Project 1 – Vegas Dice

# Abstract

The project brief required us to design, simulate and build a Vegas style dice using only 4000 series ICs, an array of 6 LEDs and an Arduino Nano microcontroller that would act as a clock. The design was first designed and simulated using Multisim from National Instruments. This was then used as a reference schematic when we implemented the circuit on a breadboard.

# Introduction

At a high level, the brief required us to create a circuit that would simulate the roll of a dice. When the user wanted they would press a button and the LEDs would display the result of their dice roll. The circuit needed to accomplish three things. It needed to be:

1. Reliable
2. Sufficiently Random
3. Easy to build and understand

For these reasons we stayed away from using a microcontroller as the heart of the circuit. While sufficient randomness could be guaranteed, it would be totally unnecessary for the task. Instead, we focused on using the 4000-series of CMOS ICs that was first introduced by RCA in 1968 [1]. Since these ICs were and still continue to be popular, it meant that SPICE models for all the chips we required were easily available in Multisim. It also allowed us to easily find datasheets for all the chips that were utilized in the design. The wide operating voltages of these chips meant that we could run the circuit at 5V without facing any issues.

# Circuit Description

The circuit was centered around the CD4029B CMOS Presettable Up/Down Counter from Texas Instruments [2]. This is a 4 bit clocked binary or decade counter that we could reset and stop at any time using the “Preset Enable” and “Clock Enable” pins (pins 1 and 5 respectively). The unique function of this chip is that when the preset enable pin is pulled high, it can use the JAM pins (3, 4, 12, 13) to reset the counter to a known value asynchronously, with pin 3 being the LSB and pin 13 being the MSB. Pin 3 was connected to VDD with pins 4, 12 and 13 being connected to ground so that when the preset was triggered, the counter would start counting from (0001)­­2 or (1)10. At all other times the Preset Enable signal was held low through a 1M pull-down resistor. The power, ground and clock signal were derived from an Arduino Nano board. This board was used because it made testing the circuit extremely easy. Changing the clock speed to be slow enough so that we could visually verify the numbers 1-6, only required the change of a few variables. An extremely fast clock (~120kHz) was used in order to simulate randomness that would be indistinguishable from true randomness. In order to “roll” the dice, the user would press a push button which would ground the Clock Enable pin and allow the counter to count. When the button is released, the Clock Enable would be pulled high through a 1M pull-up resistor, stopping the clock and allowing the number to be displayed on the LEDs.

To convert the binary numbers from the counter to the LEDs that we needed to light up, we first came up with a truth table (Table 1) based on the LED display given to us (Figure 1).

Graphical user interface, text, application, chat or text message

Description automatically generated

*Figure 1. LED Display Layout*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | A | B | C | D |
| 0 | 0 | 0 | X | X | X | X |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | X | X | X | X |

*Table 1. LED Truth Table (1 = ON, 0 = OFF, X = Don’t Care )*

Using this we then performed a Karnaugh Map Minimization for the outputs A, B, C and D to arrive at the final, minimized Boolean expressions of

Using these equations along with the CD4081B Quad 2-Input CMOS AND Gate [3] and the CD4071B Quad 2-Input CMOS OR Gate [4], we were able to design the following circuit diagram on Multisim (Figure 2).

Diagram, schematic

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*Figure 2. Full Schematic*

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• Results •

Describes tests performed to verify operation of design and circuit including multisim simulations, timing diagrams, unit / end-to-end tests etc.

# References

[1] HandWiki. "Engineering:4000-series integrated circuits." HandWiki. <https://handwiki.org/wiki/Engineering:4000-series_integrated_circuits> (accessed 18/02/23, 2023).

[2] T. Instruments. "CMOS Presettable Up/Down Counter." Texas Instruments. <https://www.ti.com/lit/ds/symlink/cd4029b.pdf> (accessed 18/02/23, 2023).

[3] T. Instruments. "CMOS AND Gates." Texas Instruments. <https://www.ti.com/lit/ds/symlink/cd4081b.pdf?ts=1676777978837> (accessed 18/02/23, 2023).

[4] T. Instruments. "CMOS OR Gates." Texas Instruments. <https://www.ti.com/lit/ds/symlink/cd4071b.pdf> (accessed 18/02/23, 2023).