THERE SEEMS TO BE A CRYING NEED FOR a good, low-cost RF signal generator on the average workbench. However, it appears that this is something that no manufacturer has realized yet. For the most part, you have to make do with an under-$100 RF generator that is usually kit-built and quite drifty. To compound the problem, the dial accuracy usually leaves something to be desired, and an external frequency counter must be used for calibration whenever high precision is required. The answer is to buy—or most often to lease—a frequency synthesizer when you need a high-performance RF signal-source. But since prices start at about $3200, owning one usually isn't too practical!

Enter the Programma-2 RF generator. Now, for less than 1/32 of the cost of a commercial model, you can build an RF output is rich in harmonics, allowing frequency coverage into higher parts of the spectrum.

Four thumbwheel switches allow you to set the exact frequency you want with ease; there's no squinting at a tightly packed dial. The switches make it easy to return to a specific frequency, and that makes alignment of equipment a lot easier!

Another important feature is a 50-ohm RF output. This low-impedance output allows you to use such accessories as attenuators, which are a must for low-level RF work. You can't use attenuators on conventional RF signal case, they can be special-ordered, although, since there are two different manufacturers for these parts, finding them may not be as difficult as you think.

Finally, a few words about calibration. Forget about conventional signal-generator alignment procedures. This unit can be aligned using only the built-in error indicator, and a receiver that can pick up one of the WWV trans-

Synthesized RF Generator

GARY McCLELLAN

The Programma-2 synthesized RF generator can be built for about $100, yet offers many of the same features found on commercial units costing over $3000.

generator with many commercial features. You get crystal-controlled accuracy at any frequency you select—typically ±0.0005%, short term. What that means is that if you set the unit for 30.01 MHz, the output is 30,010,000 Hz ± 150 Hz!

Since the unit is crystal controlled and incorporates a frequency synthesizer, any frequency you select will be locked tightly. The prototype drifts less than 10 Hz from a cold start—in an hour of operation. After that, any drift that occurs is negligible.

As far as features are concerned, this project covers a basic frequency range of 3 to 30 MHz in 10-kHz steps. Flip a switch and you get 300 kHz to 3 MHz in 1-kHz steps. Thus, this RF generator covers the frequencies most often used for IF/RF alignment, and for general experimentation. In addition, its RF generators, and that makes some tests (like checking sensitivity) very difficult.

Other features include adjustable RF output, switchable AM/CW operation, and an error indicator.

Construction isn't too difficult, despite the device's many features. The electronics are on three PC boards. RCA-type connectors are used to simplify interconnecting the boards and to make adjustments or servicing easier in the future. The boards are all single-sided (most synthesizers require double-sided boards to keep system noise down) and can be easily made (or purchased—see Parts List).

All components used in this project have been on the market for at least three years, so you should have few problems in obtaining them. The tuning diodes (D201-D203 on the VCO board) may be difficult to locate. If that is the mitters. A frequency counter is helpful, but not necessary.

About the circuit

Let's get acquainted with the Programma-2 RF generator by taking a look at the circuitry. The boards contain a number of different circuits, and the time spent discussing them should pay off. It's hard to build an advanced project like this without knowing much about it. One thing though: you should have a basic knowledge of how frequency synthesizers work to appreciate this discussion. If you have followed my previous articles on synthesizer-type projects (see the June 1980, July 1980, and October 1980 issues of **Radio-Electronics**) you should have no problems.

This device is built on three PC boards—VCO, control, and switch (see Fig. 1). The VCO (Voltage-Controlled

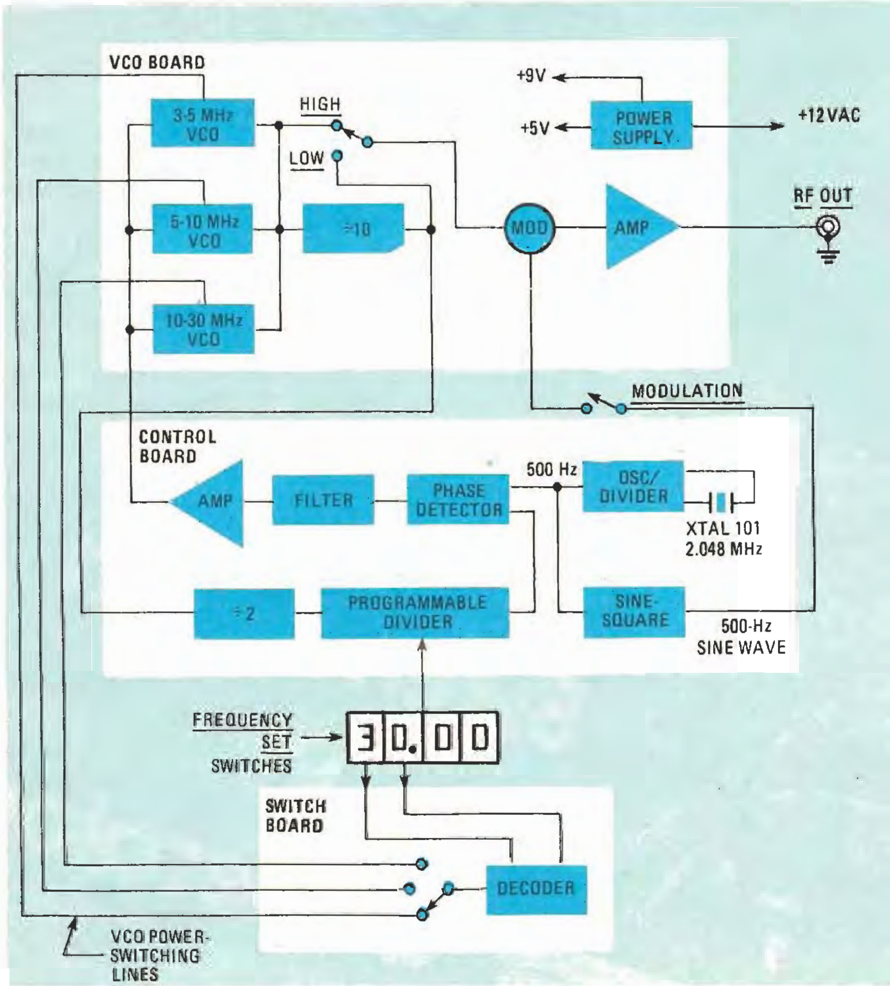


FIG. 1—RF SIGNAL GENERATOR consists of three main sections: control board, VCO, and switch decoder.

Oscillator) board contains the RF-generating circuitry, a divider, an amplitude-modulation circuit, an RF power-amplifier and a power supply. That sounds like quite a bit, but actually each circuit block is very simple. The whole thing uses seven IC's and 1 transistor.

Next comes the control board, which contains a ÷2 divider, a programmable divider, a crystal-controlled reference, a phase detector, loop filter, amplifier, and sinewave converter. All that circuitry is compressed into six IC's and 1 transistor. Isn't IC technology wonderful? It would normally take a big card cage full of boards loaded with discrete components to replace just those small boards!

The last board is the switch board that contains a decoder and switches power to the proper VCO circuit, depending upon frequency.

Let's discuss each board in general, and then cover the control board specifically. The other boards will be discussed in greater detail later.

As you can see from Fig. 1, the VCO board contains the RF-generating circuitry. Three separate VCO's are required to cover a frequency range of 3 to 30 MHz because of the limitations of the tuning diodes used to set the frequency. It is prohibitively expensive today to make a single VCO sweep the entire range; 3 VCO's simplify things and keep the cost down. Following the VCO's, there is a simple divide-by-10 circuit that reduces the VCO frequencies to values needed by the control board. (Also, the output from the divider provides IF range frequencies, extending the range of this instrument down to 300 KHz)

The RF-output range is selected by the HI-LO switch. From that point, the RF signal goes through an amplitude-modulation circuit, which can add a 500-Hz tone to the signal if desired. The RF is amplified by a single-stage amplifier and goes to the RF-OUTPUT connector. The remaining circuitry on this board is a simple 5-volt and 15-volt power supply; the 5-volts is for on-board circuitry, while the 15-volts is for the control board.

The control board is an extension of the VCO board. It receives the divided-down signal from the VCO board, and divides it again by 2. This supplies a signal that the programmable divider can handle easily; such devices trade off speed for programmability. The programmable divider divides the input

PARTS LIST CONTROL BOARD

All resistors ¼ watt, 5%, unless otherwise noted

R101-R115, R123, R124, R131—100,000 ohms
R116, R119—10,000 ohms*
R117—2200 ohms
R118—47 ohms*
R120—150 ohms*
R121—1 megohm
R122—68,000 ohms
R125, R126—33,000 ohms
R127—100 ohms
R128—5,000 ohms, trimmer potentiometer, horizontal PC-mount

Capacitors

C101—0.001 µF, ceramic disc
C102, C103, C114, C115—0.1 µF, 50 volts, Mylar*
C104—22 µF, 16 volts, tantalum*
C105—100 µF, electrolytic, 16 volts
C106-C108—0.1 F,µ16 volts, ceramic disc
C109—100 pF, ceramic disc
C110—220 µF, 6.3 volts, electrolytic
C111—5-35 pF trimmer (E.F. Johnson 275-0430-005 or equivalent)
C112—39 pF, mica
C113—68 pF, mica
C116—0.001 µF, 50 volts, Mylar

Semiconductors

IC101—CD4013 dual D flip-flop with set/reset
IC102—CD4059 programmable divide-by-n counter
IC103—CD4046 phase-locked loop
IC104—78L05 five-volt, 100 mA, regulator
IC105—CD4060 14-stage rippled counter
IC106—CA3130AE op amp (RCA)
Q101—2N3906 PNP
Q102—MPS-A13 Darlington, NPN
D101—1N5229 4.3-volt, 500 mW, Zener diode
XTAL101—2.048 MHz, 32 pF parallel-mode, ± 0.005%, HC-33/U case
S1-S4—BCD thumbwheel switch (C&K 332110000 or equivalent)
J101—8 pin IC socket

Miscellaneous: PC board, IC sockets, 4-conductor ribbon cable, wire, solder, etc.

***Do not substitute**

A complete set of three boards for the Programma-1 is available for $22.00 ppd. from: Technico Services, PO Box 20HC, Orangehurst, Fullerton, CA 92633. CA residents please add 6% tax; foreign orders please add $3.10 for shipping. Order No. SSG-1.

A complete set of *parts,* excluding boards, crystal, transformer and case, is available for $112.00 ppd. from: Circuit Specialists, Inc., PO Box 3047, Scottsdale, AZ 85281. Order No. KT-5. Phone orders (800) 528-1417; all other inquiries (602) 966-0764. AZ residents please add tax.

Crystal (see Parts List) may be obtained from: JAN Crystals, 2400 Crystal Dr., Ft. Myers, FL 33906. (813) 936-2397.

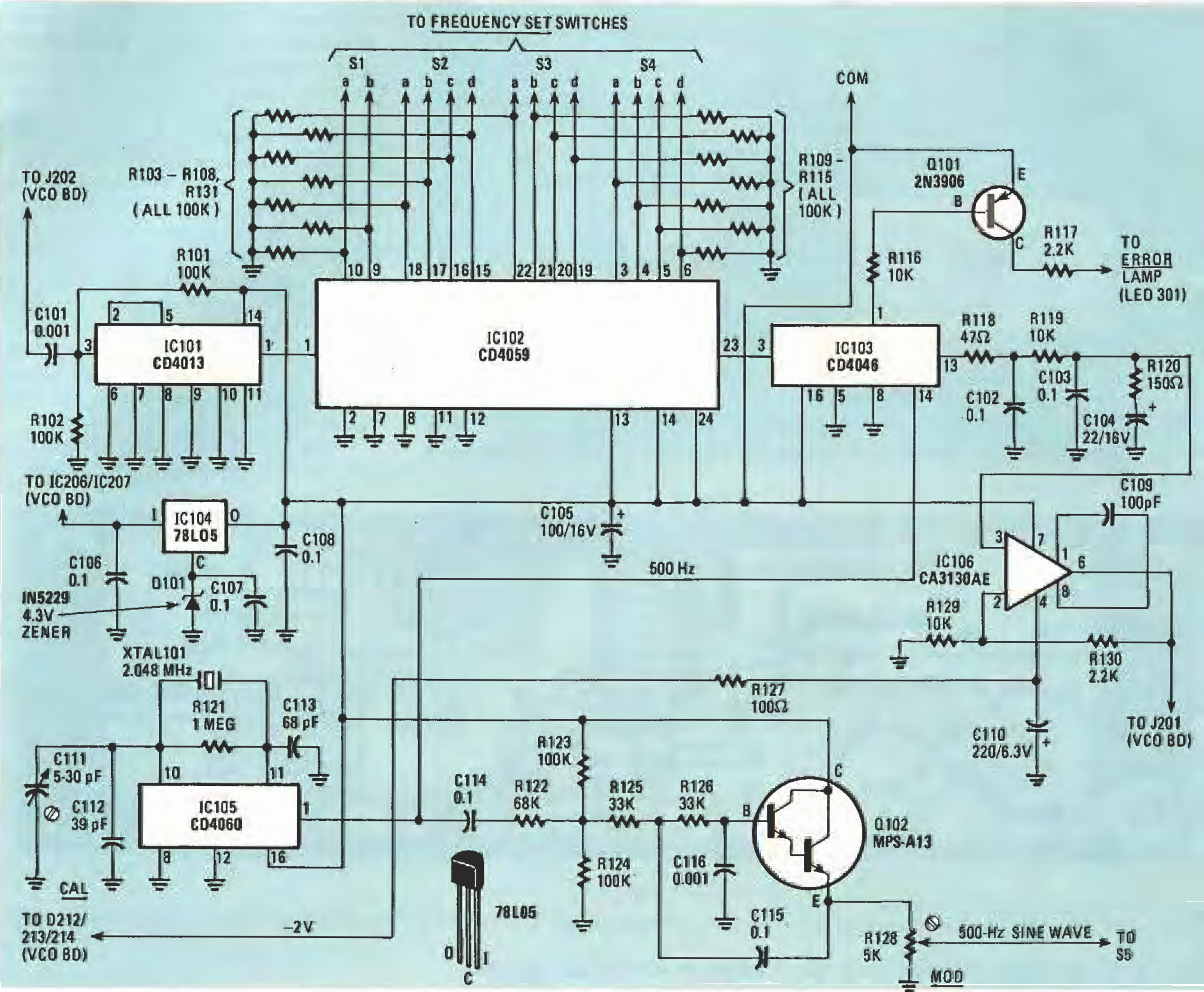


FIG. 2—HEART OF THE CONTROL BOARD is a programmable divider, IC102, used to determine the signal generator's output frequency from the switch settings.

frequency by whatever divisor has been set by the frequency switches, and outputs the resulting signal to the phase detector.

Meanwhile, a crystal-controlled clock circuit generates a 500-Hz signal that drives the phase detector. The detector compares the two signals and outputs error information to the filter, which removes any trace of 500-Hz signal. The DC voltage from the filter is fed to the amplifier, which raises it to levels suitable to drive the VCO's. Thus, the synthesizer loop is completed, and can generate RF signals set by the frequency switches. The remaining circuitry is a square-to-sine-wave converter. All it does is convert the 500-Hz clock-circuit pulses into a 500-Hz sinewave that drives the amplitude modulator, giving a clean-sounding tone.

The switch board is another extension of the VCO board. It selects the one of the three VCO circuits that matches the FREQUENCY-SET switch positions. For example, when frequencies between 03.00 and 05.00 are set on the switches, the 3-5 MHz VCO circuit is selected. Selection of the appropriate VCO is done by decoding the switch postions with a simple CMOS decoder on this board. The appropriate VCO is selected by switching power to it.

Control board theory

Let's discuss the first board to be built. Refer to the control board schematics, Figs. 2 and 3, for details as you read about it. The board uses CMOS IC's throughout. This type of design is used not only to keep power consumption down, but to minimize noise as well. CMOS logic tends to be a lot less noisy than TTL and the RF signal is cleaner. Besides that, CMOS blocks like the CD4059 programmable divider are far easier to work with than their TTL counterparts!

The circuit is quite straightforward. The divided-down RF signal is fed to the board's DIV input and drives IC101, a CD4013 divide-by-2 flip-flop. The input circuitry, C101 and R101/R102, is interesting—it acts as a level-translating interface. The signal at the DIV input is TTL level (0- or 5-volts) and all logic levels on the control board are 0- or 9-volts. Those components bias the CMOS flip-flop to the point where a TTL signal will drive it. The divided output from the flip-flop drives IC102, a CD4059 programmable divider. It divides the input signal by a frequency determined by the settings of the FREQUENCY-SET switches, and outputs the result.

Right now, that IC is one of the simplest and most effective (read "foolproof") ways of making a programmable divider. The output drives IC103, a CD4046 phase detector. The IC compares the signal from the divider with a 500-Hz reference, and outputs correction pulses to a loop filter that smooths them into a DC voltage. That's the job of C102-C104 and R118-R120. The phase detector also has an output that goes low when the two inputs are unequal. That drives transistor Q101 and lights the ERROR lamp on the front

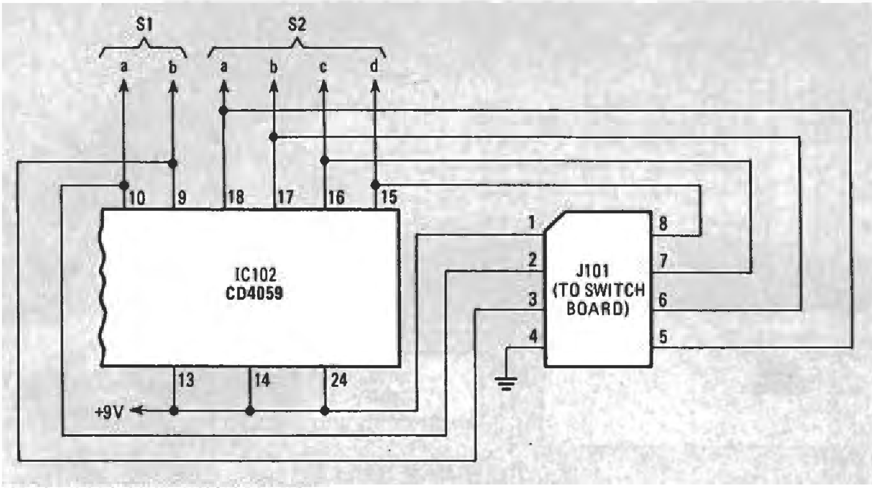


FIG. 3—PARTIAL SCHEMATIC of the control board, showing connections to J101 (to which the switch board connects).

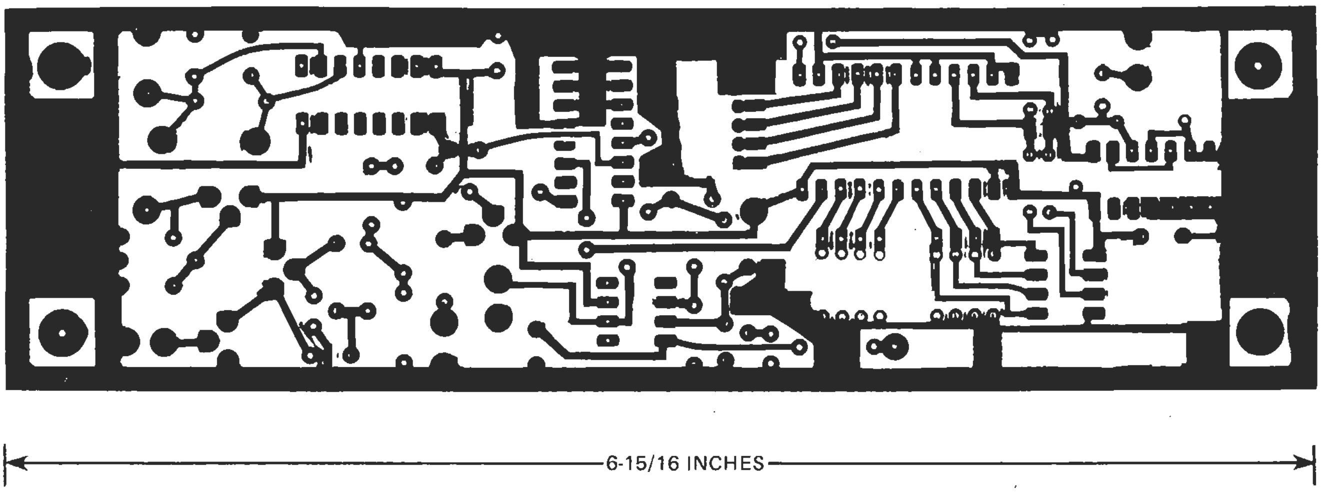
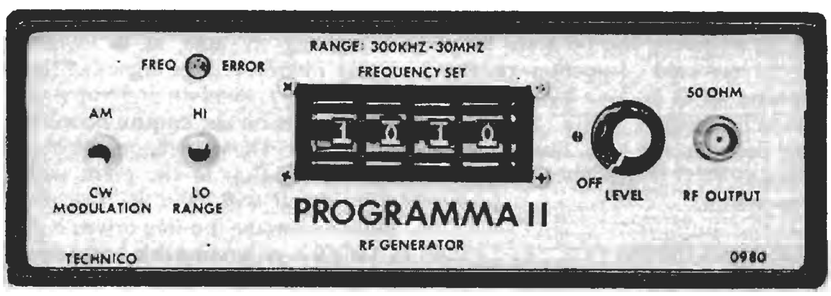


FIG. 4—FOIL PATTERN for the control board. Prepared boards are available—see Parts List.



FRONT PANEL of the completed Programma-2 synthesized RF generator. Its layout gives the unit a professional appearance.

panel. The user can easily tell if the instrument is putting out the right frequency or not.

The loop filter's output drives IC106, a CA3130 op-amp. That device is used to increase the voltage from the loop filter so that it can drive the tuning diodes on the VCO board. It's just a noninverting amplifier with a gain of 2.2.

The 500-Hz reference signal is generated by IC105, a CD4060 oscillator/divider circuit. That IC has a Pierce crystal-oscillator that works with XTAL101 to produce a 2.048-MHz signal. The signal is divided down to 500 Hz by a set of binary dividers. The 500-Hz output serves as the phase-detector reference, as outlined earlier, and generates clock pulses for the square-to-sine-wave converter.

Capacitor C114 and resistor R122 integrate the squarewave into a rough triangle wave that is then filtered into a smooth sinewave by the Q102 circuitry. The output, which appears at the MOD terminals, goes back to the VCO board where it can be used to amplitude-modulate the RF signal, if desired. Rounding up the circuitry on this board is a simple 9-volt regulator that uses IC104, a 78L05 5-volt device. Since 9-volts is required, D101, an 1N5229 4.3-volt Zener, is inserted in series with the regulator to raise the voltage to the correct value.

Construction

The control board foil pattern is shown in Fig. 4. (A complete set of all three PC boards is available for those who do not wish to make their own. See Parts List.) Do not attempt to use point-to-point wiring techniques—the result will be a noisy RF signal.

A few tips on the quality of parts you use should be mentioned. When it comes to substitutions, this project will tolerate *some* departure from the values called out. However, it isn't a good idea to make substitutions for the parts marked with an asterisk in the Parts List. Most of those components are in the loop filter, and deviations in value or quality will affect performance. Be sure you use Mylar capacitors where specified (those green capacitors often found in transistor radios). Also be sure to use tantalums where called for; other types may be too leaky and that will make the RF signal noisy. Be sure to get top quality parts and the instrument should give excellent performance and long life.

You may want to order the 2.048-MHz crystal right away. Generally, such crystals are made to order, and it takes about a month to get them. Give the supplier the specifications for XTAL101, and you should have one shortly. Price? About $5.00.

Next month, we'll finish building the Programma-2's control board and show you how to connect the unit's front panel FREQUENCY-SET switches to the board. **R-E**

Synthesized RF Generator

GARY McCLELLAN

This month we'll show you how to assemble the Programma-2's two main boards. When we're done, the RF generator will be nearly complete.

Part 2

WITH THE THEORY OF operation of the Programma-2's control board out of the way (it's always helpful to know what you're doing) we can now start work on the board itself.

Position the board as shown in Fig. 5 and start construction by installing the 24-pin IC socket. After that, install 16-pin sockets in the IC103 and IC102 positions. In the same manner, install a 14-pin socket at IC101 and then two 8-pin sockets at IC106 and J101. Tha takes care of the IC sockets.

Install crystal XTAL101 next. Push it flush against the board and quickly solder the leads. Don't apply excessive heat, or you may crack the seal.

Now you can install the 100K resistors around IC102. Insert R108 and R107 first, then solder and clip the leads. Then install the group of four just below. Start with R104, continue with R105, and R131, and end with R106. Solder each connection and clip the leads. Then move to the right, and install another group of four resistors, beginning with R111, continuing with R110 and R109, and ending with R103. Solder and clip. Finally, move up and install the last group of four resistors in the same manner. Note that this group starts with R115 and ends with R112.

Continue with the rest of the resistors. Refer to Fig. 5 for details. Starting at the top left corner, install 100K resistors at R101 and R102. Then move down below IC102 and install a 100-ohm resistor at R127. Move to the right slightly and install a 150-ohm unit at R120. Keep going right and install 10K resistors at R119 and R129. After that, install a 22K resistor at R130. Stop for a moment and check your work. There should be spaces left for C104 and C103. Continue by moving to the right and installing a 47-ohm resistor at R118. On the other side of IC103, install a 10K unit at R116. Move down and install a 2.2K resistor at R117. Keep going by installing the remaining 100K units at R123 and R124. Install 33K resistors at R125 and R126. Then move up slightly and install a 68K unit at R122. Install a 1-meg resistor at R121, next XTAL101. That takes care of the resistor installation, and the board is now taking on a finished appearance.

There are five wire jumpers on this board, and they should be installed next. Use leftover resistor leads. The jumpers are identified with a "J" in Fig. 5. Install the first two as shown between IC101 and IC102. Bend the leads to fit with needle-nosed pliers, and insert them into the holes. Make sure they aren't touching, then solder and clip off the excess lead. Install the next jumper near pin 1 of IC102. Move to pin 1 of IC103, and install a jumper just below it. Finally move over to pin 1 of IC105 and install the last jumper.

Now for a few odds and ends. Start by installing C111, a 5-30 pF trimmer, by the crystal. Before installing it, turn it over and identify which pin goes to the adjusting screw. This pin must go the ground foil, and is usually wider than the other pin. Insert the trimmer so that this pin points up, and solder. Then install R128, a 5K pot. Install as shown, being sure to press it flush against the board before soldering.

Next come the transistors. Start with Q101, a 2N3906. Install it as shown next to IC103, with the flat side pointing down. Then install Q102, an MPS-A13, as indicated next to the pot. Be sure to position the case so that the flat spot points to the right. Finish up with the power-supply components. Install IC104, a 78L05 regulator, as shown, next to the crystal. Be sure the flat side of the case is pointing down. Then install D101, a 1N5229 Zener diode near the right edge of the board. Note that the banded end points toward the center of the board. Stop at that point and double check the installation of the parts. It's a good idea to correct any mistakes before going any farther!

All that's left are the capacitors. They will be installed like the resistors, from left to right in Fig. 5. Start by installing C101, a 0.001 μF disc above IC101. Then install C108, a 0.1 μF disc, on the other side of the IC. Keep going and install C104, a 22 μF tantalum type. Note that the "plus" side faces R120. After that, install 0.1 μF Mylar capacitors at C102 and C103. Continue by installing C110, a 220 μF electrolytic. Note that the "plus" side faces the edge of the board. At the other edge, install C105, a 100 μF electrolytic. Be sure the "plus" side faces the center of

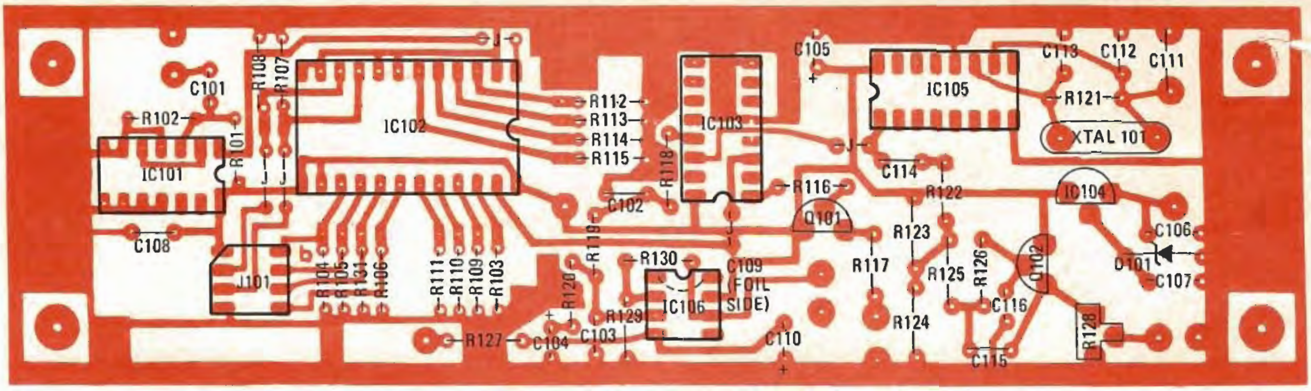


FIG. 5—STEP-BY-STEP assembly instructions are given in the text. Don't forget to install the five jumpers.

the board. Move down and install C114, a 0.1 μF disc next to IC105. Keep going down, and install C115, a 0.1 μF Mylar capacitor near the pot. Then, just above this capacitor, install C116, a 0.001 μF Mylar capacitor. At the top of the board install C113, a 68 pF mica. And right next to it, install C112, a 39 pF mica unit. Finish up by installing two 0.1 μF discs on either side of D101 at C106 and C107.

Stop at that point and check your work. Make sure the capacitors are installed in the proper places, and that the polarized ones are oriented properly. Correct any mistakes before going any farther. The board should look like the one in Fig. 6.

Turn the board over and install C109 (100 pF) on the foil side, between pins 1 and 8 of the IC106 socket. Trim the leads to about 1/4-inch first, then solder

FIG. 6—COMPLETED CONTROL BOARD. Light-colored ribbon cables around 4059 IC go to switches. Dark cables will be added later.

across the pins as shown. Bend the capacitor so that it is flush with the board. This completes the control board.

Switch connections

Now is a good time to connect the FREQUENCY-SET switches to the board, and install the IC's. Those switches, S1-S4, are the ones that mount on the front of the instrument and program the desired frequency. All wiring is done around IC102.

Refer to Figs. 7 and 8 for details as you wire the switches. It is suggested that you use short lengths of 4 conductor cable for the connections; this makes the wiring easier to follow and less messy.

The first step is to prepare the cables. Prepare four six-inch strips. Then remove two conductors from one of the strips. Separate the ends of all cables for at least 1/2-inch, then strip and tin the ends. Also cut a 6-inch piece of hookup wire and strip and tin its ends. Now you are all set for the wiring.

Look carefully at your switches' terminals. They should be marked: "C, 1, 2, 4, 8," "COM, A, B, C, D," or similarly. Run a piece of bare wire through all the "COM" lugs and solder at each. Then solder one end of the single piece of hookup wire to one of the common lugs. Now turn to the front of the switches, positioning them so you can read them. The switch position to the farthest left is S1. Connect the two-conductor cable to the "A" and

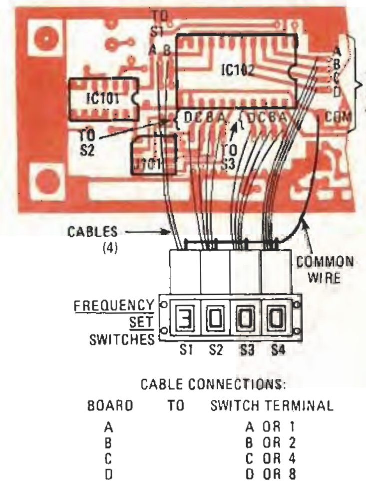


FIG. 7—DETAILS of board/switch connections. They're not difficult—just match up the letters.

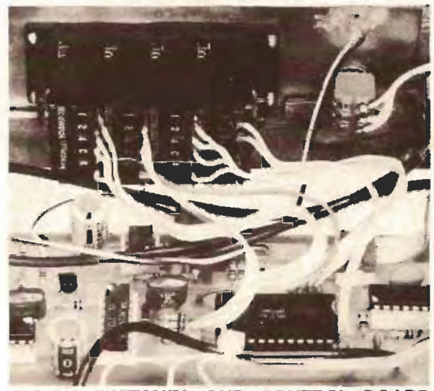


FIG. 8—SWITCHES AND CONTROL BOARD mounted in case. Usefulness of ribbon cable is obvious.

PARTS LIST
CONTROL BOARD

All resistors ¼ watt, 5%, unless otherwise noted.
R101-R115, R123, R124, R131—100,000 ohms
R116, R119—10,000 ohms
R117—2200 ohms
R118—47 ohms*
R120—150 ohms*
R121—1 megohm
R122—68,000 ohms
R125, R126—33,000 ohms
R127—100 ohms
R128—5,000 ohms, trimmer potentiometer, horizontal PC-mount
Capacitors
C101—0.001 F, ceramic disc
C102, C103, C114, C115—0.1 F, 50 volts, Mylar*
C104—22 F, 16 volts, tantalum*
C105—100 F, electrolytic, 16 volts
C106-C108—0.1 F, 16 volts, ceramic disc
C109—100 pF, ceramic disc
C110—220 F, 6.3 volts, electrolytic
C111—5-35 pF trimmer (E.F. Johnson 275-0430-005 or equivalent)
C112—39 pF, mica
C113—68 pF, mica
C116—0.001 F, 50 volts, Mylar
Semiconductors
IC101—CD4013 dual D flip-flop with set/reset
IC102—CD4059 programmable divide-by-n counter
IC103—CD4046 phase-loced loop
IC104—78L05 five-volt, 100 mA, regulator
IC105—CD4060 14-stage rippled counter
IC106—CA3130AE op amp (RCA)
Q101—2N3906 PNP
Q102—MPS-A13 Darlington, NPN
D101—1N5229 4.3-volts, 500 mW, Zener diode
XTAL101—2.048 MHz, 32 pF parallel-mode, ± 0.005%, HC-33/U case
S1-S4—BCD thumbwheel switch (C&K 332110000 or equivalent)
J101—8 pin IC socket
Miscellaneous: PC board, IC sockets, 4-conductor ribbon cable, wire, solder, etc.

" (or "1" and "2") lugs. The switch section next to S1 is S2. Solder the wires from a four-conductor cable to each of its terminals. If possible, match the colors to those used on S1 (and do the same for the other sections). It's easier to connect a switch, if, say, all "A" leads are green, "B" leads are blue, and so on. Wire up S3 and S4 in the same manner.

Finish up by connecting the switches to the board. Start by inserting the wire from the switches' common bus into the COM pad on the board. Solder it in place. Then match up the leads from S1 to the "B" and "A" holes below R107 and R108 on the board. Insert and solder. Match up the leads from S2 with the points on the board above the resistor group starting with R104. Note that the connections are "DCBA" reading from left to right. Insert and solder. Likewise, insert and solder the leads from S3 into the holes above the resistor-group starting with R111. Note that the connections are arranged as "DCBA" like those for S2. Finally, insert the wires from S1 through the holes by the resistor-group starting with R112. Note that R112 is the "A" connection, and that the others follow in order. That ends the switch installation.

Check over your wiring for errors, and correct any mistakes. Then finish up by installing the IC's. Refer back to Fig. 5 for placement. Install a CD4013 at IC101, a CD4059 at IC102, and a CD4046 at IC103. Make sure they are plugged in properly (watch out for bent pins) and then install a CD4060 at IC105 and a CA3130 at IC106.

That completes the control board. Next we'll cover the VCO board and start discussing final assembly.

How the VCO works

The VCO board contains three oscillators, a divider, a modulator, and an RF amplifier. Also included is some switching circuitry for both RF signals and power, and two power supplies. At this point you may want to refer to the schematic in Fig. 9 as you read about the circuitry.

The oscillators consist of IC201 through IC203, Motorola MC1648's, together with a few external components. The 10–30 MHz signals are generated by IC201, while IC202 generates the 5–10 MHz signals and IC203 handles the 3–5 MHz range. Tuning within these ranges is done by D201 through D203, Motorola MV1404 tuning diodes. Think of them as electrically controlled variable capacitors; an input voltage ranging from 0.5-volt to 9-volts will cause each oscillator to tune through its frequency range.

Since only one oscillator at a time can be operating in this device, some switching has to be done. Transistors Q204 through Q206 perform this task. The desired oscillator is turned on by grounding the base one of the transistors. This is done by the switch board, which will be described later.

The outputs of the oscillators are ECL-level (0.8 volt AC), but transistors

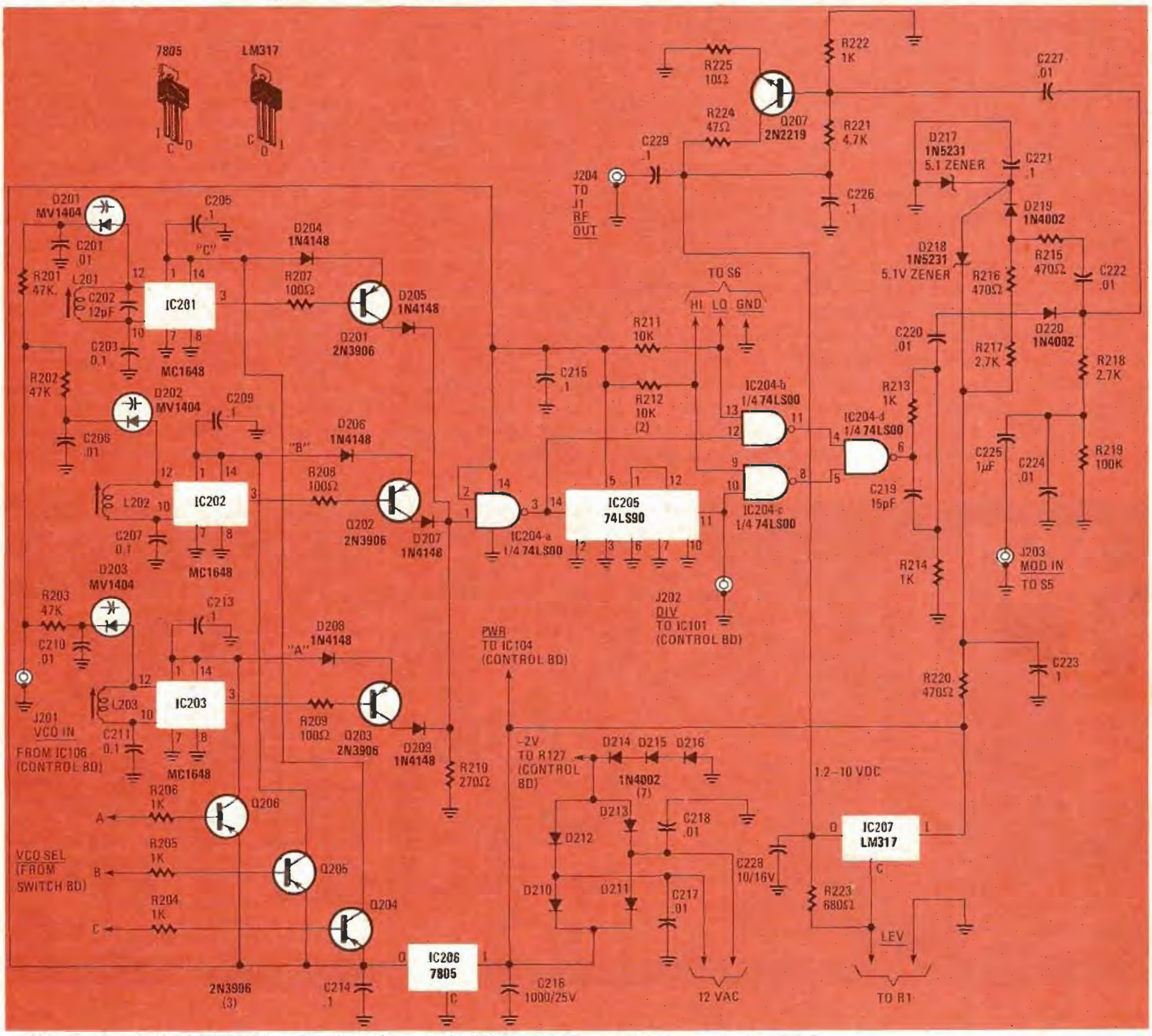


FIG. 9—THE PROGRAMMA-2 uses an ingenious method for controlling modulation and RF-out-put levels—the heart of the circuit is at diodes D219 and D220 (upper right). The scheme is described in the text.

Q201 through Q203 increase those signals to TTL levels for use by the circuitry that follows. The diodes are included for biasing and switching. Finally, IC204-a is used to buffer the signal, insuring that it is at TTL levels.

The VCO signal from the buffer is fed to both IC205, a divide-by-10 counter, and to IC204-b. That gate, together with IC204-c and IC204-d, act as an SPDT switch and select either the "direct" VCO signal or the divided-down signal from IC205. This solid-state switch is controlled by the HI/LO switch, S6, on the front panel. When the HI line from the switch is grounded, the VCO signal feeds straight through over a range of 3 to 30 MHz. When the LO line is grounded, the divided-down signal is selected (300 kHz to 3MHz). This eliminates the need for extra VCO's. The output of the divider also goes to the DIV jack, J202 , which provides the signal required for the control board's programmable-divider circuit.

The output of IC204 drives the modulator circuit. This circuit is unusual in that it uses diodes to modulate the VCO signal. Basically, it is nothing more than a voltage controlled attenuator. The amount of signal passing through it depends upon the control voltage, which is really the sine wave from the MOD IN jack. Resistor R219 sets the bias so that the signal will continue to pass through the circuit when there is no modulation.

In operation, diodes D219 and D220 are foreward biased, although to different degrees. Diode D220 tends to be more heavily biased because there is less resistance between it and the power source. At the cathode end of this diode there are several resistors. The 500-Hz modulation is also applied at this point, and the voltage across the resistors causes the current flow through the diode to vary. As the current through D220 varies, it can be greater or less than the current through D219.

At this point an interesting characteristic of diodes enters the picture—diodes can act as variable resistors; the greater the current flow through a diode, the more signal it will pass. Sometimes D219 conducts more signal—to ground, and sometimes D220 conducts more signal—to the RF amplifier. This circuit is known as a *T attenuator*. In the Programma-2 it causes the level of the RF signal to be controlled by the level of the 500-Hz tone.

From the modulator the signal goes to a broadband RF amplifier, which boosts it to useful levels. This is the job of Q207, which has a maximum gain of 5. The output level is controlled by adjusting the power supply voltage—in this case from 1.2 to 10 volts. This supplies from 10 mV to over 300 mV of signal at the RF OUT connector.

The rest of the circuitry on this board consists of power supplies. There is the usual 5-volt regulated source for the ECL and TTL devices, plus an adjustable source for the RF amplifier. An LM317-T adjustable regulator handles the latter job.

Construction

A foil pattern for the VCO board is provided in Fig. 10. If you prefer not to make your own, refer to the Parts List for a supplier.

Start construction by studying Fig. 11. To simplify matters, we'll break the board into two sections and concentrate on completing each separately; this makes construction a lot easier.

The first thing to do is to enlarge the holes for coils L201–L203. Using the IC pads as a guide, orient the board as shown in Fig. 11 and locate the three holes. Note that they are part of the ground foil that runs around the edges of the board. Using a set of progressively larger drills, increase the size of the

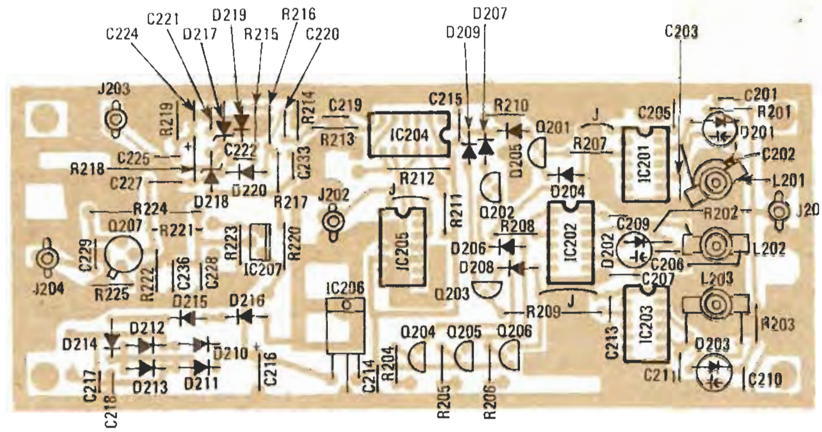


FIG. 11—CONNECTORS FROM THE COILS to the board are made using leftover capacitor leads. Capacitor C202 is soldered directly to the lugs of coil L201.

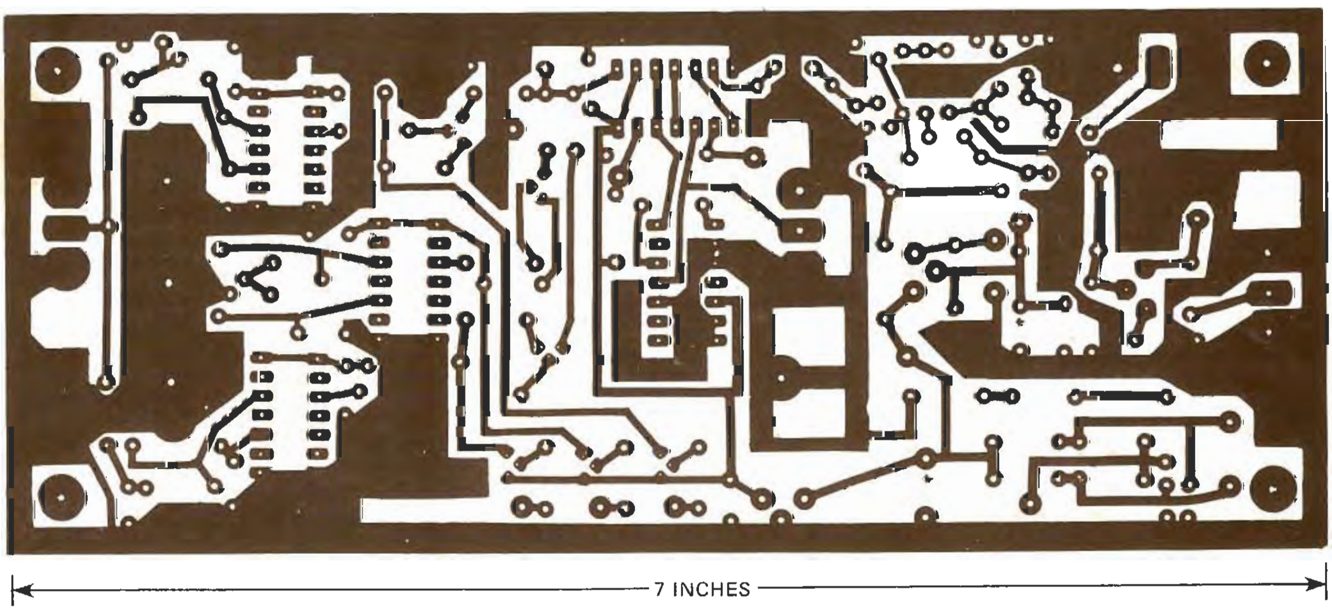


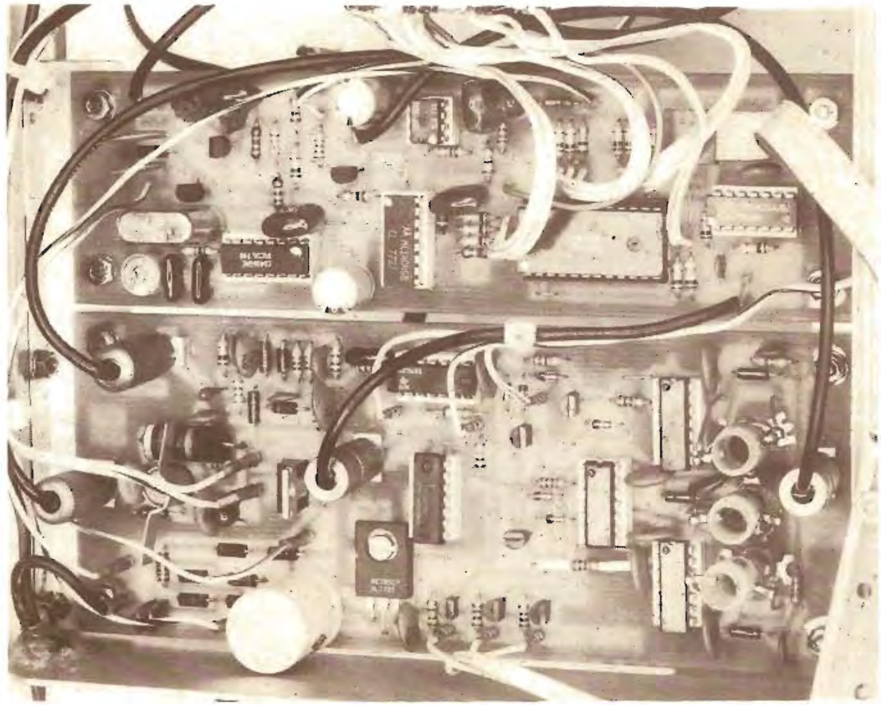
FIG. 10—THE COMPLEX VCO circuit can be built on a single-sided PC board using only three jumpers.

PARTS LIST
VCO BOARD

All resistors ¼-watt, 5% unless otherwise specified
R201-R203—47,000 ohms
R204-R206, R213, R214, R222—1000 ohms
R207-R209—100 ohms
R210—270 ohms
R211, R212—10,000 ohms
R215, R216, R220—470 ohms
R217, R218—2700 ohms
R219—100,000 ohms
R221—4700 ohms
R223—680 ohms
R224—47 ohms, 2 watts, carbon composition (see text)
R225—10 ohms
Capacitors
C201, C206, C210, C217, C218, C220, C222, C224, C227—0.01 μF, 16 volts, ceramic disc
C202—12 pF, ceramic disc or mica
C203, C205, C207, C209, C211, C213-C215, C221, C223, C226, C229—0.1 μF, 16 volts, ceramic disc
C204, C208, C212—not used
C216—1000 μF, 25 volts, PC-mount electrolytic
C219—15 pF, ceramic disc
C225—1 μF, 16 volts, electrolytic
C228—10 μF, 16 volts, electrolytic
Semiconductors
IC201-IC203—MC1648P MECL voltage-controlled oscillator (Motorola)
IC204—74LS00 quad NAND gate
IC205—74LS90 decade counter
IC206—7805 or LM340-T 5-volt regulator, TO-220 case
IC207—LM317-T adjustable voltage regulator, TO-220 case
Q201-Q206—2N3906 or equivalent
Q207—2N2219 or equivalent
D201-D203—MV1404 tuning diode (Motorola)
D204-D209—1N4148 or 1N914
D210-D216, D219, D220—1N4002, 100 PIV, 1 amp
D217, D218—1N5231 Zener, 5.1-volts, 500 mA
L201—0.3-0.58 μH coil (Miller 4201 or equivalent)
L202—2-5.5 μH coil (Miller 4203 or equivalent)
L203—10-25 μH coil (Miller 4205 or equivalent)
J201-J204—PC-mount RCA-type phono jacks
Miscellaneous: PC board, IC sockets, slip-on TO-5 heat sink for Q207, solder, etc.

A complete set of three boards for the Programma-2 is available for $22.00 ppd. from: Technico Services, PO Box 20HC, Orangehurst, Fullerton, CA 92633. CA residents please add 6% tax; foreign orders please add $3.00 for shipping. Order No. SSG-1.

A complete set of *parts*, excluding boards, crystal, transformer and case, is available for $112.00 ppd. from: Circuit Specialists, Inc., PO Box 3047, Scottsdale, AZ 85281. Order No. KT-5. Phone orders (800) 528-1417; all other inquiries (602) 996-0764. AZ residents please add tax.



THIS IS WHAT THE VCO BOARD looks like when it is finished and mounted in the case. The board below the VCO board is the control board.

holes to ¼-inch. Then use a reamer or small file to enlarge them farther, to ⅜ inch.

Next, install the IC sockets. Note that there are five of them, and that they are all 14-pin units. If the sockets have an identifying mark for pin 1, position them as shown.

The four RCA jacks, J201–J204, are installed next. You may have to enlarge the holes in the board so that they can be mounted.

Install the capacitors as shown. Begin with the 0.01-μF discs, and install one each at C201, C206, and C210. Note that these parts are located near the coils. Then continue with the 0.1-μF capacitors. There are quite a few. Install one at C205, C203, C209, C207, C213, and C211. Then move to the top left corner of the board and install one at C215. Move down and install one at C214. That almost takes care of the capacitors; there's one left to mount on a coil.

The coils are next. They just snap into place. Be sure to observe the positioning of the terminals before you snap them in place; this is important. Install the No. 4201 coil at L201, the No. 4203 coil at L202, and finally, the No. 4205 coil at L203. Wire the coils to the two pads below them as shown, using short lengths of solid wire. The clipped leads from the capacitors should work fine. Be sure to keep the leads as short as possible; that makes the coils more shock resistant. After the wiring is done, install a 12 pF capacitor, C202, directly across the terminals of L201.

The resistors come next. Install the 47K units first, with one at R201, R202, and R203. Note that you'll have to bend the leads of R202 so that they don't touch the coil wire. The 100-ohm units are next. Install one at R207, R208, and R209. Be careful to get them in the right places. Then come the 10K units by IC204. Install one at R211 and another at R212. After that come the 1K resistors. Install one at R204, R205, and R206 near the bottom of the board. Finish up by installing a 270-ohm resistor at R210.

The three jumpers go near IC201, above IC205, and next to IC203. Use leftover leads from the resistors for the jumpers. Install the jumper next to IC201 first, then the one below IC202, and last, the jumper above IC205.

Now for the diodes. Note that there are two kinds—MV1404 and 1N4148. The MV1404's come first. Be careful when you install them because they are rather expensive! Avoid bending the leads right at the body as this will break them. Install three MV1404 diodes at D201, D202, and D203 as shown. Note that the banded ends point to the right. Then come the 1N4148's. Install them at D205, D207, and D209 near R210. Then install the rest at D204, D206, and D208. Be sure to check your installation before going farther.

Continue with the transistors. They are all 2N3906's, which makes installation easier. Install one at Q201 and Q202. Be sure the flat in the case points to the right. Then do Q203 with the flat side pointing up. When done, move down and install the three remaining transistors at Q204, Q205, and Q206, with the flat side facing right.

continued on page 97

RF GENERATOR

continued from page 69

Finish up this half of the board by installing the IC's. Orient them as shown in Fig. 11. Install the MC1648's first, at IC201, IC202, and IC203. Then install a 74LS00 at IC204, and a 74LS90 at IC205.

Take a breather at this point; then carefully check your work. Correct any mistakes you find before going any farther.

Now for the rest of the board. Start with the voltage regulator IC's. Install an LM317T at IC207 with the tab to the right. Then mount a 7805 (LM340T-5) at IC206. Note that this IC mounts flat against the board, and that no heatsink is required. Use 4-40 hardware to fasten it in place before you solder the leads.

Next mount the rest of the capacitors. Use extra care with them because there are quite a few, and they can wind up in the wrong places. Start by installing a 1000-μF electrolytic at C216. The "+" lead goes nearest D216. Then install two 0.01-μF capacitors at C217 and C218. Move up and install a 10-μF electrolytic at C228, and a 0.1-μF disc beside it at C226. Install another 0.1-μF capacitor at C229. Then move up a bit and install a 0.01-μF capacitor at C227. After that install a 1-μF electrolytic at C225, just above. Note that its positive side is to the right. Three 0.01-μF disc capacitors come next. Install one at C224, another at C222, and the remaining one at C220. Continue with two 0.1-μF capacitors; one goes at C221 and the other at C223. Finish up by installing a 15-pF unit at C219.

Now, more diodes. First, there are seven 1N4002 rectifiers for the power supply. Install them as indicated at D210 through D216. Then install two more 1N4002's at D219 and D220. *Be careful not to install D219 in D217's place!* Mount the two 1N5231 Zeners as indicated at D217 and D218.

The resistors come next. Install 1K resistors at R213 and R214. Next, install 470-ohm resistors at R216 and R215. Move down the board a bit and install 2.7K resistors at R217 and R218. Then install a 100K unit at R219. Continue by installing a 47-ohm, *2-watt* resistor at R224. Note that this must be a carbon composition type, and not wirewound. If you use a wirewound type the RF output will be erratic. Below R224 install a 4.7K resistor at R221, a 1K resistor at R222, and a 10-ohm resistor at R225. Finish up by installing a 680-ohm resistor at R223 near the LM317-T, and a 470-ohm one at R220.

The last component to be installed is a transistor. Install a 2N2219 at Q207 and slip a small TO-5 heatsink over it.

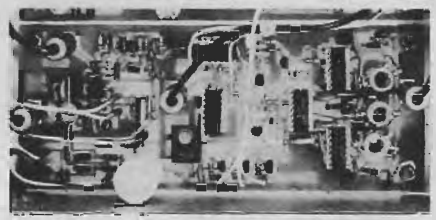


FIG. 12—A HEAT SINK must be used on Q207 (lower left). Also note that IC206 (7805) is secured to the board with 4-40 hardware.

Carefully check your work. Make sure that the diode and electrolytic capacitor polarities are right, and correct any errors you find. The assembled VCO board is shown in Fig. 12.

You've just completed the Programma-2's most complex board. In the next part we'll finish building the unit and put it to work. **R-E**

BUILD THIS

Synthesized RF Generator

Part 3

IN THIS PART WE'LL FINISH up the Programma 2, calibrate it, and put it to use. All the hard work is already done, so all that's left are a few easy things like stuffing the switch board, and putting the electronics in a case. Let's get started by discussing the circuitry on the switch board before we put it together.

Switch board theory

Surprisingly enough, the switch board isn't absolutely necessary in this project! A three-position switch could be used in its place to select the proper VCO, serving as a "bandswitch." However that isn't a very elegant approach to selecting ranges, and you'd have an extra switch to fiddle with. Top that off by realizing that the IC's cost about the same as a decent switch, and you'll want to build the board.

Basically, the switch board, whose schematic is shown in Fig. 13, is nothing but a decoder circuit. It plugs into J101 on the control board, and decodes the BCD signals from the 10-MHz and 1-MHz positions on the switches. The decoded signals then turn on one of three transistors on the VCO board, applying power to the correct VCO circuit.

In operation, BCD data from the 1-MHz switch position is supplied to the switch board, and drives display decoder IC301. Although the IC was designed to drive an LED display, it can decode in other ways, too. When binary-coded-decimal inputs of "3" or "4" are applied to the decoder, the "b" and "g" segment outputs are high, while the "e" segment is low. Gates IC302-a and -b detect those conditions, and the output at pin 1 of the IC goes low. Since those conditions also apply to a "9" input, gate IC304-a detects that condition via the "D" input, and prevents decoding of that value. Pin 1 of IC302-b drives inverter IC304-c, which puts a logic "high" on gate IC303-b whenever a "3" or "4" switch input is decoded. That "high" passes through the gate, turning on transistor Q302. On the other hand, if any other number besides "3" or "4" is applied to the decoder, it won't be decoded, and pin 1 of IC302-b will be high. That goes to gate IC303-a, and turns on transistor Q301. That takes care of the decoding scheme for the 1-MHz switch position.

Decoding the 10-MHz switch position is easier. Gate IC304-b detects a logic "high" on either the "A" or "B" inputs. When that happens, as it would if the switch were set to "1," "2," or "3," the output of IC304 goes low. That shuts down gates IC303-a and -b making transistors Q301 or Q302 turn off. At the same time, the pin-4 output of IC304-b is inverted by IC304-d, turning on transistor Q303. Thus, the 10-to-30 MHz VCO is selected.

The remaining components on the board are strictly for protection, and can save the IC's if the cable to the control board is plugged in backwards.

Switch board construction

Assembling this board is easy, and the whole thing should take little time. The foil pattern is shown in Fig. 14. Note that all the parts are common, and should be easy to get if you don't have them. That makes this phase of the project a good candidate for a Sunday afternoon when all the stores are closed. Refer to Fig. 15 for details as you stuff the board.

Start by positioning the board as shown. Then begin by installing the 16-pin IC socket at IC301. Position the notch indicating pin 1 pointing up. (Do that with the rest of the sockets, too.) Then install the three 14-pin sockets. Check to be sure you've soldered all connections.

Continue with the resistors. Install six 100K units at R301 through R306 as shown, near the left side of the board. Then install a 10K resistor at R307. Bend the leads as shown, and insert into the board. Below it, install another resistor at R308. Finish up by installing a 10K unit at R309. Again, bend the leads as shown, and then insert them into the board. Note that "spaghetti" tubing over the leads is unnecessary.

Note that the two jumpers run between the ICs. Use leftover resistor leads for the jumpers, if you wish. Install the jumper that runs horizontally between IC301 and IC304. Bend the wire into shape first, and then insert it into the board. Pull the wire tight against the board before soldering. After that, install the vertical jumper in the same

GARY McCLELLAN

In the concluding part of this article we'll finish building the Programma 2 synthesized RF generator, calibrate it, and present some hints on using it.

manner. Be sure to pull it tightly against the board so that it can't touch the first jumper.

Now for the transistors. Note that they are all 2N3904's, and that they all mount facing in the same direction. Mount Q301 first, with the flat side in the case pointing up. Then mount Q302 below it in the same manner. Finally, mount Q303 near the bottom of the board, with the flat side pointing up.

Install a 1N4148 diode at D301 as shown, with the banded end pointing toward the center of the board. Then install a 0.1 μF disc at C301 between the transistors. That takes care of the component installation on the board.

Finish up with the cables, starting with the input cable—the one with the plug on it. Cut about a six-inch piece of 8-conductor ribbon cable, and prepare the ends. Then prepare the 8-pin DIP header PL101. Solder the wires to it in order, and snap the cap in place.

Connect the other end of the cable to the board as shown in Fig. 15. (You may want to check out the connections with an ohmmeter.) Once the input cable has been installed, you can procede to the output cable. Cut about an eight-inch length of 3-conductor ribbon cable, and prepare the end. Install the wires in the holes near the transistors as shown in Fig. 16. You should make a note of where the wires go, for future reference. That completes the board wiring.

At this point you can install the IC's. Refer to Figs. 15 and 16.

Final assembly

The time has come to install the boards in a case and to connect the cables. But first, a few comments about the cabinet you should use. The prototype used a leftover cabinet from a piece of medical equipment. It's not available commercially but you can probably do just as well with an "off the shelf" product. When you shop for a cabinet, look for one that is at least 3 inches by 8 inches wide by 7 inches deep. That was the size of the prototype's cabinet, and is just right to hold the boards. Also, it should be all metal for shielding. If you use a plastic cabinet, the unshielded electronics may interfere with sensitive measurements. Knowing those two requirements, you are all set to visit your electronics supplier and make a selection. You might even want to use a plain chassis box to keep costs down. If painted and labelled carefully, the box can look better than most cabinets!

Once you have a suitable cabinet you can lay out the boards and controls. Probably the best arrangement is the simplest, so you might want to copy the layout shown in Fig. 17. Otherwise, just be sure to space the control and VCO boards as close together as practical; the rest isn't critical.

Here are some tips to make the board layout easier. The only areas to be concerned about are the front panel and the bottom. Since the front panel holds only five parts, it's not a problem. That leaves the bottom of the cabinet. Position all three boards on it to determine where to mount them; then use the boards themselves as templates to mark the mounting holes.

Be sure to allow extra room at the front of the cabinet for the switches. About three inches of clearance should be the minimum. Also, if you can, mount the switch board near the front on the bottom of the cabinet. That allows easier access to the control board, which was partly covered by the switch board in the prototype—not such a good arrangement from a service standpoint. With those suggestions, board placement should be easy to determine.

The next step is to machine the cabinet. You can start with the bottom of the cabinet by drilling out the mounting holes for the boards. Then drill a hole in the rear panel for the power cable. It may be necessary to enlarge it so that a grommet can be installed to protect the cable. (We used a plastic strain-relief salvaged from a junked appliance.) You can now drill the front panel. Generally, it will be necessary to clamp the panel in a vise so the holes can be drilled accurately. Be sure to protect the panel's finish by placing a piece of cloth between it and the jaws of the vise. When it comes to making the cutout for the FREQUENCY SET switches, probably the best way is to drill small holes around the

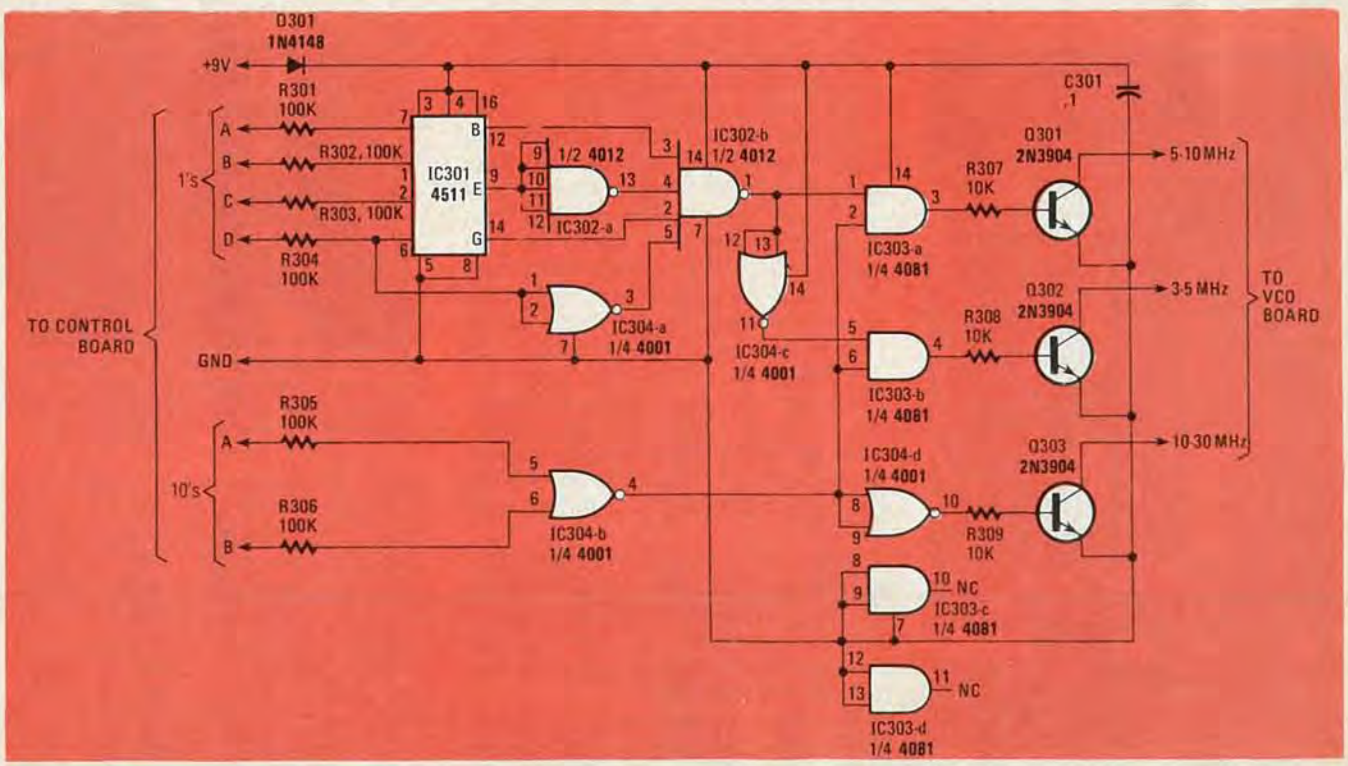


FIG. 13—A SEVEN-SEGMENT LED DECODER, IC301, is put to a rather unorthodox use on the switch board. Its segment-output states determine which of the generator's VCO's will be active.

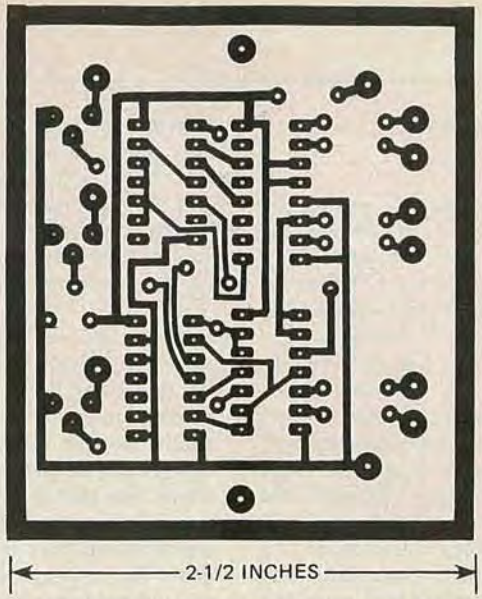


FIG. 14—FULL SIZE FOIL PATTERN for the switch board. Large pads are used to make off-the-board connections.

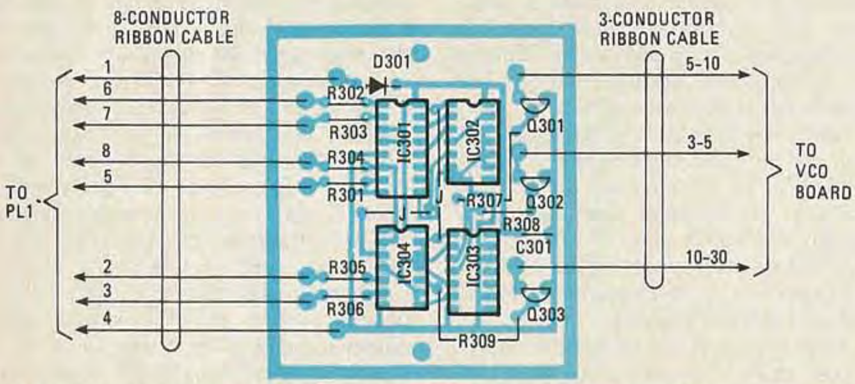


FIG. 15—EIGHT-CONDUCTOR RIBBON CABLE is used between the board and PL1. The plug itself is an 8-pin DIP header. If you can't locate one, cut down a 14- or 16-pin header.

PARTS LIST—SWITCH BOARD

All resistors ¼-watt, 5%
R1—5000 ohms, potentiometer, linear taper with switch
R301-R306—100,000 ohms
R307-R309—10,000 ohms
Capacitor
C301—0.1 F, 16 volts, ceramic disc
Semiconductors
IC301—CD4511 CMOS 7-segment latch/decoder/driver
IC302—CD4012 dual 4-input CMOS NAND gate
IC303—CD4081 quad 2-input CMOS AND gate
IC304—CD4001 quad 2-input CMOS NOR gate
Q301-Q303—2N3904 or equivalent
LED1—jumbo red LED
D301—1N4148 or 1N914
S5, S6—SPDT toggle switch
T1—wall-plug transformer, 12 volts, 600 mA
PL1—8-pin DIP header
J1—BNC connector, chassis-mount
Miscellaneous: PC board, IC sockets, ½-inch threaded standoffs, metal enclosure (see text), knob, RG-174 coax, ribbon cable, etc.

A complete set of three boards for the Programma-2 is available for $22.00 ppd. from: Technico Services, PO Box 20HC, Orangehurst, Fullerton, CA 92633. CA residents please add 6% tax; foreign orders please add $3.00 for shipping. Order No. SSG-1.

A complete set of *parts,* excluding boards, crystal, transformer and case, is available for $112.00 ppd. from: Circuit Specialists, Inc., PO Box 3047, Scottsdale, AZ 85281. Order No. KT-5. Phone orders (800) 528-1417; all other inquiries (602) 966-0764. AZ residents please add tax.

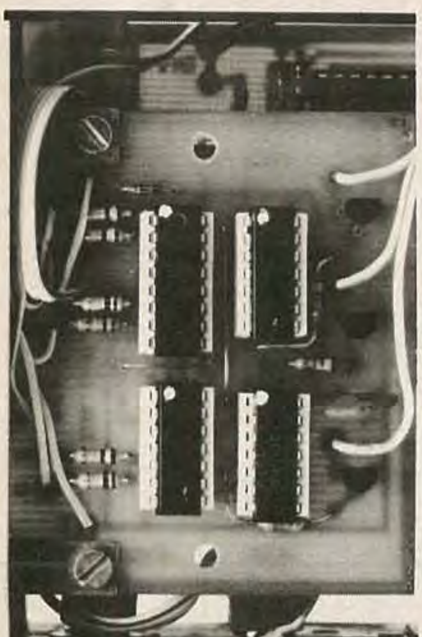


FIG. 16—NOTE THE WAY the leads of resistors R307 and R309 are bent.

inside of the outline, knock out the center, and file the opening to size.

After the holes have been drilled, scrub the cabinet with detergent and water to remove any grease. Then rinse and rub it dry. Next, label the front panel with press-on letters, label tape, or anything else you care to use. We used press-on letters successfully, and you can do the same. One thing, though, and that is when you get to the RANGE switch, use *several* labels. Include 3-30 MHz below HI, and 0.3-3 MHz below LO. The extra labels make the RANGE switch easier to use. Other than that, simply label the controls according to the prototype. Be sure to cover the labels with a coat of acrylic spray so that they don't rub off.

Once the spray is dry you can install the boards in the cabinet and hook them up. You can install the VCO and switch boards immediately, but hold off on the control board because a few wires must be connected to it first.

Cut three six-inch pieces of RG-174 50-ohm coaxial cable, and prepare the ends. Don't substitute ordinary mike cable for this miniature coax—it's too

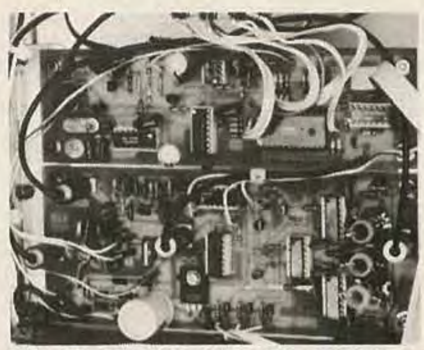


FIG. 17—CONTROL AND VCO BOARDS are mounted side-by-side. Switch board, not seen here, sits above coils at lower right. BCD thumb-wheel-switches are visible at top of photo.

lossy. Solder one end of a cable to the VCO pads (below Q101) on the control board. Note that there is a pad for the shield of the cable, even though it doesn't go anywhere. That is intentional and not a mistake. Solder one end of another cable to the DIV pads (near C101). Connect one end of the remaining cable to the MOD pads (near R128). Finish up by cutting two six-inch pieces of hookup wire, and stripping the ends. Solder one wire to the PWR pad (above C106), and the other to the -2V pad (at

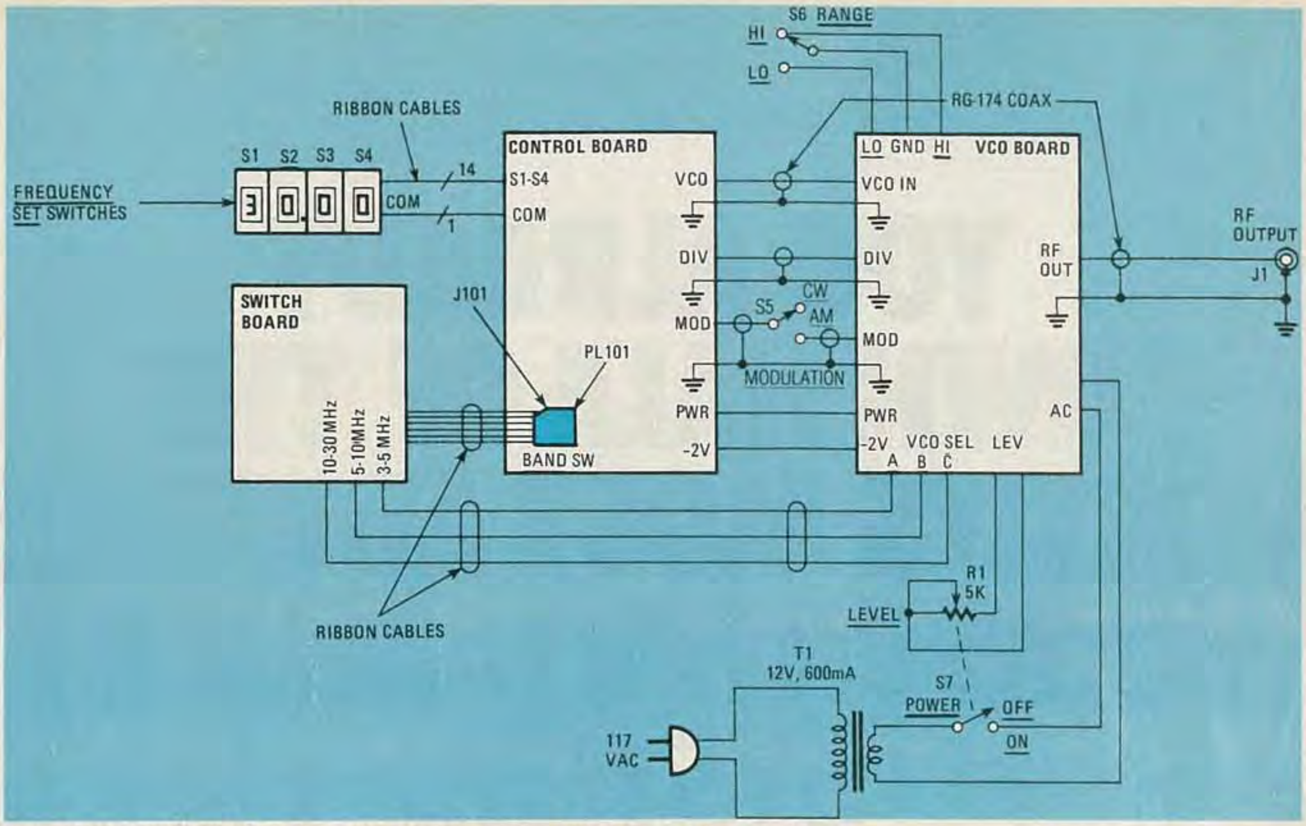


FIG. 18—INTERCONNECTIONS between *all* boards. Extensive use of color-coded ribbon cable keeps things neat and makes circuit-tracing easy.

R127). That takes care of the control board, and you can now mount it in the cabinet.

The last construction step is to interconnect the boards. Refer to Fig. 18 for details as you make the connections. Start by attaching RCA-type phono plugs to the ends of the coax cables from the control board. Then plug each one of them into the appropriate jack on the VCO board. Next, connect the leads from PWR and -2V pads on the control board to the appropriate terminals on the VCO board. Double-check to be sure they go to the right places; otherwise you may damage the control board. Connect LEVEL pot R1, and power switch S7. Wire up the pot first, using hookup wire to connect it to the board. Then wire up the power switch. If you use an external wall-plug type transformer, all that's necessary is to wire the switch in series with the VCO board and transformer. If you can't find such a transformer, and use an internally-mounted unit, switch the transformer's primary instead.

Next is the RF OUTPUT jack. Cut a piece of RG-174 coax long enough to reach from the jack to the RF OUT jack on the VCO board. Then attach an RCA plug to one end of the cable and plug it into the VCO board. Solder the other end to the jack, and *be sure to make a good ground connection*. That is important because that connector is the *only ground* in this project! Connect the RANGE switch, S6, by running three pieces of hookup wire from it to the VCO board. (Ribbon cable is great for that!)

Finish up with the switch board connections. Plug PL101 into the 8-pin socket on the control board, and then connect the three wires to the corresponding pads on the VCO board.

That completes the construction. Double-check your work and correct any problems you find before applying power.

Calibration

In all probability, the Programma 2 will work pretty well the first time power is applied, without any calibration. Still, a few adjustments are required to insure that you can get all frequencies set by the switches, and to set the modulation level and get the best accuracy. To make the adjustments you'll need either a receiver with 10-MHz WWV capability, or a frequency counter. For tools you'll need a hex alignment-tool for the coils, and a small screwdriver.

The first step is to set the frequency range of the VCO's. That means that the coils must be adjusted so that the VCO's cover 3-5 MHz, 5-10 MHz, and 10-30 MHz. The front ERROR lamp will show when the coils are adjusted properly.

Make the adjustments in this order: Set the switches to "03.00" and turn on the power. The ERROR lamp may be lit or flickering. If it isn't, adjust L203 on the VCO board until it shows some sign of life. Then adjust the coil until the lamp goes out, and keep turning the core for about ½-turn more. Switch to "04.99," and check the lamp; it should blink and go out. If not, back off the core slightly. The lamp should now blink and go out for switch settings of "03.00" through "04.99."

Set the switches for "05.00." Again, the ERROR lamp may be lit or flickering. If not, adjust L202. Then adjust the core until the lamp goes out, and turn the core about ½ turn more.

Now switch to "09.99," and check the lamp. It should blink, and then go out. If not, back off the core slightly. The lamp should blink and go out for switch settings of "05.00" through "09.99."

Set the switches for "10.00." The ERROR lamp may be lit or flickering. Adjust L201 for some indication. Then adjust the core so that the lamp goes out, and turn it about ½-turn farther. Switch to "30.00" and check the lamp. It should blink and go out. If it doesn't, back off the core slightly. The lamp should blink and go out for switch settings of "10.00" through "30.00" MHz.

That takes care of the VCO frequency-range adjustments. Now for the modulation-level adjustment. It can be made with an ordinary AM table-radio. Otherwise, you can use a shortwave receiver set to about 3 MHz. Here's how to make the adjustment:

Set your receiver to a clear frequency. Set the FREQUENCY SET switches to the same frequency. Then flip the MODULATION switch to AM. Connect a piece of

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wire to the RF OUTPUT jack, and advance the LEVEL control. Tune in the signal on your receiver carefully. Adjust the pot on the control board for a clean-sounding tone, then turn the pot until the tone sounds rough. Back off the adjustment so that the tone sounds clean again. That completes the modulation adjustment.

The last step is to adjust for the best frequency calibration. You can either use a counter for that, or station WWV at 10 MHz. Here's how to do it:

Put the MODULATION switch in the CW position, and the RANGE switch to HI. Then set the FREQUENCY switches to "10.00." Connect a piece of wire to the RF OUTPUT jack for an antenna if you are using a receiver for calibration; otherwise, connect a frequency counter to the jack.

If you are using a receiver for calibration, tune in WWV at 10 MHz. Advance the LEVEL control on the RF generator until you can just hear its carrier beating against WWV's 10-MHz signal. Then adjust the trimmer on the control board for the lowest-pitched beat note. There may be a slight warble in the project's carrier; that is a normal characteristic of synthesized RF-generators, and some care will be required to find zero beat.

If you are using a counter, simply adjust the trimmer on the control board until you read 10.000 MHz.

Using the Programma 2

Using this RF generator is a snap because there are so few controls. A few comments on the key controls, though, are in order.

Remember that the range of the FREQUENCY SET switches is "03.00" to "30.00" (MHz). If you exceed those limits, the ERROR lamp will come onto remind you that the frequency is wrong.

The RANGE switch selects direct, or divided-by-10, output frequencies. Use the HI position for outputs of 3 to 30 MHz, and LO for 300 KHz to 3 MHz. Typically, the HI position will be used for RF-stage and mixer-alignment of receivers, while the LO range will be used for IF alignment.

The ERROR lamp serves as a visual reminder that the output frequency is *not the same* as that indicated by the FREQUENCY SET switches. In normal operation, it should blink once when the frequency is changed. If a value is selected outside the range of the FREQUENCY SET switches, it will stay lit, alerting you to your mistake.

To use the Programma 2, simply select the desired frequency and range. Then adjust the LEVEL control as necessary. If you are working on a receiver, tune in the signal on the receiver first; then adjust the LEVEL control as required.

If you must work with low-level signals, insert a 50-ohm attenuator at the RF OUTPUT jack and then set the attenuator for the desired output level. That may not always be necessary, as the RF output of this project with a 50-ohm load ranges from 10 mV to 300 mV. **R-E**