

Review of some simple circuits

Sequential and Combinational Circuits

A combinational function can be completely defined using the truth table which specifies for every input combination $(x_1, x_2, x_3, \dots, x_n)$ the corresponding output value. They do not involve any *state* information (or information about time).

This is in contrast to sequential circuits in which the output is a function of the inputs $(x_1, x_2, \dots, x_n)$ and the state of the system. Hence, sequential functions are time-varying or dynamic.

The following is a brief description of some of the register level combinational and sequential components:

1 Multiplexers

A multiplexer is a device used to route data from several sources to a common destination; the source is determined by applying appropriate control signals to the *select* inputs of the multiplexer. Hence, a multiplexer with n select inputs can multiplex 2^n inputs onto one output.

Important Use of a Multiplexer: It can be used to implement *sum-of-products* form of expressions very easily. For example, for a 4 input (and hence, 2 selector inputs x and y) multiplexer, the output z is given by

$$z = a_0x'y' + a_1x'y + a_2xy' + a_3xy \quad (1)$$

2 Decoders

A 1-out-of- 2^n decoder is a combinational circuit with n input data lines and 2^n output data lines such that only one of the 2^n output lines is active at a time (and, hence the name). The primary application of a decoder is in addressing, where the n bit input is interpreted as address and is used to select one of the 2^n output lines (or memory locations).

A circuit that routes data from a common source to one of several destinations is called a *Demultiplexer*. Note that there is a very significant similarity between a decoder and a demultiplexer.

3 Encoders

An encoder is a circuit used to generate the address or name of an active input line; it is therefore the inverse of a decoder. A typical encoder has 2^k input lines and k output lines. An additional output line is used to indicate the presence or absence of any active input line.

A disadvantage of this kind of encoders is that if more than one input lines is active, then incorrect output is generated. This is avoided by assigning priorities to the input lines and design encoder so that the output address is always that of the active input line with the highest priority.

4 Comparators

The function of a comparator is to compare the magnitude of two numbers. An interesting issue here is to design a comparator for larger number of inputs than that is provided by the available comparator.

5 Latches

A latch is a basic sequential element that is used to remember the state of a signal. It typically has three inputs, S (Set signal), R (Reset signal) and D (Latch input) and two outputs, Q and its complement $\bar{Q}$. As long as S and R signals are both low, the output of the latch, i.e., Q, equals D; this mode of the latch is referred to as the *hold mode*. If S is set to 1, Q goes high; if R is set to 1, Q goes down. Setting both S and R to 1 is an illegal input combination, which results in an unstable latch behaviour.

6 D Flip-flop

D flip-flop is another sequential component. Unlike the latch component, D flip-flop is a synchronous component as it has a clock (CLK) input. The output of the flip-flop is set to the value applied from the D input of the flip-flop, whenever the CLK input makes a transition of the appropriate type (either rising or falling). When there is no transition in the CLK, the output of the flip-flop remains the same regardless of the D input value.

7 Counters

A counter is a simple sequential machine designed to cycle through a predetermined sequence of states in response to pulses on an input line. Typically, such counters are designed using flip-flops.