set to CW (21 V), the drive power requirement rises to 55 W for 1100 W input and 610 W output.

Table 1

Typical Operating Conditions of the 8874 432-MHz Amplifier

Plate voltage (idling)	2450 V
Idling plate current	55 mA
Bias voltage	4.7 V
Plate voltage (full power)	2200 V
Plate current (full power)	500 mA
Grid current	15 mA
Power input	1100 W
Power output	590 W
Drive Power	36 W
Amplifier gain	12 dB
Apparent efficiency	54 %

R10 and R11. Write-ups in *QST* and *The ARRL Handbook* omitted values for R10 and R11. These are simply bleeder resistors for the relay power supply; the values are not critical. About 10 kΩ, 1 W works fine for each.

High-Voltage Metering. Some builders have observed drift in the calibration of the high-voltage metering circuit over time. This results from too much voltage across the three 1-MΩ resistors (R5-R7) used in the original metering circuit. I replaced R5-R7 with six 470-kΩ, 1-W carbon resistors. (Check a number of 470-kΩ resistors and select a set of six that have actual values totaling 3 MΩ). There is now very little drift in the high-voltage metering calibration. Because approximately 2 W is dissipated by the metering resistors, it's a good idea to drill some cooling holes in the top and bottom covers of the enclosure that houses them.

Grid Current Metering. Another area of confusion has been R4, the grid-current meter shunt. The calculation of this resistance is based on the resistance of M2. For example, if M2 is a 1-mA meter with 45 ohms internal resistance, a 0.45-ohm shunt would make it read 100 mA full scale. More information on meter shunts can be found in Chapter 25 of *The ARRL Handbook.* Don't be too concerned with the absolute accuracy of the grid-current meter. You'll easily be able to wind a meter shunt that will get you within ±5%—that's fine for this project.

In normal operation, the grid current of various 8874 tubes in my amplifier ranged from 5 mA to 35 mA at 580-W output. Grid current should never exceed 100 mA. If greater values are obtained, the amplifier is grossly mistuned or your tube is bad. Since electron transit-time effects come into play at 432 MHz, it is normal to see slight negative grid currents with light loading on the amplifier.

Construction Details

Loading Capacitor. A new flapper-type loading capacitor (C7) will improve the loading range. The new flapper is made from 0.01-inch-thick beryllium copper. It measures ½ inch wide by 1-5/8 inches long, and its edges are rounded. (The original loading flapper was 11/16 inch wide by 1¼ inches long.) Thin material is actually better for the flapper because it is less likely to take a permanent set.

Assembly of the flapper/output connector assembly is straightforward. Using a fine-tooth hobby saw that has a blade thick enough to accommodate the flapper, slot the center pin of RF OUT connector J2. Be careful when sawing the center pin; it is very brittle. Next, mount J2 with its flange on the *outside* of the chassis. Then solder the flapper to the center pin. The movement of the loading flapper is controlled by a fishing line/tuning rod winch system as described in the original article.

Tuning Lines. Another popular question concerns the fishing lines used to control the movement of the tuning (C6) and loading (C7) flapper capacitors. I highly recommend braided Dacron® fishing line. You will probably have to go to a sporting goods store or bait and tackle shop to obtain this material. Most discount department stores only carry monofilament fishing line made from nylon or nylon derivatives. Nylon stretches considerably under tension. Because nylon is a poor dielectric at UHF, nylon lines may heat, soften and stretch—possibly to the breaking point—in the presence of the high RF fields in this amplifier. Several builders who complained of tuning drift had installed nylon fishing line. If you have trouble finding Dacron line, one source is Berkley & Co, Spirit Lake, IA 51360. The line I used is called Specialist® Fly Line Backing and is 18 pound test strength.

The tuning lines are connected to the flapper plates through Teflon insulators. You can make a simple button insulator (Fig 4) by putting a piece of ¼-inch-diameter Teflon into a drill and turning it down with a file. Size it for a press fit into the flapper capacitors. Then drill a small hole through it for the fishing line. This arrangement also provides bumper insulators to keep the flappers from contacting the plate line in case tuning lines break or come untied.

The fishing lines attach to the flapper plates and then pass through the plate compartment chassis to reach the tuning rods that control their movement. To protect the lines from abrasion where they pass through the chassis, I made bushings by removing the center pins from Teflon feedthrough posts. My bushings are a press fit in a no. 28 hole. Although the exact hole size will depend on the feedthrough posts you use, the holes in the chassis must be kept small to maintain the integrity of the shielding.

Safety Choke. I added an RF choke made from 5 turns of no. 16 wire, ¼-inch ID, from the center pin of the RF OUT connector (J2) to ground. This choke prevents damage to your feed line and relays should an arc occur between the plate line and loading flapper.

Anode Bypass Capacitor. The size of the plates for the anode bypass capacitor (C8) was omitted from the original write-up. The actual dimensions of the capacitor plates are not critical as long as the plates are large enough to give adequate capacitance. I used two 3- × 4½-inch plates for C8 in my amplifier. They form a sandwich with the chassis in the middle as shown in Fig 5. Be sure that your plates are flat, the corners are rounded, and that they are polished to a smooth finish. The plate choke (RFC4) that goes between the anode bypass capacitor and the plate stripline should be mounted perpendicular to the plate stripline to minimize stray RF coupling, and not in the position shown in the photographs accompanying the original article.

Standard Chassis. The anode compartment described in the original article was custom made from sheet aluminum and angle stock. For those wishing to simplify construction even further, it should be possible to squeeze the plate circuit for the 8874 amplifier into a standard 5 × 9½ × 3-inch chassis (such as a Bud AC-421 or equivalent). (I have not tried this myself.) Component placement would be similar to that in my homemade chassis. Mount the tube socket 1-5/8 inches from one end. Locate the hole for the RF OUT connector (J2) 7 inches from the end of the chassis closest to the tube socket. Plate tuning capacitor C6 will have to be cut down; a good starting point is 2 inches wide by 1½ inches long. If you need to reduce the plate capacitance further, it may be best to make the flapper narrower because a very short capacitor may put too much tension on the tuning line. Again, if you decide to build the amplifier in a standard chassis, please understand that I will be of limited help to you since I have not built one in that configuration.

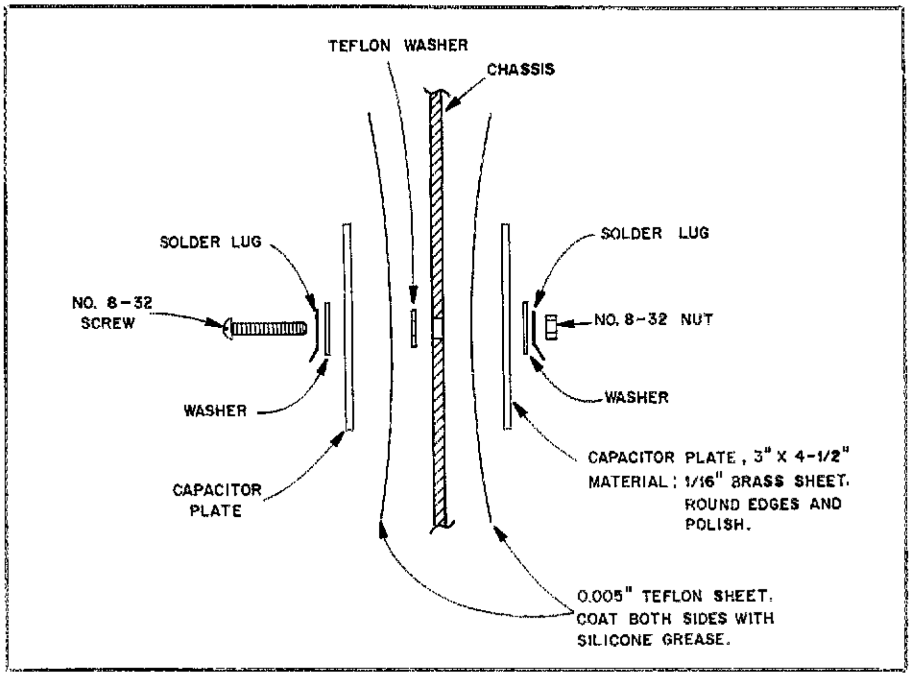

Fig 5—Details of the anode bypass capacitor. See text.

Socket and Grid Collet. I have received many questions about the tube socket and grid collet arrangement. The socket is a Johnson 124-311-100 or Eimac SK-1900. The first order of business is removal of the socket contacts for pins 4, 7 and 11. The grid should be grounded only through the grid collet.

Two different collet arrangements work equally well. Method 1: Punch a 1¼-inch hole in the chassis for the socket. Then drill the mounting holes, using the socket as a guide. Position the socket holes as shown in the original write-up. Countersink the chassis for no. 6-32 screws, and then mount the socket to the chassis using three flathead no. 6-32 screws. Next, drill eight equally spaced no. 33 holes in the Eimac 882931 grid collet flange. Place the collet on the 8874 tube. Then plug the tube and collet into the socket. Finally, mark and drill eight no. 33 holes in the amplifier chassis to match those in the collet. Then mount the collet to the chassis using eight no. 4-40 screws.

An alternate method (simpler, but more expensive) is to use an Eimac 720359 collet assembly. This assembly consists of an 882931 collet soldered to a 1/16-inch-thick brass ring. This whole assembly is silverplated and has three studs to accommodate the mounting flange on the SK-1900 socket. The 720359 assembly is mounted to the chassis using four no. 6-32 screws that pass through predrilled holes in the brass ring.

If you use the 720359 collet assembly, you must file a clearance hole so that the socket mounts directly to the collet. The 3CX800A7 144-MHz amplifier described a few years ago in *QST* and in recent *ARRL Handbooks* shows a suitable cutting pattern.[4,5] If the socket does not mount directly to the collet, the 8874 will sit too low and may contact the bottom of the collet ring. This will negate the neutralization procedure described earlier.

Cathode Circuit. The largest number of questions that I have received concern the cathode circuit. Once you have removed the three unused grid contacts from the 8874 socket as described previously, you will see that the remaining six cathode pins and two heater pins form a symmetrical pattern. Bend the six cathode-pin solder lugs over at a 90-degree angle toward the center of the socket. Make the bend above the dimple that holds the contacts in the socket and near where the hole in the lug starts. Next, tin the six cathode lugs and the short side of cathode line W1. Then simply solder the short side of the cathode line to the six cathode lugs. Cathode choke RFC1, L1 and L2 solder to the top of the cathode line. See Fig 6.

With the circuit built in this way, the input SWR can be tuned better than 1.2:1. If you cannot obtain a good input SWR, check to see if C1 or C2 is at its minimum or maximum. If so, you can try a larger or smaller capacitor as required, or try squeezing or stretching L1 or L2.

Hookup and Operation

Tube Ratings. There seems to be some confusion about the maximum ratings of the 8874 tube. The 8874 is rated at 2200 V and 350 mA plate current, continuous duty. For intermittent SSB and keyed CW service, peak plate current may be 500 mA. For tuneup, the plate current may be run up to 500 mA as long as transmit time is under 30 seconds. A recommended cool-down time between 500-mA tune-up

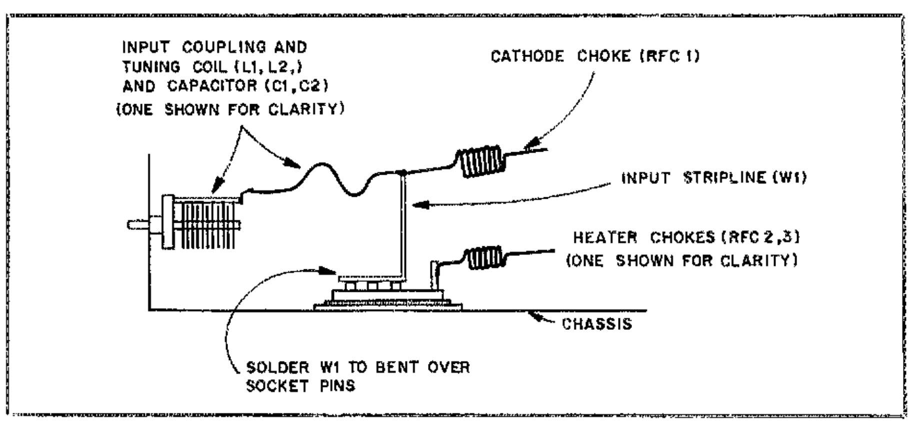

Fig 6—Construction details for the cathode circuit. See text.

sessions is 60 seconds. Keep 500-mA key down times to a minimum for best tube life. Although the minimum specified heater warmup time is 60 seconds, I recommend for best tube life that warmup time be 90 to 120 seconds. For SSB and CW service, the tube heater should be kept at 6.3 V during standby and reduced to 6.0 V during transmit. For continuous-duty modes, such as FM and ATV, the maximum plate current should be no more than 350 mA. The heater should still be maintained at 6.3 V during standby periods, but reduced to *5.7 V* during transmit periods.

Cables. At this power level and operating frequency, it's essential that you use proper coaxial cable and connectors. One builder of the 8874 amplifier traced power-output fluctuations and poor efficiency to a bad cable between amplifier and wattmeter. RG-8 and similar cables are rated to handle only 320 W continuous power at 432 MHz. Such cables will get quite warm if subjected to 600 W of RF at 432 MHz!

Foam dielectric cables in the RG-8 size are also marginal. Although they may have lower loss when new, their attenuation increases with age. In addition, foam-dielectric RG-8 cables generally have significantly less shield coverage than mil-spec RG-213. This inadequate shielding further reduces the power handling capability of the cable. I am also wary of using Belden 9913. Although its claimed and measured loss is significantly lower than RG-8 (2.9 dB versus RG-8's 5.0 dB per 100 feet at 432 MHz), its power rating is no higher than RG-8 cables. (I suspect that 9913's thin film shield cannot handle significant currents at 432 MHz. If this is the case, the inner foil shield would try to carry all the current. The outer braid probably does not have a significant effect on the cable's performance at 432 MHz.)

Use coaxial cable rated for high-power 432-MHz operation for all runs between the amplifier output and the antenna. For runs inside the station, you can use ½-inch-diameter, corrugated-jacket Hardline such as Andrew Corp Heliax™ or Cablewave Systems Cellflex. Andrew Corp also markets ½- and 3/8-inch Superflex cables (part nos. FSJ4-50B and FSJ2-50, respectively), which are especially good when tight bends are required. These cables cost more than RG-8, but they are designed for high-power UHF operation and have 100% shield coverage. Before you start blaming the amplifier for tuning drift, be sure that your cables, relays and antenna feeds can all handle high power at 432 MHz.

Power Measurements. If you intend to do any efficiency measurements, be sure your wattmeter is mounted at the amplifier. Even short lengths of cable have appreciable loss at 432 MHz. Keep the significance of wattmeter accuracy in mind. A Bird Model 43 is specified to be accurate within 5% of full scale, provided source and load impedances are near 50 ohms. In practice, this means if you measure the output of the amplifier at, say, 550 W on your Bird 43 with a 1000-W element, the actual power output could be anywhere between 500 and 600 W—provided that the element is within specification. If your load is not 50 ohms resistive, the power reading could have even greater errors.

I recently compared my Bird 500D (500 W, 200-500 MHz), 1000D (1000 W, 200-500 MHz) and 1000E (1000 W, 400-1000 MHz) elements. They all gave different readings, as shown in Table 2. Want to improve your amplifier efficiency? Change your wattmeter element! Please note that all but one of the Bird elements gave readings within specified accuracy. The efficiency figures quoted in this article are based on measurements made with a Hewlett-Packard HP 432 power meter. The HP 432's RF sample is obtained through a −30 dB coupler in combination with precision attenuators. According to the HP 432, the correct power reading at the level used in compiling Table 2 is 480 W.

Table 2
Comparison of Bird Model 43 Wattmeter Elements

Element	*Reading*
500D	500 W
1000D	460 W
1000E	580 W

I hope that these additional notes on the 8874 432 MHz amplifier clear up many of the questions that those building the amplifier may have. If you decide to build the project, you can be confident that it will work well. More than 50 successful builders can't be wrong!

Notes

[1]S. Powlishen, "A Grounded-Grid Kilowatt Amplifier for 432 MHz," *QST*, Oct 1979, pp 11-14.

[2]The amplifier write-up appeared in *The ARRL Handbook* in Chapter 7 of the 1981, 1982, 1983 and 1984 editions, and Chapter 32 of the 1985 and 1986 editions.

[3]If you can't locate a copy of the *QST* or *ARRL Handbook* write-up of this project, photocopies of the 1986 *ARRL Handbook* version are available from the ARRL Technical Department secretary for a no. 10 SASE and $4. Please refer to this article in your request.

[4]D. Meacham, "A High-Power 2-Meter Amplifier Using the New 3CX800A7," *QST*, Apr 1984, pp 11-15.

[5]The 2-meter 3CX800A7 amplifier write-up appears in Chapter 31 of the 1985, 1986 and 1987 editions of *The ARRL Handbook*.

First licensed as WA1FFO in 1965, Steve Powlishen has been a VHF/UHF devotee since 1969. He is actively involved in the design and construction of VHF/UHF equipment, as well as in weak-signal DXing. Among his operating achievements are 144-MHz WAS, 432-MHz WAC and 432-MHz VUCC, as well as several national first-place single-operator finishes in VHF contests. Virtually all of Steve's current operating is done on 432-MHz EME and tropo. Most of his off-the-air time is devoted to the design, construction and analysis of long Yagi antennas and arrays. Much of his antenna work has been done with computer analysis, and he is particularly interested in correlating real-world measurements with computer models. Steve holds a BSEE from Worcester Polytechnic Institute and is currently employed by Hewlett-Packard as a sales representative for their technical computer line.

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