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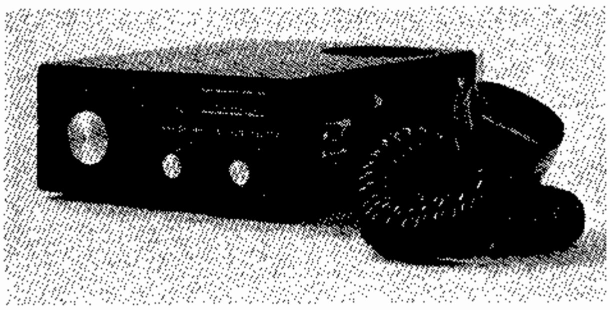


a compact
75-meter monoband transceiver

Modular design yields 30 watts PEP *and* high performance

This article describes a compact monoband SSB transceiver that employs broadband techniques, IC building blocks, and an FET power chain. A detailed block diagram that shows all module interconnections is shown in **fig. 1**. As an extension of an earlier receiver project, the design provides all of the basic features required for convenient operation.[1] The receiver section offers excellent sensitivity and selectivity, audio-derived AGC, an S-meter, headphone or speaker operation, and above-average audio quality. The transmitter has amplified ALC and delivers 30 watts PEP to a 50-ohm load. The completed package is about the size of a 2-meter FM transceiver, measuring 2 × 5 × 6 inches (5 × 12.7 × 15.25 cm) and weighing about 2 pounds (1 kg).

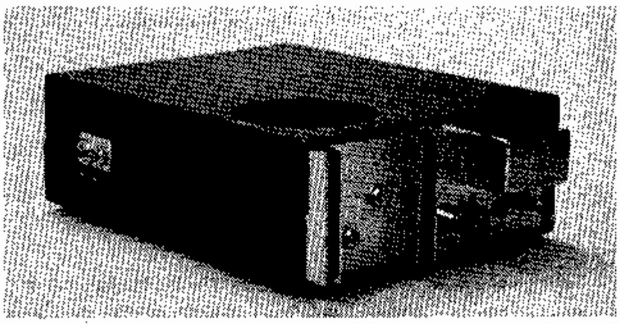
circuit description

The transceiver employs a single conversion frequency plan with a 9-MHz IF and a 5.0-MHz VFO. Receiver preselection is provided by a two-section bandpass filter (see **fig. 2**). Additional HF rejection is obtained from the transmitter's low-pass filter. Receiver mixer U1 is an active DBM which has been biased for maximum gain. Mixer output is fed to crystal sideband filter FL1 through a simple diode switching network.

IF stage U2, shared by the transmitter, provides 45 dB of gain with an AGC range of about 70 dB. Gain for the entire receiver is controlled via U2's AGC line. Automatic control is audio-derived from the output of audio amplifier U4. Manual control is provided by a voltage divider circuit. During the receive cycle, the two control voltages are gated onto the AGC line through diodes. The output of IF amplifier U2 is simultaneously fed to product detector U3 and transmit mixer U7. U3, an active DBM product detector, provides audio detection and additional system gain.

Since gain is controlled exclusively through IF amplifier U2, audio amplifier U4 operates at full gain (see **fig. 3**). U4 provides 400 mW of output — more than enough to drive the transceiver's small built-in speaker. Attenuation is provided for speaker protection and for headphone operation.

AGC voltage is sampled from the output of U4, detected, and fed to DC amplifier Q1. The RC time constant of Q1 is switched to provide slow release time during receive, and fast release time during transmit. Q2 provides additional amplification of the control signal, sets the AGC threshold for U2, and drives meter M1. M1 functions as an S-meter during receive and as an ALC indicator during transmit. The entire receiver section operates from a 12-volt source with an average current drain of only 50 mA on receive.



A small heatsink is sufficient for intermittent SSB operation, but area should be increased for CW operation. Mounting FL1 on rear panel saves internal space.

By Rick Littlefield, K1BQT, Box 114 Barrington, New Hampshire 03825

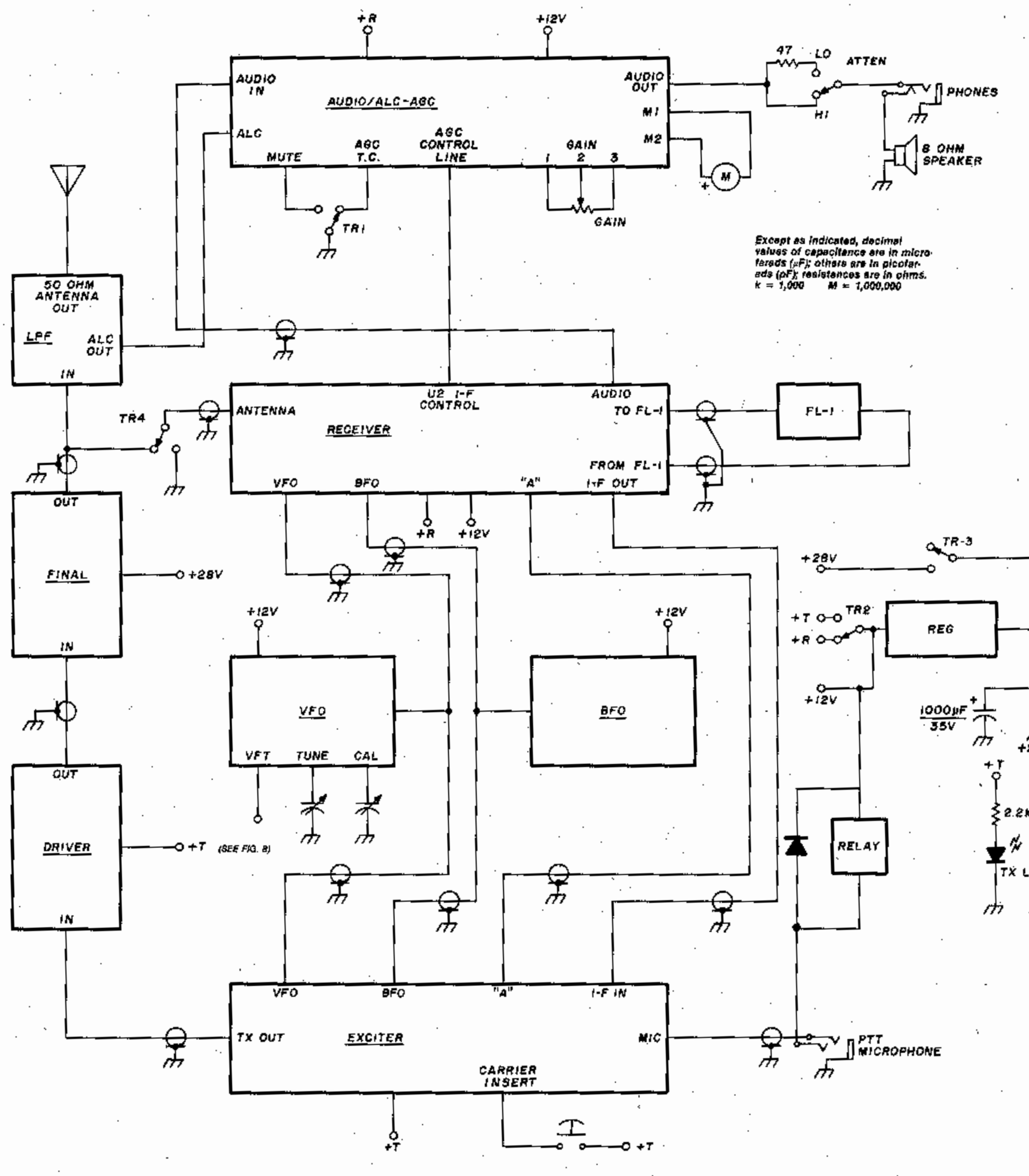


fig. 1. Module interconnections

Low-Z microphone amplifier U5 is a standard op-amp circuit which develops the necessary audio voltage to drive balanced modulator U6 (see **fig. 4**). Like all other mixing devices in the transceiver, U6 is an active DBM. Provisions are made to unbalance the device when carrier is needed for RF chain or antenna tuner adjustment. The output of U6 is fed through a diode switching network to sideband filter FL1 and IF amplifier U2. As noted earlier, ALC voltage is applied to U2 during transmit to maintain high transmitter output without driving the RF chain into saturation.

Transmit mixer U7 combines the IF signal from U2 with VFO drive to produce 75 meter output (a CW-only design would substitute BFO drive for the IF signal). The output of U7 is buffered and amplified by

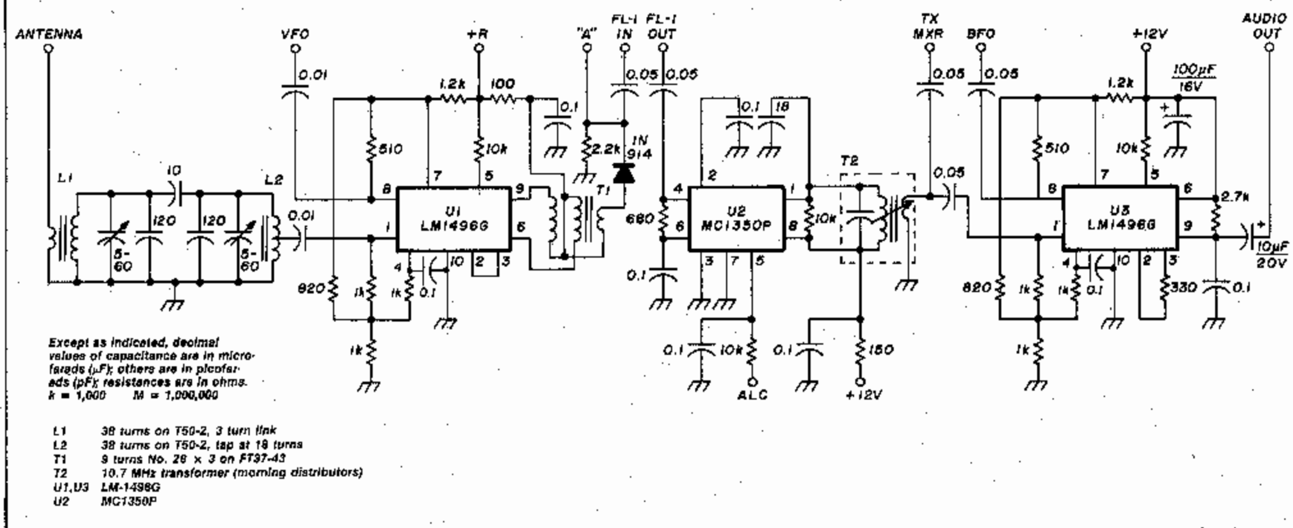
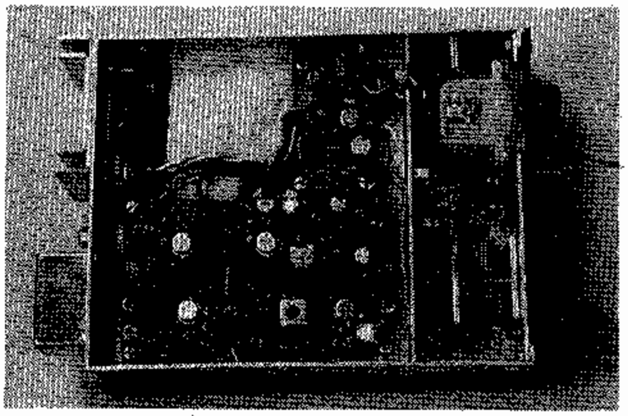


fig. 2. Receiver module. All phasing and combining of transformer leads is done via the circuit board layout. Transformer leads are simply inserted as shown.



Receiver, exciter, and audio modules are located in the top compartment of the cabinet. VFO is in a separate front compartment.

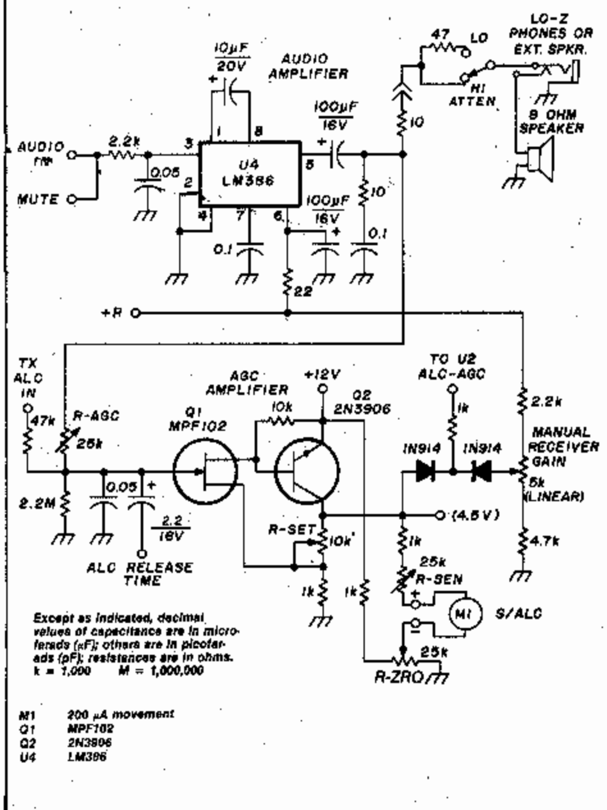


fig. 3. Audio amplifier/ALC-AGC.

pre-driver Q3 (see **fig. 5**). If CW operation is anticipated, keying can be added to this stage by simple modification. Output can be reduced for QRP operation by adjusting the bias on gate No. 2. The output of Q3 is filtered by a two-section bandpass filter. Driver Q4, an inexpensive HEXFET, develops 300 mW PEP — enough power to drive PA Q5. A three-element low-pass filter reduces harmonic content prior to final amplification

The final amplifier Q5 is a Motorola T-MOSFET operating in class AB (see **fig. 6**). At 4 MHz, this 28-volt device operates at approximately 70 percent efficiency, provides 20 dB of gain, and delivers 30 watts PEP into a 50-ohm load. The output of Q5 is transformed to 50 ohms through 4:1 balun T5 and fed into a 7-element Chebyshev low-pass filter. A diode detector at the LPF input samples amplifier output for ALC (see **fig. 7**).

All transmit and receive mixing functions are handled by active DBMs, devices which require no more

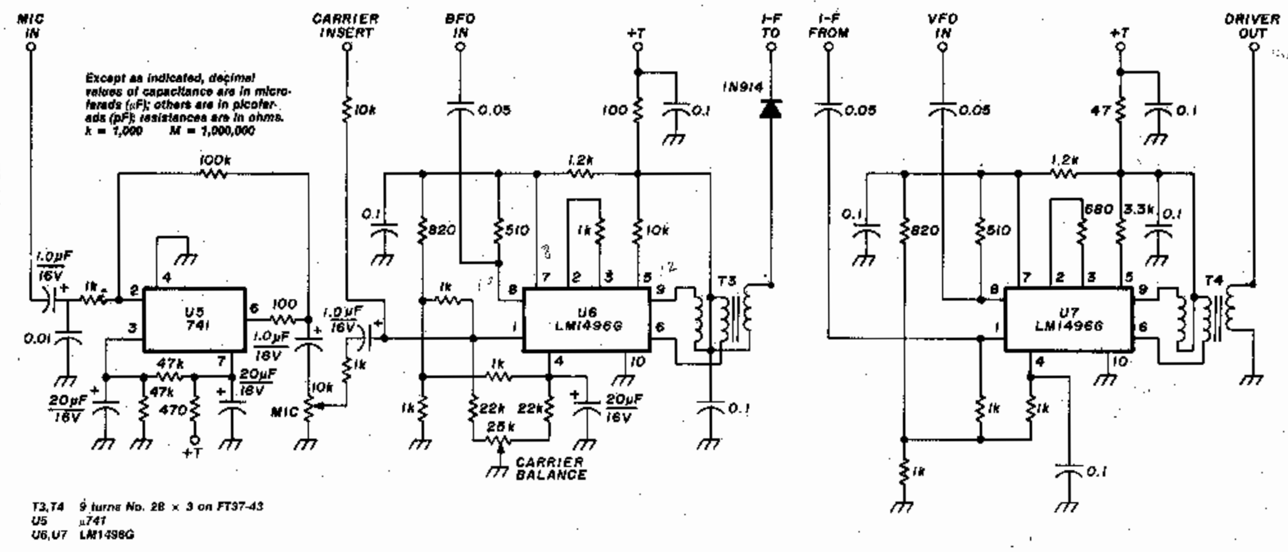


fig. 4. Exciter module.

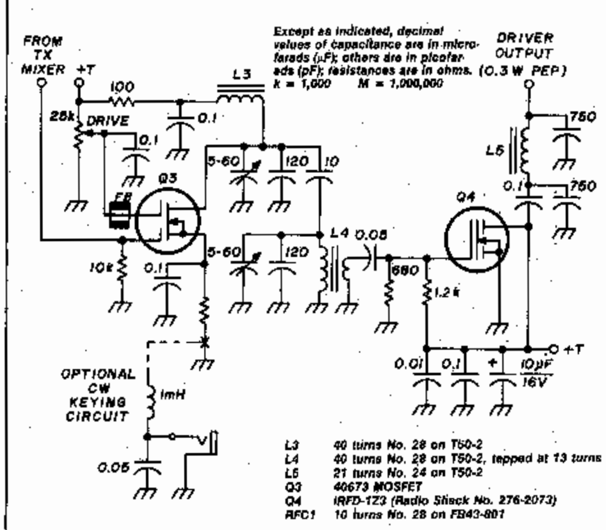


fig. 5. Driver/BPF module.

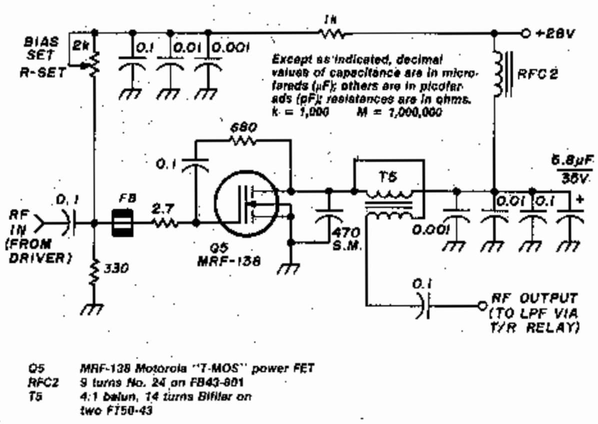


fig. 6. Final amplifier module.

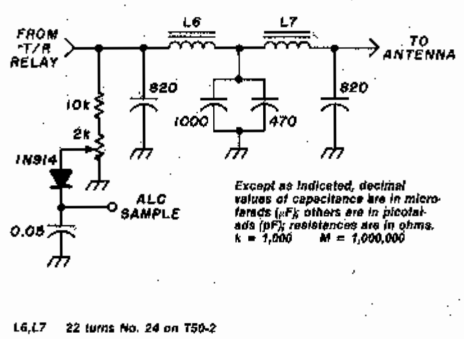


fig. 7. LPF/ALC detector module.

than 100 mV of injection. Consequently, drive demands on the VFO and BFO are minimal. VFO Q6 is a popular Hartley JFET circuit which is buffered by source follower Q7 (see **fig. 8**). An optional VFT control aids fine tuning. BFO Q8 is a simple unbuffered crystal oscillator (see **fig. 9**). If the transceiver is modified for 20 or 15-meter operation, the BFO output should be carefully matched to its load and filtered for harmonic content.

The PA is the only stage requiring a 28-volt source. An on-board monolithic voltage regulator reduces supply voltage to the other stages. The compact 28-volt

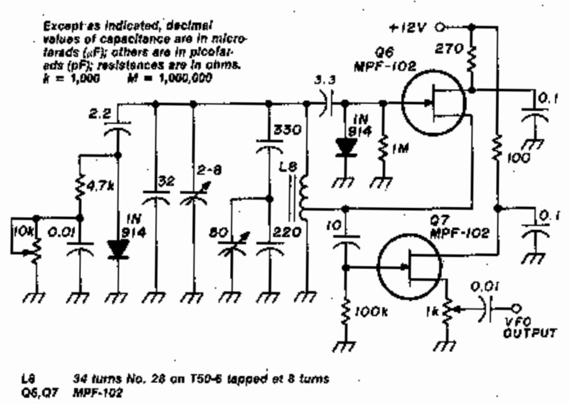


fig. 8. VFO module.

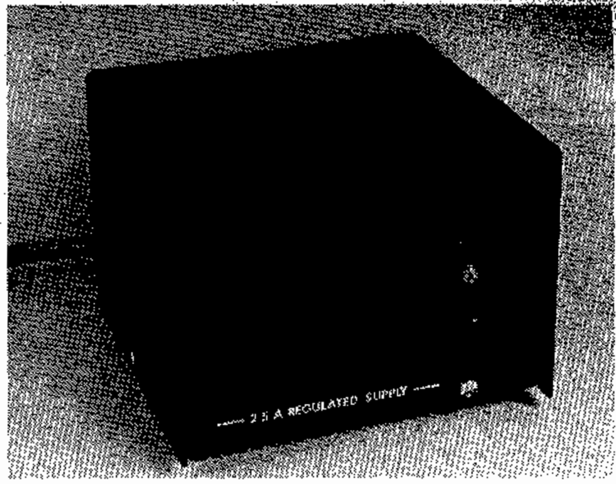


fig. 10. The transceiver's compact power supply measures only 4×3×3 inches (10×7.6×7.6 cm). The design is simple, and can be built entirely from off-the-shelf Radio Shack components.

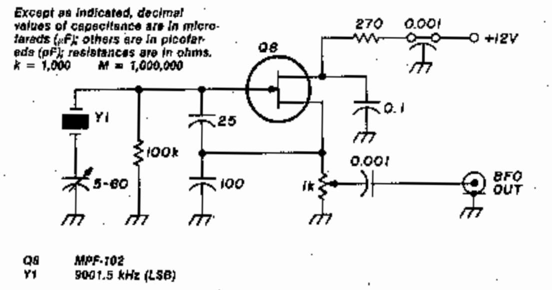


fig. 9. BFO module.

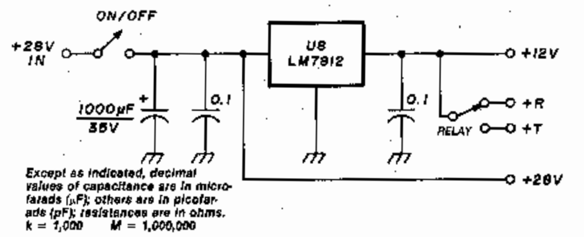


fig. 12. Transceiver on-board regulator.

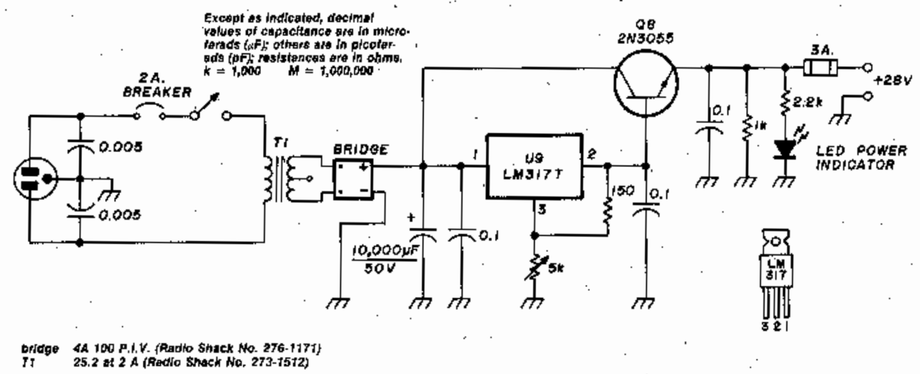


fig. 11. External power supply schematic.

external power supply and schematic shown in **figs. 10** and **11**, respectively, was built from off-the-shelf Radio Shack components. The output of transformer T1 is bridge rectified, filtered, and regulated by pass transistor Q1. Adjustable regulator U1 drives the base of Q1 to set output voltage and to provide additional electronic filtering. An on-board regulator is also incorporated in the transceiver (**fig. 12**).

construction

The boards for this project were laid out in modular strips to facilitate modification during the design pro-

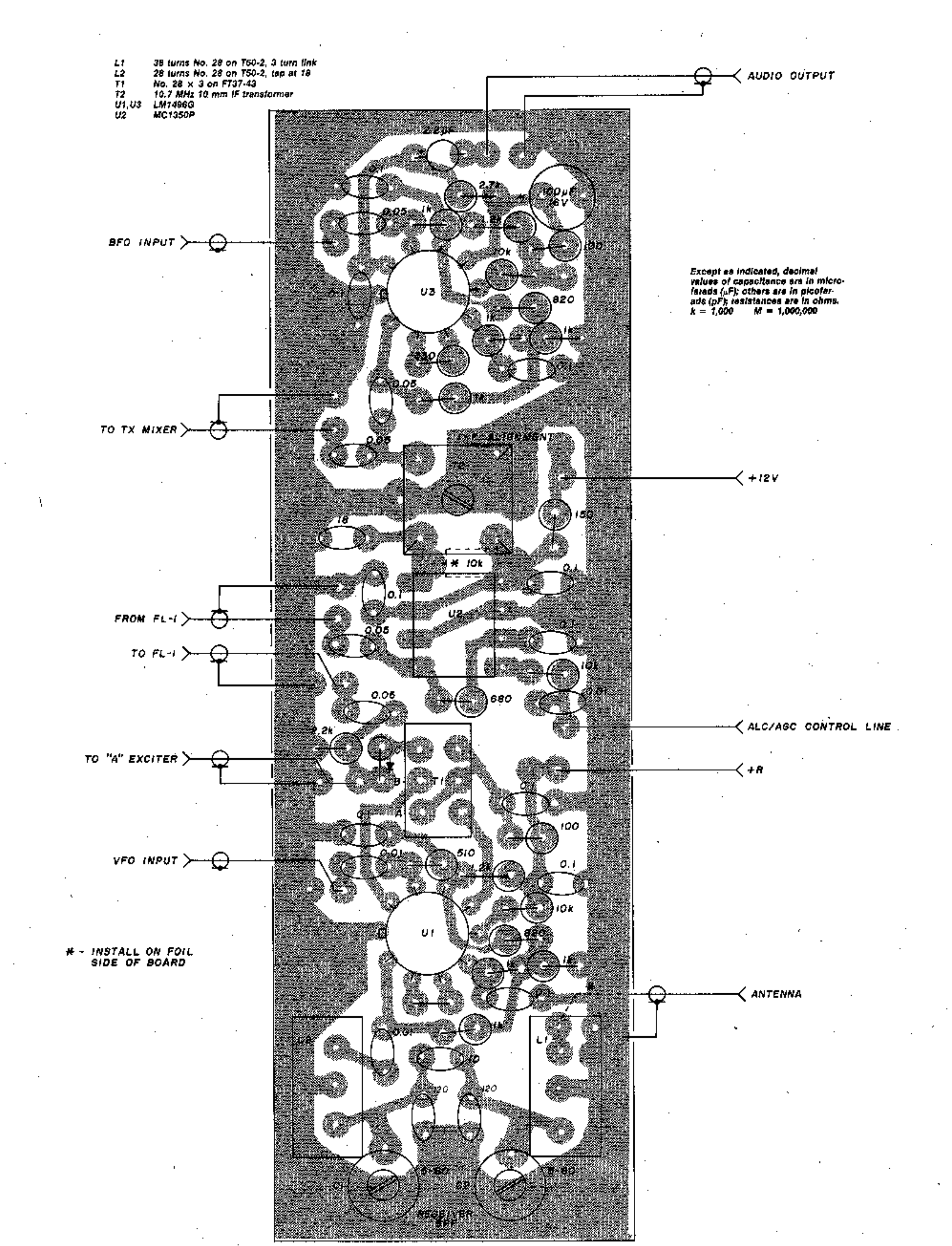


fig. 13. Receiver module.

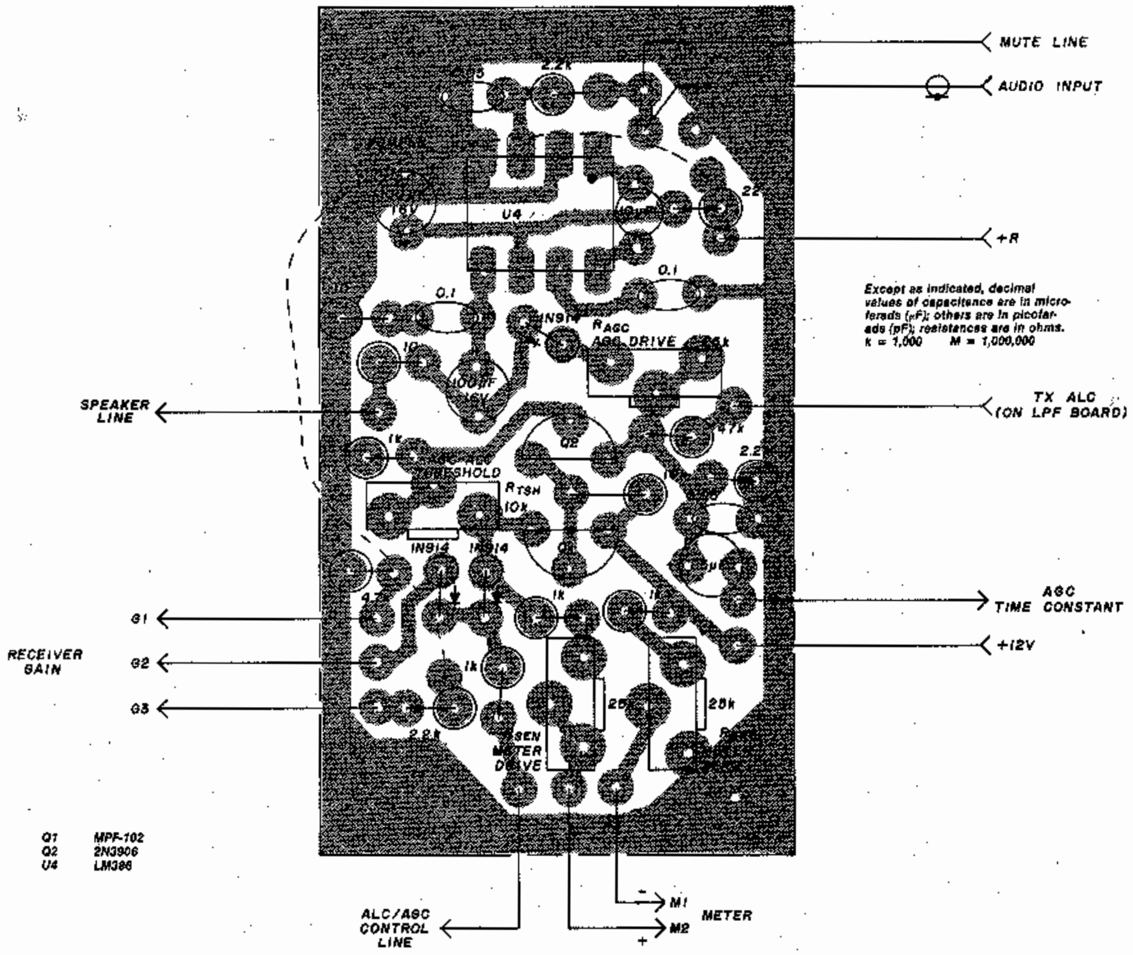
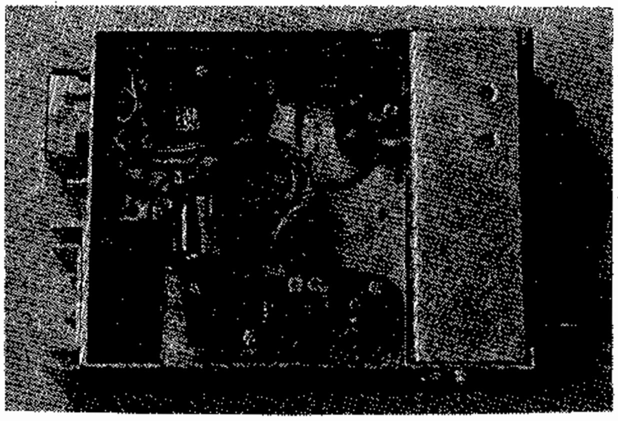


fig. 14. Audio/AGC module.



Bottom view shows BFO, driver, and low-pass filter modules. Voltage regulator is mounted on the side of the case. A 4PDT relay for T-R switching simplifies circuit design and reduces receiver power consumption.

cess. To make the job of interstage wiring easier, the exciter and receiver strips were later joined together.*

Figures 13 (receiver module), **14** (audio/AGC module), **15** (exciter module), **16** (driver/bandpass filter), **17** (MRF-138 final amplifier module), **18** (low-pass filter board), **19** (VFO module), and **fig. 20** (BFO module) show the printed circuit board patterns and component layouts.

Board assembly is routine, but a few specific points deserve mention. The boards were designed around miniature parts. Substituting 1/2-watt resistors, high-voltage capacitors, and other large components can quickly result in overcrowding. Since the parts density is quite high, double-checking parts placement against the schematic or a layout is also recommended.

Use care when winding toroidal transformers and chokes. Most FT (ferrite) cores have rough edges that can easily abrade the insulation from enamel covered

*A complete kit containing all parts, etched pre-drilled circuit boards, punched, painted enclosure, and assembly manual is available from Radiokit, Box 411, Greenville, NH 03048

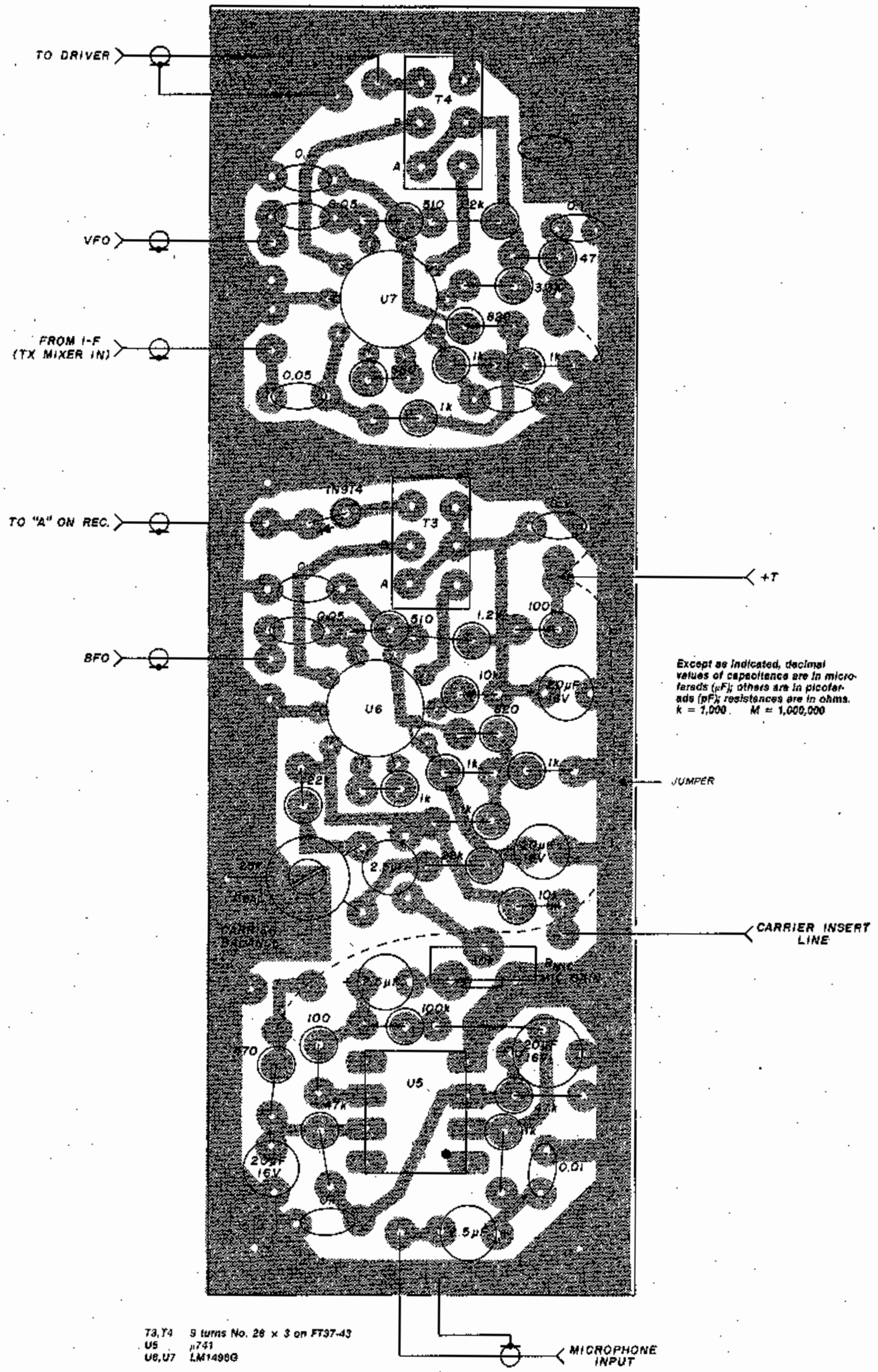
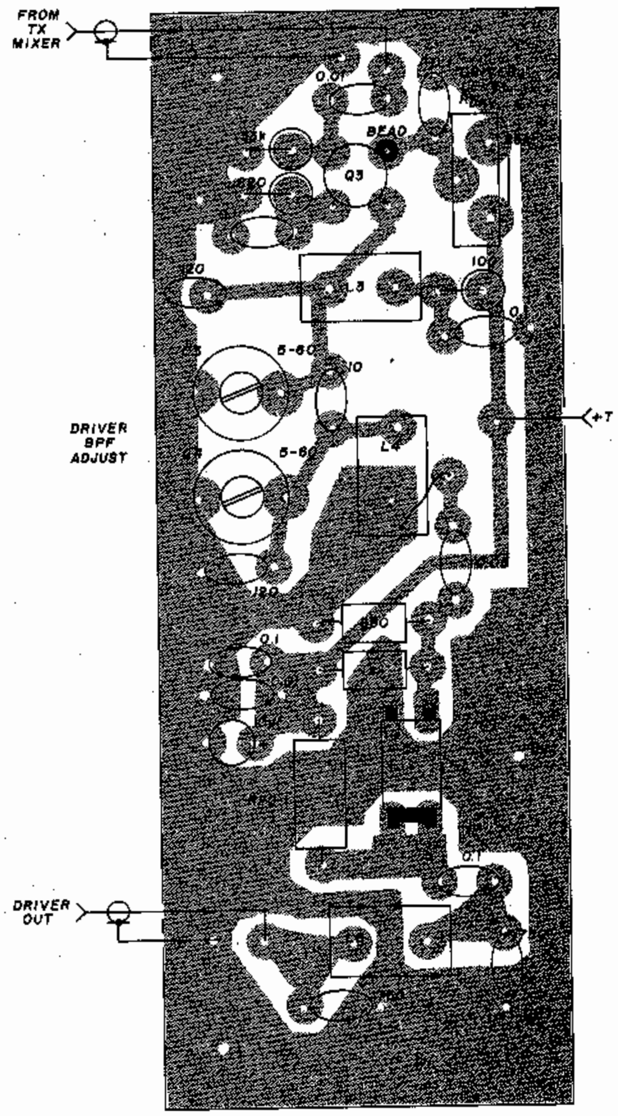


fig. 15. Exciter module.



Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms.
k = 1,000 M = 1,000,000

L3	40 turns No. 28 on T50-2
L4	40 turns No. 28 on T50-2, tap at 13
L5	21 turns No. 24 on T50-2
Q3	40673
Q4	IRFD-1Z3
RFC-1	10 turns No. 28 on FB43-801

fig. 16. Driver/bandpass filter.

wire. Prepare all FT cores in advance by smoothing the corners and applying two coats of clear nail polish ("T cores are usually epoxy coated and require no preparation). Since most toroid devices have delicate leads that are easily broken, they should be mounted last and glued securely to the board with Ambroid™ cement.†

†T2, a 10.7 MHz 10 mm green-core transformer, is available from Morning Distributing Co., P.O. Box 717, Hialeah, Florida 33011.

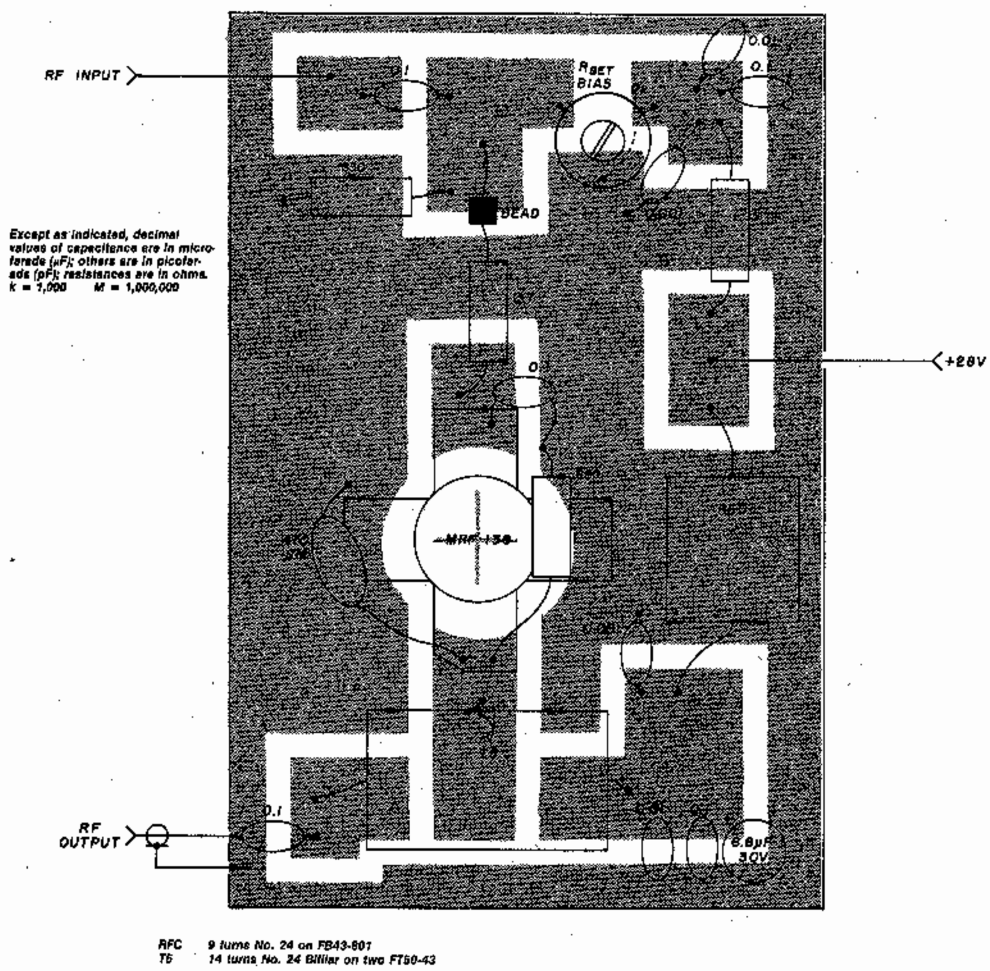
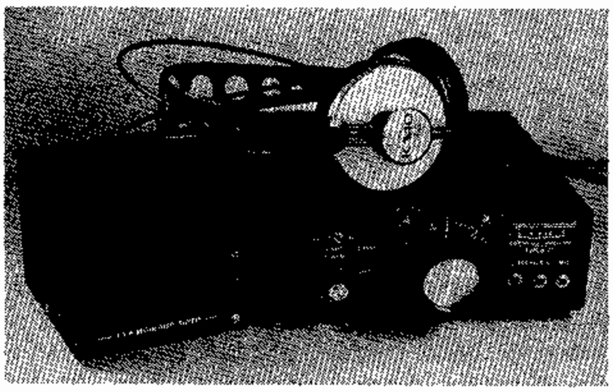


fig. 17. MRF-138 final amplifier.



The transceiver can be packaged to suit the builder. The larger cabinet shown here provides more panel space and room for a larger speaker.

Because the VFO circuit is vulnerable to thermal and mechanical instability, its construction requires special attention. These hints should be followed to insure satisfactory performance:

• Use NPO capacitors in the tank circuit wherever possible — the thermal characteristics of silver mica capacitors are often unpredictable.

• To immobilize VFO inductor windings, dip or paint the coil in clear nail polish and sandwich it to the board between fiber washers with a non-inductive screw.

• To insure smooth tuning, the main VFO variable should be a ball-bearing design with either a built-in or external reduction drive.

• The calibration trimmer should be a miniature air-variable (ceramic trimmers drift).

• When installing the VFO module, make all leads connecting external VFO components as short and rigid as possible.

• To avoid thermal instability, locate the VFO away from heat-generating stages such as the PA and the voltage regulator.

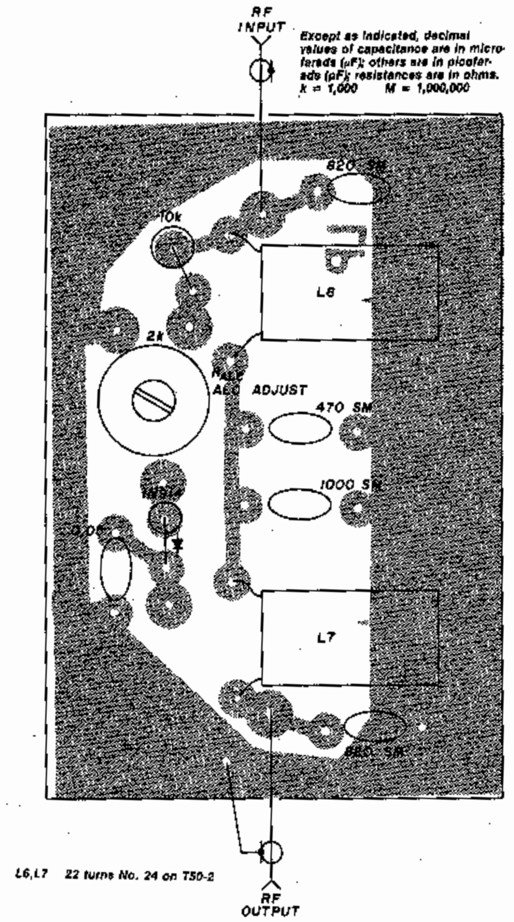


fig. 18. Low-pass filter board.

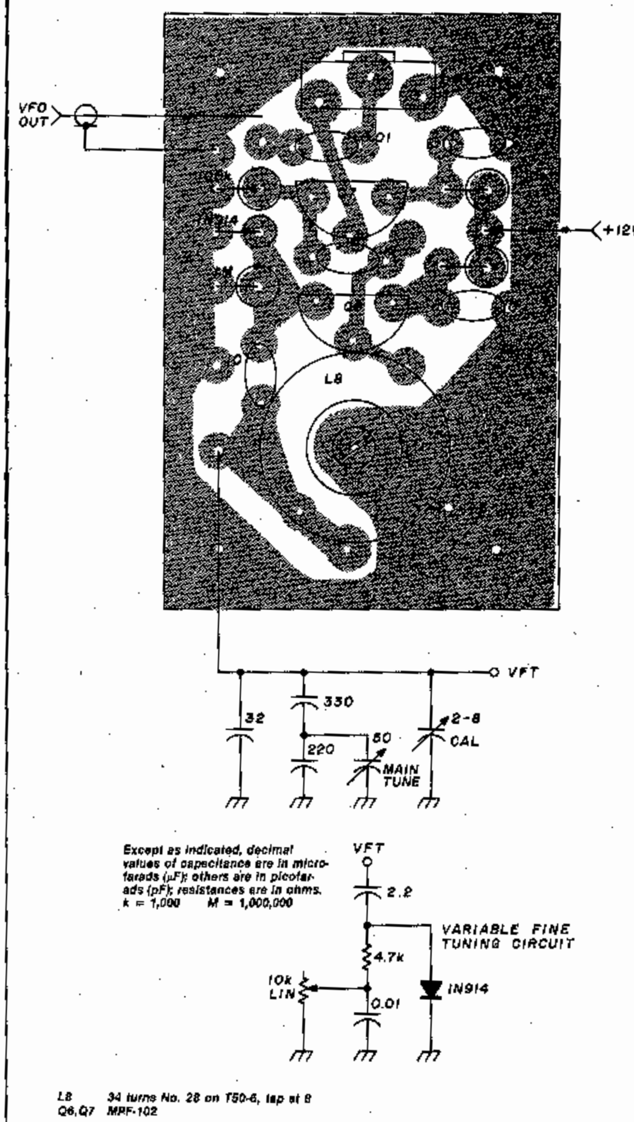


fig. 19. VFO module.

- Shield the VFO compartment against strong RF fields.
- Locate the transceiver's T-R relay away from the VFO compartment. If located too close, the relay's magnetic field will produce an unwelcome frequency shift.

The only other stage requiring special care during construction is the final amplifier. To prevent the possibility of VHF parasitics, strip-line construction is used and components are soldered directly to the top of the board. To insure strong solder connections, each lead should have a short 90-degree bend at its end in order to make flat contact with the board's surface. The transistor should be mounted first. The MRF-138 is an unprotected MOS device, and I recommend using a grounded iron and wrist-strap to prevent static build-up during installation. Once the module is completed, the circuitry will protect the device.

The transceiver cabinet is a bi-level design fabricated in a custom sheet-metal shop. While this packaging contributes to the appearance and small size of the finished unit, much simpler cabinetry is perfectly acceptable as long as a few basic conditions are met. First, all recommendations to insure VFO stability should be observed. Second, the PA module should be mounted to the inside of the back panel with a suitable external heatsink provided on the opposite side. Additional heatsink area is required for extended phone, RTTY, or CW operation. Finally, the VFO and BFO should be fully shielded.

In any modular project, interstage wiring can become a nightmare if the wire is prone to breakage or is difficult to handle. Selecting only highly flexible small-diameter wire and shielded cable keeps interstage harnesses small and manageable. I have found that lavalier microphone cable is smaller and much

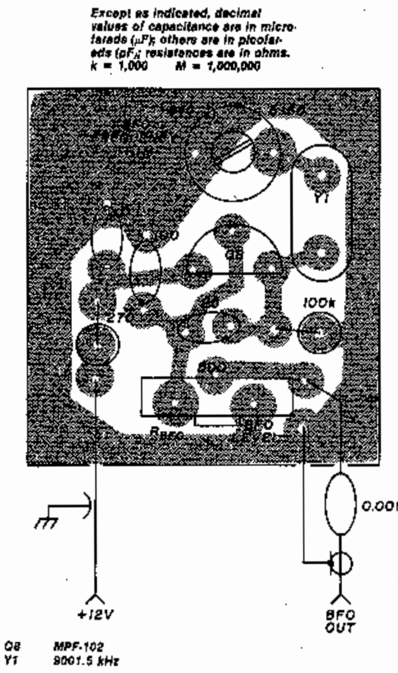


fig. 20. BFO module.

easier to handle than RG-174 miniature coax. Mounting boards on 1/4-inch standoffs also contributes to a neat layout, since this provides space for interstage wiring to pass underneath. Once the modules are mounted and interstage wiring is completed, testing and alignment can begin. Power distribution and T-R switching should be thoroughly checked first, since an error here could damage components.

alignment

Fixed capacitor values in the VFO tank may require some substitution to establish the desired operating range (5000 kHz to 5200 kHz for 4000 to 3800 kHz operation). Once this range is established, a tuning dial can be calibrated. A frequency counter facilitates the calibration process. Once the VFO dial is calibrated, receiver alignment can proceed. Use **fig. 21** to locate the calibration and alignment controls.

- Connect the receive and transmit mixers to the VFO, and adjust R_{VFO} for 100 mV RMS output.
- Connect the product detector and balanced modulator to the BFO, and adjust C_{BFO} for an operating frequency of 9001.5 kHz. Adjust R_{BFO} for an output of 100 mV RMS.
- Set the receiver AGC threshold by adjusting R_{TSH} for 5 volts as measured at TP1. Zero the S-meter via R_{ZRO}.
- Set the receiver gain fully clockwise for maximum gain and adjust IF transformer T2 for a peak in background noise.
- Connect a 50-ohm antenna and tune the VFO to 3900 kHz. Peak bandpass filter trimmers C1 and C2 for maximum sensitivity.

The receiver should now be fully functional. Check AGC action by tuning in an extremely strong SSB signal. If the audio cracks and distorts at full gain, the AGC is under-controlling IF stage U2. Increase AGC gain via R_{AGC} to eliminate this condition. If the audio "pumps" on voice peaks or motorboats with no signal, the opposite conditions exist and AGC gain should be decreased. Meter sensitivity control R_{SEN} should be adjusted so that extremely strong signals register in the upper 10 percent of the scale.

To prepare for transmitter alignment, disconnect the 28-volt supply line from the final amplifier board. Terminate the output of the driver with a 47-ohm resistor and connect a scope across the termination. Microphone gain R_{MIC} should be set fully off, and predriver gain R_{DRV} set to the middle of its range (maximum gain). Tune the VFO to 3900 kHz.

- Key the transmitter and activate the carrier insert switch. Adjust IF transformer T2 and bandpass filter trimmers C3 and C4 for maximum output.
- Key the transmitter and adjust R_{BAL} for minimum carrier output. A receiver tuned to the output frequency may provide a better null indication.
- Connect a 500-ohm dynamic microphone and advance R_{MIC} to 75 percent. Speak into the microphone and watch the scope for signs of instability ("grass" or parasitic oscillations on the waveform). The pattern may show flat-topping on voice peaks, since the ALC is not yet functional.

If instability or parasitics are observed, find their source before going on. Check the RF amplifiers in isolation, and check IF amplifier U2 (reducing the value of the 10-kilohm resistor across the primary of T1 should tame unstable operation in U2). If operation is normal through the driver stage, alignment can continue.

- Connect the 28-volt supply line to the final amplifier board through an ammeter. Short the amplifier's input terminal to ground. Key the transmitter, and adjust R_{SET} for an idling current of 250 mA. Note that this adjustment is sensitive to changes in supply voltage. If the power supply voltage is changed significantly at a later date, the bias should be re-set.
- Remove the driver termination, unshort the input to the PA, and hook up the driver. Connect a 50-ohm dummy load to the output of the transceiver. Place a single turn pick-up loop through balun T5, and connect it to the scope. The driver low-pass filter and bandpass responses are shown in **figs. 22A, B**.

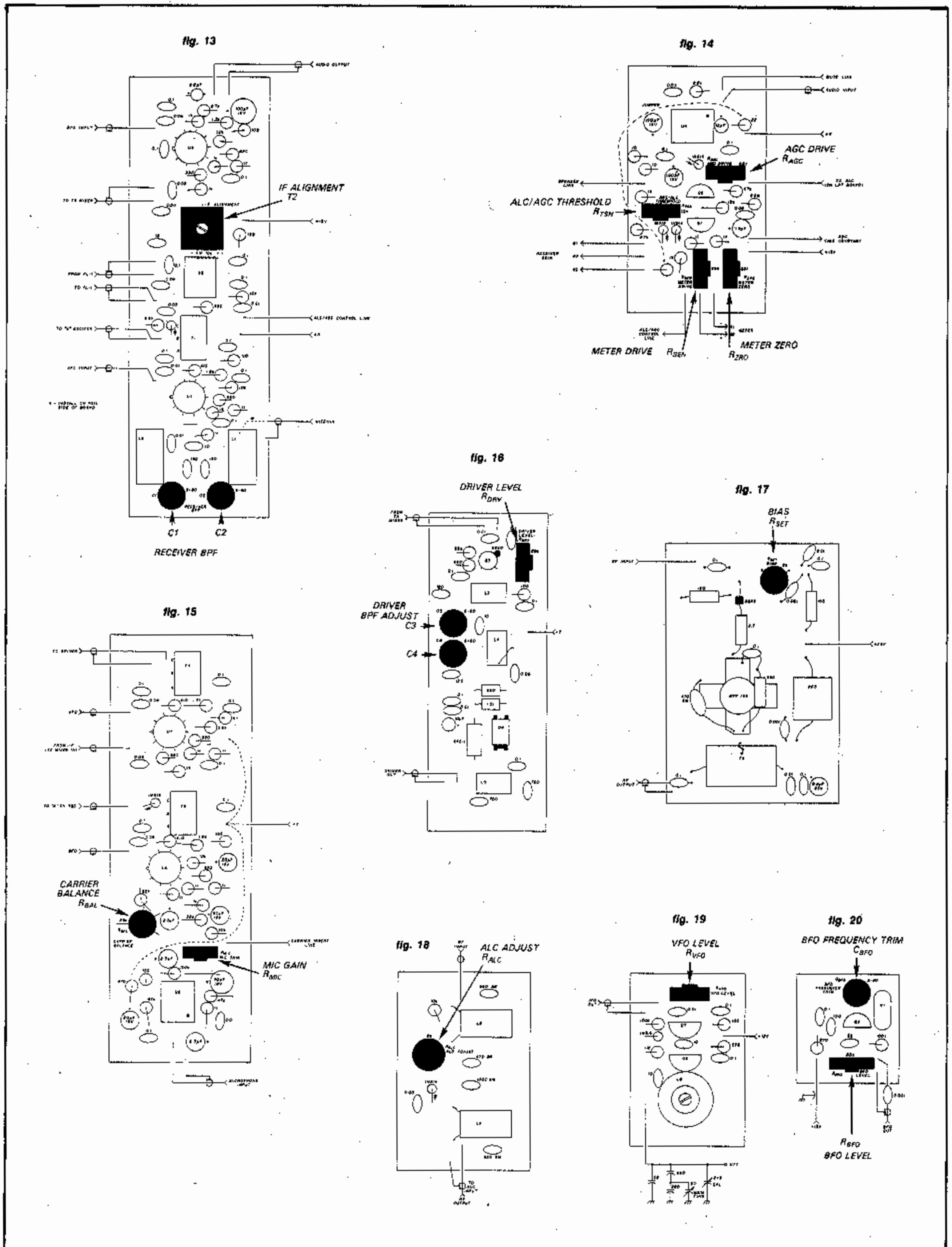


fig. 21. Calibration and alignment controls.

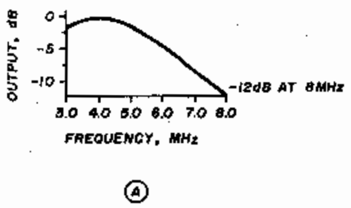


fig. 22A. Driver low-pass filter response.

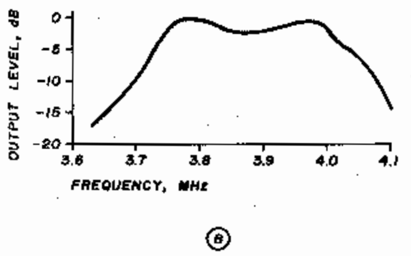


fig. 22B. Driver bandpass filter response.

• Key the transmitter and speak loudly into the microphone, adjusting R_{ALC} for maximum transmitter output. The scope pattern should show flat-topping on voice peaks. If saturation does not occur, increase microphone gain until it does. If the final cannot be saturated, system gain is low and a problem exists (check the AGC threshold voltage at TP1 first; if set above 5 volts, transmitter gain is reduced).

• To set ALC level, close-talk the microphone and adjust R_{ALC} to the point where flat-topping just disappears. The ALC meter should deflect past mid-scale on voice peaks and a power meter should indicate an average output of 10-15 watts.

This completes transceiver alignment.

performance

The transceiver was tested to see if performance approximated industry standards and met FCC regulations for spectral purity. Receiver noise floor was measured at −120 dBm. Selectivity reflected the published specifications of filter FL1. AGC held a 60 dB change in signal strength to a 3 dB change in audio output. AGC attack was a bit slow, resulting in some audible "cracking" on extremely strong signals. This condition is not uncommon in simple audio-derived systems. Overall receiver audio quality was judged excellent when compared against a popular imported multi-band transceiver. Tests for receiver intermodulation distortion were not conducted.

At 30 watts PEP output, transmitter IMD was measured at −30 dB. Second and third harmonics were −47 dB and −55 dB, respectively. Saturation occurred at 35 watts PEP. Transmit audio reports were generally excellent, but microphone selection was an important factor. Low-Z broadcast dynamics produced the best overall quality, but an inexpensive mobile microphone provided a bit more "punch" under difficult band conditions. The MRF-138 final amplifier survived open and shorted port conditions without damage, indicating acceptable immunity to high SWR.

operation

The transceiver's small size makes it a natural for traveling, or for use as a second station at home. Mine resides in a corner of the family room on a small writing desk, close to the wood stove, kitchen, and other comforts of home. On-air performance has been very gratifying. Using an inverted-V antenna at 50 feet, I have worked all U.S. call areas, operated contests, controlled nets, and elbowed my way through evening QRM with excellent regularity. In evaluating the transceiver's effectiveness, it is important to remember that dropping transmitter output from 100 watts to 30 watts reduces the received signal less than 1 S-unit. Under most band conditions, this is not significant.

conclusion

My goal was to design and build a simple monoband SSB transceiver that would be compact, easy to replicate, and powerful enough to provide reliable communication on 75 meters. Off-the-shelf components and contemporary design techniques were employed wherever possible to make the job easier. The transceiver described in this article is my third, and carries with it the experience of the first two. With minor modifications, the design should be transferable to other bands. I hope this article will encourage others to take the plunge and build — there's no magic involved, and the enjoyment that comes from operating a homebrew rig is fantastic.

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