Get rid of switching woes, and that "pile of spaghetti" in back of your TV set, with the "Select-A-Matic" RF switcher.

RF SWITCHER

ROBERT GROSBLATT

IN THE DIM PRE-HISTORY OF THE ELECTRONIC age, just after the disappearance of the dinosaurs, the family television set had but one simple job—displaying broadcast TV signals (although many of you probably thought that it was to keep your children from doing their homework).

Not any more.

Today's family television set has a whole new set of functions. And it sometimes seems that not a day goes by without the development of yet another device that uses the tube for a display. Computers, videodiscs, VCR's, and videogames all compete with the simple antenna for access to the back of the set. But since the input on most televisions is limited to the two little screw terminals for the antenna, you can find yourself doing a lot of wire swapping anytime you decide to watch a tape or blast a few aliens.

That is, unless you build the Select-A-Matic. That device can take any one of eight inputs and assign it to any one of four outputs. Not only will that make it much easier to organize things, it will also help eliminate the usual pile of "spaghetti" found at the back of the set. Keyboard entry and a visual display make operation of the Select-A-Matic a snap. And even if you don't have a lot of interest in RF switching, the theory and design can easily be incorporated into audio, appliance control, or just about any area where you need to choose among several devices.

The theory behind the Select-A-Matic is evident when you take a look at Fig. 1, the block diagram of the circuit. One input and one output are selected from a keyboard, and the control signal that results is stored in a latch at the selected part of the circuit. It's really that simple. There's nothing exotic in the parts list and the basic design of the Select-A-Matic is easy to adapt to a whole host of other uses.

The simplicity of the circuit can be seen further in Fig. 2, the schematic. Since we're dealing with eight inputs and four outputs, there are 32 possible combinations we have to be able to select. Although there are several ways to handle it, the most straightforward approach is to arrange the I/O in a matrix with the inputs on the columns and the outputs on the rows as shown in Fig. 3. Selecting an input turns on the whole column and selecting an output turns on a whole row. That scheme routes the selected input exclusively to the selected output.

The easiest way to see how that theory is translated from ink to electrons is to go

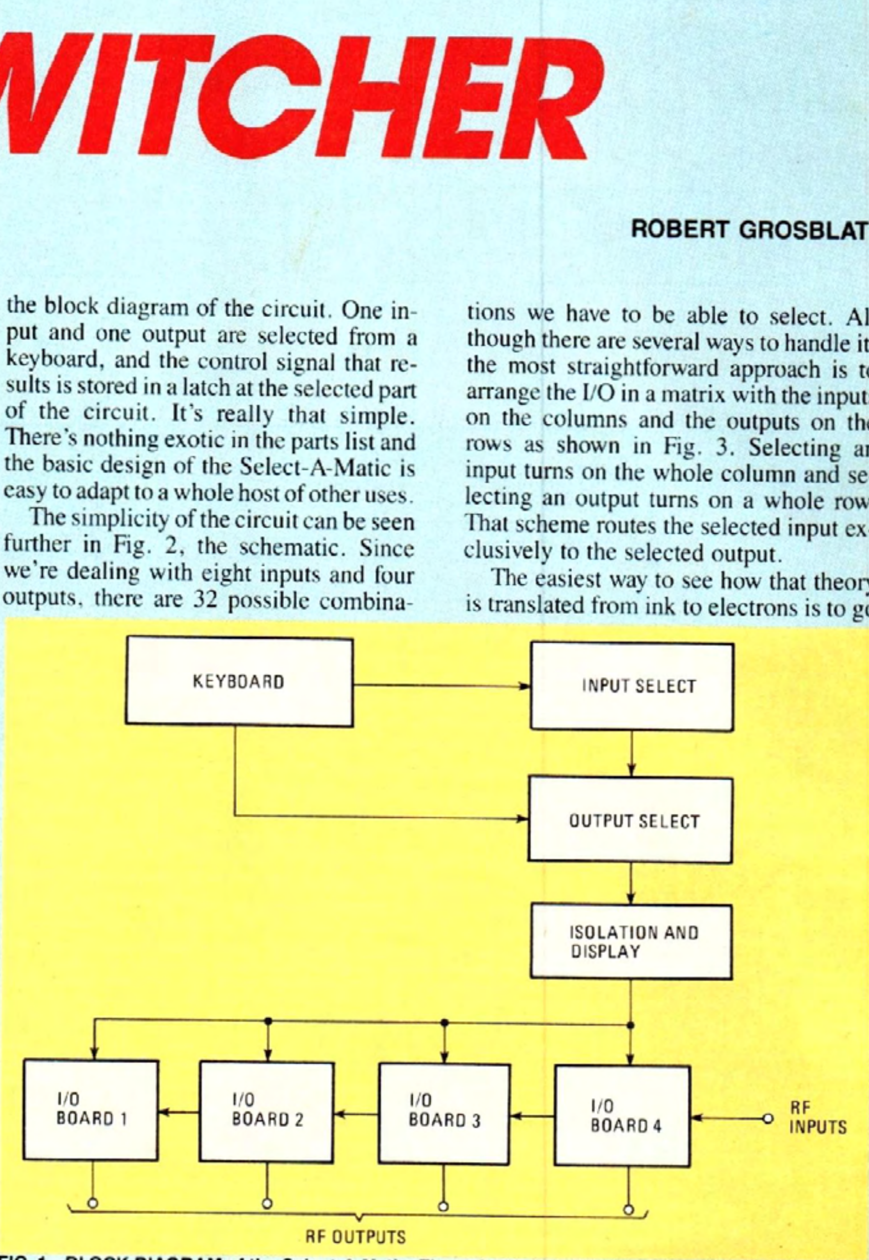

FIG. 1—BLOCK DIAGRAM of the Select-A-Matic. The unit can switch things other than RF signals by modifying the I/O boards to suit the particular application.

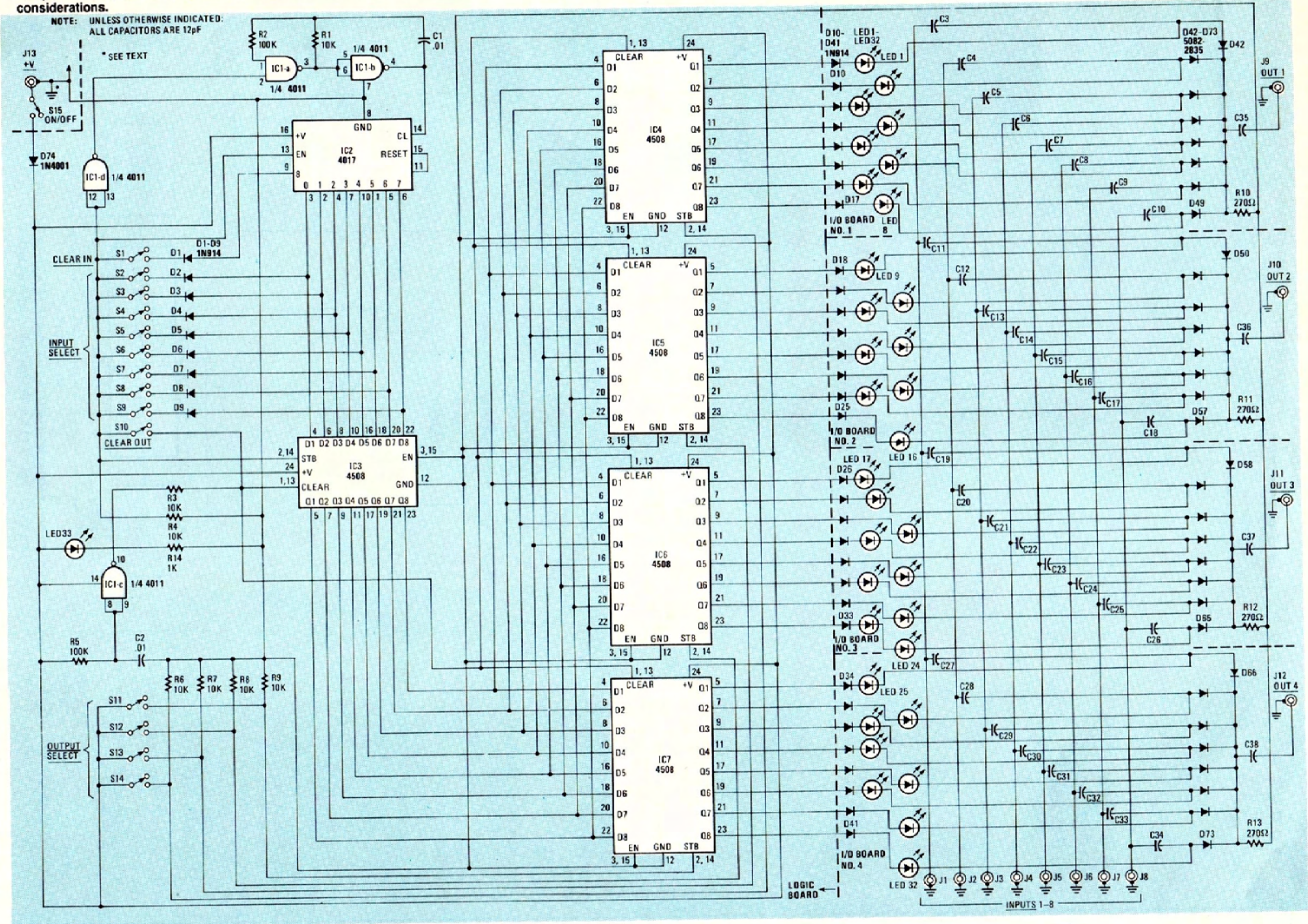

FIG. 2—SCHEMATIC DIAGRAM of the unit. Note that the unit is built on five PC boards; which components mount on which boards is clearly noted in this illustration. Refer to the text for grounding considerations.

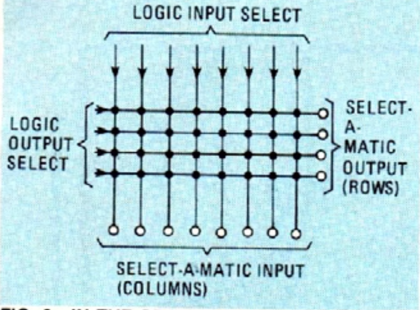

FIG. 3—IN THE SELECT-A-MATIC, switching is handled using a matrix arrangement.

back to the schematic and follow the operation of the circuit. IC1-a and IC1-b are half a 4011 quad NAND gate set up as a gated oscillator running at about 8 kHz. That simply means that a high on pin 2 turns the oscillator on, and a low turns it off. The output is connected to the clock input of IC2, a 4017 decade counter. That IC sequentially turns each of its outputs high as long as pin 13, the $\overline{\text{ENABLE}}$ input, is held low. When one of the INPUT SELECT switches, S1 to S9, is closed, nothing happens until that particular output of the 4017 goes high. As soon as it does, one of the corresponding keyboard diodes, D1 to D9, is forward biased: that disables both the clock (through IC1-d) and IC2 (by presenting a high to its $\overline{\text{ENABLE}}$ input).

That same high also stores the selected column information in IC3, a 4508 dual quad latch. Although that IC has two separate quad latches, we've set it up—and shown it in the schematic—as an octal latch by connecting the control pins of each side in parallel. Pins 2 and 14 control the IC's inputs. When they're high, data presented to the inputs will be stored, and when they're low, the inputs are ignored. Closing one of the input switches, therefore, selects one of the inputs and stores it in the "column" latch. You should also notice that we're able to get an input-clear function for free by selecting one of the 4017 outputs that's not connected to IC3. That's taken care of by connecting the CLEAR IN switch to pin 9, an unused output of the 4017. When it's pressed, eight lows are stored in IC3, overwriting any other data that was stored there.

Pins 3 and 15 of the 4508 are the output control pins. Bringing them low will enable the outputs, and making them high will put the IC in its high-impedance mode. Since there's no need for that in the circuit all these pins are connected together and tied low, permanently enabling the outputs of all the 4508's in the circuit. The importance of that can be seen by looking at the row selectors, IC4 to IC7. The inputs of those IC's are all in parallel and are connected to the outputs of IC3. If IC3 was allowed to go to its high-impedance state, the inputs of IC4 to IC7 would be able to float and, since we're dealing with CMOS, that is a definite no-no.

The operation of the row selector is much the same as the column selector. Closing one of the OUTPUT SELECT switches, S11 to S14, causes the selected IC to store whatever information is presented at its inputs. Since the outputs are always enabled, they follow the inputs, and the selected control signals are available on the appropriate line of the 32-bit-wide output bus. Selecting one input and one output, therefore, will turn on one of the output, control lines. Since the outputs are grouped in four rows of eight lines, selecting an output for IC4, for example, won't change the information stored in IC5 to IC7, the other output latches.

Turning off the outputs can be done one of two ways. You can press the CLEAR IN key and then select the output you want to turn off. That will store a low in each cell of the output latch and turn off everything controlled by it. Closing switch S10 will turn off all the outputs as well as clearing the input latch, IC3. That happens because all the CLEAR pins of the 4508's are tied together and pressing S10 brings them all high. Ordinarily they're controlled by IC1-c. That gate is set up as a power-on reset to make sure that all the latches are cleared when the Select-A-Matic is first turned on. Resistor R5 and capacitor C2 generate a negative pulse at power up. The pulse is cleaned up and inverted by IC1-c, causing a short positive pulse to be sent through R3 to all the clear pins of all the latches. After that, the clear pin is held low unless S10 is closed.

Each of the output control lines go through a 1N914 diode and an LED. Both of those devices help isolate the digital control circuitry from the things they're controlling. The LED's also serve to show which outputs are turned on, but it's interesting to note that they're also used as old fashioned diodes. The great majority of the circuits that have LED's in them use them only as status indicators of one kind or another and it's easy to forget that they're really diodes, not some kind of long lasting light bulb. One side benefit of using them like this is they don't have to have their own current limiting resistors. You can't forget about that altogether because some other part of the circuit can take care of it.

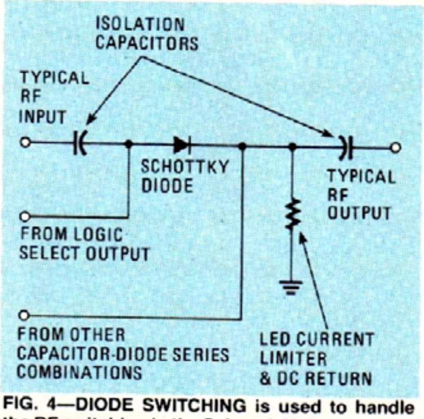

FIG. 4—DIODE SWITCHING is used to handle the RF switching in the Select-A-Matic. Because they can handle the frequencies involved, Schottky diodes are used.

The RF switching of the Select-A-Matic is a straightforward application of diode switching. Figure 4 makes it a lot easier to see what's going on. The input signal passes through a capacitor to isolate the source of the signal from the DC control voltages generated by the Select-A-Matic. The next thing the signal sees is a Schottky diode that does the actual switching in the circuit. As long as the Select-A-Matic has the output turned off, the diode is turned off. When the output is turned on, the diode is forward biased and starts conducting. The input RF passes through the diode, the output capacitor, and shows up at the output connector of the Select-A-Matic. The resistor not only provides the DC return for the Schottky diode, it also serves as the current limiter for the LED.

The layout

As you can see, the basic operation of the Select-A-Matic is easy to understand and, although we're using it to switch RF, the same approach can be used to switch just about anything. The PC layout (the foil patterns for the boards are shown in Figs. 5, 6, and 7) was designed with the aim of making the Select-A-Matic as versatile as possible. All the digital control circuitry is located on the main logic board (see Figs. 5 and 6). The output bus shows up at the far end of that board and is grouped conveniently in four groups of nine solder pads—the ninth connection is system ground. If you want to switch audio signals, for example, you only have to design your analog I/O (to replace the RF I/O used by this project) and connect it to the logic I/O on the logic board of the Select-A-Matic.

The I/O boards of the Select-A-Matic (see Fig. 7) have female connectors (see Fig. 8) to mate with right-angle male connectors on the logic board making the assembly of the whole unit a plug-in operation. The connectors used are header strips with 0.1-inch spacing. Of course you can replace the board connectors with wire, but since we're switching RF, you'll have to be really careful about length, layout, and shielding. The frequencies being switched by the Select-A-Matic can go up as high as 800 MHz., (the top of UHF), and signal behavior can get really strange when you get up in that kind of rarefied atmosphere. Stray capacitance, leakage, and some unplanned-for resonance are only a few of the pitfalls that can completely foul up the operation of the circuit. If you take a look at the foil pattern for the I/O boards, you'll see that component leads are kept as short as possible and several options are provided for handling

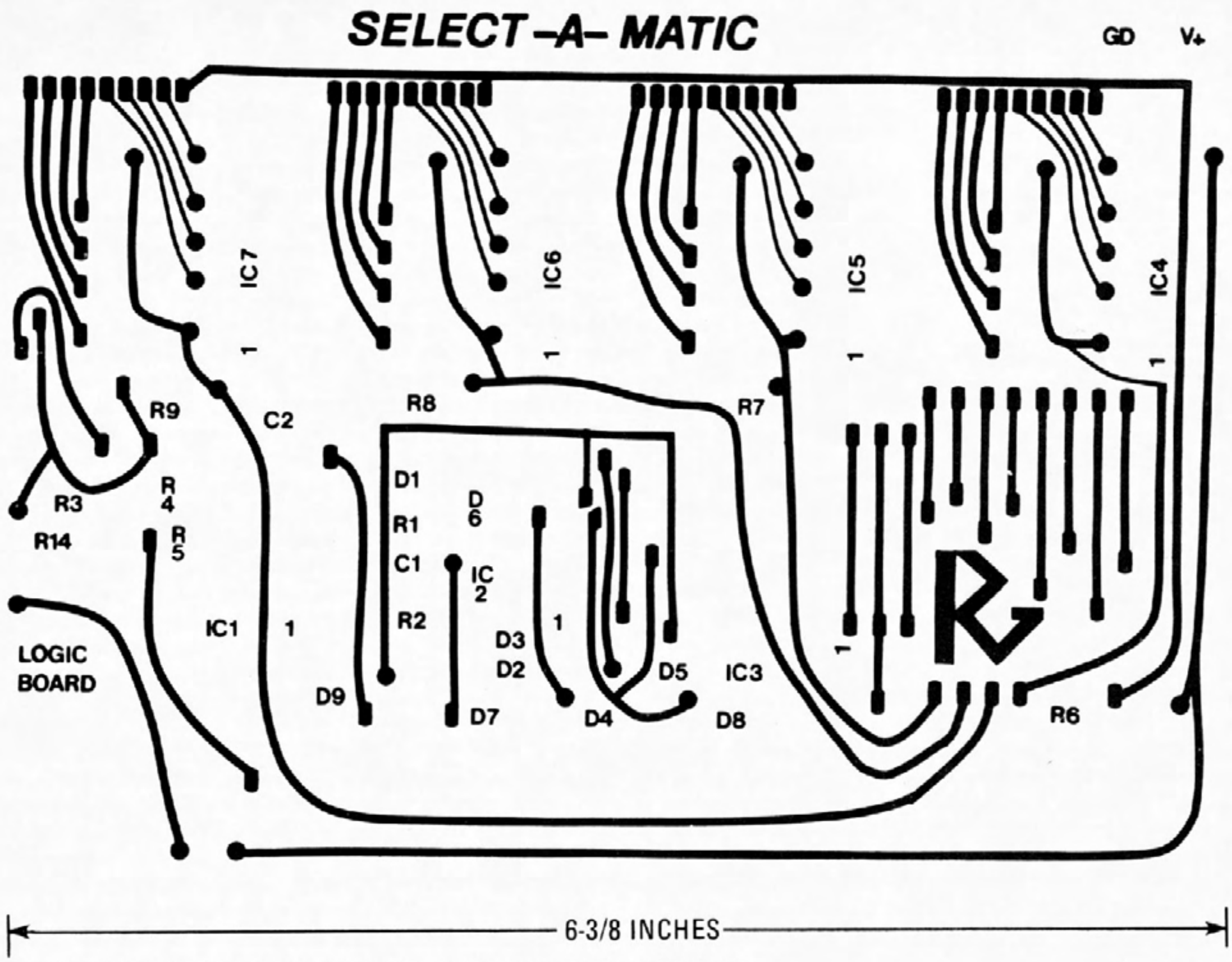

FIG. 5—COMPONENT SIDE of the double-sided logic board. The board is shown full sized.

ground.

A ground plane is provided for both the RF ground, (at the top of the board), and logic ground, (at the bottom of the board). The answer to how you should handle this is a resoundingly unsatisfying "it depends." There are as many theories about grounding as there are about why the dinosaurs disappeared. The best approach is to try various things and decide what works best. It pains us to say this, but as far as this problem is concerned, a logical approach is no help whatsoever. Anyone who uses a simple dipole antenna for FM knows that there is a prescribed way to orient it. They also know that the best orientation is usually found by bunching it up and throwing it on the floor!

Pads are provided on the I/O board to connect RF and logic ground as well as mounting holes if you want to surround all the components on the RF circuit with a metal shield. You should use shielded cable to go from the chassis-mounted F-connectors at the back of the unit to the I/O boards. There are places on the I/O board to connect the cable shield (see Fig. 9). But whether connecting the shield there, elsewhere, or nowhere works best is something you'll have to find out by experiment.

For what it's worth, here's what happened in our case. We had a lot of trouble with crosstalk when we first assembled the Select-A-Matic. We got rid of it completely by lining the inside of the case with aluminum foil (see Fig. 10). That tied together all the RF grounds at the chassis-mounted F-connectors. We connected the shield of the cable on the case side but left it unconnected at the I/O boards. Jumpers on the I/O boards were used to connect the RF and logic ground. That eliminated all of our crosstalk problems. If it had not, the next step would have been to build shields for the I/O boards—probably with aluminum foil at first and then with copper foil so we could solder a connection from the shield to the board. Fortunately that nightmare was unnecessary in our case.

Since signal strength in our location is very good, the slight loss of signal through the Schottky diodes didn't present us with any problem. You may find that to be different—it all depends where you live. In general, signals that come in well won't be degraded much by putting the Select-A-Matic in the signal path. If, however, you're looking at reception that's marginal even on a good day, you've got a problem. You can use the Select-A-Matic to handle home-grown RF from such things such as VCR's, videogames, and the like, but broadcast signals are probably out of the question unless you add an RF amplifier to the Select-A-Matic output lines. That can be a one-transistor circuit or anything you need to get the job done.

Construction

There's nothing especially difficult about constructing the Select-A-Matic if you use PC boards. As previously mentioned, the foil patterns for that board, one of which is double-sided, are shown in Figs. 5, 6, and 7; the parts placement diagrams are shown in Figs. 9 and 11. Wirewrapping or breadboarding are unsuitable because of the frequencies running around the circuit. The breadboarded version we built worked, but the performance of the circuit was terrible. When it was put on PC boards, noise, crosstalk, rejection, and all the other things that had been a problem completely disappeared. Remember, CMOS digital signals are just about noise immune—even if you grind the wires into the ground with your heel. Look cockeyed at RF and the whole circuit can go bananas.

The power supply for the Select-A-Matic is designed to be located elsewhere. All you've got is a jack for a small wall unit that puts out more than 5- but less

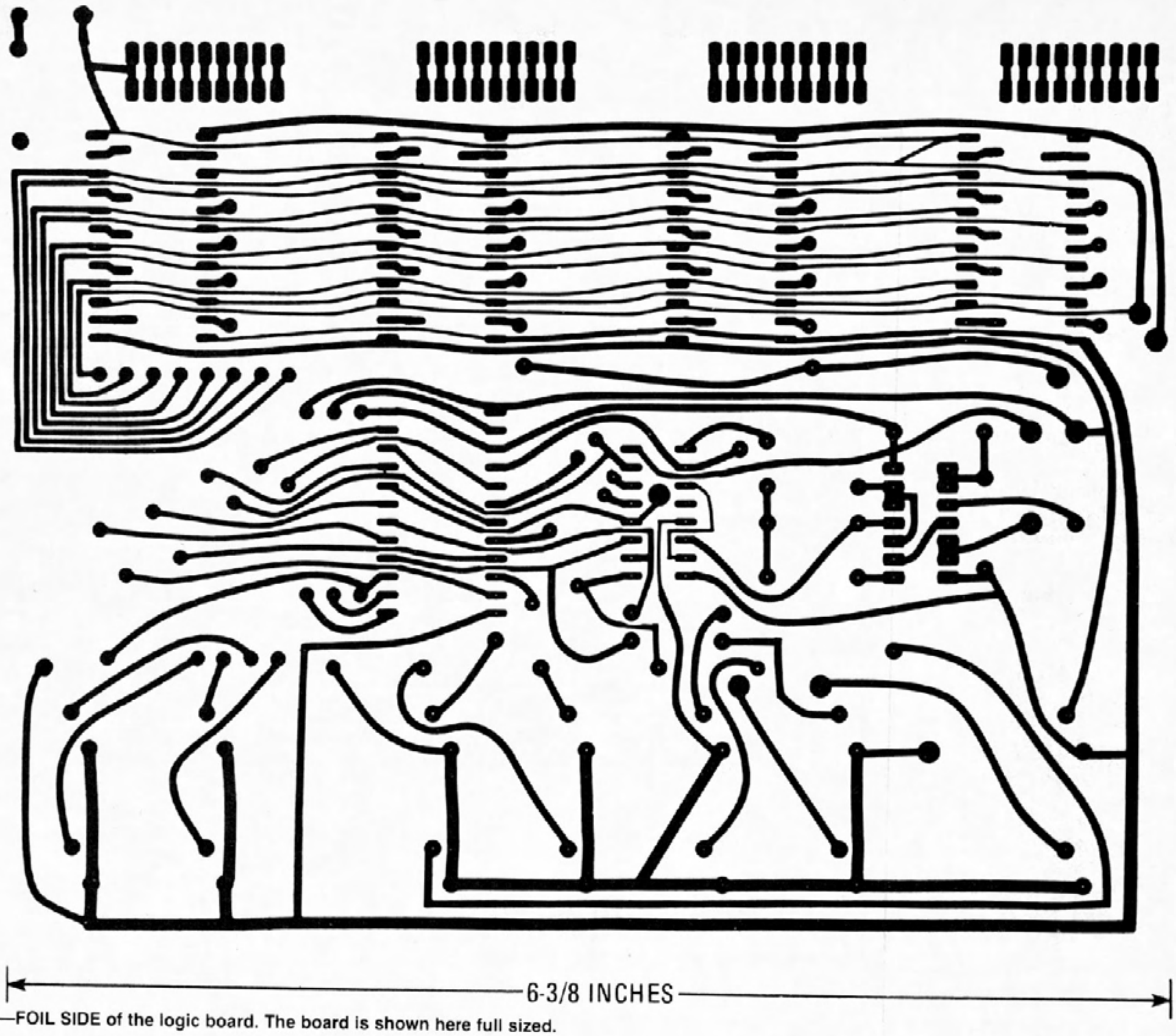

FIG. 6—FOIL SIDE of the logic board. The board is shown here full sized.

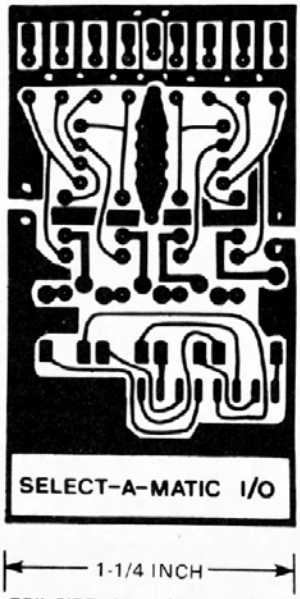

FIG. 7—FOIL SIDE of the I/O board. Four of these single-sided boards are required.

than 7-volts DC with a reasonably small amount of ripple. If you use one that's really noisy, you can put a nice chunky capacitor across the pins of the jack on the chassis. If it's really a problem isolate the circuit by putting a resistor in series between the power supply and the Select-A-Matic—you can use the power jack for that as well. Since the whole circuit draws less than 20 mA, a value around 200 ohms should be in the ballpark. You can also leave out the protection diode on the +V line, but it's always better to be safe than sorry.

The switches used in the Select-A-Matic are soldered directly to the logic circuit board. They're made by Oak Switches and the pin spacing on the board was designed to accommodate them.

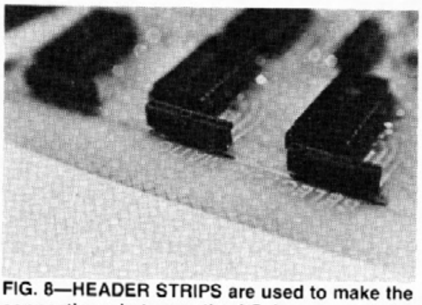

FIG. 8—HEADER STRIPS are used to make the connections between the I/O boards and the logic board.

Those switches are brand new (and a special thank you to Henry Richter, Inc. for providing them to us for use in this project), but should be available from most Oak distributors by the time you read this. If you have a hard time finding them, you can make up a wiring harness and locate the switches off the board. The same is true of LED33, the power pilot-light. Just make sure you keep the leads straight and remember that the current limiter for that LED, R14, is located on the board.

When you're assembling the board, watch the polarity of all the diodes, especially the Schottky diodes. These are a lot more expensive than your garden-variety diodes and it's distressing, to say the least, to break one when you solder it. We used those diodes because they're fast enough and have a low enough turn on voltage to be perfect for UHF mixing. Although we haven't tried it, 1N914 or 1N34A germanium diodes could be used as well, but we don't know how far up the spectrum you'll be able to go before signal loss gets excessive. All we can tell you is they work for channel three but we don't know if they can even make the frequency jump found around Channel 6. If you want to try them, go ahead.

Since the logic board is double-sided, you'll have to solder feedthroughs from one side of the board to the other. Thread hookup wire back and forth through the indicated holes (marked with an asterisk in Fig. 11), solder on both sides and then cut it off. We tried to do all the side jumping on component legs, but there aren't a lot of components on the board so there are quite a few stand alone feedthroughs.

Use IC sockets, caution, and common sense to keep potential problems from the board. And make sure you use a low-wattage iron when you're soldering the diodes—glass-cased diodes are really fragile.

One note on the I/O board. While there are four such boards required, only one is shown in the interest of space. All four

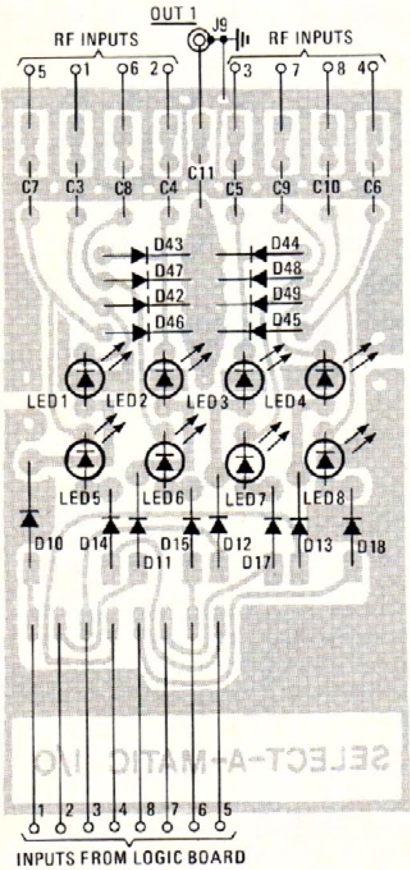

FIG. 9—PARTS PLACEMENT DIAGRAM for the I/O boards. Note that only board 1 is shown; four I/O boards in all are used by the project (see text).

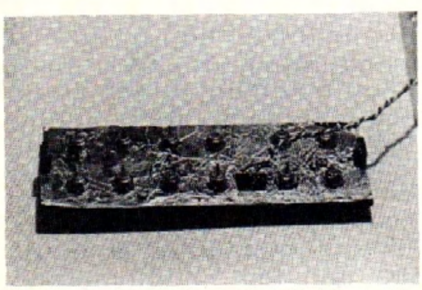

FIG. 10—TO ELIMINATE CROSSTALK, the inside of the case was lined with aluminum foil.

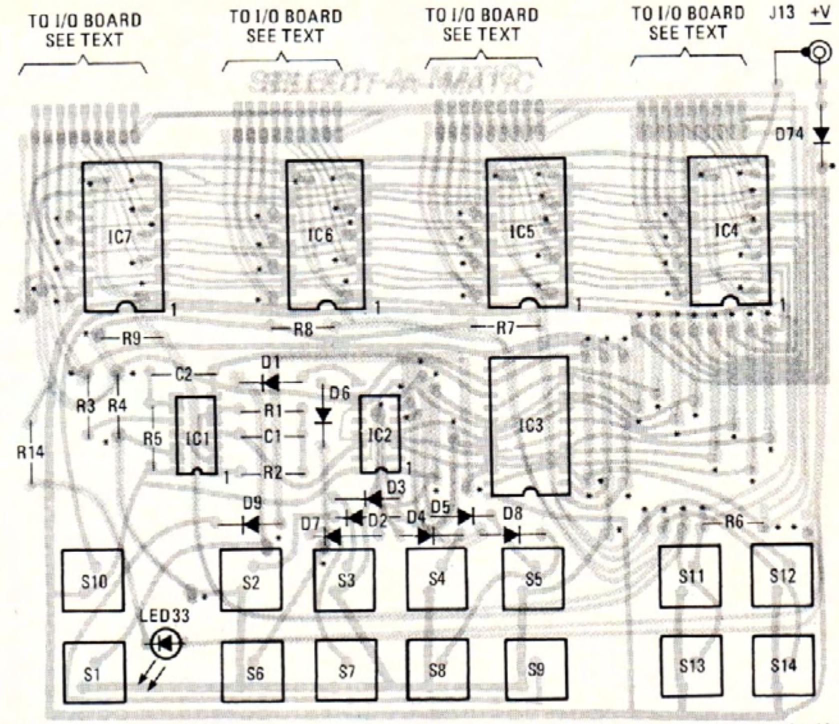

FIG. 11—PARTS PLACEMENT diagram for the main logic board. Note that—although not marked by an asterisk—feed throughs are required at the I/O connections.

PARTS LIST

All resistors ¼ watt, 5%, unless otherwise noted
R1, R3, R4, R6–R9—10,000 ohms
R2, R5—100,000 ohms
R14—1000 ohms
R10–R13—270 ohms

Capacitors
C1, C2—.01µF, ceramic disc
C3–C38—12pF, ceramic disc

Semiconductors
IC1—4011 quad NAND gate
IC2—4017 decade counter
IC3–IC7—4508 dual quad Latch
D1–D41—1N914 diodes
D42–D73—5082-2835 Schottky diodes
D74—1N4001 diode
LED1–LED34—miniature LED's
S1–S14—SPST switch, momentary pushbutton (Oak 225)
S15—SPST switch, toggle
J1–J12—F-type connectors, chassis mount
J13—miniature jack

Miscellaneous: PC boards, aluminum foil for shield, case, wire, solder, male header strips, right angle (AP products 929835 or equivalent), female header strips (AP products 929974 or equivalent), etc.

A set of the five PC boards, etched and drilled, but not plated through, is available from Hal-Tronix, PO Box 1101, Southgate, MI 48195. The price is $39.95. Please add $2.00 for shipping and handling. MI residents add 4% tax.

boards are identical. In other words, where board 1 (shown) uses eight 12-pF capacitors (C3–C10), board 2 (not shown) uses eight 12-pF capacitors (C11–C18) and so on. A quick look at the schematic (Fig. 2) should help remove any confusion; which components go on which board is clearly shown there.

Troubleshooting

If the unit doesn't work when you get it all assembled, and it probably won't the first time, use all the standard troubleshooting techniques. The most suspect things are mechanical—solder bridges, bad joints, components in backwards, and all of the rest of the usual stuff. If everything seems OK as far as that goes, then start suspecting the components. Is the clock clocking? Are signals showing up where they should?—but you've heard all of that before. Exercise simple caution and you shouldn't have any major problems (famous last words). Actually, though, the circuit is simple enough to severely limit the number of problems you can have. Save all your energy for figuring out how to take care of the ground.

If you find that nothing you do will solve the kinds of RF problems we talked about before, you always have the option of substituting small relays for the Schottky diodes and capacitors (RF). That kind of last resort solution should work no matter what the problem is. And you'll be able to switch anything—including audio and video. Another benefit you'll get is that the coil resistance of the relay will probably be great enough to work as a current limiter for the LED's. **R-E**