

Theory

A. Binary Operation

In electrical components, data is represented as a **stream of bits**. These bits are processed in the components, creating processed bits of data. This process is called a **binary operation**. Binary operations are further classified into:

1. Parallel Operation

The parallel operation works **instantly without a timer**. **Input bits are processed together at the same time**, producing output bits in a short amount of time. This operation is very effective for quick outputs but is expensive for larger bits.

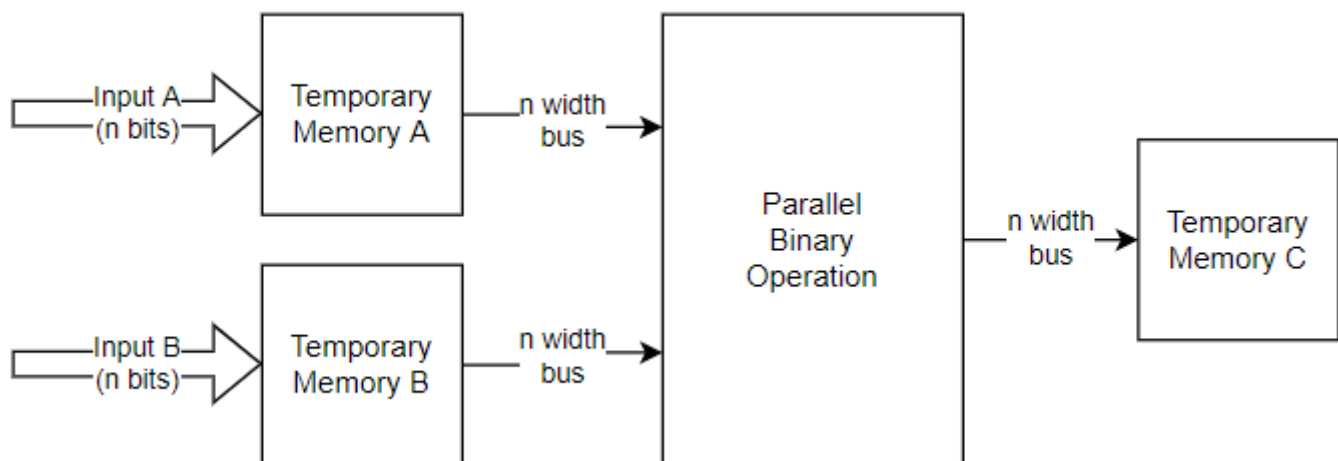


Figure 1-1: Parallel Operation Block Diagram In this design type, optimized design is key to produce efficient and cost effective designs.

2. Serial Operation

In serial operation, **input bits** are processed **one by one**, creating output **sequentially**. A **timer** ensures that the input produces the correct output and shifts the data in the correct order. Memory is also needed to store the input and output bits, often achieved using a **shift register**.

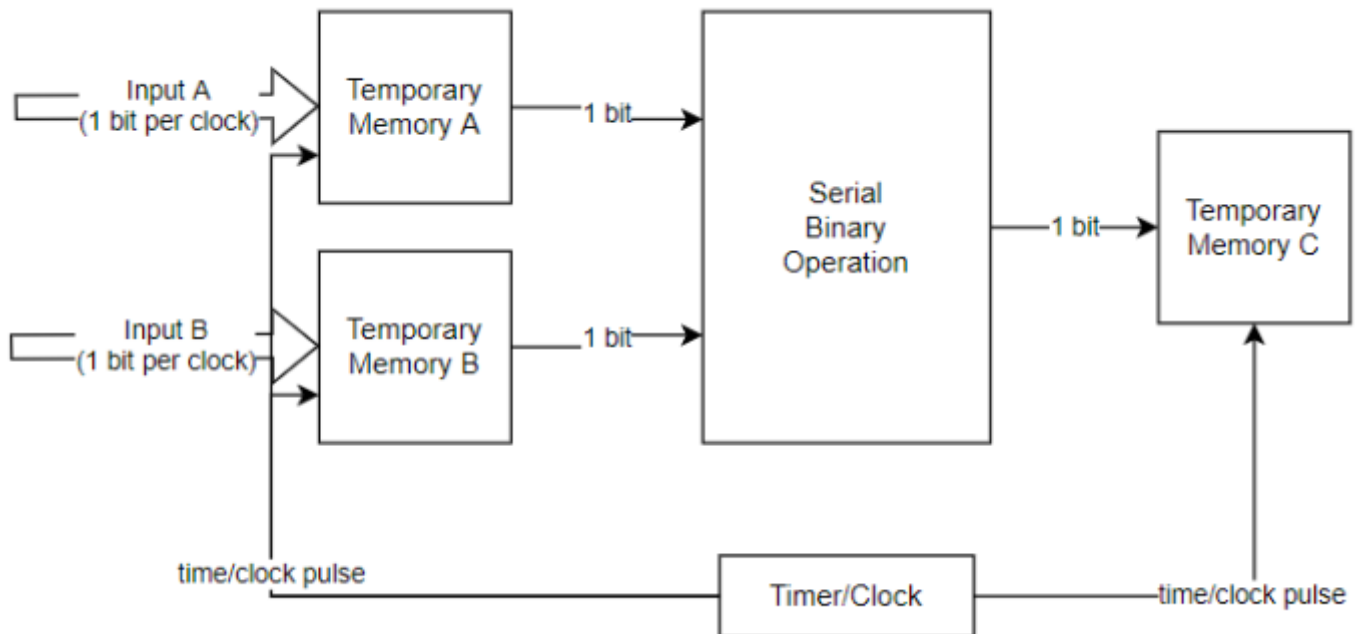


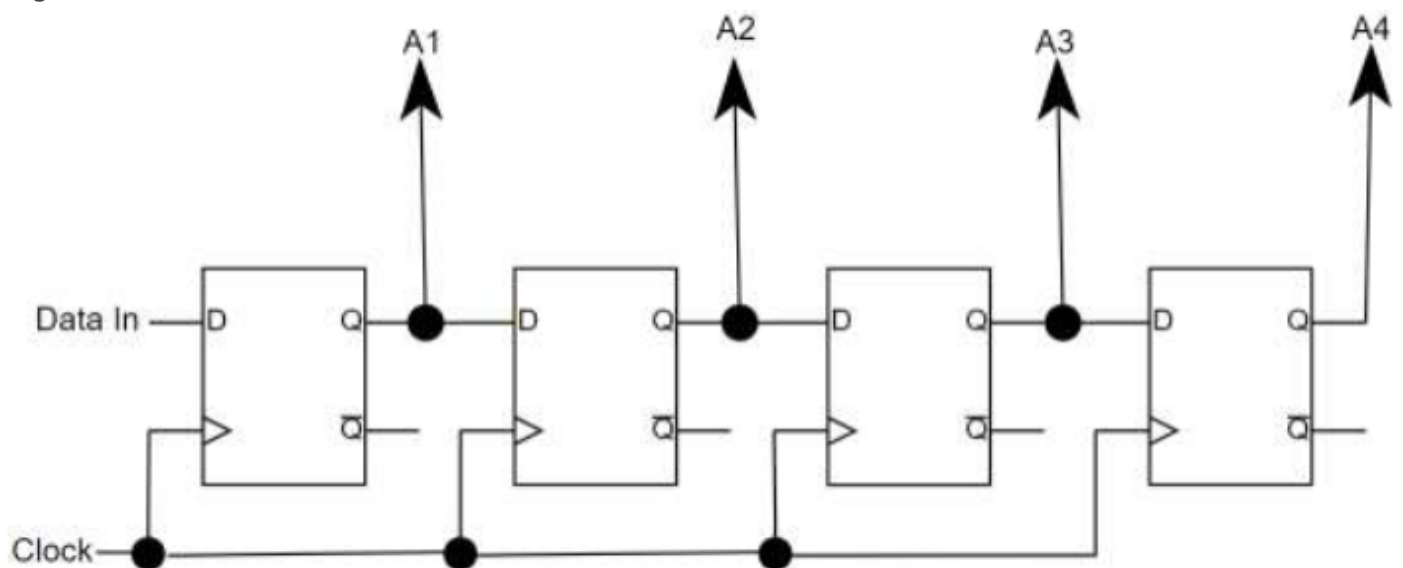
Figure 1-2: Serial Operation Block Diagram The block doesn't need a timer pulse since it works instantly for every input change. The output is also saved at every pulse, sequentially.

3. Combination

A combination of parallel and serial operations can be used to balance speed and cost. This hybrid operation requires a timer to mark the beginning and end of the serial part before and after the parallel part.

B. Register

To save data in a digital circuit, a **register** is used. A register saves data using signal bits with flip-flops and states. Registers can be designed using a combination of serial and parallel operations, such as **Serial Input Parallel Output (SIPO)** and **Parallel Input Serial Output (PISO)** registers.



The main component of a register is the **flip flop, a clock (or enabler), input, and output**. The main difference between parallel and serial is how the signal is handled. If **more than one** signal is handled simultaneously, then it is called **parallel**. If only **one signal is handled one by one**, then it is called **serial**.

A **counter** is used to control sequences and execution steps in a logical circuit by counting bits. Counters consist of flip-flops that switch states in sequence. There are two types of counters:

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- The diagram illustrates a 4-bit ripple-carry counter using four J-K flip-flops. The flip-flops are labeled A1, A2, A3, and A4 from left to right. Each flip-flop has J and K inputs, a clock input, a Q output, and a Q-bar output. The clock input of the first flip-flop (A1) is connected to the external Clock signal. The Q output of A1 is connected to the clock input of A2. Similarly, the Q output of A2 is connected to the clock input of A3, and the Q output of A3 is connected to the clock input of A4. The J and K inputs of each flip-flop are connected to logic 1 (indicated by a dot). The Q outputs of the flip-flops are labeled A1, A2, A3, and A4. The Q-bar outputs are connected to a chain of four 2-input AND gates. The first AND gate has inputs from the Q-bar output of A1 and the Count Enable signal. The output of the first AND gate is connected to the clock input of A2. The second AND gate has inputs from the Q-bar output of A2 and the output of the first AND gate. Its output is connected to the clock input of A3. The third AND gate has inputs from the Q-bar output of A3 and the output of the second AND gate. Its output is connected to the clock input of A4. The output of the fourth AND gate is labeled 'To next state'.

Figure 3-1: 4-bit Synchronous Counter

- **Asynchronous Counter:** Flip-flops are controlled by the output of the previous flip-flop, except for the first one, which is controlled by an external clock.

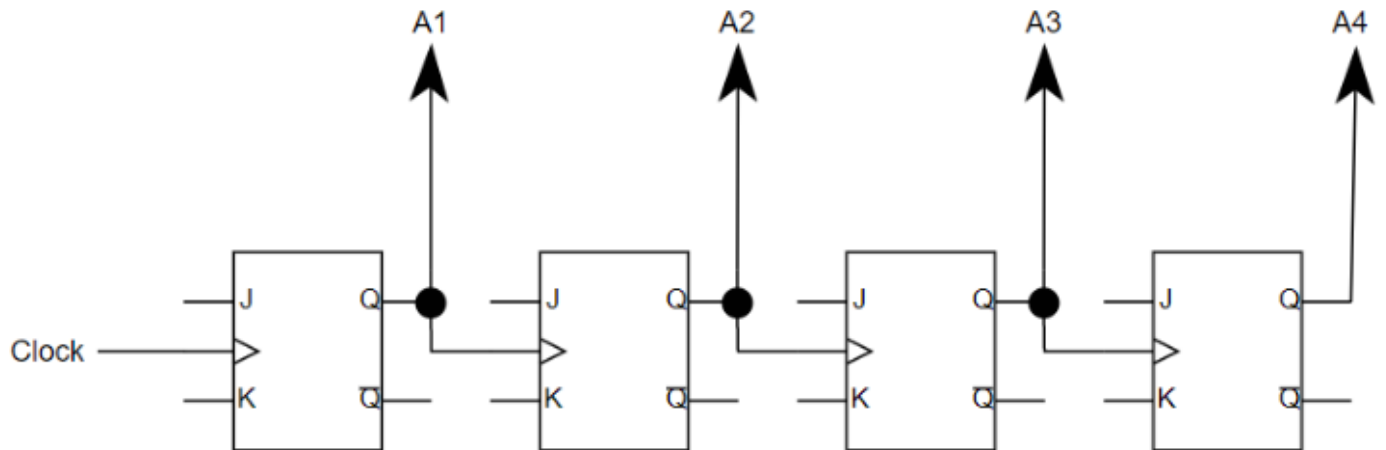


Figure 3-2: 4-bit Asynchronous Counter

Counters can count up, count down, or both, and may use different coding schemes, such as **n-bit binary counters** or **n-bit BCD counters**. A counter that counts from 0 to 9 (0000 to 1001) is called a **decade counter**.

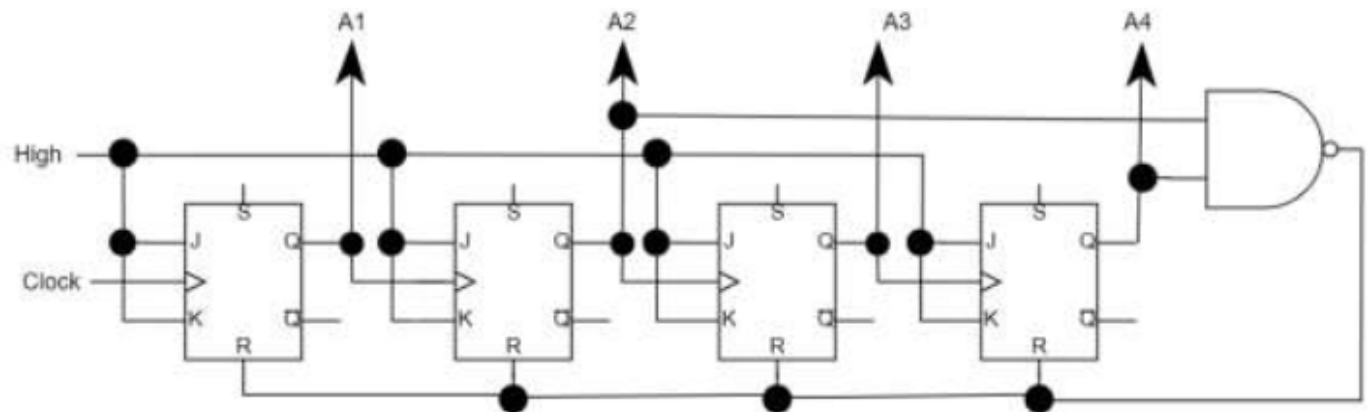


Figure 4-1: 4-bit Decade Counter

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