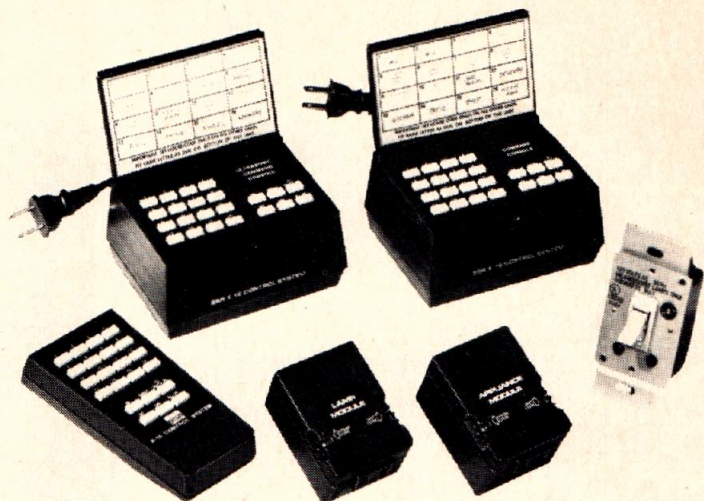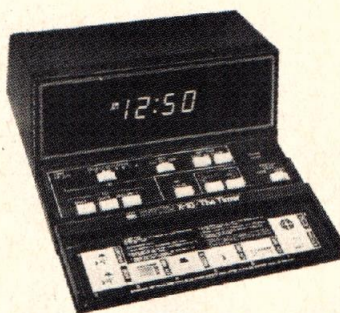# Plug-in Remote Control SYSTEM

LSI technology now brings us armchair control of electrical devices throughout the home. Here's the inside story on how those controllers work.

STEVEN A. CIARCIA*

"SAVING ENERGY AND SAVING STEPS" are two of the basic selling points in the advertising for the BSR *Model X-10* Home Control System. In actuality, the features of this unit combine to make the X-10 one of the most ingenious remote control systems yet introduced to the consumer market.

The X-10 (also sold under the trade names of Sears' *Home Control System* and Radio Shack *Plug'n Power*, and in Europe by Busch-Jaeger Electro) incorporates custom-made IC's that allow the user to turn lights or appliances on or off from the comfort of an easy chair. Typical applications can include such things as turning on the outside lights, the TV, and the toaster oven—all with just the push of a few buttons.

If you are too practical to accept that concept on convenience alone, consider energy and security applications as well. The X-10 makes it easier to turn off extra lights and appliances when you are not using them. It can turn on all lights in the event of an emergency, turn everything off when you go to bed, or dim lights in order to reduce power consumption.

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FIG. 1—PROGRAMMABLE TIMER permits control of lights and appliances without any human intervention.

The X-10 system components

The X-10 system consists of five separate modules: the Command Controller, Cordless Controller, Lamp Module, Appliance Module, and Wall Switch Module. There is also a new programmable timer unit (see Fig. 1) that provides the system with a semblance of automatic control.

The command controller is the central element in the system. It sends commands to the three types of receiver modules by coded messages sent through the AC power lines. The cordless controller is a remote extension of the command controller and has a matching keyboard. When pointed at the command console from up to 30 feet away, any command that is selected on

it will be transmitted to the command controller and carried out. The communication between the two units is done ultrasonically.

Lamp- and wall-switch modules are essentially the same. They are triac-controlled on/off switches that include dimmers. The lamp module is plugged into a wall outlet in series with the light to be controlled while the wall-switch module replaces a conventional wall switch. Those units are rated at 300 watts. For heavier, or non-resistive loads, a contact-closure-output appliance module is used. It is rated at 15 amps (about 1700 watts).

Inside the command controller

Figure 2-a is a block design of the command console. There are two versions of that unit on the market. One has the ultrasonic receiver/cordless-controller capability; the other hasn't. An internal view of a controller including the ultrasonic circuitry is shown in Fig. 3. At the heart of that, as well as of the other system components, are custom LSI IC's manufactured for BSR by General Instruments Corporation. Fully expanded, the BSR system can accommodate 256 independently addressable receivers. That is accomplished using 16 sets of addresses called "house codes" and 16 "device codes"
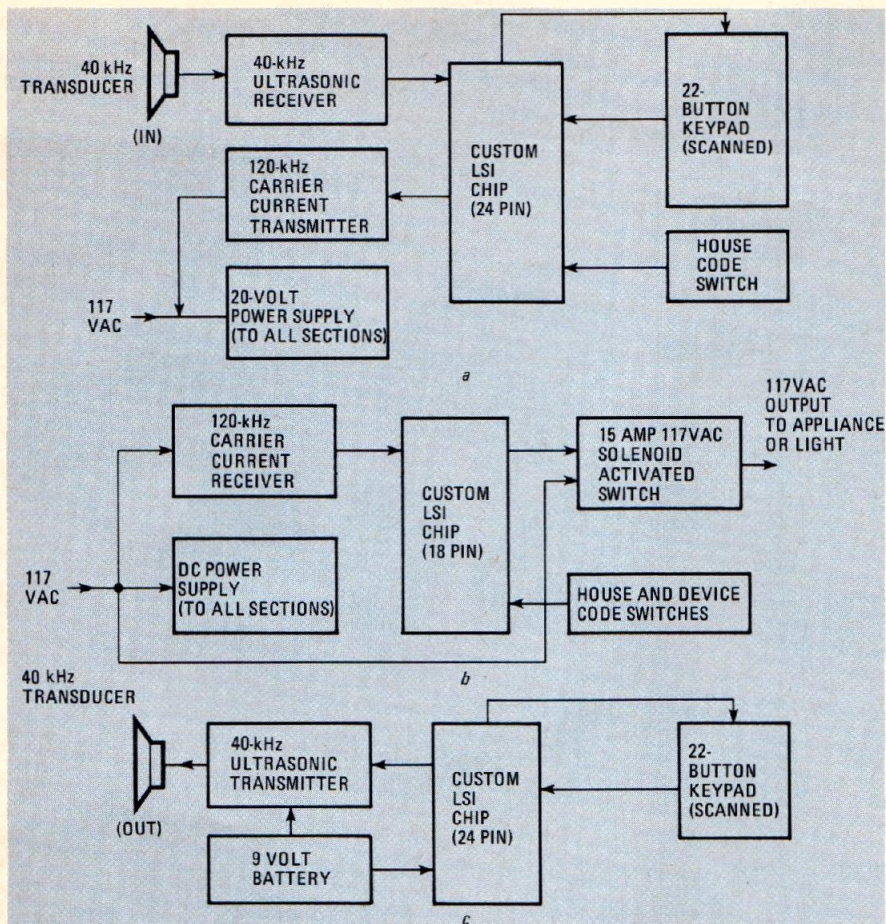
FIG. 2—FUNCTIONAL DIAGRAMS of *a* command module, *b* appliance module, and *c* remote-control transmitter. Text describes operating principles.
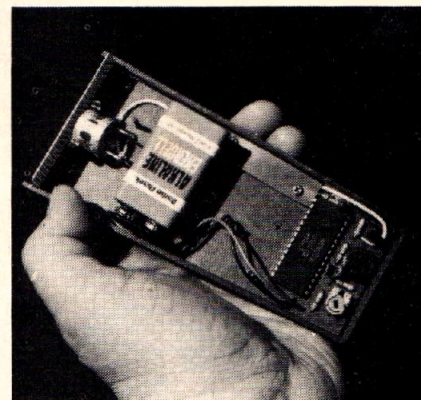

HANDHELD remote controller uses a single IC to encode and transmit all commands.

ALL COMMANDS available from main console are also found on remote-control keypad.

FIG. 3—CONTROLLER MODULE, despite its complexity, is surprisingly small—only 4½ × 3½ × 2½ inches.
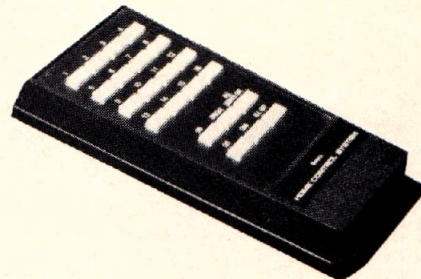
for each house code. The separate house codes allow next-door neighbors to use X-10's without interfering with each other. A thumbwheel switch on the bottom of the command console sets the 4-bit house code. The keyboard selection determines the channel code. This is shown in Fig. 4 and Table 1.

In normal operation the 22-button keypad, which is wired as a 3×8 matrix, is scanned at a rate of 3.8 kHz. When a button is pressed, its designated function and the house code are combined into a single message. The digital message is directed to the transmitter section where it generates 120 kHz signals that are used to pulse-width modulate the AC line. (See Fig. 5.)

In order to synchronize the digitally-encoded serial output (pin 15) with the 60-Hz AC line, the circuit must include zero crossing detection. That is done by feeding the AC line into the trigger input (pin 12) where the switching point is detected within 100 microseconds of zero crossing. (Incidentally, pin 13 provides for 50- or 60-Hz operation.)

The transmitted message, now synchronous with the line, is clocked, a bit at a time, on zero crossing. A command message contains 9 bits of information consisting of the 4-bit house code and 5-bit matrix (keyboard function) code. Each message is transmitted in true and inverted format on successive half-cycles of the AC waveform. That is illustrated in Figs. 6 and 7. A logic-1 bit is three 1-millisecond bursts of 120 kHz signal commencing approximately 200 μs after the zero crossing of each of the phases. A logic-zero bit is represented by no signal for that half cycle. To synchronize the receivers with the transmitter, a trigger code consisting of three successive logic-1 bits followed by a logic-zero bit is used. The complete message takes 11 full AC cycles (183 ms) to complete.

Actual attachment to the line is by means of a transformer and capacitor coupler. That combination is necessary both for protection and economics. The effective range of this system is generally all the wiring from the controller to the nearest power company step-down transformer. There are usually five or six houses on each transformer and some coordination with respect to the choice of house codes may be
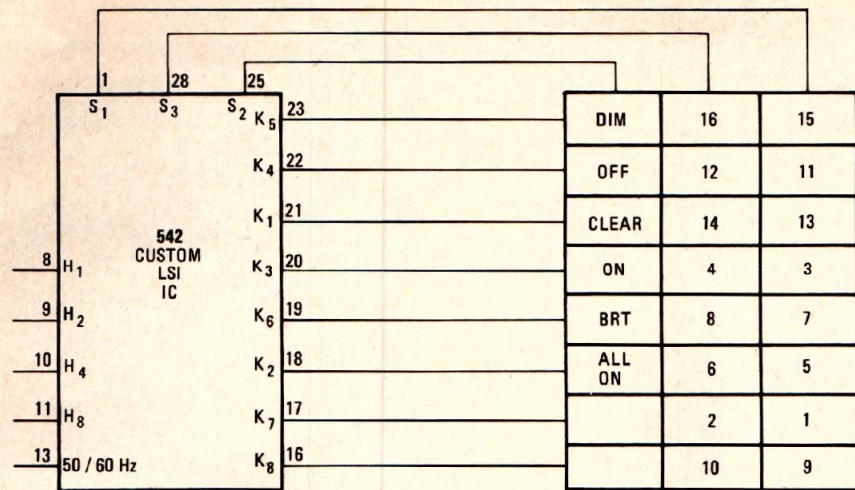
FIG. 4—KEYPAD FUNCTIONS and connections to 542C custom IC. Pin 13 of the IC allows for 50 or 60 Hz operation...at 117 volts AC.

House Code	H8	H4	H2	H1
A	1	0	0	1
B	0	0	0	1
C	1	0	1	1
D	0	1	0	1
E	1	1	1	0
F	0	1	1	0
G	1	0	1	0
H	0	0	1	0
I	1	0	0	0
J	0	0	0	0
K	1	1	0	0
L	0	1	0	0
M	1	1	1	1
N	0	1	1	1
O	1	0	1	1
P	0	0	1	1

necessary. Also, since the version of the X-10 sold in the U.S. is a 117-volt unit, and most homes derive their 117-volt power from both sides of a 220-volt line, sometimes there can be problems in obtaining consistent operation when receiver modules are used on both the 117-volt lines and relatively few 220-volt appliances are in operation to act as a communication bridge. Placement of the receivers could require some experimentation.

Ultrasonics and the X-10

There is a second method by which the command console designates a control function and transmits instructions. That is through the ultrasonic handheld controller. When a key is pressed, a code is generated and transmitted as a series of 40 kHz tone bursts. The command console, receiving that information through its ultrasonic receiver section and injecting it into pin 7 of its LSI IC, accepts it as if a button had been pushed on the command console. It then adds the house code and retransmits the command message over the house wiring.

Figure 8 and Table 2 show in detail the communication between the two subsystem components. Each of the 22 buttons has a unique 5-bit code. For example, channel 5 would result in a code of 00010 corresponding to bit positions D8, D4, D2, D1, and F respectively. "All lights on" would be 00011.

The actual message which communicates that selection is approximately 100 ms long and comprised of thirteen 8-ms segments. Each segment consists of a burst of 40 kHz directed to an ultrasonic transducer. A logic-1 is a 4-ms burst and a logic-0 is a 1.2-ms burst. To signify channel 5 the cordless controller first sends a trigger bit to alert the receiver in the command console that a message is coming. That is a 40
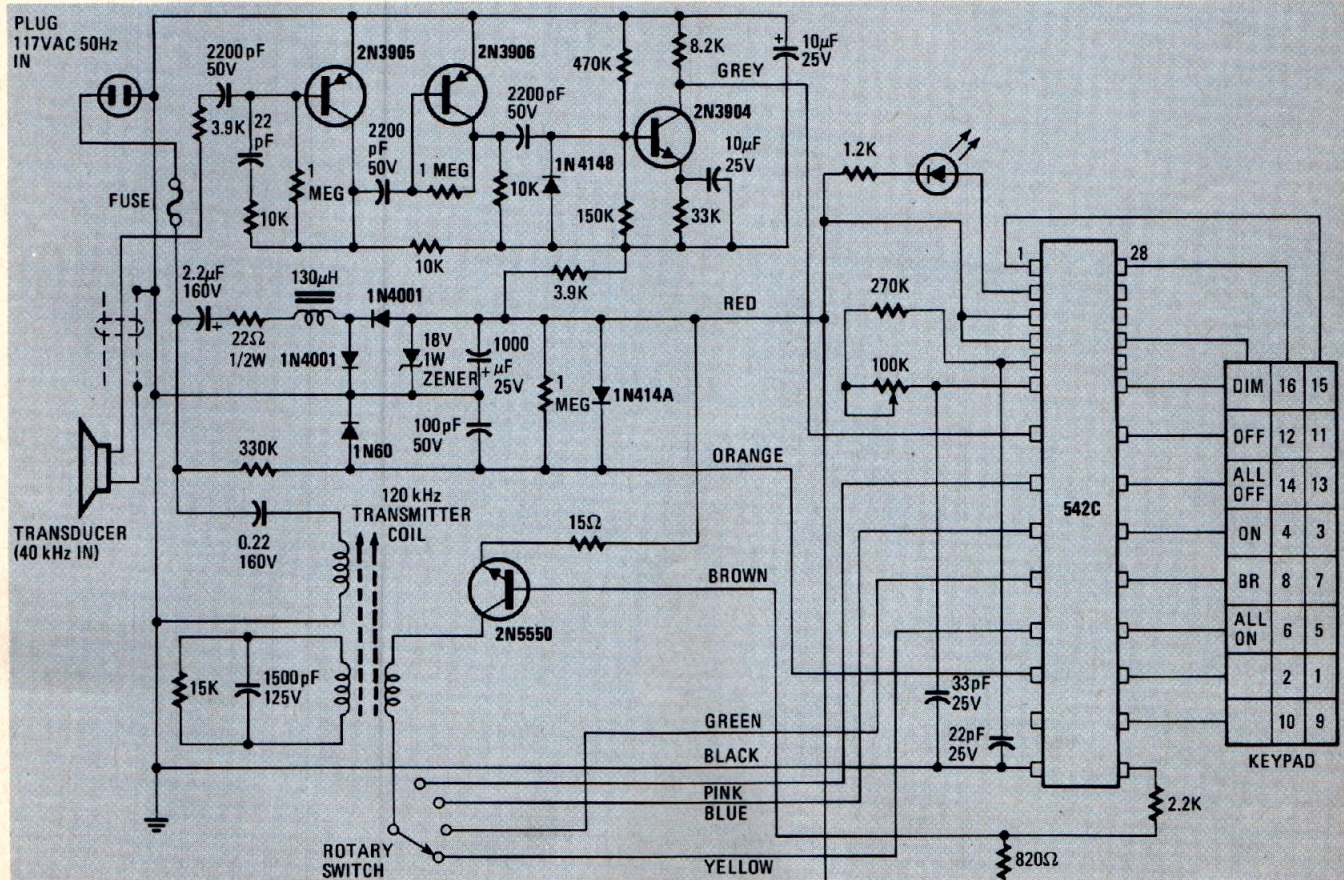

FIG. 5—COMMAND CONSOLE schematic allows you to visualize how information is encoded and transmitted over AC line. Also shown is transducer for use with ultrasonic remote control. (Courtesy BSR [USA] Ltd.)
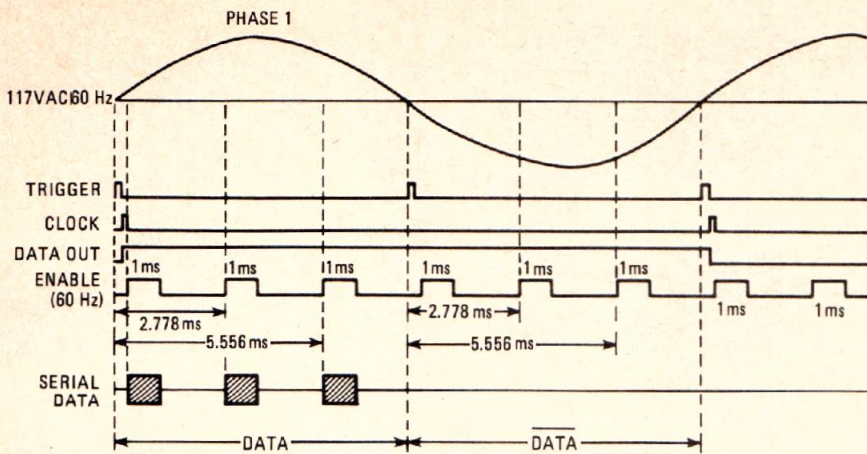
FIG. 6—TIMING DIAGRAM shows how AC line current is pulse-width modulated to transmit information from command console to appliance and lighting modules.
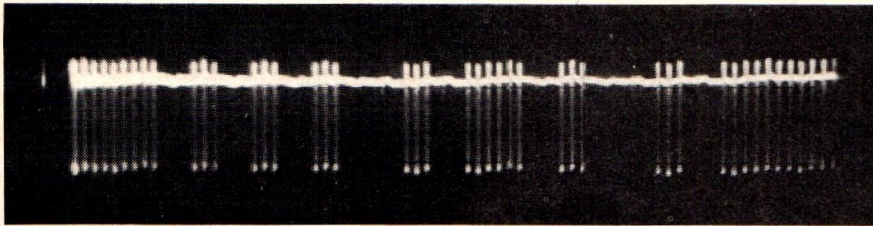

FIG. 7—DEMODULATED 120 kHz signals that make up control message.. The three 1-ms bursts signifying a logic "1" are clearly seen.
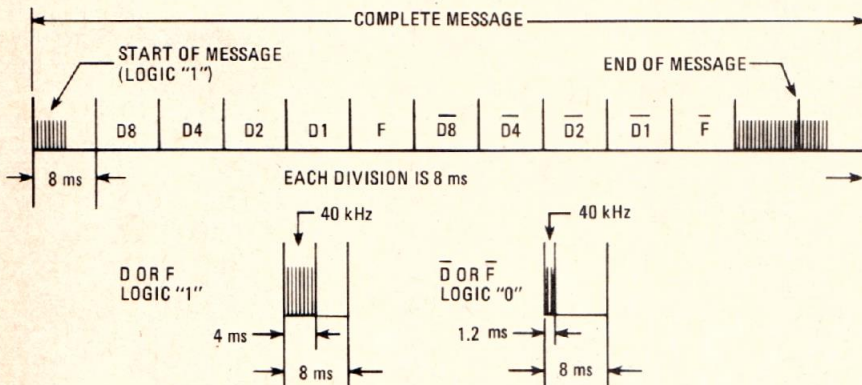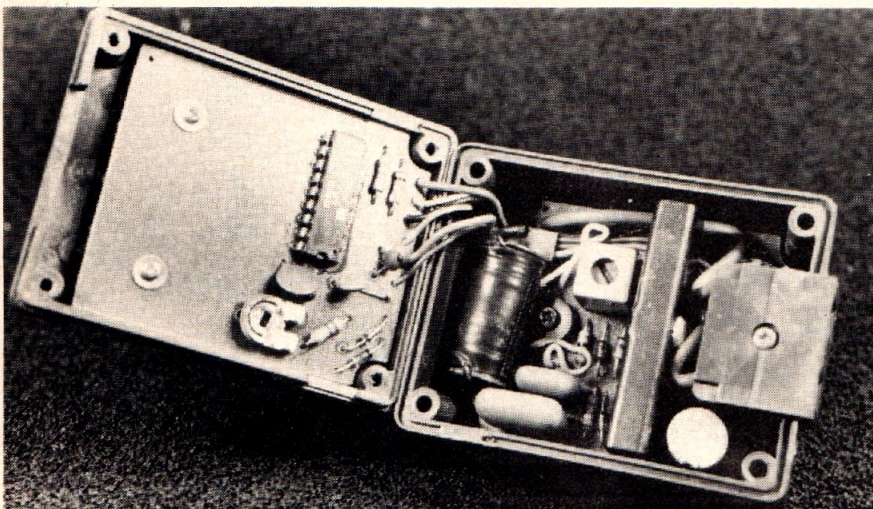

FIG. 8—MESSAGE FORMAT used by the ultrasonic remote controller. Tone bursts are 40 kHz.

APPLIANCE MODULE interior is tightly packed. The solenoid and 15-amp switch mentioned in the text are at the left of the case; the AC outlet at right.

TABLE 2

Channel Number or Function	Binary Code				
	D8	D4	D2	D1	F
1	0	1	1	0	0
2	1	1	1	0	0
3	0	0	1	0	0
4	1	0	1	0	0
5	0	0	0	1	0
6	1	0	0	1	0
7	0	1	0	1	0
8	1	1	0	1	0
9	0	1	1	1	0
10	1	1	1	1	0
11	0	0	1	1	0
12	1	0	1	1	0
13	0	0	0	0	0
14	1	0	0	0	0
15	0	1	0	0	0
16	1	1	0	0	0
Clear	0	0	0	0	1
All Lights On	0	0	0	1	1
On	0	0	1	0	1
Off	0	0	1	1	1
Dim	0	1	0	0	1
Brighten	0	1	0	1	1

already has a preset house code, that is not sent ultrasonically. The handheld controller is limited to operation on the 16 channels of the single house code set on the command console.

The serial-input capability of the X-10 is not limited to use with ultrasonic data transmission. Specific control of the receivers can be accomplished by injecting a digital command message directly into the serial input pin. At least one personal computer manufacturer is marketing an AC remote-control system using this method. Be advised, though, that the X-10 has a live-wire ground and any attachment to it should be done through optoisolators.

The receivers

The receiver end of the system is quite sophisticated considering that each receiver costs less than $17. All receivers (lamp modules, appliance modules, and wall switch modules) are essentially the same. A block diagram of an appliance module is shown in Fig. 2-b. Also incorporating a custom LSI IC, the receiver section monitors the AC line, waiting for a coded message corresponding to its unique house code (A through P) and unit device code (1 through 16). To turn on channel 10, one simply press 10 and ON. one after the other. When the appliance module activates, it sounds like a relay energizing. In actuality, the appliance modules use an inexpensive solenoid to operate a 15-amp snap-action switch. The lamp and wall switch modules use a triac instead, and have the capability to brighten or dim in response to control commands. The appliance module has only on/off capability. Schematics of the appliance and lamp modules are shown in Figs. 9 and 10.
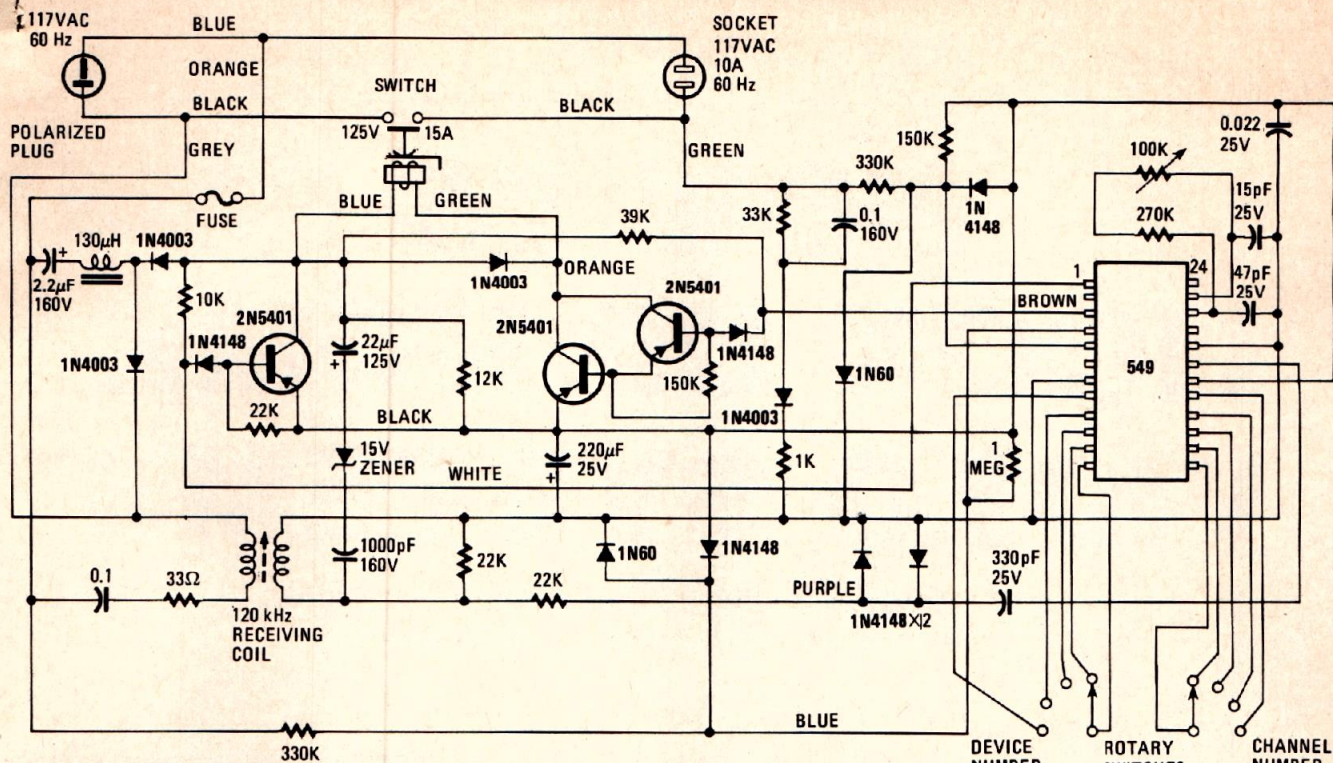
kHz tone for 4 ms. Next, the 5-bit matrix-selection code is sequentially transmitted as a series of 1.2- and 4-ms bursts of 40 kHz signal. It is followed by a transmission of the logical inver-

sion of the previous 5-bit selection code and then a 12-ms "end of message" burst. All messages use the same format—only the 5-bit selection code varies. Also, since the command console

FIG. 9—APPLIANCE MODULE uses solenoid and 15-amp switch to control devices having high current-requirements. (Courtesy BSR [USA] Ltd.)
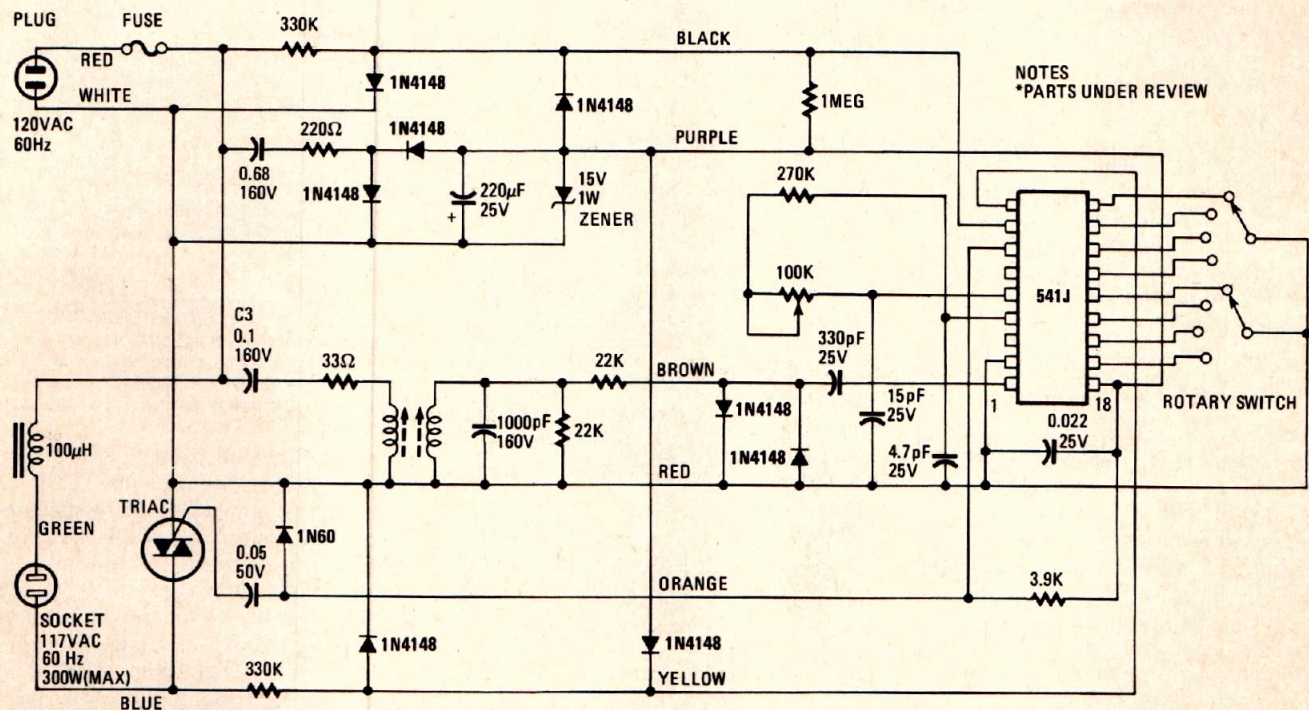

FIG. 10—LAMP MODULE can turn on or off, or dim, resistive-load devices up to 300 watts by means of triac (lower left). (Courtesy BSR [USA] Ltd.)

The next step—automatic control

The X-10 is basically a manual remote-control system. There are however two easy methods to automate the controller's activities. One is the BSR *model TC-201* automatic timer and the other is the BUSY BOX. The BUSY BOX (available from the MICROMINT, 917 Woodmere, NY 11598; 516-374-6793) allows an Apple II, TRS-80, or S-100-based personal computer to control the BSR system.

Security while away from home, and convenience while at home, are two of the benefits that may be provided by using the *model TC-201* automatic timer. By preprogramming on/off times for various lights it is easy to give a house a "lived in" look to discourage intruders. The timer has the capacity to control up to eight lights or appliances and incorporates a built-in green fluorescent digital clock. Each module can be programmed for as many as two "on"

and "off" times in a 24-hour period.

We have just barely scratched the surface of potential applications for this system. Convenience is an easy justification for owning the BSR X-10 but environmental, and energy-management, considerations also come to mind. In combination with a computer, the X-10 can bring the concept of computer-controlled living within reach of the average person.

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