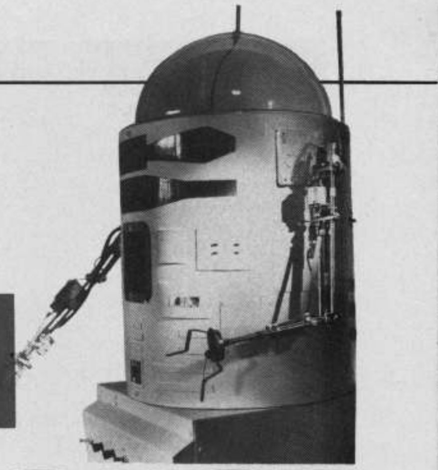
BUILD THIS

UNICORN-1 ROBOT



Part 8—Last month we began to look at a remote-control system for the Unicorn-1 robot. In this part we will continue with that system by describing our control scheme, a simple FM transmitter, and a relay-driver board.

JAMES A. GUPTON, JR.

A LOT OF THOUGHT WAS GIVEN TO HOW Unicorn-1 could be controlled remotely. A number of schemes were considered—ultrasonics (not reliable enough and not enough range); infra-red (the same, but more so), and, of course, radio. A system was even devised using model-airplane R/C equipment, but that proved to be expensive and not easily expandable to computer-control.

The system finally chosen was inspired by one used by amateur radio operators for VHF and UHF repeater control and its principles are probably familiar to most **Radio-Electronics** readers from at least one other source—the telephone company.

Before getting into the actual construction of the robot's R/C system, it might be a good idea to fill you in on this scheme, so you have an idea of the direction we're headed in.

The heart of the system is the DTMF (*D*ual *T*one *M*ulti-*F*requency) system—also known as *Touch-Tone*. A 16-key pad (shown in Fig. 65)—or a matrix of switches providing the equivalent function—is used to instruct a DTMF generator IC, in this case a ICM7206JPE, to produce a pair of tones unique to the key pressed.

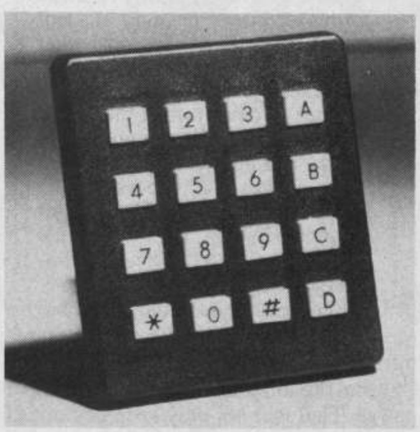


FIG. 65—A 16-KEY *Touch-Tone* pad similar to this one was used in the prototype to modulate an FM transmitter.

That tone-pair modulates an inexpensive, low-power FM transmitter operating in the FM-broadcast band. The signal is received by a standard FM broadcast-band receiver located in the robot and the tone-pairs are decoded to generate a one-out-of-sixteen control signal. That control signal is fed to a relay-driver board to energize the coils of the appropriate relays (as described in Part 7 of this series) and operate the robot's motors and solenoids.

This method will lend itself particularly well to computer control. The 16-key pad is arranged as a 4-row by 4-column switch matrix where each row generates its own tone, as does each column. The result, if the rows and columns are considered together (lined up in one row) is the equivalent of a computer *byte*—the standard 8-bit word.

A computer can output, through a parallel port, an eight-bit binary number that can represent those same switch closures. That byte can be used in place of the keypad to cause the tones to be generated, thus allowing a computer program to direct the robot's actions.

Alternatively, if the robot carries an on-board computer, the output of its parallel port can easily be translated into control signals for the relays.

Several installments will be required to describe the control system in detail. This one will talk about FM transmitters and the relay-driver board. The next will talk about the *Touch-Tone* encoding and decoding circuits, and their interfacing to the others.

Finally, we'll talk about computer interfacing and a little about programming as it pertains to robot control.

FM transmitter

This transmitter can actually be used for two purposes, although not simultaneously. In essence, it is what's commonly called an FM wireless mike. Usually it is used to transmit voices or music on an unused frequency of the FM broadcast band for personal entertainment purposes.

In that mode, using the robot's built-in amplifier and speaker (see Part 5), the robot can talk to persons in its vicinity—with a little help from the operator. In fact, if the robot carries a second wireless mike, operating on a different frequency, a two-way conversation can be carried out.

However, that is secondary to our main purpose—actually controlling the robot. (Come to think of it, though, the control tones could also be fed to the robot's amp and speaker, making him sound a little like good old *R2-D2*.)

A schematic for a wireless mike is shown in Fig. 66. No foil pattern is given, since the circuit can be easily constructed on perforated construction board. Suitable FM transmitters are also available from a number of companies who advertise in **Radio-Electronics.**

Transmitter construction

If you build your own transmitter, it can be constructed on a piece of perfo-

PARTS LIST—FM TRANSMITTER

All resistors ¼ watt, 5%
R1, R2—1 megohm
R3, R6, R9—8200 ohms
R4—330 ohms
R5—470,000 ohms
R8, R11—15,000 ohms
R12—3900 ohms
R13—220 ohms
R14 (optional)—390,000 ohms
Capacitors
C1, C3, C4, C6—5 μF, tantalum
C2—0.1 μF, ceramic disc
C5—10 μF, tantalum
C7, C11—0.01 μF, ceramic disc
C9—5-15 pF, variable (E.F. Johnson 274-0035-005 or equivalent)
C10—7 pF (approx.), ceramic disc
L1—see text
L2—see text
Miscellaneous: construction board, high-impedance microphone, solder, wire, etc.

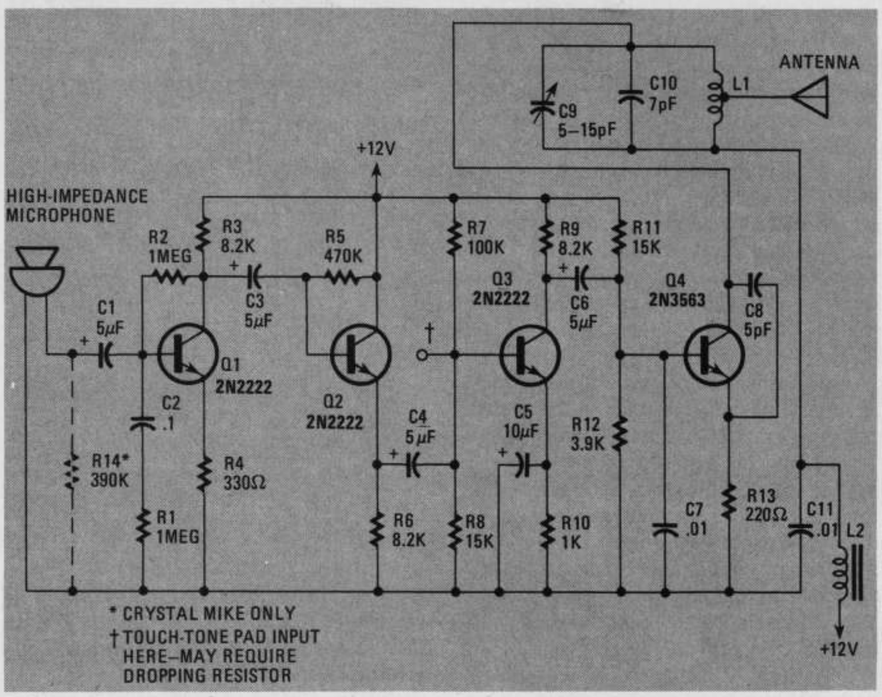


FIG. 66—SCHEMATIC DIAGRAM for the FM transmitter. Value of dropping resistor R14 may range from several hundred kilohms to two megohms or more.

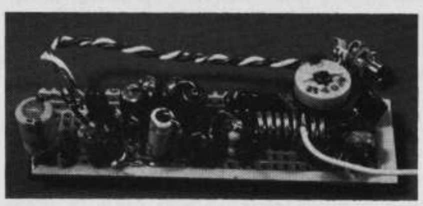


FIG. 67—PROTOTYPE TRANSMITTER built on a small piece of board. Any construction technique may be used.

rated construction board or on a prototyping board. A prototype transmitter, built on a piece of board about 1 × 4 inches, is shown in Fig. 67. Wire-wrap or point-to-point wiring techniques can be used. Keep the leads as short as possible—lead length begins to get critical at these frequencies (80-108 MHz).

The transmitter shown in the schematic, and most of the ones available as kits, are intended to be modulated by a high-impedance microphone. (If you intend to use a crystal mike, be sure to include resistor R14.)

If you are going to use the transmitter only with the *Touch-Tone* pad for control purposes, the first two stages—Q1 and Q2—can be omitted, and the output of the tone-generator IC applied to the base of Q3, since its output level is much higher than that of a microphone, and not as much amplification is needed. In fact, you probably will have to add several hundred kilohms of resistance to attenuate the tones so they do not overdrive the transmitter and cause distortion.

Best results with the homebrew transmitter were obtained when tantalum capacitors were used where values of five and ten μF were needed. The tuning capacitor, C9, should have a value such that, when it is parallelled with C10, the total capacitance does not exceed 22 pF. A good place to look for something to use as C9 is in a junked portable FM radio.

Coil L1 is made using eight turns of No. 16 copper wire. Its outside diameter is ¼-inch and the total length of the coil is 0.6 inches. Coil L2 consists of 12 turns of No. 30 wire (wire-wrap wire will do nicely) closely wound around a quarter-watt resistor of the highest value you have on hand (it should be at least 100K). The ends of that coil can be soldered to the resistor leads, which, of course, then become the leads of the coil.

The antenna lead is soldered to the third turn of L1, counting from the 12-volt end of the coil. The antenna itself can be either a fancy telescoping type, or simply a piece of stiff wire. Since we are deliberately *not* trying to obtain maximum efficiency, the length of the antenna is not critical—about ten inches seems to work well.

Locate the antenna right at the transmitter, which can be mounted inside the command console if you like. It is not necessary to feed the antenna with coaxial cable—it can be connected directly to the output of the transmitter. What is important, though, is that the antenna be insulated from the case containing the transmitter, if that case is metallic, to prevent it from shorting out to ground.

The frequency of the transmitter can be affected by the antenna. It should be as rigid as possible and, more important, because of capacitance effects, it should be as far away from possible contact with your body as possible. Keep that in mind when you are tuning the transmitter, especially if the transmitter and antenna are mounted on the case containing the keypad and tone encoder.

The best section of the FM band for your use is probably the bottom—around 88 MHz. Tune your receiver to a clear spot in that area and turn up the volume so you can hear some background hiss. Then, using an insulated—or plastic—screwdriver, *slowly* adjust C9, or its equivalent, if you assembled a kit, until the hiss is blanked out. That will indicate that you are receiving your transmitter's carrier. Be patient—the tuning process is critical. It may also be necessary for you to stretch or compress L1 slightly to get into the right portion of the band.Before you fire up the transmitter, you should be aware of the FCC regulations governing the use of such devices. Those regulations may be summarized as follows:

- The use of such devices for personal surveillance is illegal!
- The range of such devices is limited to 100 feet. Do not attempt to extend that range through the use of higher power or more efficient antenna systems—use only what you need! Improve your *receiver*, if necessary.
- Do not attempt to use the transmitter below 88 MHz or above 108 MHz. The former may interfere with commercial two-way radio services; the latter with aircraft communications. Do not use the transmitter anywhere near commercial airlanes!

To be safe, make sure the signal begins to fade out about 90 feet from the transmitter. If it is too strong at that range, shorten the antenna or reduce the input power. That will not only keep you out of trouble, but will ensure that you can clearly observe—and control—the robot's actions before it does something to embarrass you.*

In the next part of this series we'll go into detail on connecting the tone genera-

*Due to the difficulty in obtaining positronic brains, Isaac Asimov's Three Laws of Robotics do not apply here, and we have to use our own judgment, rather than rely on the robot's.

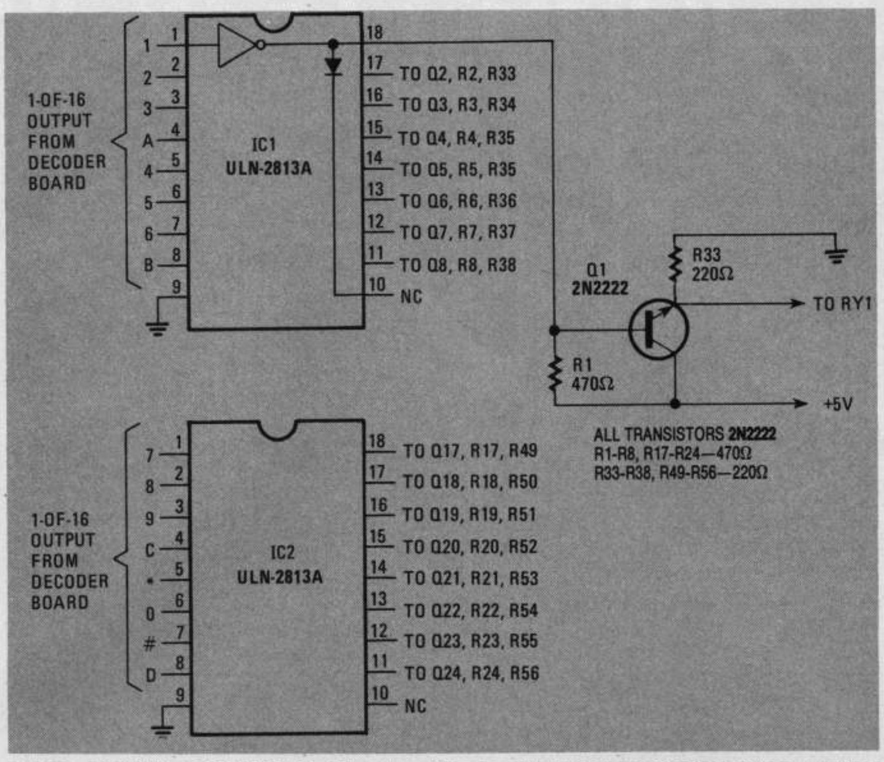


FIG. 68—SIMPLIFIED SCHEMATIC of the relay-driver board. Only one section is shown as all others are the same.

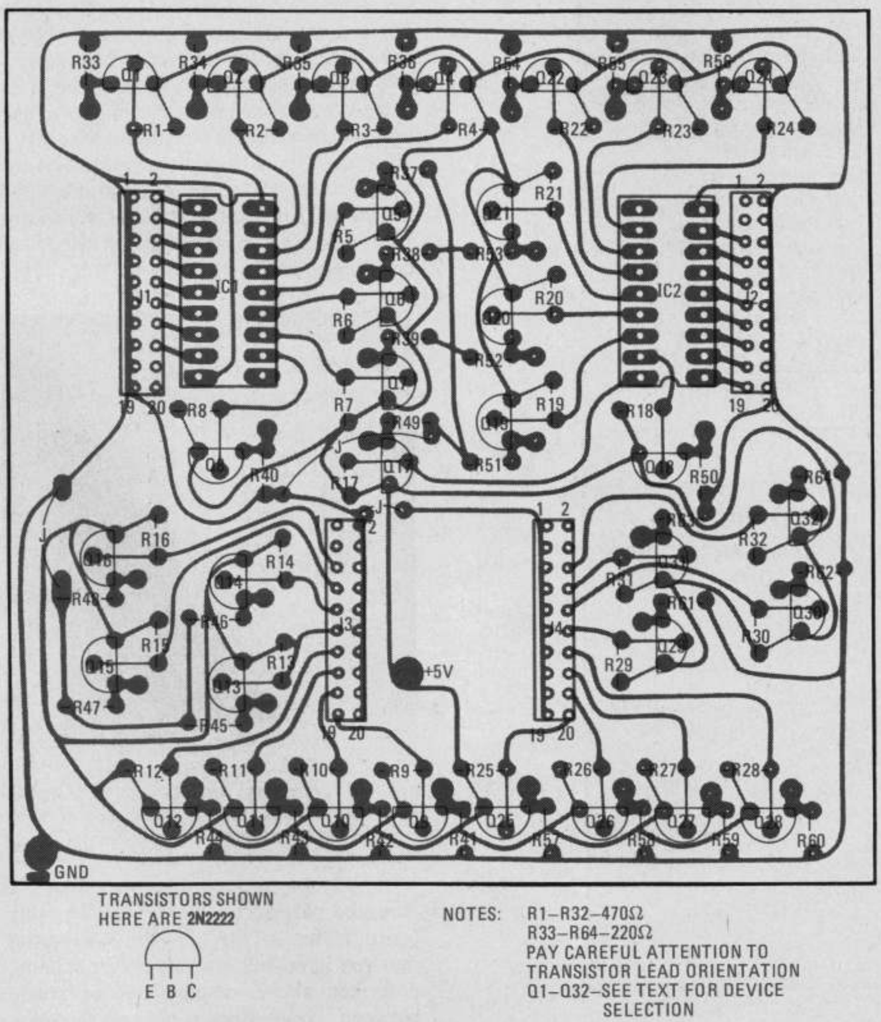


FIG. 70—PARTS PLACEMENT diagram for the relay-driver board. If 2N2222 transistors are not handy, almost any other type may be used.

tor to the transmitter, and the tone decoder to the receiver (and to the robot).

Relay-driver board

A portion of the relay-driver board circuit is shown in Fig. 68. There is really very little more to it than that—the same circuit, for all intents and purposes, is repeated 32 times.

A foil pattern for the relay-driver board is shown in Fig. 69, and the parts-placement diagram in Fig. 70. Don't be put off by its complexity, though. Initially, we'll use only half of that board—each relay will have its own output from the ULN-2813A driver IC and its own transistor. The balance of the board is reserved for future use—primarily when it becomes necessary for the robot, when it gets its on-board computer, to respond to stimuli from its environment. It can also serve to provide other control functions if a more sophisticated control system is used, and suggestions for that will appear in a future part of this series.

Jacks J1 and J2 will be used to connect the relay-driver board to the decoder board.

Here's how the circuit works: The ULN-2813A is an inverting octal driver. What that means is that it has eight identical sections; and when a logic-high signal (about five volts) from the decoder board is applied to the input of one of the sections, the output of that section goes to a logic-low state (zero volts, or ground) and will act as a ground for any voltage that is applied to it.

When an output of the IC goes "low," it causes its associated transistor to be saturated. That allows five volts to pass from the collector and out the emitter to the coil of the relay assigned to that transistor, causing the relay contacts to close. That's all there is to it.

Although IC pin and function assignments are arbitrary, Table 1 shows a suggested arrangement for use with a 16-key *Touch-Tone* keypad.

Because we are limited to 16 on/off control signals, several of the robot's original functions temporarily have had to be eliminated or combined. For example, we can no longer beep the horn, and both end-effectors now operate simultaneously.

Regaining those lost functions will be easy under computer control and later we'll present a couple of ideas for some simple logic circuits that will allow the 16 radio-control channels to provide more than 16 functions.

Construction of the board is straightforward. The 2N2222 transistors were used because they were handy. As Fig. 71 shows, almost any transistor can be used—you can see four different types there. If you have PNP—say, 2N2907—instead of NPN transistors, the only change that has to be made is to insert the transistors in the board backwards—the emitter goes where the collector would

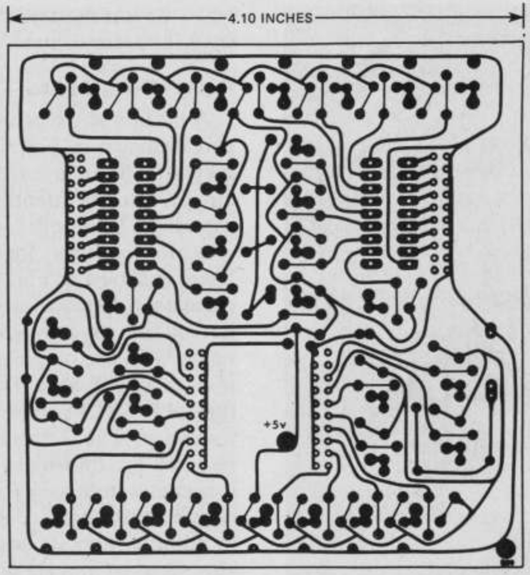


FIG. 69—FOIL PATTERN for the relay-driver board. Only half the board will be used at this time, with the rest reserved for expansion.

TABLE 1

IC No., Pin No.	Key No.	Function
IC1, 1	1	Both wheels, forward
″ , 2	2	Both wheels, reverse
″ , 3	3	Left wheel, forward
″ , 4	A	Left wheel, reverse
″ , 5	4	Right wheel, forward
″ , 6	5	Left & right arm solenoids
″ , 7	6	Body rotate, right
″ , 8	B	Body rotate, left
IC2, 1	7	Left shoulder, up
″ , 2	8	Left shoulder, down
″ , 3	9	Right shoulder, up
″ , 4	C	Right shoulder, down
″ , 5	*	Left arm, up
″ , 6	0	Left arm, down
″ , 7	#	Right arm, up
″ , 8	D	Right arm, down

TABLE 2

Transistor	Relay No.	Finger No.
Q1	RY3, RY5	R, 6
Q2	RY4, RY6	M, 3
Q3	RY3	R
Q4	RY4	M
Q5	RY5	6
Q6	RY19, RY20	18, 4
Q7	RY1	20
Q8	RY2	17
Q17	RY9	P
Q18	RY10	L
Q19	RY11	7
Q20	RY12	2
Q21	RY15	N
Q22	RY16	8
Q23	RY17	5
Q24	RY18	1

be, and vice-versa. The resistor placement can stay as shown.

PARTS LIST—RELAY-DRIVER BOARD

All resistors ¼ watt, 5%
R1-R32—470 ohms
R33-R64—220 ohms
Semiconductors
IC1, IC2—ULN-2813A inverting octal driver (Sprague)
Q1-Q32—2N2222 or equivalent NPN-type; 2N2907 or equivalent PNP-type (see text for details)
J1, J2—20-pin, double row, header connector (AP Products AP923862-R or equivalent)
Miscellaneous: PC board, 22/44-finger prototyping board (Radio Shack 276-154 or equivalent), two 22/44-pin sockets (Radio Shack 276-1551 or equivalent), 18-pin IC sockets, mating connectors for J1 and J2, 20-conductor ribbon cable, hardware, wire, etc.
A PC board for the relay driver board is available from PPG Electronics Co., Inc, 14663 Lanark St., Van Nuys, CA 91402. (213) 988-3525. Price is $9.95 plus $1.00 for shipping and handling. CA residents add 6% tax. MC and Visa accepted.

Installation

After the relay-driver board has been completed, it is piggy-backed onto a 22/44-finger board like the one that was used for the relay board, using ¼-inch spacers. Make positively sure that the two boards are electrically isolated from each other.

The emitter (output) of each 2N2222 transistor is connected to a finger on the piggy-back board. You can use wire-wrap wire for that. The most straightforward way is to use the same finger number (or letter) as that which is connected to pin 16 of the appropriate relay on the relay board (See Table 2).

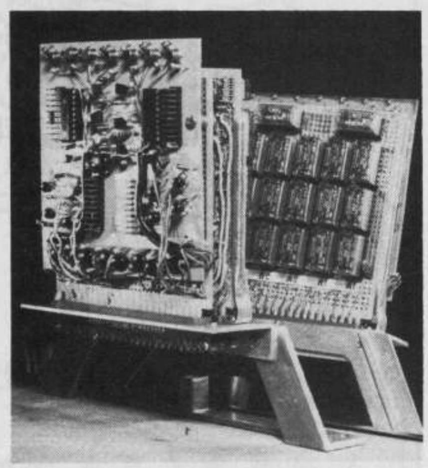


FIG. 71—THE RELAY-DRIVER BOARD is mounted parallel to the relay board, seen reflected in the mirror.

A 22/44-pin edge connector is mounted parallel to the one for the relay board (refer to Fig. 71) and, assuming that you have followed the wiring scheme described above, connections are made between like-numbered pins on the driver-board socket and the relay-board sock-

continued on page 82

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of three coaxial antenna outputs, one long-wire antenna, and one coaxial tuner bypass. The impedance is 10-300 ohms. A direct-reading SWR meter on the front panel is calibrated from 1.1 to infinity.

The front-panel power meter displays RMS power with continuous (CW) carrier and automatically displays the peak power when in the SSB mode in ranges of 0-250 W and 0-2500 W.

The price of the *model AT2500* is $698.00. **—Bell Industries,** J. W. Miller Division, 19070 Reyes Ave., P.O. Box 5825, Compton, CA 90224.

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The *Varifilter* has its own internal power supply, which is switchable from 115 to 230 VAC, and can also run from 12 to 18 VDC. Each unit has a tuning eye that lets the operator see when he has filtered the signal he wants to.

The *Varifilter* is priced at $139.95.**—Kantronics,** 1202 E. 23rd Street, Lawrence, KS 66044.

UNICORN-

continued from page 66

et. Table 2 will also help you with that.

Because it is possible to insert the boards into the sockets backwards, we recommend that you use a marker pen or nail polish to indicate the finger-1 edge of the board and the pin-1 end of the socket. If the boards are removed and then replaced, lining up the marks will prevent embarrassing accidents.

Things to come

Because the radio/computer-control section of the robot involves so many parts, it is impossible to present everything in one section and make the transition from a cable-controlled robot to a radio-controlled one in a single jump.

The circuit described here, though, can be checked out by disconnecting the switches in the command console from the 12-volt supply, and providing them with five volts, instead. The motor and solenoid wiring inside the robot, which has served us well, can now be connected to the relays via the pins on the relay-board socket. Refer to Tables 1 and 3 in Part 7. The five-volts from the command-console switches can now be supplied, via the existing umbilical cable.

Next month we'll present the radio-control tone-encoding and decoding circuits, and Unicorn-1 will be able to cut its apron strings. **R-E**

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