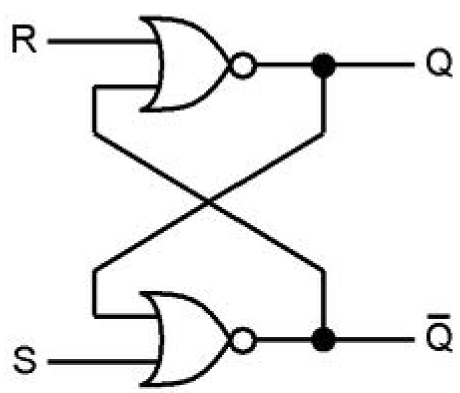
1. How Hamming(7,4) works

111	110	101	100	011	010	001
7	6	5	4	3	2	1
D3	D2	D1	C2	D0	C1	C0

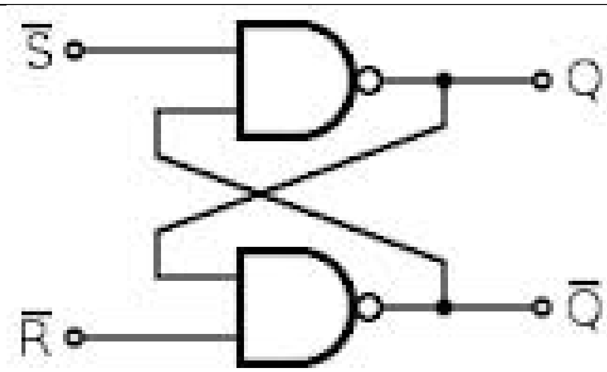
   a. Each data bit must be covered (checked) by at least 2 parity bits
      i. Doesn't matter which parity bits cover which data bits
      ii. However, doing it in the way we did allows you to determine the error location easily
   b. Why we start numbering from 1
      i. Need a bit pattern that indicates there were no errors
      ii. If the recreated check bits match the original check bits, XOR returns 0
      iii. We use that position to indicate no errors
   c. Which parity bits check which data bits
      i. C0 is in location 1
         1. Checks all bits with bit 1 high (except for itself)
         2. 3, 5, 7, 9, 11, so on
      ii. C1 is in location 2
         1. Checks all bits with bit 2 high (except for itself)
         2. 3, 6, 7, 10, 11, so on
      iii. C2 is in location 4
         1. Checks all bits with bit 4 high (except for itself)
         2. 5, 6, 7, 12, 13, so on
      iv. If we had a C3, it would be in location 8
         1. Would check all bits with bit 8 high (except for itself)
         2. 9, 10, 11, 12, so on
      v. In general
         1. Next check bit lies at bit positions that are powers of 2
   d. Why we can XOR to determine the bit position
      i. We are essentially creating a binary number based on all the check bits
      ii. Whether or not a given data position is set or not affects all the check bits that check that location
         1. If a data bit is changed, all the check bits associated with that location will be affected
         2. All of them will differ by 1 from the original calculation for the check bit at that position
         3. Take the example from the previous class
            a. Original data 0110011 → 0010011 with bit 6 flipped
            b. Bit 6 was the one that changed
            c. The two check bits that were checking it (C2 and C1) changed as well
         4. Combination of affected check bits form the position of which bit was changed
   e. Expanding it further
      i. Expanding to cover a larger data size
         1. $2^K - 1 \geq M + K$, where M = data bits, and K = check bits
         2. From above, $2^3 - 1 \geq 4$ data bits + 3 check bits
      ii. Covering more errors
         1. Given T errors:
            a. Hamming distance between valid code words must be T + 1 to detect
            b. Hamming distance between valid code words must be 2T + 1 to correct

2. Sequential circuits
    a. So far, only discussed combinational circuits
        i. Output strictly dependent on the inputs only
    b. Sequential circuits – output depends on the current inputs as well as the *history* of inputs
        i. Other way to phrase it – they have memory
        ii. History of inputs determines "state" of the circuit
    c. Examples
        i. House alarm that needs to be reset once an intrusion is detected
        ii. Combination lock

3. Latches
    a. Circuit that has two stable states, can be used to store information
        i. Change state via signals applied to the control inputs
    b. S-R latches
        i. Set sets the latch
        ii. Reset clears the latch
        iii. Q and !Q give the output and complement
    c. S-R latch implementation



S-R NOR Latch



S-R NAND Latch

    d. Characteristic tables
        i. Expected operation of latch

S	R	Q_{n+1}
0	0	Q_n
0	1	0
1	0	1
1	1	Undefined

S-R NOR Latch

S	R	Q_{n+1}
1	1	Q_n
1	0	0
0	1	1
0	0	Undefined

S-R NAND Latch