Consider the gray code angular encoder in Fig. 2. (a) If the shaft rotates 180 degrees, how many bit changes occur? (b) If it rotates 180 degrees, and the initial gray code is 0000, what is the final gray code? (c) With 4-bit gray code, how many distinct angles can the shaft encode? What is 360 degrees divided by this number (i.e. the angular precision)? (d) What would be the angular precision of an 8 bit encoder?

a) 8 bit changes   b) 1100   c) 16 distinct angles, 22.5°
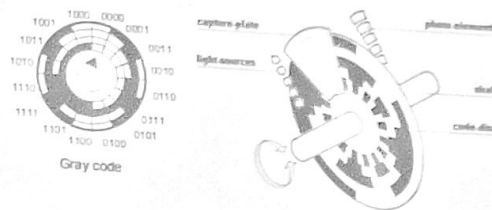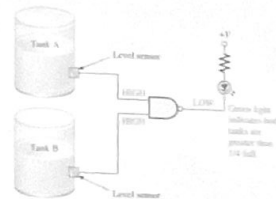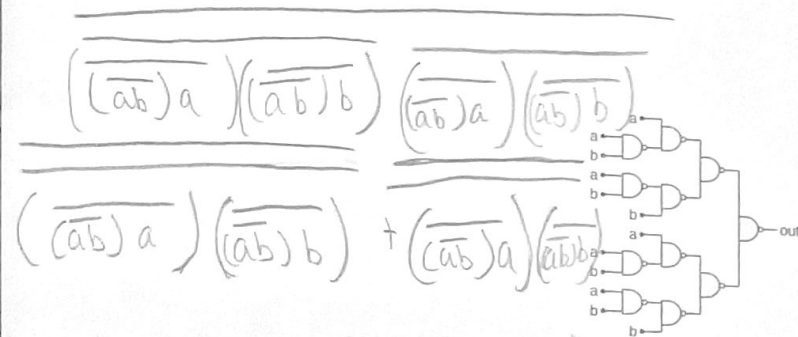
d) 1.41°

Figure 2: A gray code shaft encoder, or angular encoder, reports the angular position of an object digitally, using the gray code.

3 Chapter 3 - Logic Gates

$$\overline{\left(\overline{ab}\right)a}\quad\overline{\left(\overline{ab}\right)b}\quad\overline{\left(\overline{ab}\right)a}\quad\overline{\left(\overline{ab}\right)b}$$

$$\left(\overline{\overline{ab}\,a}\right)\left(\overline{\overline{ab}\,b}\right)\ +\ \left(\overline{\overline{ab}\,a}\right)\left(\overline{\overline{ab}\,b}\right)$$

$$\left(\overline{\overline{ab}\,a}\right)\left(\overline{\overline{ab}\,b}\right)$$
$$\left(\overline{\overline{ab}}+\overline{a}\right)\left(\overline{\overline{ab}}+\overline{b}\right)$$
$$\left(\left(\overline{a}+\overline{b}\right)+\overline{a}\right)\left(\overline{a}+\overline{b}+\overline{a}\right)$$
$$\left(ab+\overline{a}\right)\left(ab+\overline{b}\right)$$
$$abab+ab\overline{b}+\overline{a}ab+\overline{a}\,\overline{b}$$

Figure 3: (Left) A logic gate combination. (Right) A liquid tank-level system built from a NAND gate. $ab+\overline{a}\,\overline{b}$

1. Generate the simplified logic expression and truth table for Fig. 3, left. What do you call this type of gate?

$$ab+\overline{a}\,\overline{b}\ =\ XNOR\ gate$$

2. Suppose signals D_0 and D_1 in Fig. 1 are connected to a and b in Fig. 3, left. Generate the timing diagram for out.

XOR =

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

3. **Creative design**: A liquid tank system is depicted in Fig. 3. The sensors are HIGH when the liquid is above the level (green ON). (a) Create a red LED system that activates when both tanks are *below* the level, and draw it below. (b) Create a yellow LED system that activates when one tank is below and one tank is above the level. (c) Add a third tank with more liquid, and two pipes guiding liquid to tank A and B. Each pipe should have a valve. Add logic that opens the correct valve so as to fill only the low tank until it is no longer below the level.