DIGITAL ELECTRONICS

Counters and Registers

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4.7 Counters

- A counter is a circuit made up of a **series of flip-flops** connected in a suitable manner to **record sequences** of pulses presented to it in digital form. Counters are used in digital systems to:

1. **Count events** - converts a given number of event cycles into a prescribed binary code.

2. **To time events** - The duration that an event lasts can be determined from the count and the clock frequency.

3. **To generate special code sequences** - In this application, the counter is used as the heart of a logic sequencer and is used to generate the next-state information as well as the control information.

4. **Frequency division**.

4.7 Counters

Characteristics of Counters:

A counter should have one or more of the below attributes defined:

- The **maximum number** of counts it can achieve.
- Whether it is an **up or down** counter.
- Its **mode of operation**: synchronous or asynchronous.
- Free-running or self-stopping.

4.7.1 Classification of Counters

1. **Mode of operation**

- Single mode counter - Counts **without** external control inputs.
- Multi-mode counter - Counters **with** external control inputs that can be used to **alter the counting sequence**, the beginning of a sequence or the end of a sequence.

2. Modulus of the counter - The maximum number that a counter can sequence through is called the **modulus** of the counter, e.g. if the counter goes through the sequence 000, 001, 010, 011, 100, it goes through five states hence the **modulus of the counter is five**.

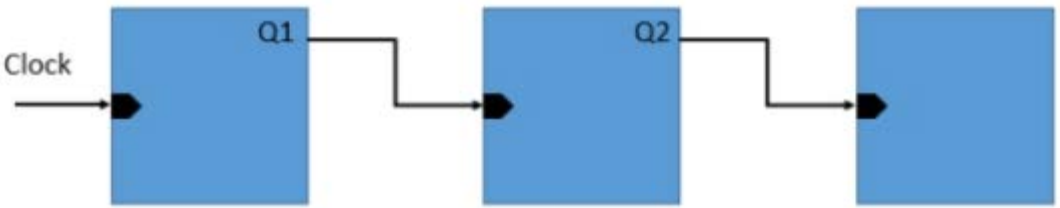
- A modulus N counter is also referred to as a **MOD N** counter or a DIVIDE by N counter hence the above counter can be referred to as a **MOD 5** counter or a DIVIDE by 5 counter.

4.7.1 Classification of Counters

- Generally speaking, a counter that can sequence through N states is known as a MODULO N counter or a DIVIDE by N counter. If N is a power of 2 (2, 4, 8,16 etc.), the counter is called a **binary counter**. If N is a power of 10 (10, 100,1000 etc.), the counter is known as a **decimal** or **a decade counter**.

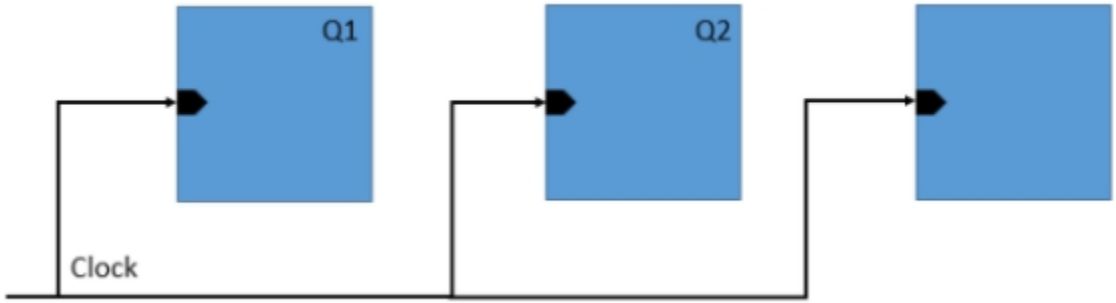
3. **Clocking method** - There are two types of clocking for counters:

i. **Asynchronous (ripple)** - Type of counter where each flip-flop output serves as the clock input signal for the next flip-flop in the chain.



4.7.1 Classification of Counters

ii. **Synchronous** - Counter in which all the flip-flops are clocked simultaneously/flip flops share a clock signal.



4. Code Sequence Generated - A counter may be a straight forward up or down counter (a counter generating codes 00 – 01 – 10 – 11 is an **up counter**, while one generating codes 11 – 10 – 01 – 00 is a **down counter**). Other counters are gray code counters and shift register counters.

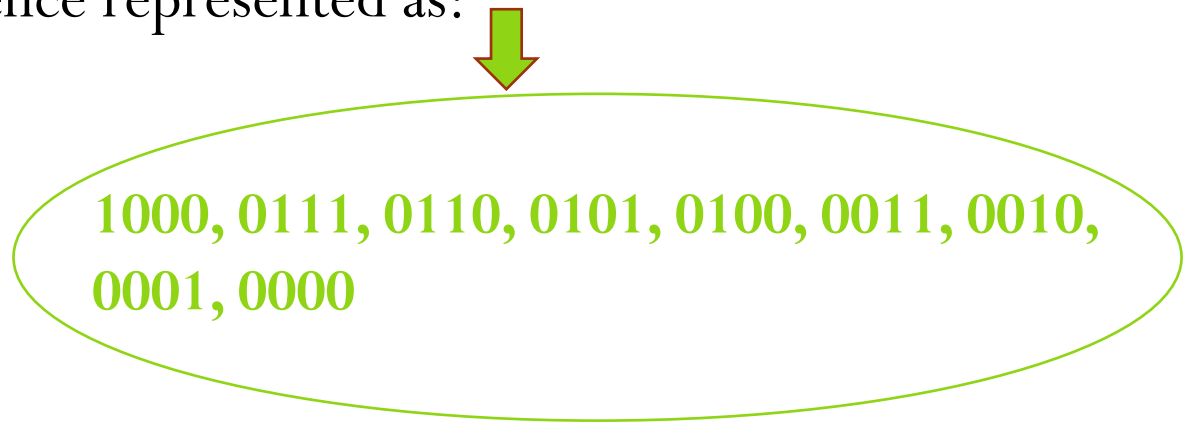
Example 1:

What is the binary counting sequence of a MOD 9 **down** counter?

Solution:

The counter should count the numbers 8,7,6,5,4,3,2,1,0. The binary counting sequence is hence represented as:

Decimal Number	Binary Equivalent
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000



4.8 Registers

- A flip-flop is used to store 1 bit of information. When flip-flops are organized to store many bits of information, they are called **registers**. We can therefore say that a flip-flop is a single bit register.
- A flip-flop is a single bit register.
- Data can be entered into a register in parallel form (i.e. all bits simultaneously), or in serial form (one bit at a time).
- If data is entered to all flip-flops in a register at the same time, the register is referred to as a **parallel register**.
- If data is entered and removed one bit at a time, the register is known as a **serial register** or a **shift register**.

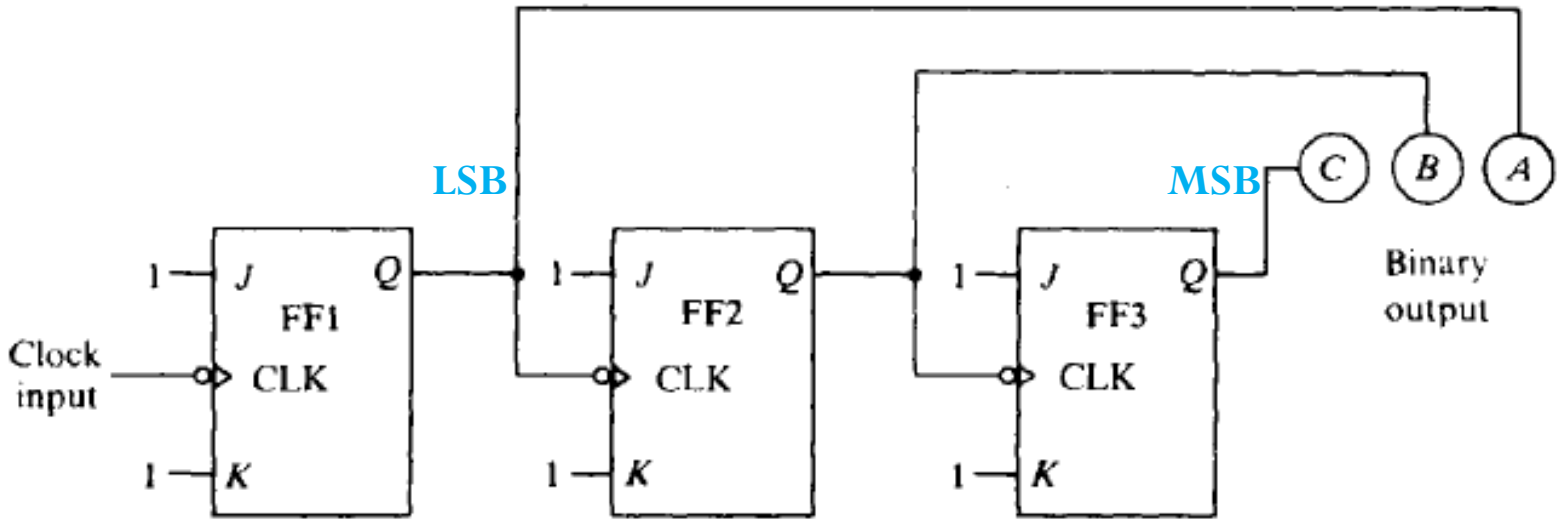
4.7.1 Classification of Counters

Example 2:

Draw the logic diagram of a mod-8 **ripple counter** using three JK flip-flops.

Solution:

A mode 8 ripple(asynchronous) counter shall count between 0 and 7 (**i.e. 000 to 111**. The JK flip flops are connected as below:



*Note J and K are connected to a digital high (1) hence are in toggle mode

4.8 Registers

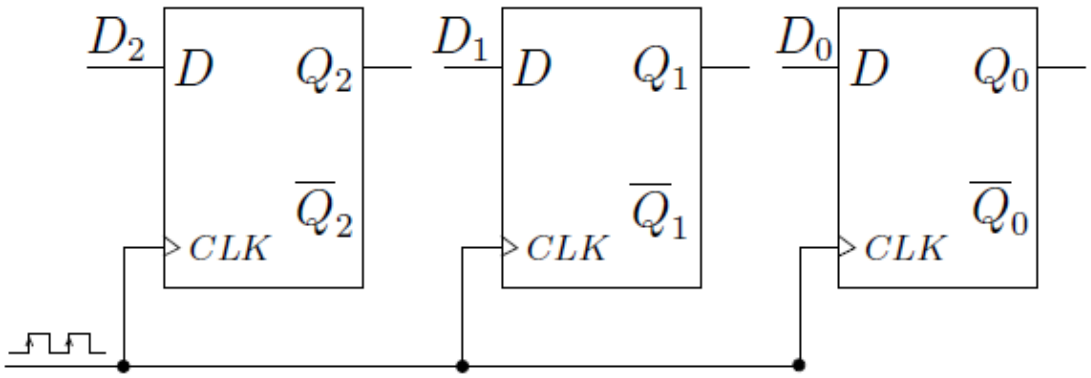


Fig 4.8.1: A three bit parallel register.

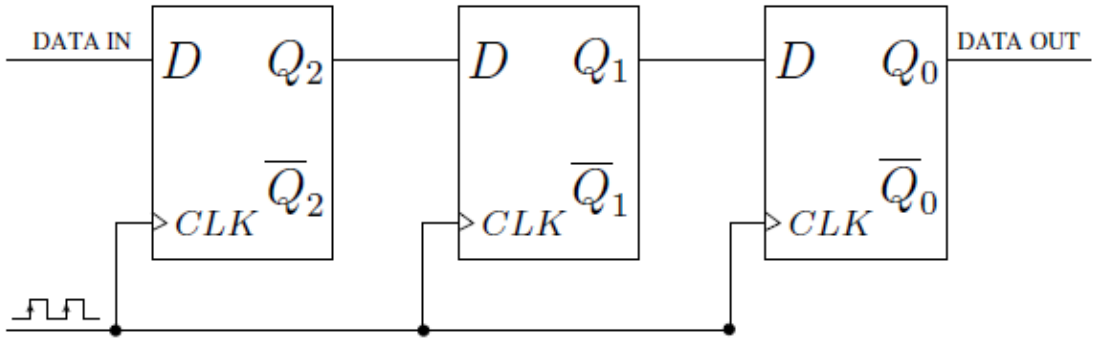


Fig 4.8.2: A three bit serial register.

4.8 Registers

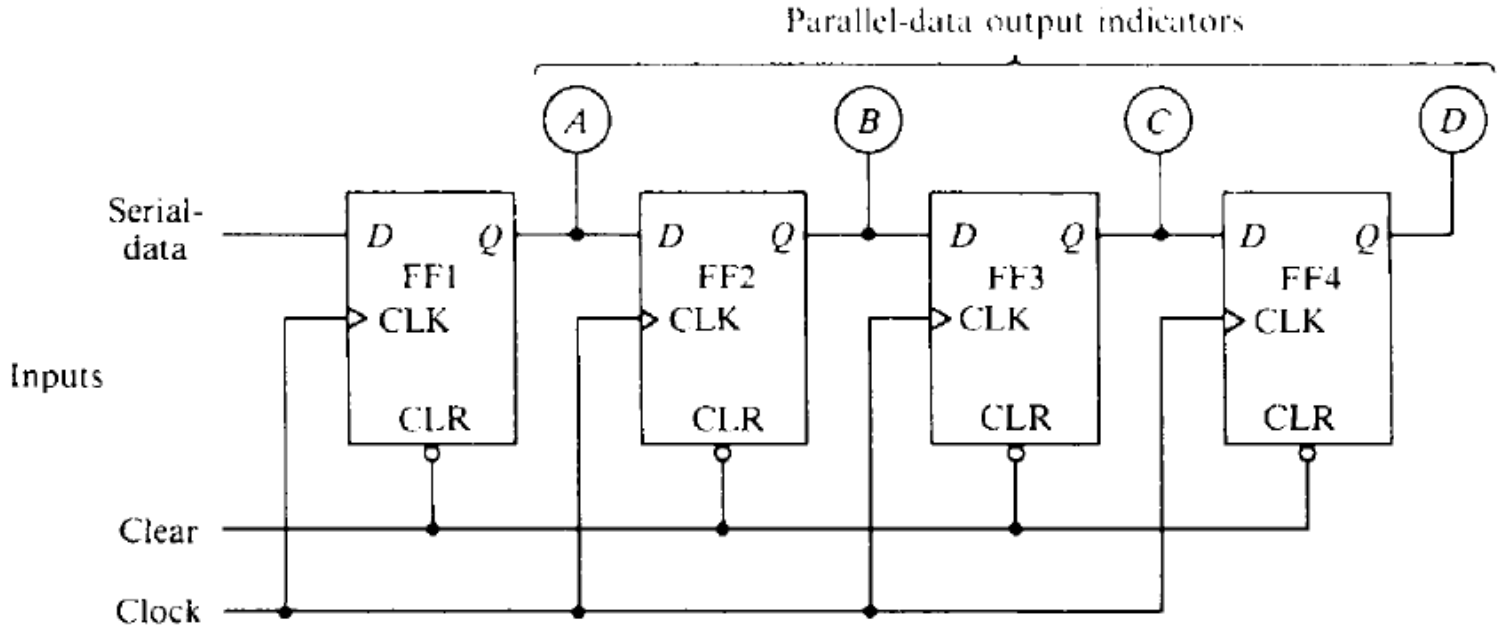
- A shift register where data can only be shifted to the right is known as a **right-shift register**, while the ones where data can only be shifted to the left are known as **left-shift registers**. The shift registers where data can be shifted both left and right are known as **bidirectional shift registers**.

4.8 Registers

Example:

- Draw the logic diagram of a 4-bit serial-load shift-right register using D-flip flops.

Solution:



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