Engr354 : Digital Logic Circuits

Chapter 7: Registers and Counters

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Overview

• In this presentation we cover:
  – Registers, which store multiple bits;
  – Shift registers, which shifts the contents of registers;
  – Counters of various types.
Review - Sequential Circuits

- **Combinational** – outputs depend only on the inputs;
- **Sequential** – output depends on input and past behavior:
  - Requires use of storage elements;
  - Content of the storage elements is called *state*;
  - Circuit goes through a sequence of states as a result of changes in inputs.
- **Synchronous** – Controlled by a clock;
- **Asynchronous** – No central clock.

Latches and Flip-Flops
Multibit Registers and Latches

74x374 8-bit Register
Shift Registers

- A *shift register* is an n-bit register with a provision for shifting stored data by one bit position at each tick of the clock.

![Shift Register Diagram]

Shift Registers – Serial-in, Parallel-out

![Shift Register - Serial-in, Parallel-out Diagram]
74x194 4-bit Universal Shift Register

<table>
<thead>
<tr>
<th>Function</th>
<th>$S_1$</th>
<th>$S_0$</th>
<th>$Q_{A'}$</th>
<th>$Q_{B'}$</th>
<th>$Q_{C'}$</th>
<th>$Q_{D'}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hold</td>
<td>0</td>
<td>0</td>
<td>$Q_{A}$</td>
<td>$Q_{B}$</td>
<td>$Q_{C}$</td>
<td>$Q_{D}$</td>
</tr>
<tr>
<td>Shift right</td>
<td>0</td>
<td>1</td>
<td>$R_{IN}$</td>
<td>$Q_{A}$</td>
<td>$Q_{B}$</td>
<td>$Q_{C}$</td>
</tr>
<tr>
<td>Shift left</td>
<td>1</td>
<td>0</td>
<td>$Q_{B}$</td>
<td>$Q_{C}$</td>
<td>$Q_{D}$</td>
<td>LIN</td>
</tr>
<tr>
<td>Load</td>
<td>1</td>
<td>1</td>
<td>$A$</td>
<td>$B$</td>
<td>$C$</td>
<td>$D$</td>
</tr>
</tbody>
</table>

Table 8-24
Function table for the 74x194 4-bit universal shift register.

74x194 4-bit Universal Shift Register

![Logic diagram for the 74x194 4-bit universal shift register, including pin numbers for a standard 16-pin dual in-line package.](image-url)
74x194 4-bit Universal Shift Register

Figure 8-42
Simplest design for a 4-bit, 4-state ring counter with a single circulating 1.

74x194 4-bit Universal Shift Register

Figure 8-43
Timing diagram for a 4-bit ring counter.
Counters

- **Counter** – generally used for any clocked sequential circuit whose state diagram contains a single cycle;
- **Modulus** – the number of states in the cycle;
- A counter with m states is called a *modulus-m* counter or a *divide-by-m* counter;
- **Ripple** counters (rare due to delays);
- **Synchronous** counters (common):
  - Connects all of its flip-flop clock inputs to the same common *CLK* signal so that all flip-flop outputs change at the same time.

Synchronous 4-bit Binary Counter – 74x163

![Synchronous 4-bit Binary Counter – 74x163](image)

**Figure 8-27**
Traditional logic symbol for the 74x163.

**Table 8-13**
State table for a 74x163 4-bit binary counter.
Synchronous 4-bit Binary Counter – 74x163

Figure 8-28
Logic diagram for the 74x163 synchronous 4-bit binary counter, including pin numbers for a standard 16-pin DIP package.

Synchronous 4-bit Binary Counter – 74x163

Figure 8-29
Connections for the 74x163 to operate in a free-running mode.
Synchronous 4-bit Binary Counter – 74x169

Figure 8-32
Logic symbol for the 74x169 up/down counter.

Ring Counter

(a) An n-bit ring counter

(b) A four-bit ring counter
Johnson Counter

Three-Bit Up-Counter
Three-bit Down-Counter

(a) Circuit

(b) Timing diagram

Four-bit Synchronous Up-Counter

(a) Circuit

(b) Timing diagram
Inclusion of Enable and Clear Capability

Counter with Parallel-load Capability
Modulo-6 Counter with Synchronous Reset

![Circuit Diagram]

(a) Circuit

![Timing Diagram]

(b) Timing diagram

Modulo-6 Counter with Asynchronous Reset

![Circuit Diagram]

(a) Circuit

![Timing Diagram]

(b) Timing diagram
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