This month we discuss the motor-controller board.

Build the Lawn Ranger

RAYMOND RAFAELS

LAST MONTH WE DIDN'T GET A CHANCE TO FINISH THE MOTHERBOARD and the motor-controller board. So let's finish up those two boards now, and then continue with the story.

Construction

Assemble the motherboard by soldering the three edge connectors onto the PC board with the connector pins protruding through the circuit side of the PC board. The schematic is shown in Fig. 1. The circuit side of the board contains the large ground plane.

Figure 2 shows the parts-placement diagram for the motor-controller board. First, solder the IC sockets to the PC board (one can be obtained from TSI or you can make one from the foil pattern provided in PC Service). Next, solder in all remaining components except for the following components that require special installation: R71, R76, R85, R88, R93, C6, C17, C46, C48–C51, D20, and D22.

Capacitors C6, C17, and C46 are tall and have radial leads (both leads stick out of the bottom). In order to keep the height of the motor-controller board at a minimum, we need to mount those capacitors on their side. That can be accomplished by adding ⅛-inch of insulating plastic sleeving to each of the leads before the capacitor is installed. Then solder, trim leads, and bend the capacitor over on its side. A small drop of RTV or epoxy can be added to secure the capacitors to the PC board.

Diodes D20 and D22 must be soldered in series, and then installed as a single component in the location indicated in Fig. 2. Resistors R93 and R1 consists of two 16-ohm, ½-watt resistors connected in parallel. The resistors are then installed as a single component as indicated in Fig. 10. Resistors R71, R76, R85, and R88 should have 0.1 μF capacitors soldered in parallel with them before installation. The capacitors are identified in Fig. 2 as C48, C49, C50, C51, respectively.

There are some jumpers that must be installed on the solder side of the board. The first one goes from J22 pin 41 to IC1 pin 4. Another goes from J22 pin 47 to IC2 pin 6. Next, two twisted pairs of jumpers, each pair consisting of a length red and black wire twisted together, must also be installed on the solder side of the board. The red wire of the first pair must go from J22 pin 42 to R81, and the black wire goes from J22 pin 45 to R82. The red wire from the second twisted pair goes from J22 pin 38 to R63, and the black wire goes from J22 pin 39 to R64.

Alignment

Alignment of the motor-controller board consists of adjusting potentiometers R201, R202, and R203. R201 and R202 are used to adjust the speed of the left and right drive motors, respectively, and R203 adjusts the offset voltage to the D/A circuit.

First adjust R201 and R202 to their center position. R203 should be adjusted until the D/A output (pin 7 of IC4-b) is 0 volts when the D/A input is as follows: DA0 = 0, DA1 = 1, DA2 = 1, DA3 = 1, DA4 = 1, and DA5 = 0. The D/A input can be set by temporarily applying +5 volts for a "1" and ground for a "0" when the

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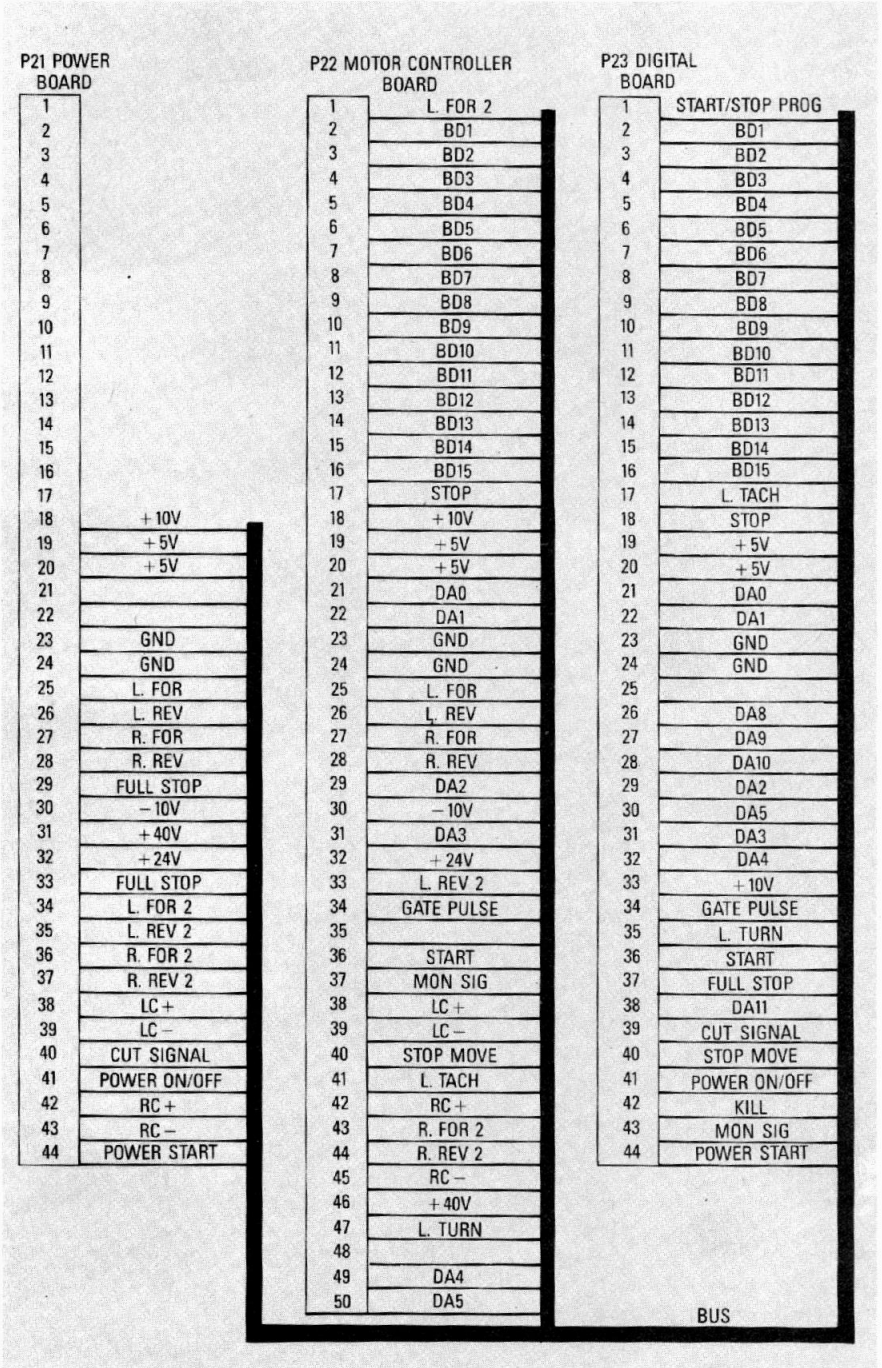


	P21 POWER BOARD	P22 MOTOR CONTROLLER BOARD	P23 DIGITAL BOARD
1		L. FOR 2	START/STOP PROG
2		BD1	BD1
3		BD2	BD2
4		BD3	BD3
5		BD4	BD4
6		BD5	BD5
7		BD6	BD6
8		BD7	BD7
9		BD8	BD8
10		BD9	BD9
11		BD10	BD10
12		BD11	BD11
13		BD12	BD12
14		BD13	BD13
15		BD14	BD14
16		BD15	BD15
17		STOP	L. TACH
18	+10V	+10V	STOP
19	+5V	+5V	+5V
20	+5V	+5V	+5V
21		DA0	DA0
22		DA1	DA1
23	GND	GND	GND
24	GND	GND	GND
25	L. FOR	L. FOR	
26	L. REV	L. REV	DA8
27	R. FOR	R. FOR	DA9
28	R. REV	R. REV	DA10
29	FULL STOP	DA2	DA2
30	−10V	−10V	DA5
31	+40V	DA3	DA3
32	+24V	+24V	DA4
33	FULL STOP	L. REV 2	+10V
34	L. FOR 2	GATE PULSE	GATE PULSE
35	L. REV 2		L. TURN
36	R. FOR 2	START	START
37	R. REV 2	MON SIG	FULL STOP
38	LC+	LC+	DA11
39	LC−	LC−	CUT SIGNAL
40	CUT SIGNAL	STOP MOVE	STOP MOVE
41	POWER ON/OFF	L. TACH	POWER ON/OFF
42	RC+	RC+	KILL
43	RC−	R. FOR 2	MON SIG
44	POWER START	R. REV 2	POWER START
45		RC−	
46		+40V	
47		L. TURN	
48			
49		DA4	
50		DA5	

FIG. 1—ALL OF THE INTER-BOARD CONNECTIONS are made via the motherboard.

PC board is disconnected from the motherboard. The same D/A inputs could be established by temporarily blocking (with electrical tape) grass sensors 1–8 after the Lawn Ranger is completely assembled.

Motor controller test

The best way to test the motor-controller board is after the Lawn Ranger is completely assembled. By blocking grass sensors with your fingers or electrical tape, you can simulate a grass border that the Lawn Ranger can track. As you block different grass sensors, you can verify that the motor controller is working properly by observing the drive wheels as they change speed and direction.

However, that will have to wait until next month, when we will discuss the construction and operation of the power board. We'll also discuss the manual controller and mechanical frame. Start building your own Lawn Ranger now so you can have fun learning valuable electronic skills and, at the same time, produce a personal robot that can perform useful work while amazing your friends

Power board

The power board is responsible for providing regulated DC voltages, controlling the power on/off function, switching +24-volts DC to the motors (for forward and reverse rotation), and stopping the cutting motors after power is turned off. Figure 3 shows a photograph of an assembled power board.

Figure 4 shows the block diagram of the power board. The +24-volt DC input power is supplied by two 12-volt lead-acid batteries that are connected in series. The batteries are rechargeable and can be purchased from suppliers of electric wheel chair batteries for about $35–$45 a piece.

Three DC/DC converters are used to efficiently convert the +24-volt input to ±10-, +5-, and +30-volts DC. The DC/DC converters can be purchased from Power General directly (see parts list).

The left and right motor power drive circuits energize the drive motors. The circuitry contains a series of power MOSFET's that act as low-resistance (0.035 ohm) switches. The MOSFET switches can turn the motors on and off, as well as apply a reverse voltage to make the drive wheels spin in reverse.

The cutting-motor drive circuitry controls the rate at which the cutting disks spin when they are initially turned on. The amount of current that is sent to the cutting motors is monitored and limited to 15 amps (peak) or approximately 10 amps (average). The circuitry is also used to quickly stop the cutting motors when power is turned off by shorting the motor leads together. That technique is typically referred to as dynamic braking. The shorting of the motor leads causes a reverse magnetic field to be generated inside the motors causing the cutting blades to stop within 3 seconds. A 0.01-ohm resistor (R32) is used to limit the motor current to a safe level during dynamic braking.

Circuit description

Figure 5 shows a detailed schematic of the power board. The +24-volt battery power is routed through J11 pins 4 and 5 and fuse F1. Relay RY1 is used to connect and disconnect power from the entire robot. Power is switched on by the operator when the ignition key is turned. The momentary ignition switch grounds J21 pin

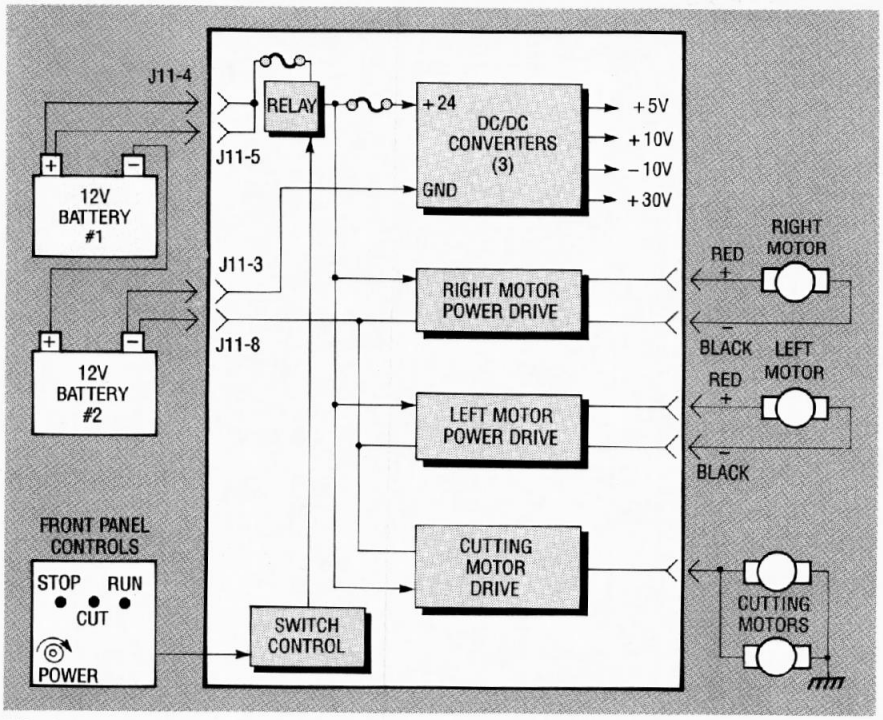


FIG. 4—HERE IS A BLOCK DIAGRAM of the power board.

PARTS LIST—POWER BOARD

All resistors are ⅛-watt, 5%, unless otherwise indicated.

R1–R10, R13–R15, R17, R18, R20–R28, R45–R49—not used
R11, R44, R50—3300 ohms
R12—680,000 ohms, 6-pin, ¼-watt, SIP resistor network
R16, R19, R32, R43—0.01 ohm, 5 watts
R29—150,000 ohms
R30, R31, R34, R35—270,000 ohms
R33, R36—1 megohm
R37—147,000 ohms, ¼-watt, 1%
R38—10,000 ohms, potentiometer
R39—82,000 ohms
R40—100,000 ohms
R41—27,000 ohms
R42—22,000 ohms
R51–R54—560,000 ohms

Capacitors

C1–C5, C7–C13, C16, C17—not used
C6—1000 µF, 35 volts, axial electrolytic
C14, C15, C23–C26—0.1 µF, 50 volts
C18, C21—100 µF, 50 volts, radial electrolytic
C19, C20—100 µF, 16 volts, radial electrolytic
C22—220 µF, 16 volts, radial electrolytic

Semiconductors

IC1, IC2—not used
IC3—LF412N op amp
D1, D2, D11–D13, D30, D31—not used
D3, D4, D16, D17, D20–D24, D33–D38—1N4001 diode
D5, D14, D18, D19, D32—1N4148 diode
D6, D15—1N5402 diode
D7–D10—1N5256B 30-volt Zener diode
D25–D29—1N4740 10-volt Zener diode
Q1, Q2, Q12—not used
Q3–Q10, Q13, Q14—IRFZ42 MOSFET
Q11, Q15, Q16—293904 NPN transistor

Other components

J11—terminal strip
RY1—T90N1D12-24 relay (Potter Brumfield)
RY2—68P-111P-US-DC24 relay (Omron)
F1—3AG 30-amp fast-blow fuse
F2—2AG 0.5-amp fast-blow fuse
MOD1—Model DC2-2-24/12, ± 12-volt DC converter (Power General)
MOD2—Model DC2-2-24/15, ± 15-volt DC converter (Power General)
MOD1—Model 710, 5-volt DC converter (Power General)

Miscellaneous: 3AG fuse holder, 2AG fuse holder, solder posts for the "E" terminals, 18-gauge solid insulated wire, 18-gauge stranded insulated wire, solder, etc.

PARTS LIST—CONTROL PANEL

S1–S4—momentary pushbutton switch
S5—SPDT switch
LED1—red light-emitting diode
Wire and sheet metal for the panel itself

Note: The following equipment can be purchased from Technical Solutions, Inc., P.O. Box 284, Damascus, MD 20872 (301-253-4933): etched and drilled PC boards for CPU Board, Motor Controller Board, Power Board, and Motherboard, $39 each; programmed EPROM, $39; grass sensors, $8.99 each; hand-held manual controller kit, $39; full kit for CPU Board, $129 (PC board, EPROM, all parts); full kit for Motor Controller Board, $169 (PC board and all parts); full kit for Motherboard, $69 (PC board and all parts); Power Board kit (PC board, and all parts except DC/DC converters), $149; Detailed drawing package, $59; Lawn Ranger demo videotape and information package, $19; complete electronic kit with everything mentioned above, $757. Please add $8.00 for S/H. Maryland residents add sales tax.

nected in parallel in order to share the switching load. They are turned on by pull-up resistor R42 and turned off by Q16.

After the MOSFET's are turned on, the +24-volt power supply will be routed to through R32 to pin 5 of relay RY2. As the operator presses the cut button, +5 volts will be applied to J21 pin 41 and Q15 will turn on; that grounds pin 4 of RY2 causing it to switch the +24-volt battery power to the cutting motors. The cutting motors will begin to spin, and as they begin to, the current through resistor R32 will rise sharply; R32 is used as a current monitor and the voltage across it will rise in proportion to the current flow.

Differential amplifier IC3-a amplifies the voltage drop across R32 and feeds it to pin 5 of IC3-b, which is a comparator circuit that compares the current flow with a preset value of 15 amps. When the current through R32 reaches 15 amps, the comparator output (IC3-b pin 7) will swing positive and Q16 will turn on. The power MOSFET's will turn off and the current will stop flowing through the cut-

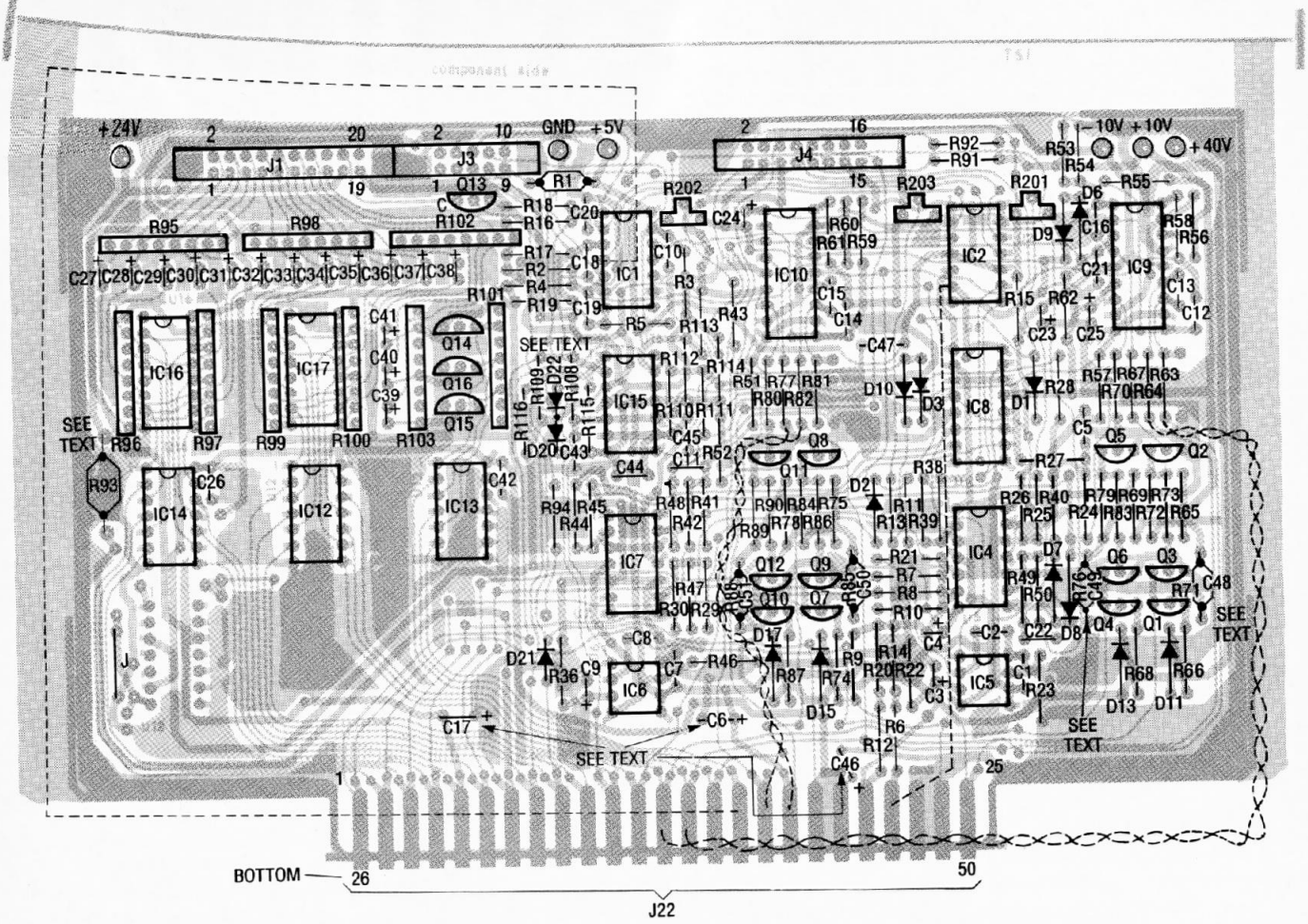


FIG. 2—PARTS-PLACEMENT DIAGRAM for the motor-controller board.

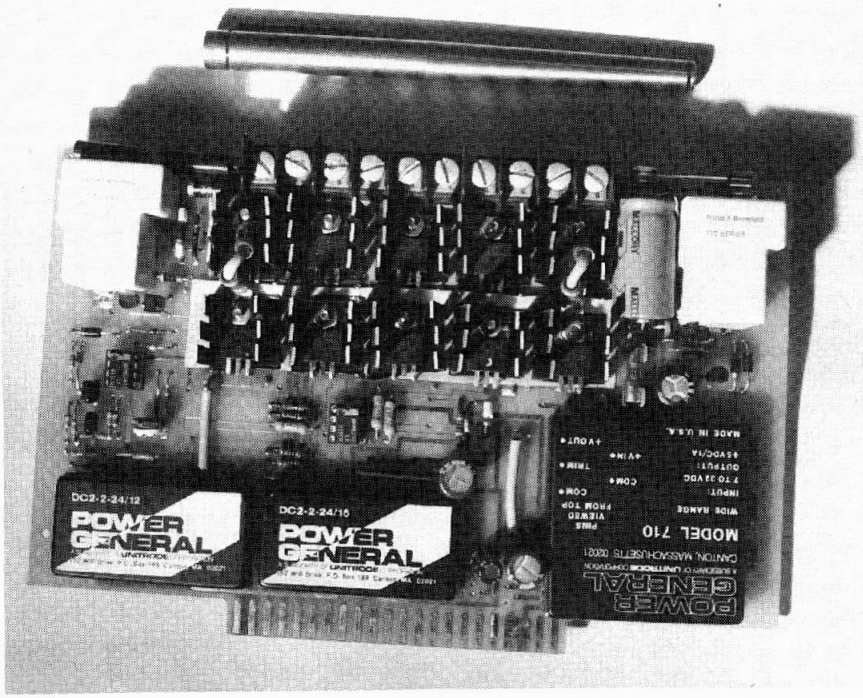


FIG. 3—AN ASSEMBLED POWER BOARD should look similar to this one.

44 and energizes the relay. When the relay switches, the three DC/DC converters will begin to produce the appropriate voltages and the CPU board will come alive. The CPU board will begin to run diagnostic checks and then place +5 volts on J21 pin 41 in order to turn Q11 on; that keeps the relay energized after the operator removes the key.

Forward/reverse motor drive

Transistors Q3–Q6 and Q7–Q10 are power MOSFET's that are used to control the left and right drive motors, respectively. When the left drive motor spins in the forward direction, Q3 and Q5 are turned on and Q4 and Q6 are turned off. Figure 6-a shows the path that current follows when the left drive motor is going forward. On the other hand, if Q3 and Q5 are turned off and Q4 and Q6 are turned on, the current will flow through the motor in the opposite direction causing the motor to spin in reverse (see Fig. 6-b).

Cutting-motor control

The cutting motor circuitry contains power MOSFET's (Q13 and Q14) for switching, as well as a feedback control system for current limiting. Current limiting allows the cutting motors to come up to speed in a controlled manner by limiting large current spikes when the CUT button is pushed. The MOSFET's are con-

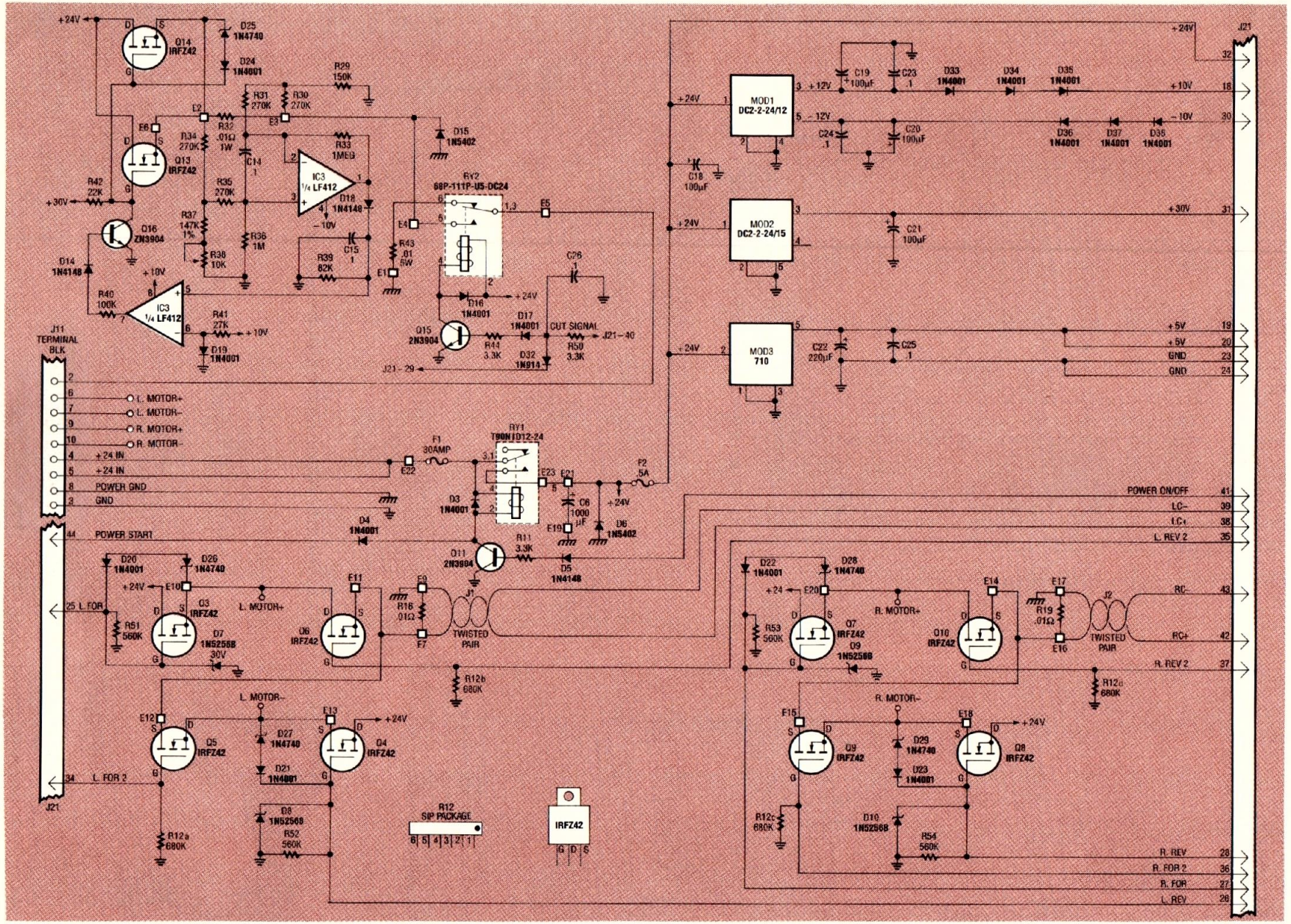


FIG. 5—DETAILED SCHEMATIC of the power board. High-current jumpers have to be installed on the solder side of this board.

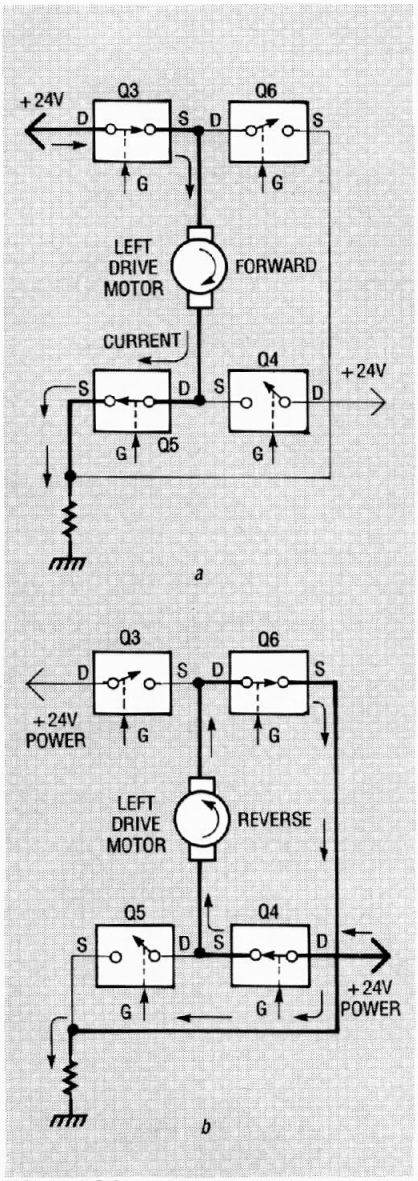


FIG. 6—LOOKING AT *a*, YOU CAN SEE the path that current follows when the left drive motor is going forward. However, in order for the motor to spin in reverse, *b* shows the path that the current must take.

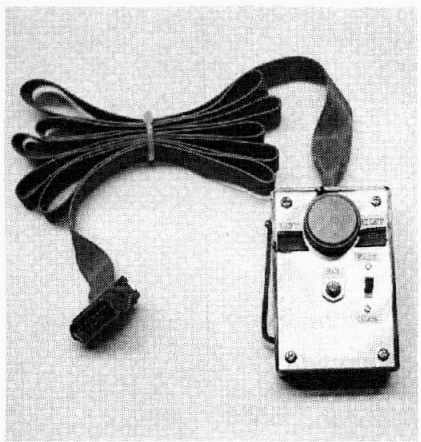


FIG. 7—THE HAND-HELD CONTROLLER allows you to "walk" the mower around the yard to cut a perimeter for it to follow.

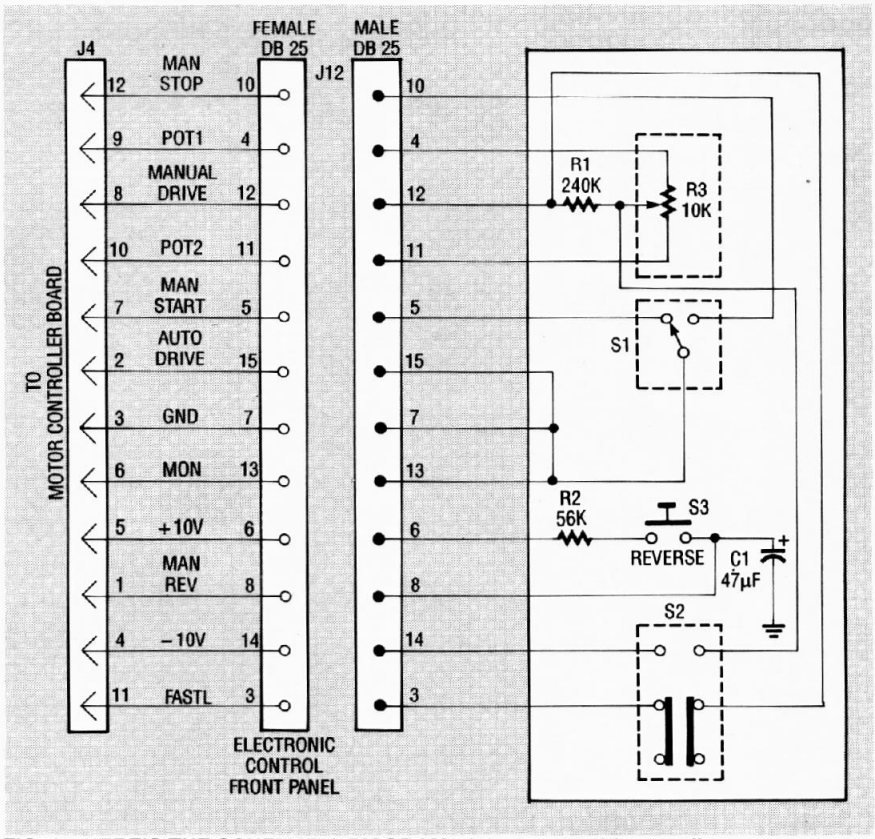


FIG. 8—HERE'S THE SCHEMATIC DIAGRAM of the hand-held controller.

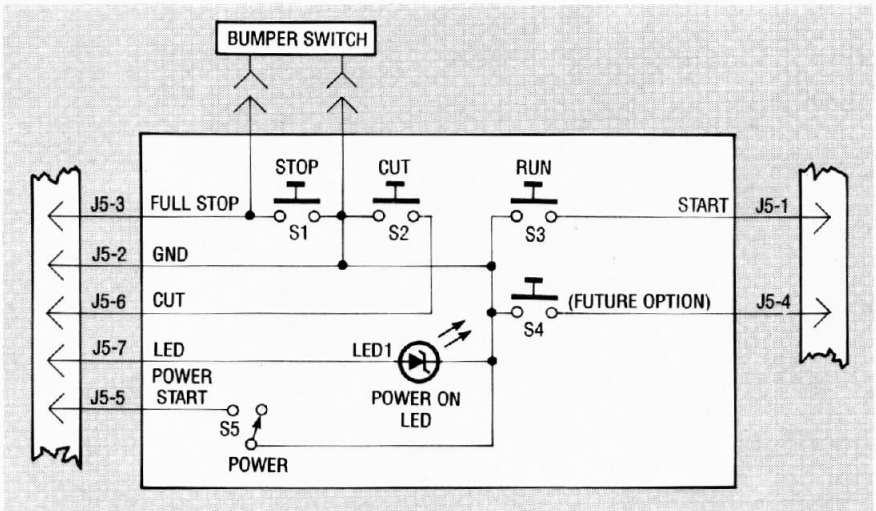


FIG. 9—THE ELECTRONIC CONTROL PANEL must be wired as shown.

PARTS LIST
HAND CONTROLLER

R1—240,000-ohm resistor
R2—56,000-ohm resistor
R3—10,000-ohm potentiometer
C1—47 µF electrolytic
S1—SPDT switch
S2—DPDT slide switch
S3—momentary pushbutton switch
Male and female DB-25 connectors, ribbon cable, suitable enclosure

ting motors and R32. That causes the comparator output to swing negative and the MOSFET's will again turn on causing the current to be applied to the cutting motors. The process is repeated until the cutting motors have reached their maximum velocity. Because the MOSFET's are turning on and off, instead of supplying full power all at once, the cutting motors will slowly come up to speed in a well-controlled manner.

(Continued on page 80)

LAWN RANGER

continued from page 50

Hand-held controller

The hand-held controller allows the operator to manually steer the robot forward and backward. It contains a potentiometer and switches that interface with the electronic control system. The cable from the controller plugs into the electronic control panel located at the rear of the Lawn Ranger. Figure 7 shows a photograph of the hand-held controller, and Fig. 8 shows the schematic diagram.

Potentiometer R3 is used to steer the robot to the left or right. Microswitch S1 is hand-activated and stops and starts the forward motion of the Lawn Ranger. As the operator squeezes the hand control, S1 closes and allows the robot to move. If the operator opens his hand or drops the controller, the robot will automatically turn itself off. Switch S3 is a momentary pushbutton that is used to activate the cutting motors. An RC delay circuit formed by R2 and C1 slows the Lawn Ranger down before it goes into reverse after the operator pushes the REVERSE button. DPDT slide switch S2 allows the operator to choose either a slow or fast driving speed. As far as the contruction of the controller goes, simply install the components as shown in Fig. 8 in a suitable enclosure.

Electronic control panel

The electronic control panel is located at the rear of the Lawn Ranger. The control panel consists of a DB-25 female connector (for the manual controller), three momentary pushbutton switches, a POWER switch (ignition), and a flashing power-on LED indicator. The schematic diagram of the control panel is shown in Fig. 9. The POWER switch is a key-operated ignition switch that supplies power to the robot. The STOP button cuts the power and stops the cutting blades. The CUT button is used to energize the cutting motors. The START button is used to start the automatic cutting operation after the hand-held controller is disconnected.

Next month the Lawn Ranger story will continue. We will be covering the power board and the mechanical assembly. We'll also show you how to thoroughly test each section of the mower. **R-E**

LAST MONTH WE FINISHED BUILDING THE MOTHERBOARD AND THE motor-controller board. Then we covered the operating theory of the power board. So, now let's get to building whatever we haven't covered yet, including the control panel, power board, and mechanical assembly.

Let's mow the lawn already—rather, let's watch the lawn get mowed!

Build the Lawn Ranger

RAYMOND RAFAELS

Construction

Fabricate an aluminum sheet-metal enclosure to house the control-panel electronics; we showed you how to wire everything last month.

As for the manual controller, drill holes in a plastic box to accommodate the components; we showed you a schematic of the controller last month. Feed the ribbon cable through a hole on the side of the plastic box and put a knot on the inside of the box so that the wire can't be pulled through. Fasten the top cover to the box and attach the knob to the potentiometer (P1).

Power-board construction

Following Fig. 1, mount the following components on the solder side (back side) of the PC board: R42, R52, R54, D7–D9, D20–D29, and all E-terminals (they are basically solder posts that allow you to solder heavy-gauge wire to the PC board). Those components are mounted on the solder side in order to create more space for the other components. It is probably a good idea to add a ⅛-inch piece of sleeving insulation to the leads of those components before assembly (with the exception of the E-terminals). That will prevent any accidental shorting of the exposed component leads. After they are installed, trim the component leads. Now install the remaining parts on the component side with the exception of the power MOSFETs.

The MOSFETs require the installation of heat sinks and insulators before assembly. For each MOSFET, place an insulator on the PC board and then cover with a heat sink. Carefully clip off the center lead (drain) of the MOSFET as close to the device body as possible. The lead is not used because the drain connection is also provided by the metal tab on the MOSFET. Bend the MOSFET leads at a 90° angle and insert into the PC board so the device lies flush with the heat sink. Secure the device and heat sink to the PC board with 4-40 hardware.

The high-current jumpers should now be installed on the solder side of the PC board; solder them to the E-terminals. The jumpers are required because the etched traces on the PC board can not handle 15–30 amperes. The jumpers should be made of solid insulated 18-gauge wire. Figure 2 illustrates the three types of jumpers. Install the jumpers on the solder side

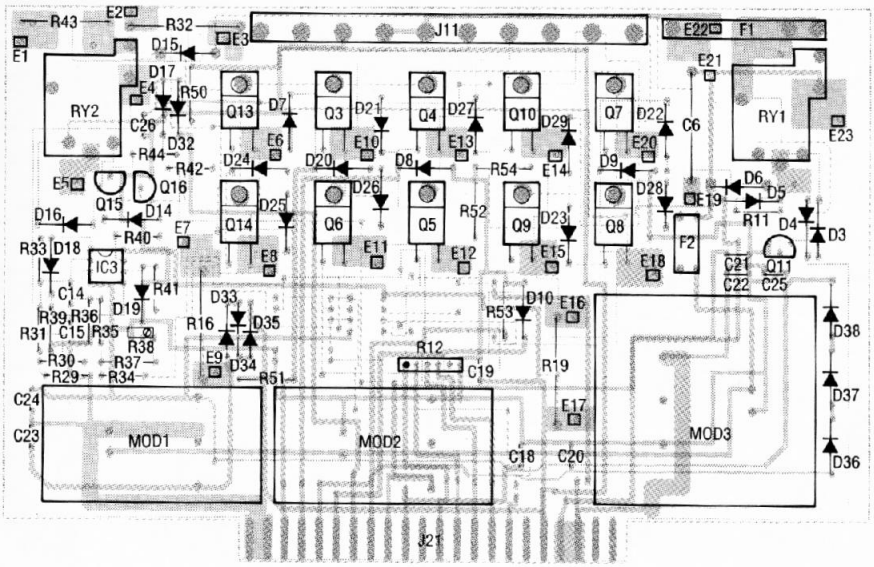


FIG. 1—PARTS PLACEMENT DIAGRAM for the power board. Remember that several components must be mounted on the solder side of the board to leave room for the other components (see text).

of the board as follows:

TYPE-A JUMPERS
E-23 to drain of Q8
E-18 to drain of Q9
E-20 to drain of Q10
E-13 to drain of Q5
E-10 to drain of Q6

TYPE-B JUMPERS
Drain of Q4 to Drain of Q7
Drain of Q3 to Drain of Q4
Drain of Q8 to Drain of Q14
Drain of Q7 to Drain of Q18 (mount on component side)
Drain of Q13 to Drain of Q14 (mount on component side)

TYPE-C JUMPERS
E-23 to E-21
E-18 to J11-10
E-19 to J11-8
E-20 to J11-9
E-17 to J11-8
E-14 to E-15
E-15 to E-16
E-13 to J11-7
E-10 to J11-6
E-12 to E-11
E-11 to E-7
J21-23 to J11-3
E-6 to E-8
E-2 to E-6
E-5 to J11-2
E-1 to E-17
E-1 to E-9
E-3 to E-4
E-22 to J11-4
E-22 to J11-5

Grass-sensor assembly

Build the mechanical portion of the sensor assembly as shown in Fig. 3, and wire the grass sensors themselves as shown in Fig. 4. The length of the ribbon cable that connects the sensor assembly to J1 on the motor-controller board should be approximately 3½ feet long. Crimp J1 onto the end of the ribbon cable using an IDC crimping tool or vise.

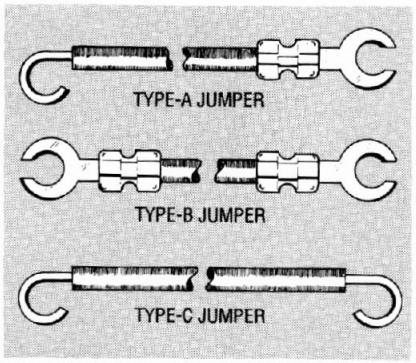


FIG. 2—HERE ARE THE THREE TYPES OF JUMPERS. They are used to handle the high currents that exist on the power board.

Power-board testing

Inspect all solder joints and jumper connections to ensure that everything is properly assembled. Place the power board on a flat surface (not plugged into the motherboard) and temporarily jumper J11-3, J11-8, and J21-44 with clip leads. Now connect the +24-volt input to the PC board through J11-4 (+) and J11-3 (ground). You should hear the relay "click" on. Measure the DC voltages at J21-32, J21-18, J21-30, J21-31, and J21-19. The voltage readings should match the values listed on the schematic diagram that we showed you last month. If all the voltages read correctly, the DC/DC converters are working properly. Remove the test clip leads from the PC board.

Mechanical assembly

Figure 3 shows the mechanical assembly of the Lawn Ranger. Although it does not include all of the details, detailed mechanical drawings can be purchased from Technical Solutions. However, the chances are that you won't follow the original plans exactly—just as long as you follow the general layout. Also, make sure that the cutting section is safely constructed, and that the blade shield protects the cutting deck a full 360 degrees. WARNING—The cutting blades should not be connected until it has been proven that the Lawn Ranger has been properly constructed, is fully functional, and safe.

Many of the mechanical parts are available from various manufacturers listed in Table 1. The rest of the mechanical components shown in Fig. 3 are not available from TSI; you must either fabricate them yourself or have a local machine shop make them for you.

WHAT'S BEEN COVERED

This series on the Lawn Ranger began in the June issue. In that issue, we covered the general operation of the unit, the software, and we discussed and built the CPU board.

In the July issue, we went over the electronic control system, the motor controller board, D/A converter circuitry, grass-sensor circuitry, motherboard, and velocity-feedback loops. We gave you the parts lists for the motor-controller board and the motherboard, although we didn't get to build them that month.

In August, we began with the construction of the motherboard and the motor-controller board. Then we covered the operation of the power board, drive motors, cutting motors, hand-held controller, and the Lawn Ranger's electronic control panel.

In this issue we have finished up the series. We hope you have found it to be an interesting and worthwhile project. R-E

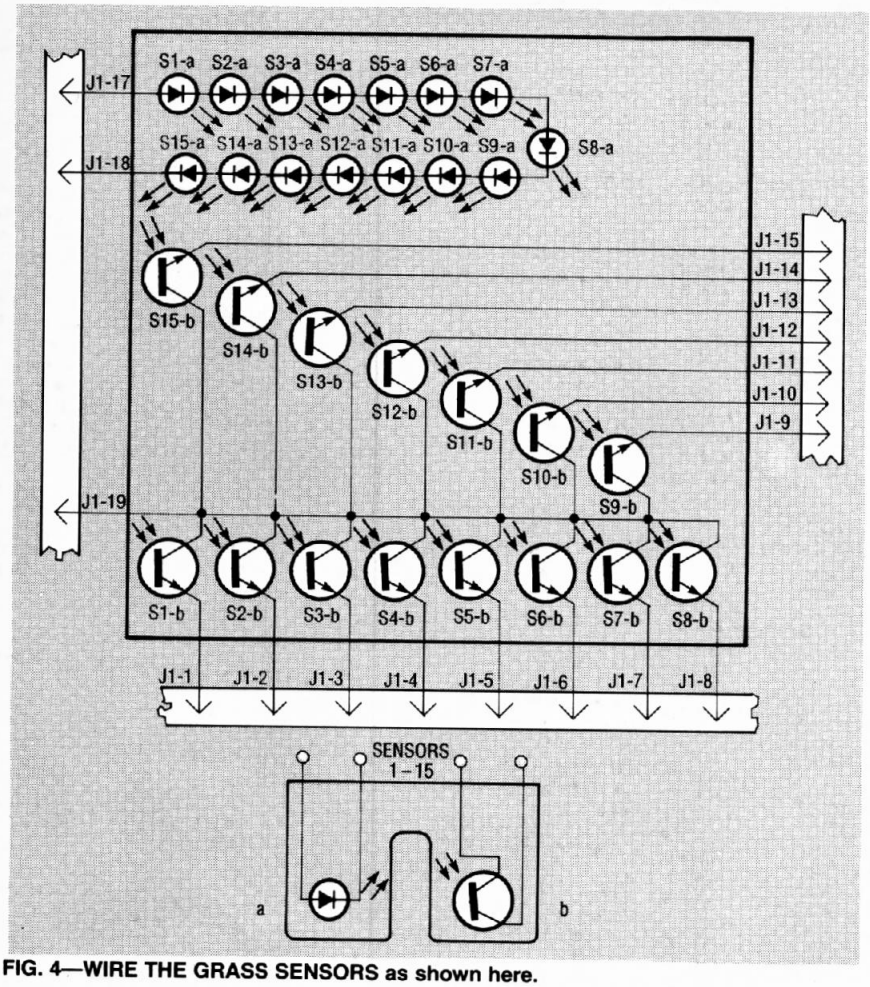


FIG. 4—WIRE THE GRASS SENSORS as shown here.

Chassis wiring

Wire the chassis as shown in Fig. 5. Use 18-gauge stranded wire for the high-current cutting- and drive-motor connections. Secure the cable harness with tie wraps and secure the cable harness to the Lawn Ranger's chassis. Make sure all external cables from the motors, electronic control panel, bumper switch, and grass sensors are connected properly.

Control-system test

Remove all input power and insert the power board into J21 on the motherboard. Repeat the test procedure that was just described, except measure the DC supply voltages at edge connector J23 and J22 on the motherboard. The supply voltages should agree with the values indicated on the CPU and motor-controller board schematics (refer to **Radio-Electronics**, June and July 1990). If the values are correct, remove the input power and plug the CPU board in edge-connector J23. Reapply the +24-volt input power and recheck the voltage levels. If all is well, perform the digital-board check-out procedure outlined in the June

PARTS LIST—POWER BOARD

All resistors are ⅛-watt, 5%, unless otherwise indicated.

R1–R10, R13–R15, R17, R18, R20–R28, R45–R49—not used
R11, R44, R50—3300 ohms
R12—680,000 ohms, 6-pin, ¼-watt, SIP resistor network
R16, R19, R32, R43—0.01 ohm, 5 watts
R29—150,000 ohms
R30, R31, R34, R35—270,000 ohms
R33, R36—1 megohm
R37—147,000 ohms, ¼-watt, 1%
R38—10,000 ohms, potentiometer
R39—82,000 ohms
R40—100,000 ohms
R41—27,000 ohms
R42—22,000 ohms
R51–R54—560,000 ohms

Capacitors

C1–C5, C7–C13, C16, C17—not used
C6—1000 μF, 35 volts, axial electrolytic
C14, C15, C23–C26—0.1 μF, 50 volts
C18, C21—100 μF, 50 volts, radial electrolytic
C19, C20—100 μF, 16 volts, radial electrolytic
C22—220 μF, 16 volts, radial electrolytic

Semiconductors

IC1, IC2—not used
IC3—LF412N op amp
D1, D2, D11–D13, D30, D31—not used
D3, D4, D16, D17, D20–D24, D33–D38—1N4001 diode
D5, D14, D18, D19, D32—1N4148 diode
D6, D15—1N5402 diode
D7–D10—1N5256B 30-volt Zener diode
D25–D29—1N4740 10-volt Zener diode
Q1, Q2, Q12—not used
Q3–Q10, Q13, Q14—IRFZ42 MOSFET
Q11, Q15, Q16—293904 NPN transistor

Other components

J11—terminal strip
RY1—T90N1D12-24 relay (Potter Brumfield)
RY2—68P-111P-US-DC24 relay (Omron)
F1—3AG 30-amp fast-blow fuse
F2—2AG 0.5-amp fast-blow fuse
MOD1—Model DC2-2-24/12, ± 12-volt DC converter (Power General)
MOD2—Model DC2-2-24/15, ± 15-volt DC converter (Power General)
MOD1—Model 710, 5-volt DC converter (Power General)

Miscellaneous: 3AG fuse holder, 2AG fuse holder, solder posts for the "E" terminals, 18-gauge solid insulated wire, 18-gauge stranded insulated wire, solder, etc.

Note: The following equipment can be purchased from Technical Solutions, Inc., P.O. Box 284, Damascus, MD 20872 (301-253-4933): etched and drilled PC boards for CPU Board, Motor Controller Board, Power Board, and Motherboard, $39 each; programmed EPROM, $39; grass sensors, $8.99 each; hand-held manual controller kit, $39; full kit for CPU Board, $129 (PC board, EPROM, all parts); full kit for Motor Controller Board, $169 (PC board and all parts); full kit for Motherboard, $69 (PC board and all parts); Power Board kit (PC board, and all parts except DC/DC converters), $149; Detailed drawing package, $79; Lawn Ranger demo videotape and information package, $19; complete electronic kit with everything mentioned above, $777. Please add $8.00 for S/H for all orders. Maryland residents add sales tax.

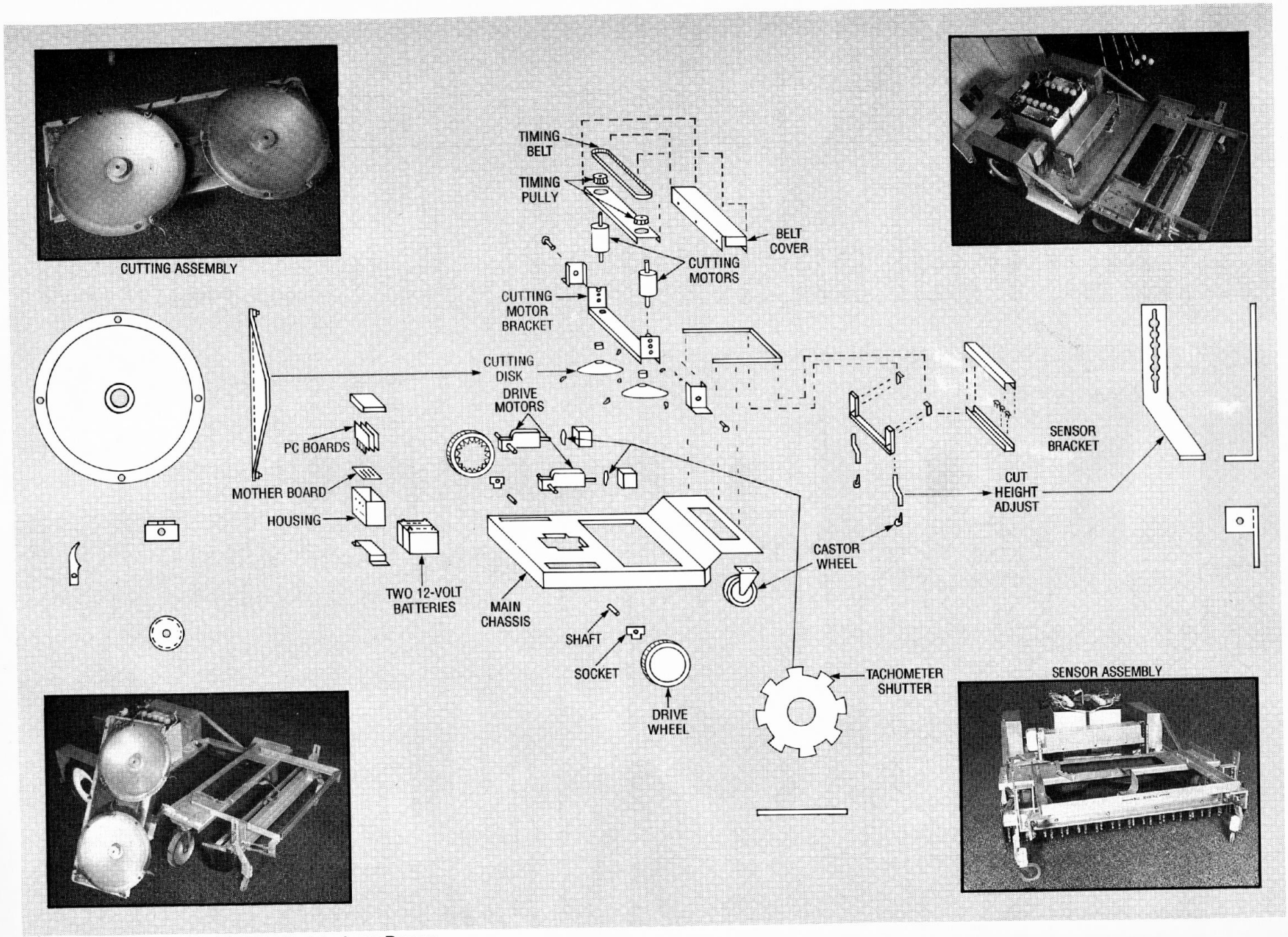


FIG. 3—THE MECHANICAL ASSEMBLY of the Lawn Ranger.

issue while the boards are plugged into the motherboard.

Now plug the motor-controller board into J22 on the motherboard. Also, plug the grass-sensor connector (J1) into the motor-controller board. Reapply the +24-volt input power to the power board.

If you have an oscilloscope, verify that a 5-volt 10-kHz square wave is found at the following points: J22-34, J1-1 through J1-15, and J22-2 through J22-16. The square wave is a gating pulse created by the CPU board which is used to turn the grass sensors on and off. The gating technique is used in order to conserve battery power and extend the life of the grass sensors. If you don't have a scope, Use an AC voltmeter to read the voltage levels at those points. The square wave should create a reading of approximately 4.5-volts AC. If the square wave is not there, you should read 0 volts on the AC voltmeter.

Now it is time to check the *P*ulse *W*idth *M*odulator (PWM) circuitry. Plug the hand-held controller into J4 on the motor-controller board. Temporarily jumper J22-40 to ground. Turn the steering control knob (the potentiometer on the hand-held controller) counterclockwise until you see a 30-volt square wave at J22-26 (L. REV), J11-7 (L. MOTOR −), J22-27 (R. FOR), and J11-9 (R. MOTOR +). If you don't have a scope, an AC voltmeter should give you a reading of 0 to 35.5 volts AC, depending upon the knob setting. Test points J22-25 (L. FOR) and J22-28 (R. REV) should read 0 volts.

The "left wheel reverse" (L. REV) and "right wheel forward" (R. FOR) signals become active since the Lawn Ranger has been commanded to turn to the left. If the steering knob is turned clockwise, the robot circuitry will be commanded to turn to the right. That causes J22-25, J11-6, J22-28, and J11-10 to become active with the 30-volt PWM square wave, and J22-26 and J22-27 to read 0-volts DC. If the steering knob is centered, J22-25, J11-6, J22-27, and J11-9 will be enabled and a voltmeter placed at J22-28 and J22-26 will read 0 volts since the robot has been commanded to steer straight.

TABLE 1—SUPPLIERS

Manufacturer	Description	Model #	Qty
Motor Products Owosso 201 S. Delany Rd. Owosso, MI 48867 (517) 725-5151	cutting motors, 3,000 RPM @ 80 oz-in torque, 24 volt DC	LES-25A	2
RAE Corporation 5801 West Elm St. McHenry, IL 60050-7480 (800) 323-7049	drive motors, 187 RPM @ 30 in-lb torque, 24 volt DC	P-20705	2
McMaster-Carr P.O. Box 440 New Brunswick, NJ 08903-0440 (201) 329-3200	slip joint hinge (for plastic top)	1606A41	1
	rubber sheet (for front of plastic top) 1/16"	8635K11	1
	yoke ends	6071K12	4
	ball joints	6072K35	4
Stock Drive Products 2101 Jericho Pike New Hyde Park, NY 11040 (516) 328-0200	timing pulley	6A4-14DF0	2
	timing belt	6R4-08005	1
General Battery P.O. Box 1425 Reading, PA 19612-4205 (215) 378-0500	lead-acid battery	22NF	2
Tape Switch 100 Schmitt Blvd. Farmingdale, NY 11735 (516) 694-6312	bumper switch, 8 oz	102-BPH	1
Agri-Fab 303 W. Raymond Sullivan, IL 61951 (217) 728-4334	drive wheels	3108-148	2
	drive gear	2692-006	2
Colson 3700 Airport Rd. Jonesboro, AR 72401 (800) 643-5515	Caster Wheels	2-6056-45	2
Power General P.O. Box 189 Canton, MA 02021 (617) 828-6216	+5 volt DC	710	1
	+ 30 volt DC	DC2-2-24/	1
	±12 volt DC	DC2-2-24/	1
Pioneer 9100 Gaither Rd. Gaithersburg, MD 20877 (301) 921-0660	E-terminals	160-2085-02-01	30
Techni-edge 389 Liberty St. Ferry, NJ 07643-1008 (201) 641-7776	hook blade	TE-28	6

Control panel test

Disconnect J11-2, J11-6, J11-7, J11-9, and J11-10 on the terminal block. Ensure that the cable from the electronic control panel is connected to J5 on the CPU board and that the batteries are connected to J11-4 and J11-5 on the power board. Turn the ignition key; the red power-on LED should begin to flash. This indicates that power has been switched on to all circuits. Push the STOP button. The Lawn Ranger should turn off. Check that the cutting-motor connection J11-2 is still disconnected. Turn the ignition key again and

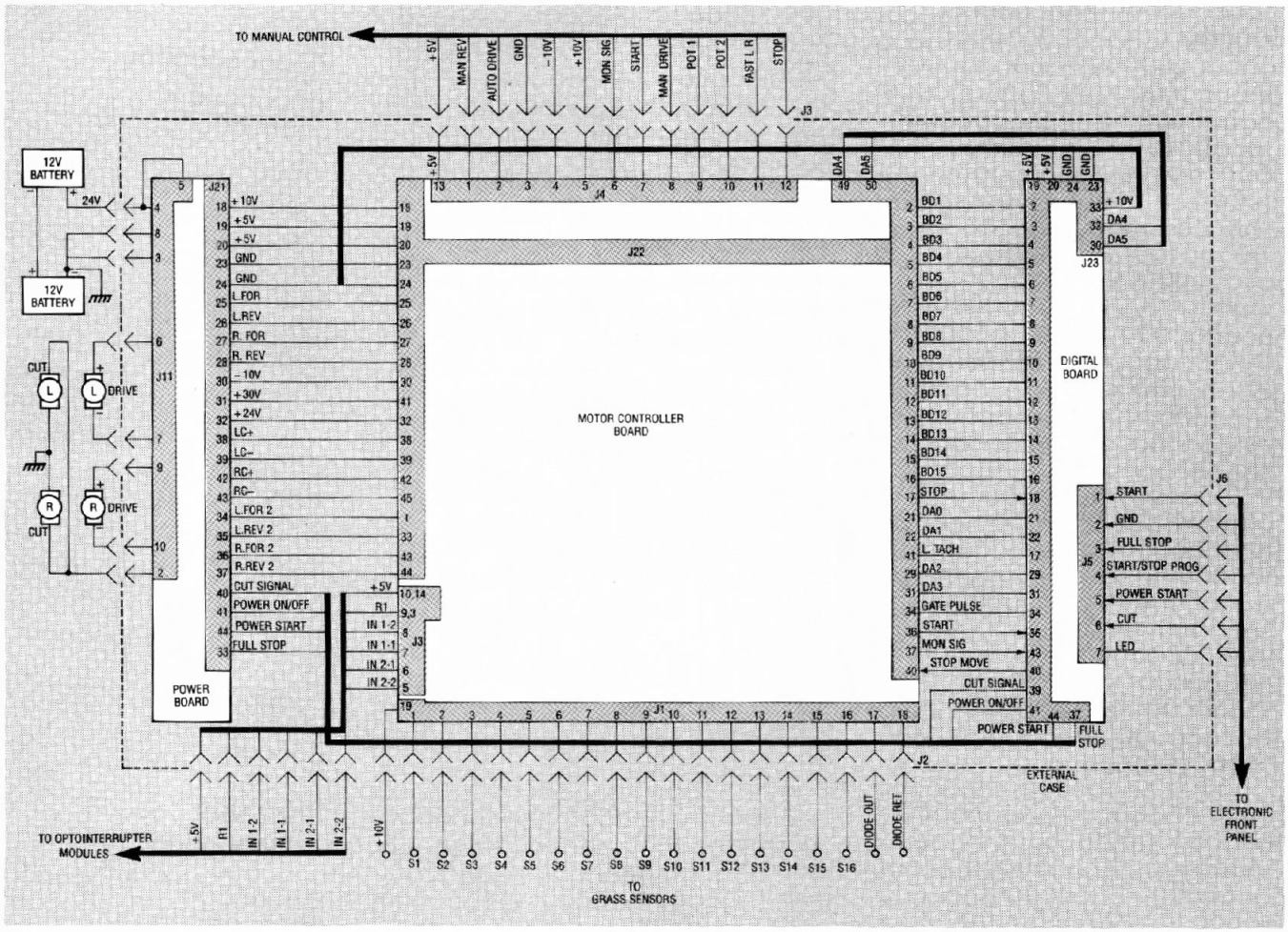
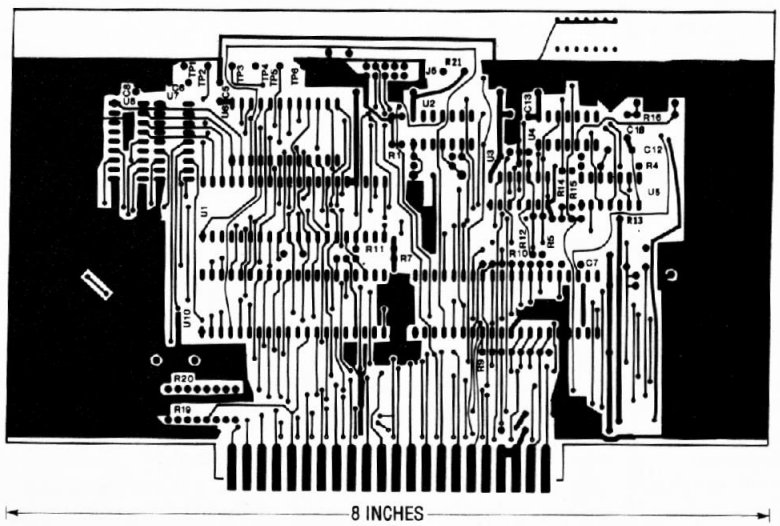


FIG. 5—WIRING DIAGRAM FOR THE CHASSIS. Use 18-gauge stranded wire for any high-current connections.

then push the CUT button. The voltage at J11-2 should now read +30-volts DC. Press the bumper switch and the Lawn Ranger should turn itself off. Turn the unit on again and push the RUN button. J23-40 (STOP MOVE) should now read +10-volts DC. Reconnect the motor wires to J11-6, J11-7, J11-9, and J11-10 on the terminal block.

Drive-motor test

Make sure that the hand-held controller is connected to J4 on the motor-controller board, and that everything is connected on the terminal block J11 except for J11-2 (cutting motors). Turn the ignition key (the power LED should be flashing), and turn the steering knob to its centered position. Squeeze the hand switch on the manual controller. Both rear drive motors and wheels should be spinning forward. Push the REVERSE button. The wheels should slowly stop and then turn in reverse. Turn the steering knob and observe the drive wheels as they change speed for steering. Release the hand switch and the Lawn Ranger will turn itself off.



CPU BOARD COMPONENT SIDE AT HALF SIZE.

Cutting-motor test

WITHOUT THE CUTTING BLADES ATTACHED TO THE CUTTING DISKS, reconnect the cutting motor wire to J11-2. Put the Lawn Ranger on a flat level hard surface, and keep the cutting deck area free of obstructions. With your hands away from the cutting deck area, push the CUT button; the cutting disks will begin to spin. Push the STOP button; the cutting disks should stop within three seconds. If the

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cutting disks take too long to come up to speed, adjust R38 on the power board. If they take too long to stop, check relay RY2 and resistor R43. Disconnect J11-2.

Automatic guidance test

By blocking grass sensors with your fingers or electrical tape, you can simulate a grass border that the Lawn Ranger can follow. As you block different grass sensors, you can verify that the motor controller is working properly by observing the drive wheels as they change in both speed and direction.

Before turning the Lawn Ranger on, ensure that the cutting blades and disks are disconnected. Place the rear end of the unit up on blocks so the wheels do not touch the ground. Ensure that the grass sensors are not blocked by grass or other objects and that the manual controller is disconnected. Turn the ignition key clockwise and push the START button. The right wheel should spin clockwise and the left wheel should spin counter clockwise. The Lawn Ranger will initiate a left turn because it cannot detect tall grass. If it were allowed to move on the ground, you would see it steer to the left in a counterclockwise circle. It would continue to move in a circle searching for tall grass for approximately 6 seconds and then turn itself off.

Now it is time to test the full range of the steering. Block sensors 1–8 with electrical tape. Adjust potentiometer R203 as described in the July issue. Now, Adjust R201 and R202 until both wheels spin at the same rate. You can calculate wheel speed by counting the number of revolutions that each wheel performs within one minute (rpm's). This test validates that the Lawn Ranger steers straight ahead when the grass border is in the center of the grass-sensor assembly (between sensors 8 and 9).

Clear all the grass sensors so they are free of obstructions; the Lawn Ranger should return to its left turn mode. Now, block sensor 1, then 2, then 3, and so on, until

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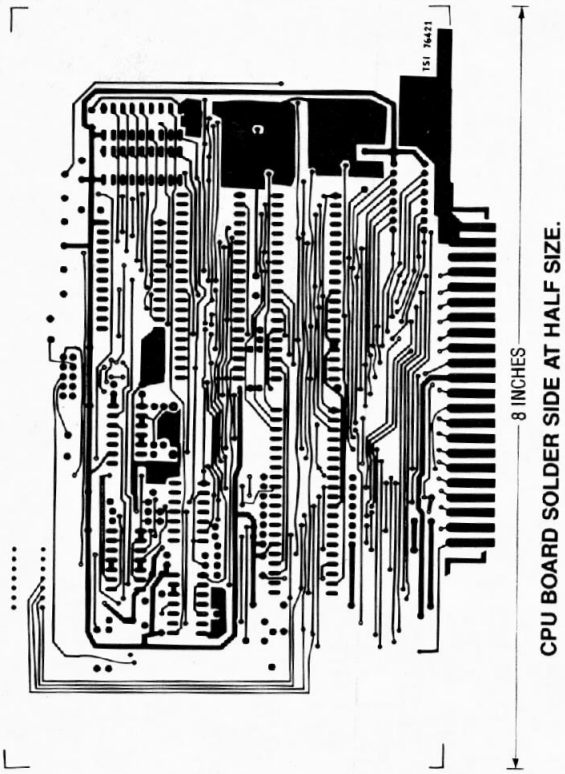
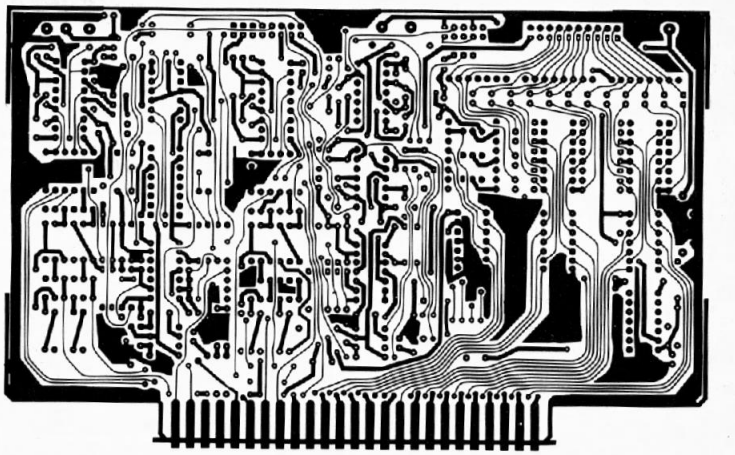
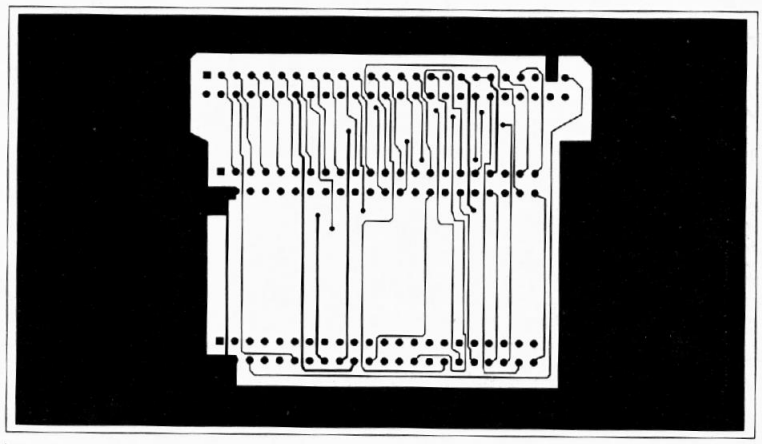
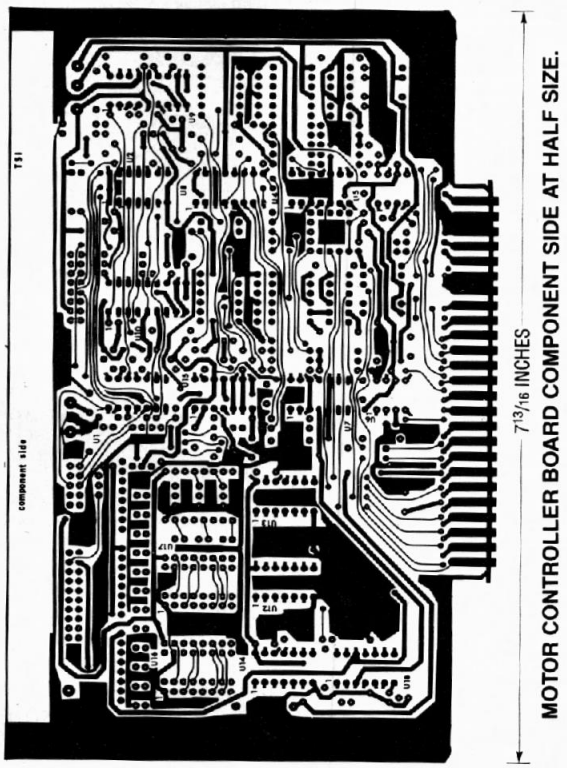
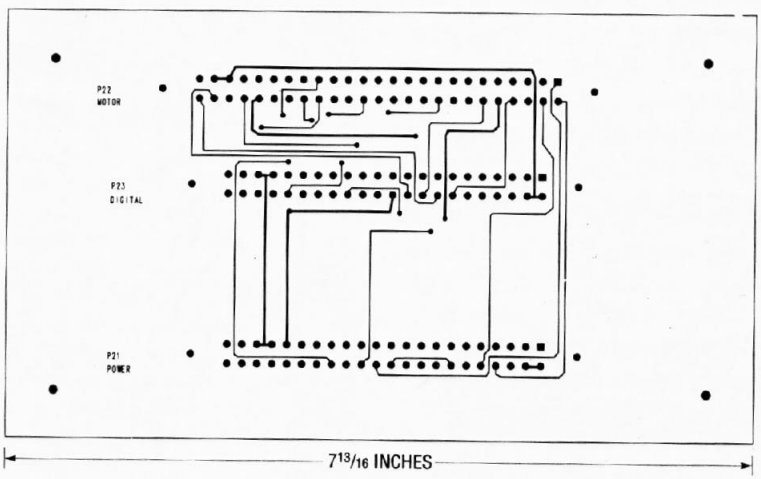








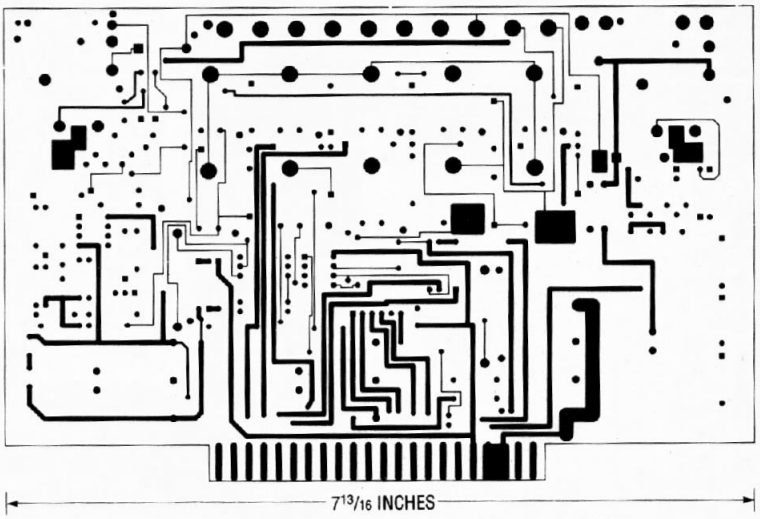


all the sensors are blocked. You should notice that the left wheel will slowly change from a counter-clockwise to a clockwise direction and the right wheel will change from a clockwise to a counter-clockwise rotation. If the Lawn Ranger has passed all tests so far, it is ready for outdoor testing.

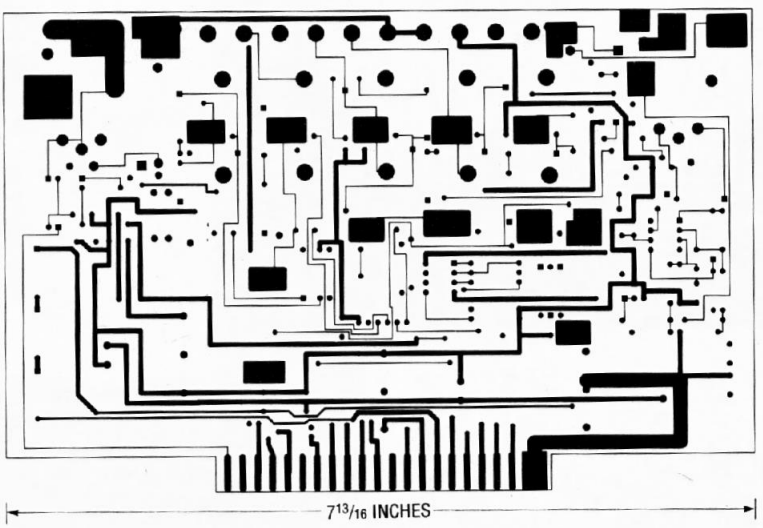
If it did not pass one or more of the tests, double check the operation of the CPU board as described in the June issue.

Outdoor guidance testing

Now it is time to have some real fun! Make sure your neighbors or friends are out because they will love to see the capabilities of your new creation. Cut a six-foot thick square border around a small grassy test area with a conventional lawn mower (don't use the Lawn Ranger yet). Connect the manual controller, squeeze the



POWER BOARD COMPONENT SIDE AT HALF SIZE.



POWER BOARD SOLDER SIDE AT HALF SIZE.

hand switch and turn the Lawn Ranger on. "Walk" the unit to the cutting area and place it on the edge of the grass border with the tall grass positioned to the left—see Fig. 1 of the June issue.

Adjust the height of the grass sensors so their tips lie approximately one inch above the cut grass. The uncut grass should be around two inches higher than the cut grass for your first test. Remove the manual controller and push the RUN button. The mower will begin to track along the border you previously cut. It should continue tracking this border until you stop it. If it passes this test, you are ready to connect the cutting blades and really show off.

Final test

Now you are ready to connect the blades as shown in Fig. 3 (make sure the batteries are disconnected before attaching blades). Double check the shields that surround the cutting blades; they should be able to withstand a force as high as 60 pounds upon impact to allow for safe operation.

After the blades are attached, grab yourself a cold drink and "walk" the Lawn Ranger with the manual controller to the test area. Set up the mower as described above and connect the cutting-motor wire to J11-2. Remove the manual controller and turn the Lawn Ranger on.

Push the CUT and RUN button. Now, watch in amazement as the mower automatically cuts the grass contained within the test area. You will love the way it "turns on a dime" when it reaches the end of a row. When it is finished with the job, it will steer in a tight circle searching for tall grass and then turn off. **R-E**