

Digital System Design Lab

Lab 5

Investigation of Open-Drain Gate Characteristics

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Date: 2023/10/18

1. Objectives

- To better understand open-drain gate static and dynamic behavior
- To effectively choose the proper value of pull-up resistor for an open-drain circuit

2. Theorem

(1) Open Drain:

Open-drain (also known as open-collector) is a type of output or signal configuration commonly used in digital electronics, particularly in microcontrollers, integrated circuits, and communication buses. In an open-drain configuration, a device can actively pull the output low (logical 0), but it relies on external components to pull the output high (logical 1). This arrangement allows for wired-OR logic and is often used in applications like I2C, SMBus, and signaling on the GPIO (General Purpose Input/Output) pins of microcontrollers. Key characteristics and applications of open-drain:

a. Active Low Output:

In the open-drain configuration, the device can actively drive the output low by closing a transistor switch between the output pin and ground. However, it cannot actively drive the output high (logical 1).

b. External Pull-Up Resistor:

To achieve a logical high state (1) in open-drain output, an external pull-up resistor is connected between the output pin and the supply voltage (V_{cc}). This resistor is essential for restoring the logical high state.

c. Wired-OR Logic:

Open-drain outputs are commonly used in applications where multiple devices share the same signal line. If any of these devices actively pulls the signal low, it affects the entire line. The logical high state is maintained by the pull-up resistor, and this configuration allows for a wired-OR logic function.

d. I2C and SMBus Communication:

The open-drain configuration is a fundamental component of I2C (Inter-Integrated Circuit) and SMBus communication protocols. These protocols use open-drain lines for bidirectional data and clock lines to allow multiple devices to communicate on the same bus.

e. GPIO Pins:

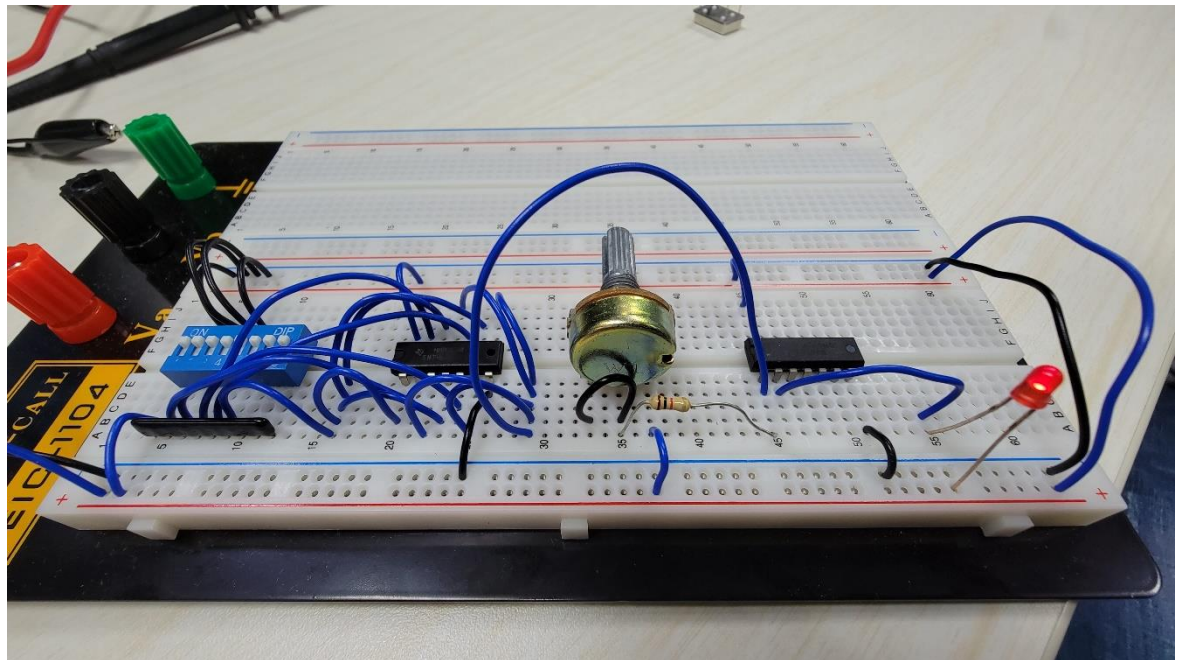
Many microcontrollers offer GPIO pins that can be configured as open-drain outputs. This is useful for interfacing with other devices that expect open-drain signaling.

f. Noise Immunity:

Open-drain outputs can be more noise-immune than push-pull outputs because they do not actively drive the line high. The pull-up resistor acts as a weak reference, making it less susceptible to interference.

3. Experimental Results

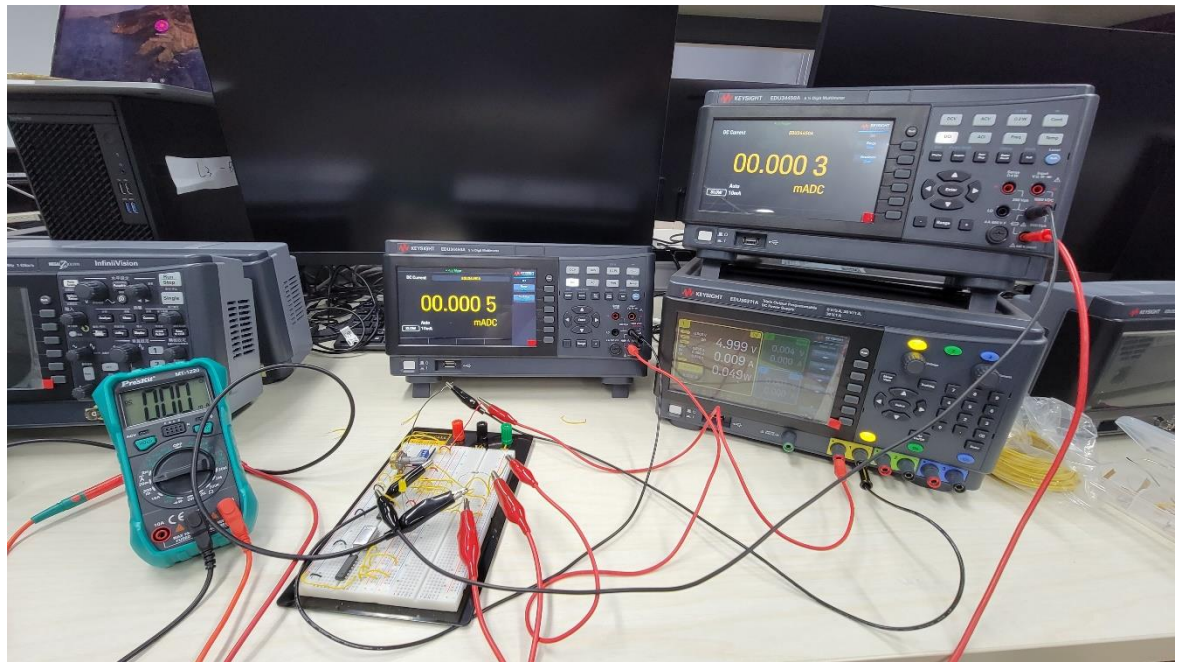
(1) Step 1



$$F(A, B, C, D) = (A + B + C + D)'$$

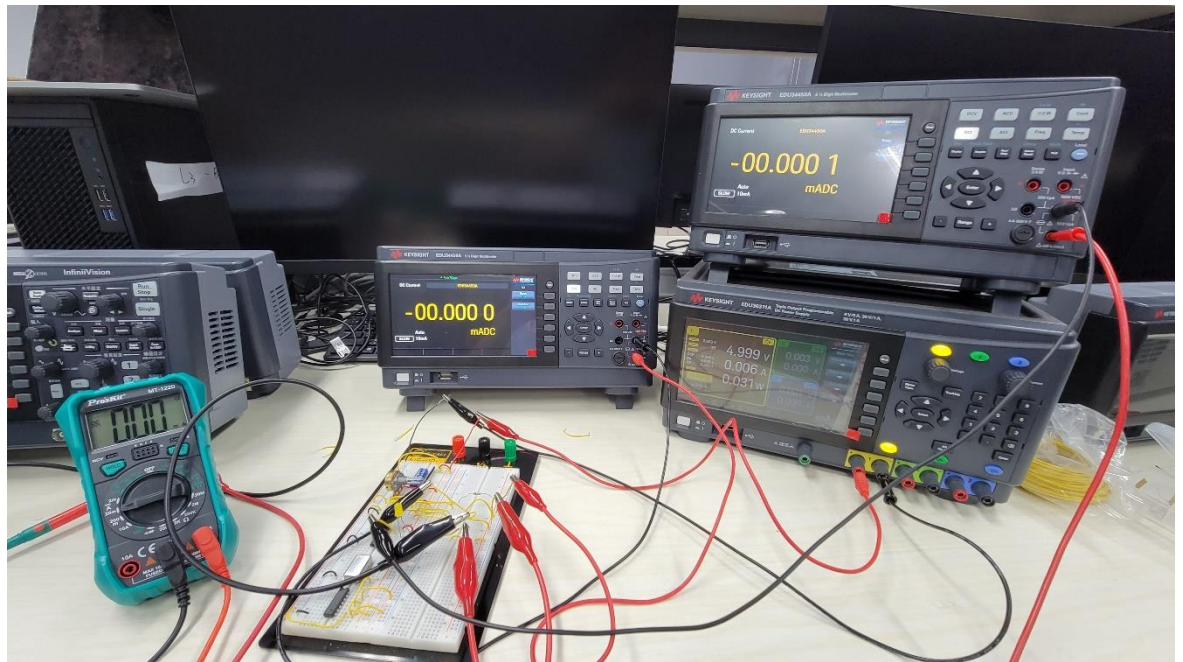
A	B	C	D	F(A, B, C, D)
0	0	0	0	1
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0

(2) Step 2



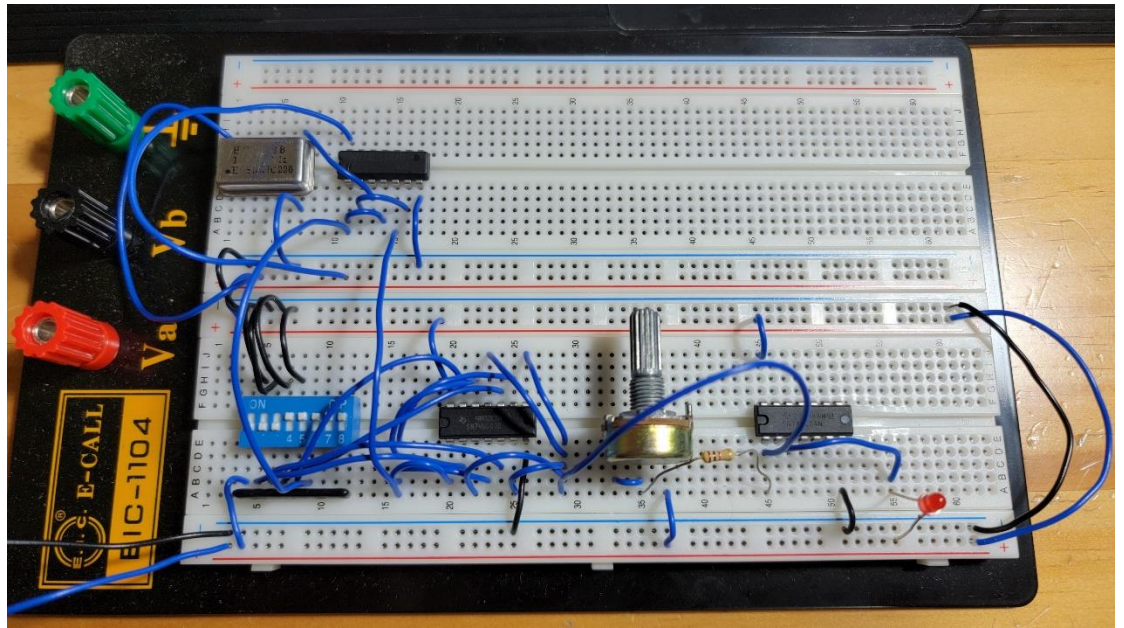
A	B	C	D	V_o	I_o	I_A	I_B	I_C	I_D	I_I
L	L	L	L	4.987 V	0 A	0 A	0 A	0 A	0 A	0 A
H	L	L	L	12.072 mV	4.901 mA	4.886 mA	0 A	0 A	0 A	0 A
H	H	L	L	6.400 mV	4.966 mA	2.412 mA	2.437 mA	0 A	0 A	0 A
H	H	H	L	4.534 mV	4.988 mA	1.525 mA	1.631 mA	1.698 mA	0 A	0 A
H	H	H	H	3.604 mV	5.000 mA	1.193 mA	1.216 mA	1.227 mA	1.230 mA	0 A

(3) Step 3



A	B	C	D	V_o	I_o	I_A	I_B	I_C	I_D	I_I
L	L	L	L	4.989 V	0 A	0 A	0 A	0 A	0 A	0 A
H	L	L	L	0 V	0.432 mA	0.466 mA	0 A	0 A	0 A	0 A
H	H	L	L	0 V	0.431 mA	0.234 mA	0.195 mA	0 A	0 A	0 A
H	H	H	L	0 V	0.432 mA	0.164 mA	0.156 mA	0.146 mA	0 A	0 A
H	H	H	H	0 V	0.433 mA	0.092 mA	0.101 mA	0.099 mA	0.095 mA	0 A

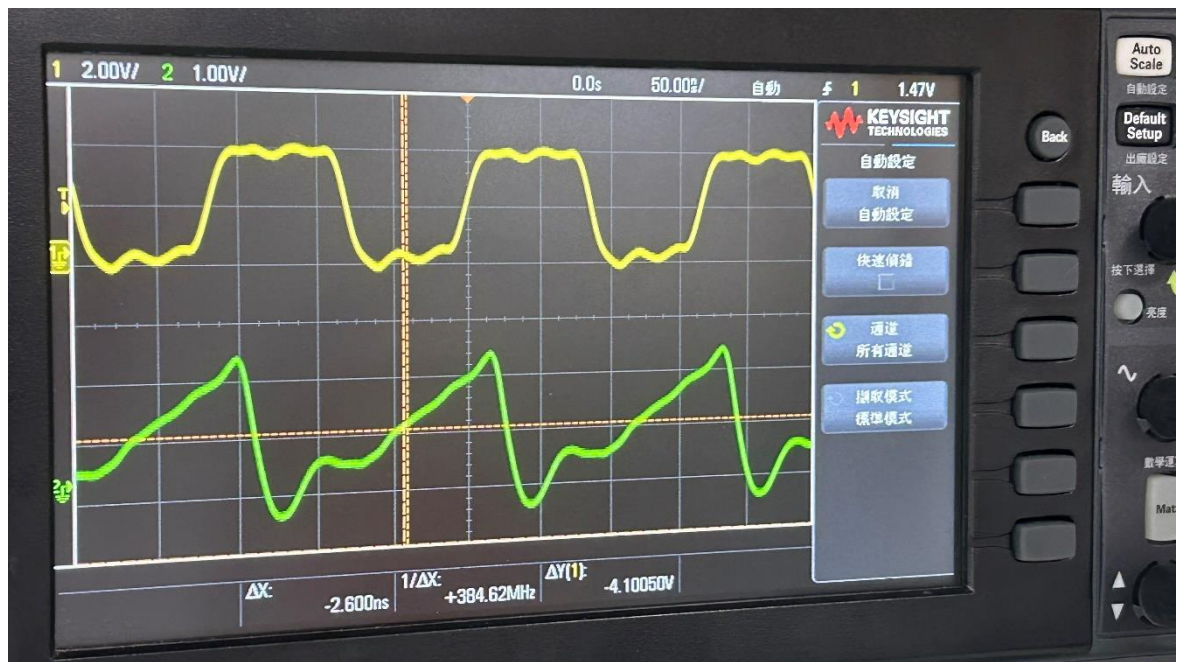
(4) Step 4



a. HLLL:



b. HHHH:



A	B	C	D	tPLH	tPHL	tTLH	tTHL
H	L	L	L	43.6 ns	47.8 ns	93.5 ns	75.3 ns
H	H	H	H	43.8 ns	31.3 ns	98.4 ns	74.5 ns

(5) Step 5

As we adjust the pull-up resistor, we observe an interesting correlation. Rise and fall times extend as the resistance increases. Notably, this isn't static; it also affects propagation delay. As the gap between rise and fall times widens, propagation delay naturally increases. This intricate balance highlights the dynamic relationship between these parameters in digital circuit design.

4. Comments

None

5. Problems & Solutions

During my first interaction with a variable resistor, I incorrectly connected the wires, resulting in an inaccurate circuit output. Seeking guidance from an experienced individual, I learned to revise the parallel connections, ultimately ensuring the circuit's successful operation. This experience underscored the importance of mentorship and troubleshooting skills in electronics.

6. Feedback

None