A CMOS Digital Dice

Students will assemble a battery operated electronic die. This circuit uses a CMOS oscillator, counter, and 7-segment decoder to display a random number between 0 and 7 each time the button is pressed. An ingenious power control circuit automatically shuts off the display after 40 seconds of inactivity.

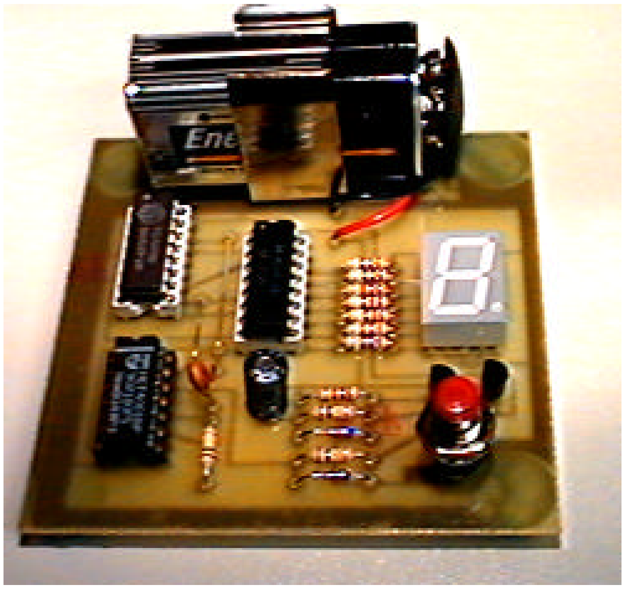


Fig 1 Finished assembly. Battery clip is soldered to printed circuit board. Push button switch requires special soldering in order to make both electrical contact and strong physical support

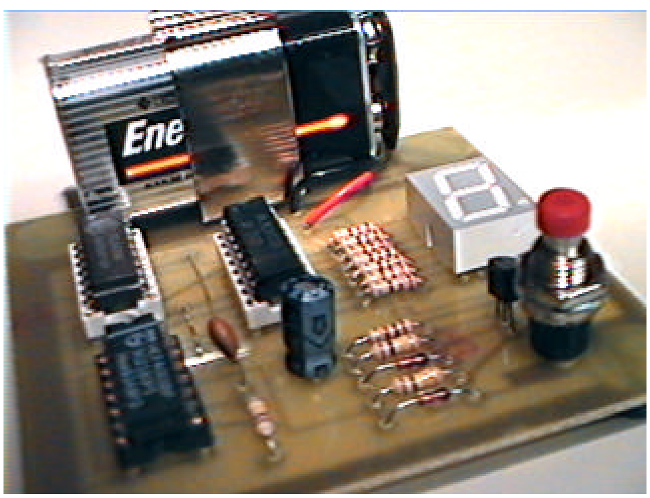


Fig 2 Note the use of scokets for the CMOS parts. CMOS parts may become damaged by ESD, Electrstatic Discharge. By employing sockets in this project I.C. devices can easily be replaced.

<u>Assembly Instructions:</u>

As with previous printed circuit boards install wire jumpers and small components first. It is more difficult to install small components after larger ones are in place.

All components will be directly soldered to the printed circuit board. Pay special attention to the location of pin 1 on I.C.s and and make certain to install the correct parts in their respected locations. For proper parts location see the diagram on page 4 and schematic on page 5.

When installing the transistors make certain the flat sides are correctly oriented. Capacitor C1 is polarized and must be installed correctly. Capacitor C2 can be installed either way.

The switch and battery holder are the largest items and should be <u>installed last.</u> Install the switch by inserting the two tabs through the large holes provided. The pushbutton connections may need to be bent or trimmed in order to provide a better fit. Make certain that the contacts are well soldered as they provide mechanical support as well as electrical contact.

The battery holder will be soldered to the component side of the printed circuit board. A small wire fragment is used to anchor the holder then soldered to the copper foil. Polarity of the battery terminals is of paramount importance. Make certain that they are correct. Mis-polarization may destroy CMOS I.C. parts.

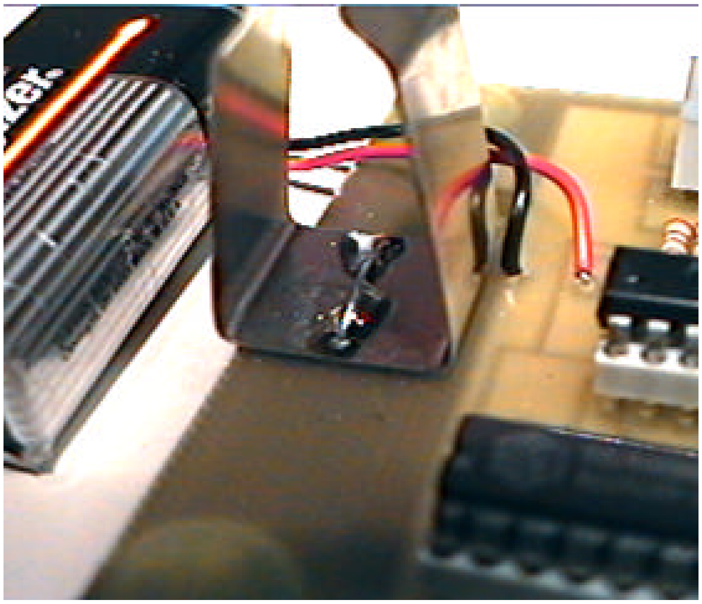


Fig 3. Installation of the 9V battery holder shown with soldered on wire fragments.

Final assembly includes the attachment of 4 self - adhesive rubber feet. Locator circles have been incorporated into the printed circuit foil pattern for the stick on rubber feet.

Fig 4(a) Note the orientation of the Transistors.

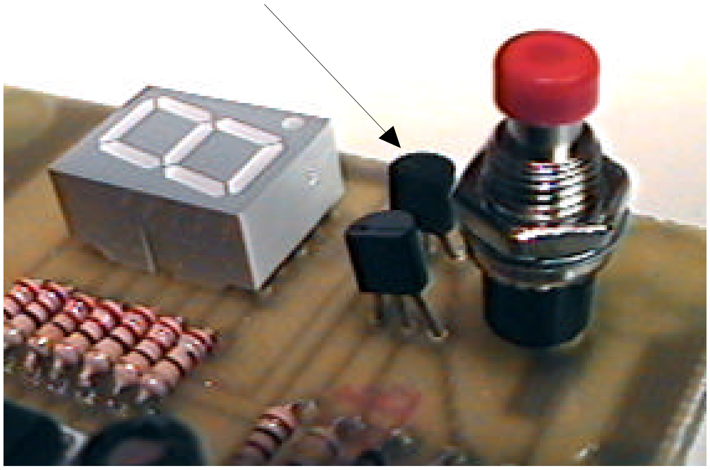


Fig 4(b) Resistors. Note the seven (7) resistors needed for current limiting the LED display segments. In figure 4(b) discrete resistors are shown. Resistors can also be obtained in arrays that resemble I.C. packages. For applications like this sometimes resistor packs can reduce component count and speed assembly.

Theory of Operation:

This relatively simple circuit illustrates what can be done with standard CMOS logic devices. (*See schematic on page 5)* IC1 is a dual NOR gate plus inverter. We are not using the inverter part of this chip. The two NOR gates are connected as an oscillator, the frequency being determined by R4 and C2. The values chosen cause an oscillation at about 40 KHz. The output (on pin 6) goes to IC2, a preloadable counter. Each time the signal from the oscillator changes from low to high logic level, the counter increments 1. The number appears on pins 6, 11, 14, and 2 as a binary number. Output 2, the most significant bit, is connected to the prowled input. When the prowled input goes high, the number represented by pins 4, 12, 13 and 3 are loaded into the counter. These pins are wired as the binary number 0001. As a result, the counter will count 1(=0001), 2(=0010), 3(=0011), 4(=0100), 5(=0101), 6(=0110), 7(=0111). The next signal from the oscillator will cause it to count to 8(=1000), but this causes pin 2 to go high, which immediately preloads the 0001 into the counter again.

The binary number from IC2 goes to IC3 which decodes it into the 7 signals for a 7 segment LED display. This chip also has the output drivers required to drive the relatively high currents of an LED. The 470 ohm resistors limit the current to each LED segment to a reasonable value.

The transistors are used to power up the circuit while the button is pressed, and to keep it powered for a few seconds after the button is released. Q1 and Q2 are in what is called a Darlington arrangement. The emitter of one transistor is directly connected to the base of the other. This results in phenomenal current gain, on the order of 10,000 times! When the push button is pressed, the cathodes of the diodes are grounded. This pulls the anodes of both diodes down to 0.7 volts, or so. This charges C1 and causes a small current to flow into the base of Q2 via R2. As long as the button is pressed, C1 stays charged and current flows to Q2. The high current gain of the Darlington transistors results in Q1 saturating and pulling its collector up to nearly the full battery voltage. This provides power to the LEDs and the three logic chips. When the button is released, C1 is still charged, but slowly discharges through R2 and Q2. When it has discharged to a low voltage, there will be insufficient current into Q2 to keep Q1 saturated; the circuit then turns off.

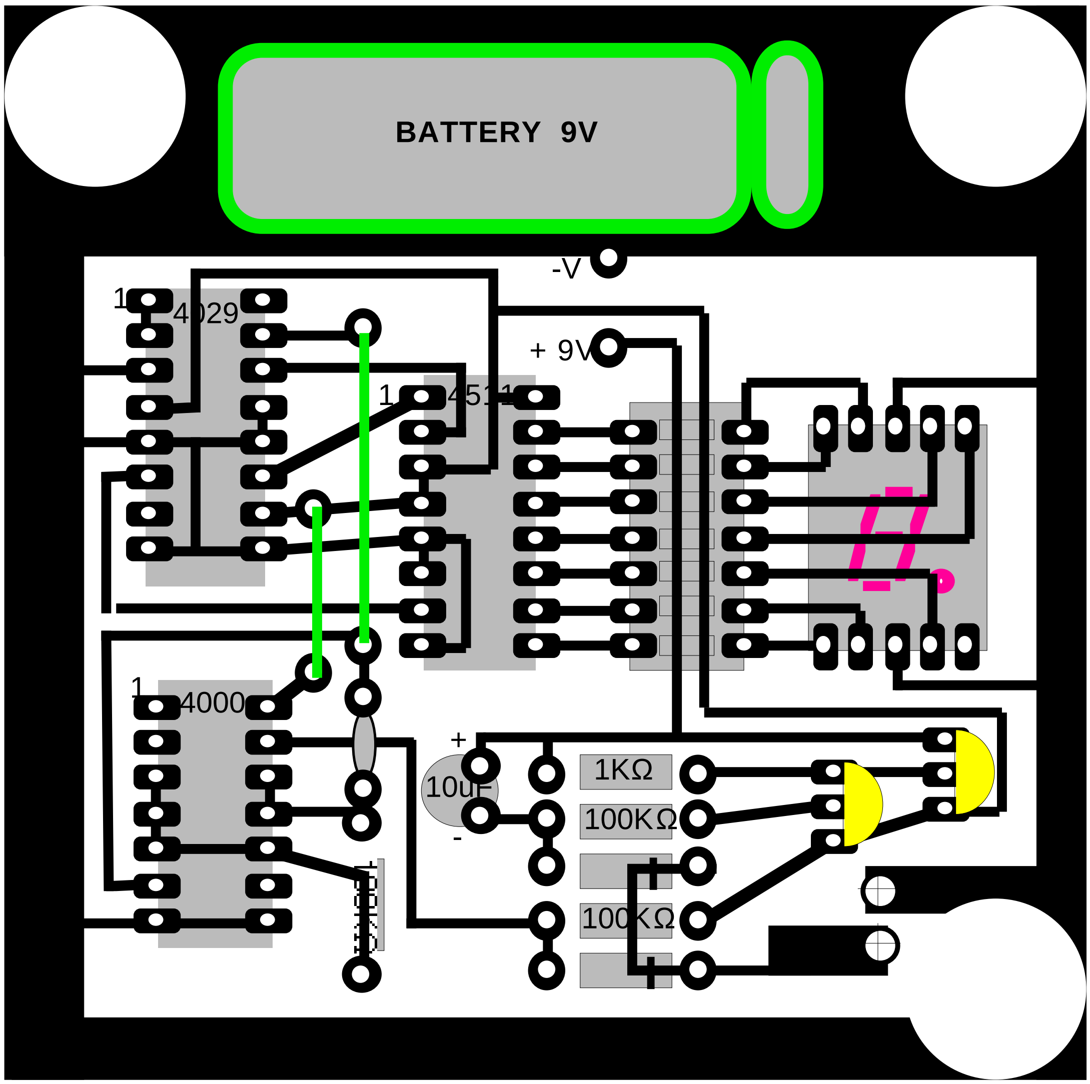
While the button is depressed, D2 pulls pin 13 on IC1 LOW. This enables the oscillator which then starts the counter counting. Because the oscillator counts much faster than your eye can see, the display is just all seven segments on at once. When the push button is released, pin 13 on IC1 is pulled HIGH by R4. This stops the oscillator and you see the last number that was in the counter. The display continues to show this number until C1 discharges and power is turned off, or if the button is press again.

Possible circuit modifications:

It is possible to modify this circuit so that it counts to 6 instead of 7. This is done by diode OR-ing pins 6, 11, and 14 of IC2 together using three 1N914 diodes. First, you will need to cut the copper trace between pins 1 and 2 on IC2. Next connect the cathode side (the one with the stripe) of one diode to each of pins 6, 11, and 14. Solder together the anode sides and connect them to pin 1 on IC2. Finally, connect a 100K resistor from pin 1 to pin 16.

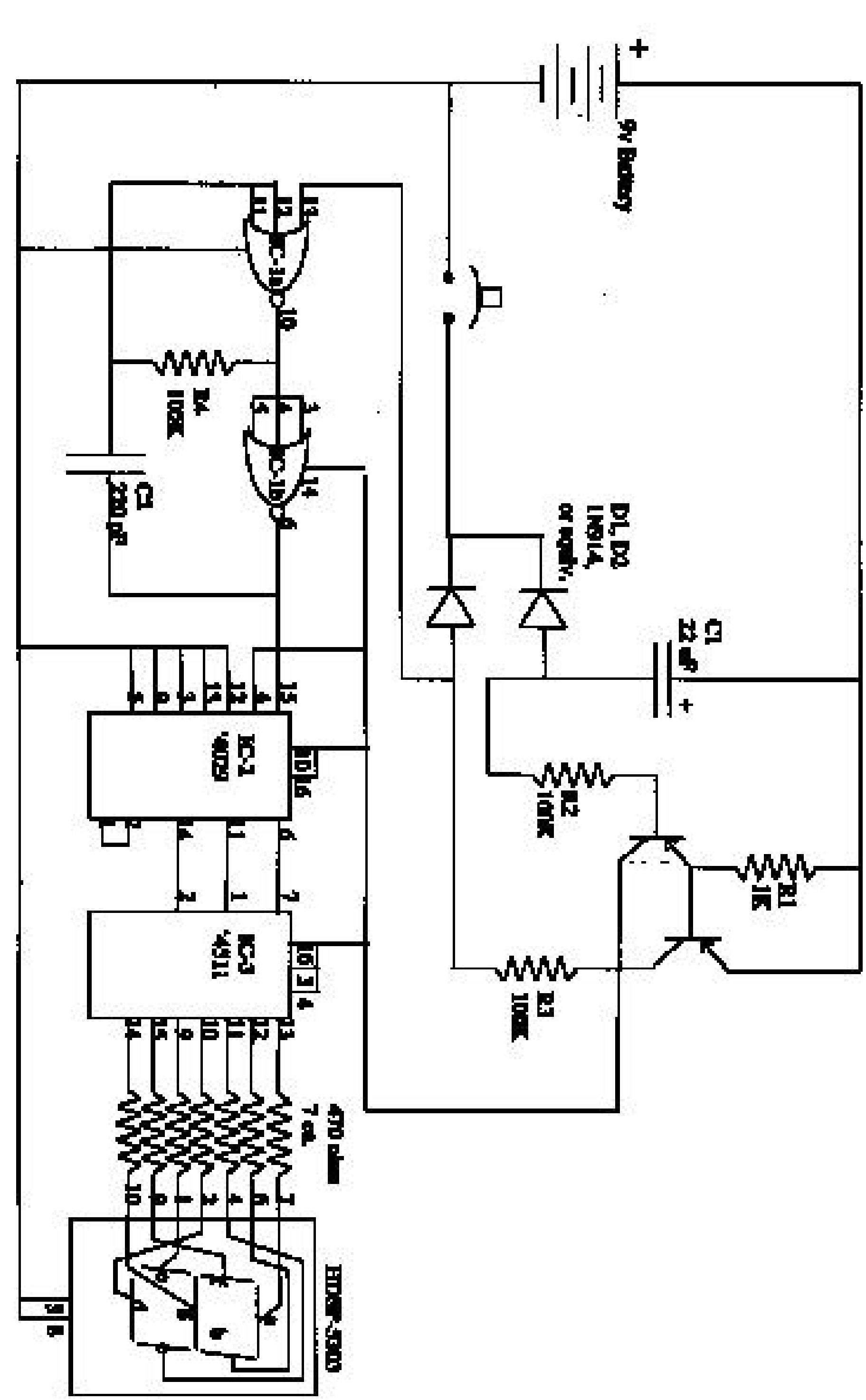
This modification works because each of the numbers from 1 through 6 has at least one binary zero in the lower three bit positions, but the binary representation of 7 is 0111 which doesn't. With the diodes connected as described, as long as there is one bit that is LOW, the diode forces pin 1 (the prowled input) to be low. As soon as the counter counts a 7, all three pins are high and the 100K resistor is finally allowed to pull pin 1 high. This causes the counter to prowled at 7 instead of 8, thus it will never stop on 7 and will only display between 1 and 6, like a standard die.

A CMOS Digital Dice
Component Locator (top view)



Document Description: **COMPONENTS LIST** | Date: **September 1999** | Project Title: **DIGITAL DIE**

A	B	C	D	E	F
ITEM	**QUANTITY**	**PART NUMBER**	**DESCRIPTION**	**UNIT COST**	**TOTAL COST**
				PROJECT TOTAL	**$10.22**
1	1	MC14000	CMOS NOR/INV	$0.15	$0.15
2	1	MC14029	CMOS counter	$0.48	$0.48
3	1	MC14511	CMOS LED	$0.58	$0.58
4	2	2N3906	PNP TRANSISTOR	$0.22	$0.44
5	2	1N914	diode (or similar)	$0.05	$0.10
6	1	10WX7464	HDSP-5303 7-segment LED display	$1.35	$1.35
7	1	29SJ250-1K	1K resistor, 1/4 W	$0.01	$0.01
8	3	29SJ250-100K	100K resistor, 1/4 W	$0.01	$0.03
9	7	29SJ250-470K	220 ohm resistor, 1/4 W	$0.01	$0.07
10	1	14ER0322U	22uF electrolytic capacitor 10v	$0.30	$0.30
11	1	14DK00220P	220 pF ceramic capacitor	$0.12	$0.12
12	1	280RG9	9v Transistor battery	$0.65	$0.65
13	1	105793	battery mounting clip	$0.12	$0.12
14	1	2801BST	battery connector/leads	$0.15	$0.15
15	2		16 pin solder tail IC socket	0.89	$1.78
16	1		14 pin solder tail IC socket	0.75	$0.75
17	1	17MOMNO	N.O. Push Button Switch	$0.60	$0.60
18	9	SQ INCHES	PRINTED CIRCUIT BOARD	$0.26	$2.34
19	4	64-2346	rubber feet, stick on	$0.05	$0.20


9v Battery
D1, D2
1N914,
or equiv.
470 ohms
7 ea.
R1
1K