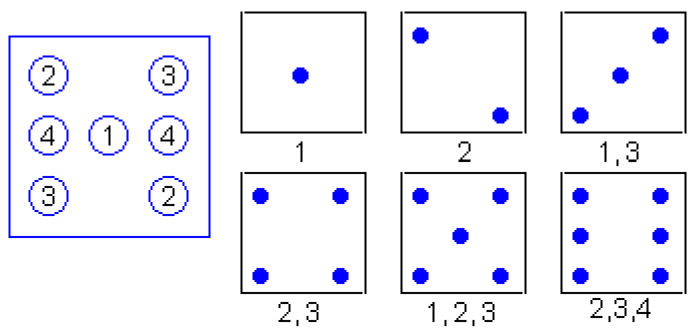
Experiments for the

Lab9500

Experiment 213
- Pair of Dice -

Introduction: The original PAL handbook by MMI (Monolithic Memories Inc.), inventors of the PAL, had some interesting designs. One of the most clever was a design for a pair of dice. To generate a random die, one would need a modulo six counter. The counts of the counter would be decoded to drive LEDs representing the dots on a die. There are seven dots. One could then envision a design requiring ten macrocells: three for the mod 6 (3-bit) counter, and seven combinational outputs for driving the seven LEDs. The MMI design, however, required only eight registered outputs for a pair of dice, or four per die! How was this possible?

First, consider the six dot patterns on a die as shown to the right. Careful observation with show that some dots never appear individually, but paired with another dot. The lone exception is the center dot, labeled "1". The paired dots are one pair of opposite corners, labeled "2", the other pair of opposite corners, labeled "3" and the pair of side dots which occur only in six, labeled "4". So in fact, only four outputs are needed to drive the LEDs in each die.



Consider that the four outputs needed could be flip-flops in a mod six counter. While it only takes three bits to make a mod six counter, there is no reason why you can't use four. Thus, the cells that make the counter can be the very cells that drive the LEDs, and only four cells total are need to make a single die, or eight for a pair of dice.

For uniformity, let's specify that the bits making up the LSB counter/driver be called w,x,y and z, with w corresponding to the dot pair "4", x to the dot pair "3", etc. Thus, the counter pattern to drive the die side four would be the two opposite corner pairs, or 0,1,1,0 or, /w*x*y*/z.

To get a pair of dice, we make a two-digit mod 6 counter. The LSB is as described above. For the MSB, let us use upper case W,X,Y, and Z. While the count sequence (and logic) is the same for the MSB, note that it should count only once for each cycle of six counts of the lower die. For five of the six counts of the lower die, the count for the upper die should be held.

The LAB9500 board has a bank of eight LEDs. From left to right L7, L6, . . L1, L0. The output bits are brought to the dual row .100 connector J6 at the top of the chip. The instructor should have a board with LEDs wired in the pattern for a pair of dice that will connect into J6.

The clock for the two-digit mod 6 counter can be derived from the 60 Hz input. Let us specify that pushbutton PB3 is used to apply the clock. When applied, the LEDs should flash rapidly. When the button is released, a two-die pattern will remain.

Experimentation

1. Create a single die with counter bits w, x, y and z. Use a DIPswitch to select the clock to be either a rapid clock taken from the 60 Hz applied via PB3, or pushbutton PB1. This makes it possible to manually step through the count to see the correct counting action. Use LED bank outputs L3, L2, L1 and L0 to display w, x, y and z respectively.

2. Extend the counter to two digits adding bits W, X, Y and Z displayed by L7, L6, L5 and L4 respectively.

3. For a pleasanter effect design the clock so that a rapid clock is applied as long as PB3 is pressed, but continues and slows down before stopping when PB3 is released.

If you want to observe your pair of dice with the normal dot patterns, the instructor will have a board that will show the dice.