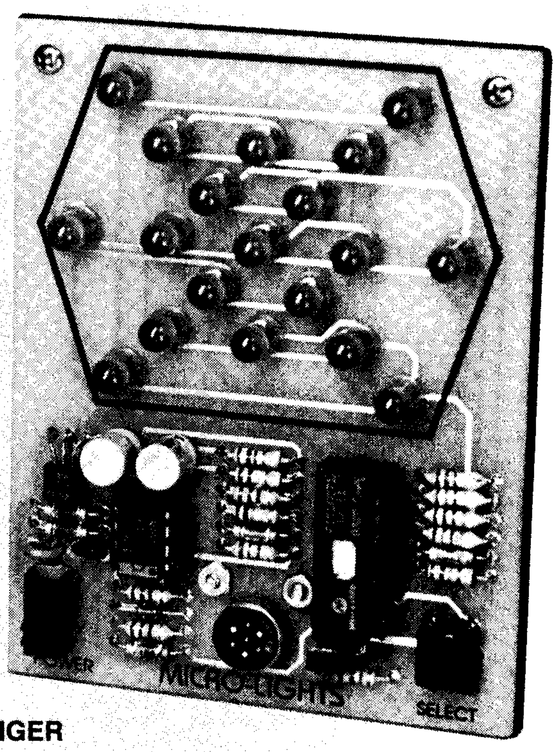
BUILD

MICRO LIGHTS

Learn how the PIC16C71 microcontroller works and produce your own mini light show with Micro-Lights.



DAN RETZINGER

FLASHING LIGHTS ATTRACT THE ATtention of people and can lure or warn them. Police cars and ambulances are equipped with flashing lights. Retail stores use strobe lights to attract attention to opening day and special sales, and aircraft strobe lights call attention to them day or night. This article describes how to build a pocket-sized miniature light show called Micro-Lights. It's a neat little project that's sure to get the attention of anyone passing by your desk or coffee table. The cigarette-pack-sized device is controlled by a versatile PIC microcontroller.

The display is composed of 19 LED lamps arranged in a geometric pattern. A microphone built into Micro-Lights makes it responsive to sound. A pushbutton selects one of eight preprogrammed sound-display routines. The circuit is powered from a 9-volt battery, so it's completely portable.

The circuit

Figure 1 is the schematic diagram of the Micro-Lights circuit. At the heart of the circuit is a Microchip Technology PIC16C71 eight-bit, CMOS microcontroller with built-in EPROM. The PIC16C71 is packaged in an 18-pin DIP package that contains a central processor, clock, EPROM, RAM, eight-bit analog to digital converter, 13 TTL/CMOS-compatible input/output (I/O) lines, and a timer.

An electret microphone (MIC1) is connected to the noninverting input of dual, low-power operational amplifier IC2-a, a National Semiconductor LM358, which amplifies the microphone signal by a factor of about 1000. The op amp's output feeds two inputs to the PIC16C71. Both inputs can be internally routed to the A/D converter inside the microcontroller. The signal on one input (RA0) is partially filtered by D1, C5, and R7, making the sound amplitude easier to distinguish. The other input (RA1) is fed directly from the op-amp. Software determines which input will be selected at any given time.

An LED array—19 LEDs arranged in a snowflake-like pattern—is connected to nine of the PIC's I/O lines. Resistors R10 through R13 limit the LED current, and help to reduce power drain. The LEDs are multiplexed under software control, with each column of three or four LEDs turned on (if dictated by the display routine) for 20% of the total display time, or about 1 millisecond. A complete display refresh occurs every 5 milliseconds, or 200 times a second. This rate is fast enough so that the human eye will see no visible flicker.

The select pushbutton is connected to I/O RA3 (pin 2). The pin is routinely sampled under software control. By repeatedly pressing the select pushbutton, the circuit cycles through all eight of Micro-Light's display routines.

The PIC16C71's clock circuit can be controlled by a standard quartz crystal, a resonator, or a simple RC combination. For power considerations and simplicity, an RC clock was selected. Resistor R8 and capacitor C7 form the PIC's clock which runs at approximately 100 kilohertz.

Switch S2 turns power on and off. A 78L05 regulator (IC3) supplies power to the circuit. Capacitors C1 and C2 stabilize the regulator output.

The PIC16C71

Figure 2 is a block diagram of the PIC16C71. Only 35 single-word instructions make up the microcontroller'sRISC-like instruction set.

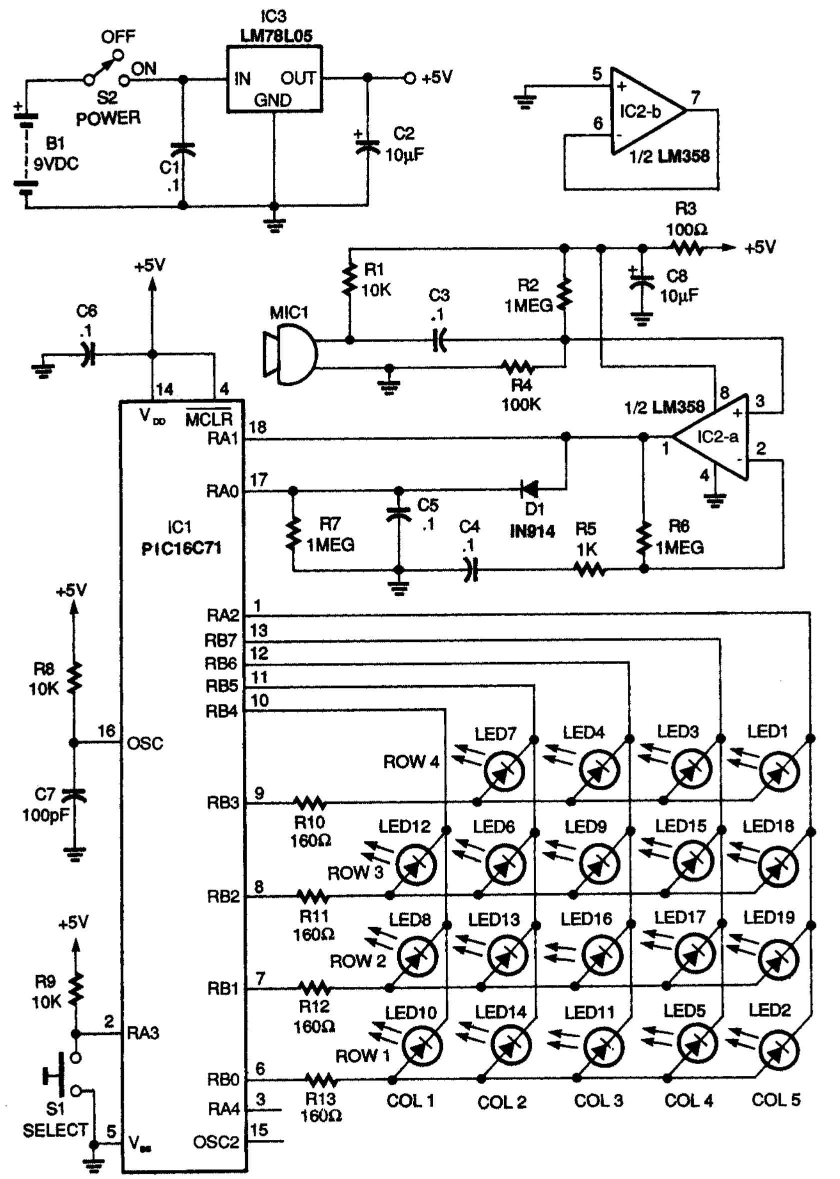


FIG. 1—MICRO-LIGHTS SCHEMATIC. At the heart of the circuit is Microchip Technology's PIC16C71 8-bit, CMOS microcontroller with built-in EPROM.

PARTS LIST

All resistors are ¼-watt, 5%.
R1, R8, R9—10,000 ohms
R2, R6, R7—1 megohm
R3—100 ohms
R4—100,000 ohms
R5—1000 ohms
R10-R13—160 ohms

Capacitors
C1, C3–C6—0.1 µF, 50 volts, ceramic
C2, C8—10 µF, 16 volts, radial electrolytic
C7—100 pF, 50 volts, ceramic disc

Semiconductors
IC1—PIC16C71 microcontroller (Microchip Technology)
IC2—LM358 dual op-amp (National Semiconductor or equivalent)
IC3—78L05 100 milliampere, 5-volt regulator
D1—1N914 diode
LED1–LED19—green light emitting diode, T1¾ package

Other components
S1—Pushbutton switch, PC-mount
S2—Slide switch, SPST PC-mount
MIC1—Electret condenser microphone (Panasonic WM54BT or equivalent) B1—9-volt alkaline battery

Miscellaneous: PC board, 9-volt battery clip, 9-volt battery holder (Keystone part No. 71), one 18-pin IC socket, one eight-pin IC socket, PC board backing material, four No. 2 screws and nuts, solder.

Note: The following parts are available from Silicon Sound, P.O. Box 371694, Reseda, CA 91337-1694 (818) 996-5073:

- **Starter kit (includes PC Board and programmed PIC16C71 microcontroller)—$39.00**
- **Complete kit (includes all parts)—$59.00**
- **Assembled and tested Micro-Lights—$69.00**

Please add $3.50 for shipping and handling. California residents add 8.25% sales tax.

The PIC16C71's 13 I/O pins (made up of RA0–RA4 and RB0–RB7) can be programmed individually as inputs or outputs. Configured as outputs, each pin can source 20 milliamperes of current or sink 25 milliamperes. This feature is very convenient for driving LED lamps directly.

The PIC16C71 has four interrupt sources and an eight-level hardware stack. The A/D converter has four channels, eight-bit resolution, built-in sample-and-hold circuitry, and can perform a conversion in under 30 microseconds.

Software

The Micro-Lights software takes advantage of several PIC features. Figure 3 is a simplified flow chart. The key to controlling the LED display is a timed interrupt routine. Immediately after power-up, an initialization routine presets and enables a timer within the microcontroller. The timer continuously counts up, and upon overflow causes an interrupt routine to be executed. At approximately 1-millisecond intervals, the interrupt software reads internal RAM locations (LED buffers) and outputs on/off states for each LED corresponding to the bit values in the RAM. One column of LEDs is updated per interrupt. Within 5 milliseconds all LEDs are refreshed. The select switch is also sampled during the interrupt.

The main program loop decides which display routine will be entered. The display routines decide which LEDs will be lit by writing to the same internal

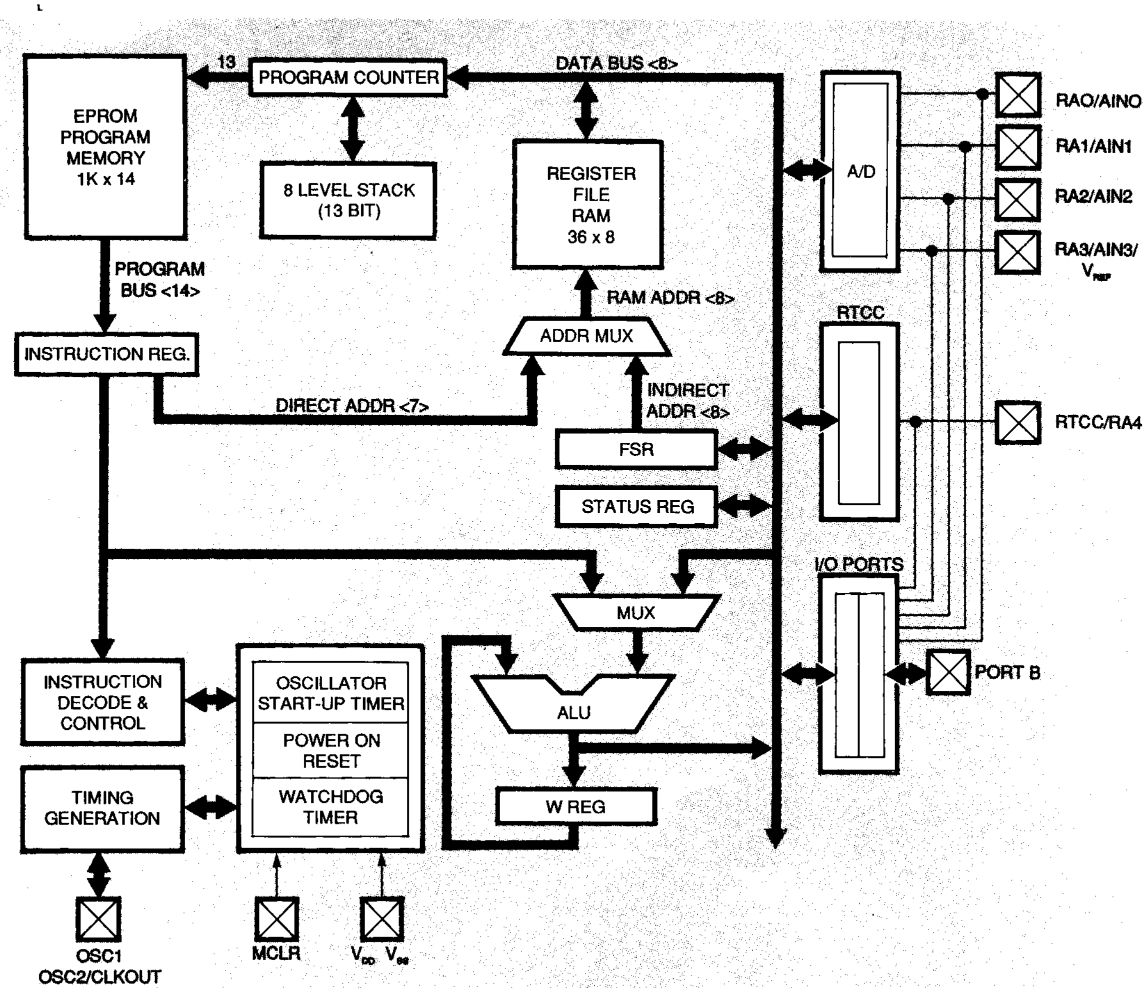
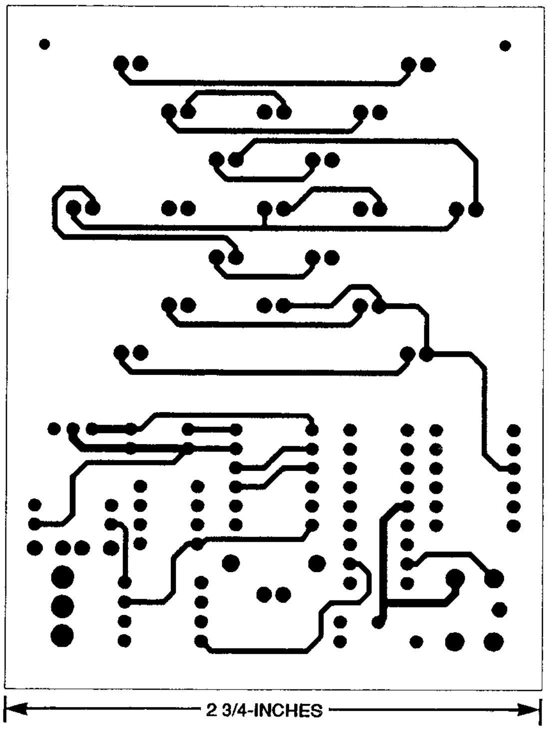
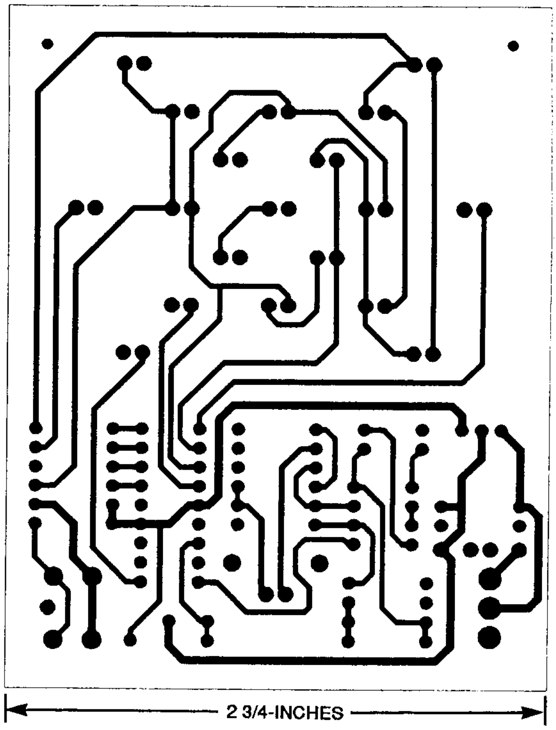


FIG. 2—PIC16C71 BLOCK DIAGRAM. The chip includes fully static CMOS circuitry, flexible I/O pin programming, timed interrupts, and a built-in eight-bit A/D converter.



MICRO-LIGHTS COMPONENT SIDE.



MICRO-LIGHTS SOLDER SIDE.

RAM locations accessed by the interrupt routine. The display routines have access to several subroutines: one reads the A/D converter, and the other generates a random number.

The value produced by the A/D converter corresponds to the sound intensity at the microphone. Some display routines distinguish between different values read from the A/D converter to determine how to turn on the LEDs, and others just look for a minimum amplitude for triggering a pattern. The frequency of sounds can be determined by rapidly reading the A/D amplitudes. A delay subroutine helps control the on and off duration of the LEDs.

Table 1 lists the eight Micro-Lights routines and includes a brief description of each. For example, look at the description for routine 2, "Random Single LEDs." When this routine is selected, the software controls the flashing of single LEDs, one at a time, in random locations on the LED array. When a sound of sufficient amplitude occurs, the rate at which the LEDs are lit is increased correspondingly. The effect is a pleasing twinkling pattern. The other seven routines produce their own unique effects, as mentioned in Table 1.

LISTING 1

```
                 ;Routine 5: Star From Center
                 ;Lights emanate from center, proportional to sound

024C  1C1E  r_5    btfss  bitvar,0   ;check pushbutton
024D  281C         goto   main       ;if pushed, we're done
024E  199E         btfsc  bitvar,3   ;check for auto select
024F  2A52         goto   r_5ok      ;ok to continue
0250  1A1E         btfsc  bitvar,4   ;0 = continue
0251  281C         goto   main       ;if 1, new routine
0252  2284  r_5ok  call   getad      ;get A/D value
0253  1996         btfsc  adata,3    ;skip if bit 3 low
0254  3001         movlw  0x01       ;value for center led
0255  1D96         btfss  adata,3    ;skip of bit 3 high
0256  0100         clrw              ;center led off
0257  008C         movwf  col_1      ;write to led buffer #1
0258  1A16         btfsc  adata,4    ;check bit 4 (A/D)
0259  300F         movlw  0x0f       ;value for 4 leds col_2
025A  1E16         btfss  adata,4    ;check bit 4
025B  0100         clrw              ;turn leds off
025C  008D         movwf  col_2      ;write to led buffer #2
025D  1A96         btfsc  adata,5    ;check bit 5 (A/D)
025E  300F         movlw  0x0f       ;4 leds col_3
025F  1E96         btfss  adata,5    ;check bit 5
0260  0100         clrw              ;turn leds off
0261  008E         movwf  col_3      ;write to led buffer #3
0262  1B16         btfsc  adata,6    ;check bit 6 (A/D)
0263  300F         movlw  0x0f       ;4 leds col_4
0264  1F16         btfss  adata,6    ;check bit 6
0265  0100         clrw              ;turn leds off
0266  008F         movwf  col_4      ;write to led buffer #4
0267  1B96         btfsc  adata,7    ;check bit 7 (A/D)
0268  300F         movlw  0x0f       ;4 leds col_5
0269  1F96         btfss  adata,7    ;check bit 7
026A  0100         clrw              ;turn leds off
026B  0090         movwf  col_5      ;write to led buffer #5
026C  0816         movf   adata,w    ;adata -> w
026D  3C40         sublw  0x40       ;is there sound?
026E  1803         skpnc             ;if sound, skip
026F  2A73         goto   r_5b       ;no sound
0270  3006         movlw  0x06       ;outside leds
0271  048C         iorwf  col_1      ;turn on leds
0272  2A75         goto   r_5c       ;skip turn-off steps
0273  108C  r_5b   bcf    col_1,1    ;turn off led 2
0274  110C         bcf    col_1,2    ;turn off led 3
0275  3007  r_5c   movlw  0x07       ;get hex 07
0276  0093         movwf  delay      ;set delay variable
0277  228A         call   delay1     ;wait, show leds
0278  2A4C         goto   r_5        ;continue with r_5
```

Listing 1 is a portion of the Micro-Lights source code. The complete source code (a file called MLIGHTS.SRC) can be downloaded from the Electronics Now BBS (516-293-2283, V.32, V.42bis) as part of a ZIP file called MLIGHTS.ZIP. The hex code (MLIGHTS.HEX) is also part of the ZIP file. Listing 1 shows the assembled code for the Star From Center routine 5, and Fig. 4 is the flowchart for that routine.

The status of the select push-

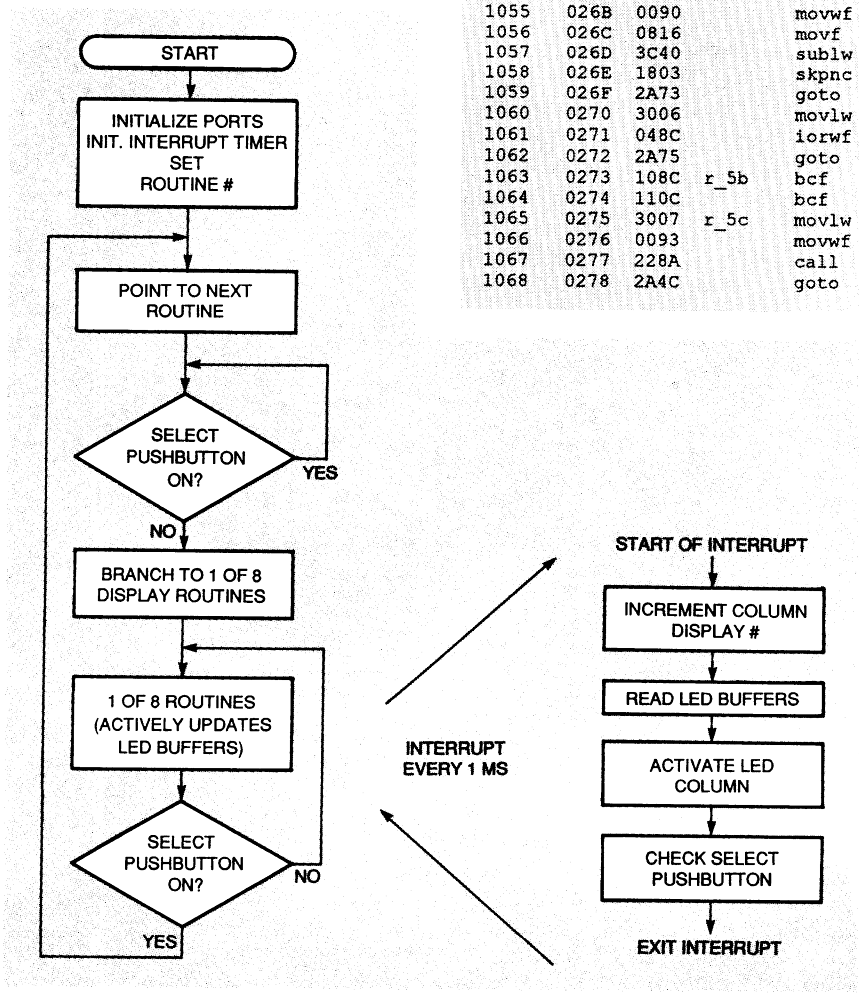


FIG. 3—SIMPLIFIED FLOW CHART. Immediately after power-up, an initialization routine presets and enables a timer within the microcontroller.

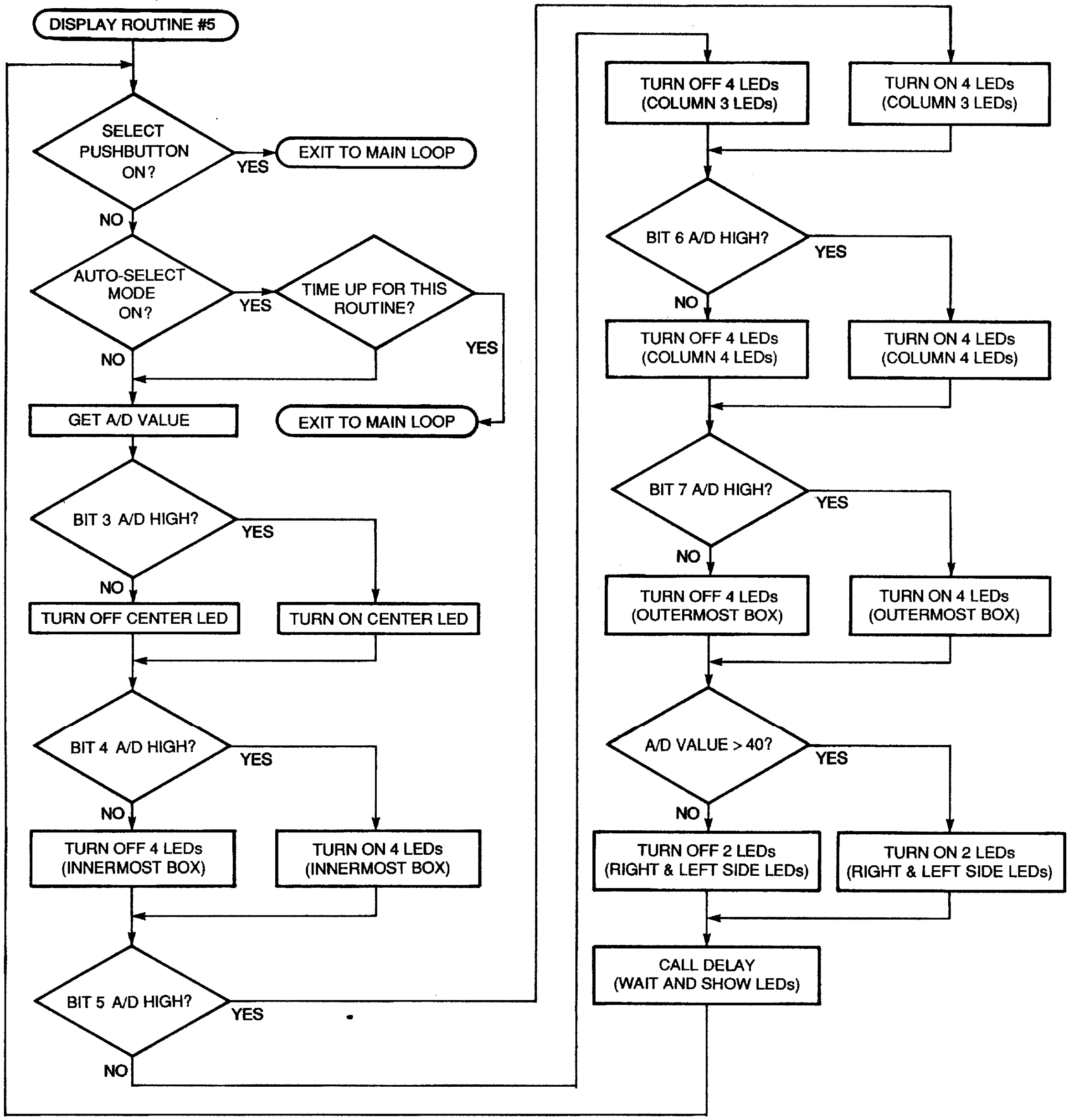


FIG. 4—FLOWCHART for the Star From Center routine. The select pushbutton is checked near the top of the routine; if the button is pressed, the routine is exited.

TABLE 1—MICRO-LIGHTS ROUTINES AND FEATURES

Routine	Features	Effect of Sound
1	Spinning Bars	Triggers Speed & Direction
2	Random Single LEDs	Triggers Speed
3	Bar Graph	Increased LEDs with Amplitude
4	Random LIghts	Triggers Speed
5	Star From Center	LEDs Extend from Center
6	Boxes Hold	Triggers Various Groups
7	Worms Run Rampant	Selects "Worm" and Rate
8	Bars Hold	Selects Bar to Display

button is checked near the top of the routine; if the button is pressed, the routine is exited. Next, the autoselect mode is checked. If it is enabled it will cause the routine to be exited after approximately five minutes of operation.

A subroutine to read the A/D converter is then called to sample the sound amplitude. The main body of routine 5 then decides which LEDs to turn on, depending on the magnitude of the A/D value. If the magnitude is high (because of loud sound), all LEDs will be turned on; if the sound is low, only a few LEDs will turn on.

The testing is accomplished by checking each bit value in the A/D's byte. When all LEDs have been turned on, a delay

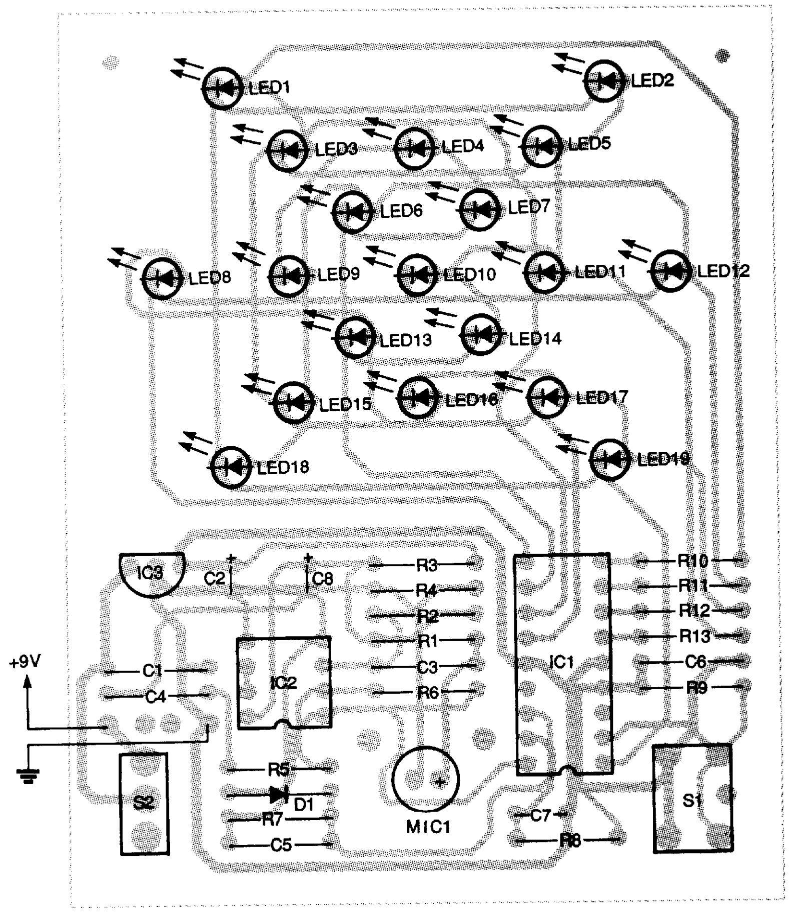


FIG. 5—PARTS-PLACEMENT DIAGRAM. Be sure to mount the LEDs flush with the board so that all cathodes face to the left.

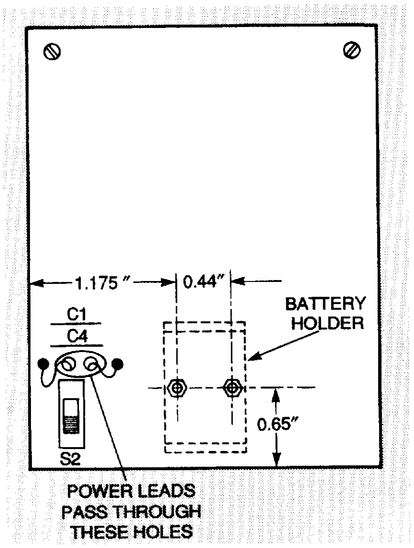


FIG. 6—DRILLING GUIDE. Four No. 2 screws and nuts hold the plastic backplate and battery holder in place.

routine is entered to freeze the display for a few milliseconds. The overall effect of routine 5 is a star that increases and decreases in size, according to sound intensity.

FIG. 7—THE 9-VOLT BATTERY and battery clip act as a stand.

Construction

There are no critical requirements in the construction of this circuit. All of the components are available from the source given in the Parts List, including a pre-programmed PIC16C71 microcontroller and a double-sided silk-screened PC board. The parts are available from many other distributors, as well. For the best finished appearance of the project, a printed circuit board should be used. Foil patterns are provided here for those who wish to make their own boards. Note that Micro-Lights is designed so that it does not require an enclosure.

Figure 5 is the parts placement diagram for Micro-Lights. Be sure to mount all the LEDs with their cathodes facing to the left (as you view the component side of the PC board). Any brand of LED lamp will work, although the best is a bright, diffused-lens lamp in the standard 5-millimeter (T1¾) plastic, radial-leaded package. Standard LEDs have flattened edges on their bases to indicate the cathode lead. Mount the LEDs flush with the PC board to protect the leads from being bent if the LEDs are bumped. Install sockets for the PIC16C71 and the op-amp.

To protect your fingers from any sharp edges of cut off leads on the back of the PC board, and to help make Micro-Lights look more like a professionally made product, install a plastic backing on the PC board. Install a 1⁄16- to 1⁄10-inch thick ABS or acrylic plastic rectangular piece cut to the outline dimensions of the PC board. As shown in Fig. 6, drill four holes and attach the backing with No. 2 screws and nuts.

The two lower backplate mounting screws also secure the 9-volt battery holder in place. The 9-volt battery and battery clip act as a stand to support Micro-Lights when it is placed on a table for viewing (see Fig. 7). Be careful when positioning the holes for the battery holder. Their placement determines the angle at which the PC board will rest on a table. Figure 8 shows the completed Micro-Lights board.

Checkout

After you verify that all parts are installed correctly, connect a battery and turn on the power switch. Micro-Lights should immediately enter routine 1 and display a pattern of spinning bars. The bar's speed of rotation

(Continued on page 66)

MICRO-LIGHTS

continued from page 44

and direction of spin will depend on the sounds in the room.

Cycle through the routines by pressing the select pushbutton and check to see that sound, and the absence of sound, affects each of the eight Micro-Lights routines. Perform the checkout in a quiet room.

coat pocket and wear the board on your lapel.

Applying power to Micro-Lights always causes routine 1 to start. Pressing the select pushbutton always advances the operating routine to the next one. However, if power is applied and the select pushbutton is not pressed, Micro-Lights will automatically increment through all the routines, spending about 5½ minutes on each. The whole cycle repeats after approximately 45 minutes.

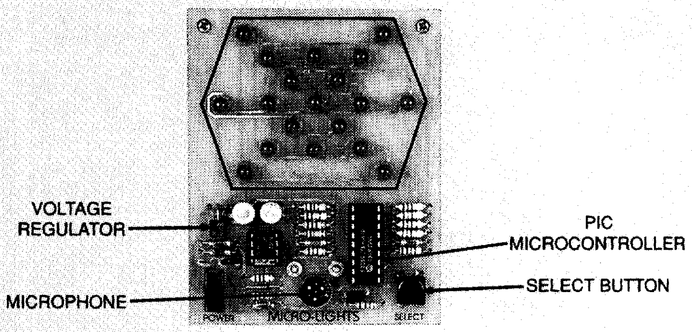


FIG. 8—THE COMPLETED MICRO-LIGHTS BOARD. The board is designed so that it does not need a case.

If nothing happens when power is applied, use a voltmeter to check for +5-volts DC at the output of the regulator, on pin 8 of the op-amp, and pins 4 and 14 of the PIC16C71. Verify that ground is present where it should be on both ICs. If you have an oscilloscope, check for an audio waveform (in the presence of sound) at the op-amp's output at pin 1. The voltage should swing from ground to about 3.6 volts.

To verify the circuit's overall current consumption, connect a multimeter (set on the 200-milliampere DC scale) in series with the 9-volt battery. A reading of 5 to 35 milliamperes, depending on how many LEDs are lit, is a normal measurement.

Operation

Operate Micro-lights in a dimly lit room to obtain the most striking effects. A desk top, coffee table, or bookcase is a good location. If the battery cable is lengthened by several inches, the circuit board can be worn. Tuck the battery in your shirt or

Although the circuit draws fairly low current, consider an AC-to-DC adapter for powering Micro-Lights, especially if you want it to operate continuously. The circuit draws an average of 15 milliamperes—about that of a small transistor radio. Expect 15 to 20 hours of operation from a fresh alkaline battery.

The circuit has no sensitivity control. The author believed the addition of one would detract from the simplicity and elegance of this project. A little experimentation with placement will resolve any problems related to noisy environments. In locations where there is consistently loud noise, a small piece of tape placed over the microphone will reduce the circuit's sensitivity. Check out the effect of music as well as voice on the sound routines.

Micro-Lights might not be as spectacular as the Northern Lights, or a fourth of July fireworks show, but it will provide you with your own miniature light show—and an understanding of microcontrollers. Ω