REGISTERS

A register is a group of flip-flops, each one of which shares a common clock and is capable of storing one bit of information.

An n-bit register consists of a group of n flip-flops capable of storing n bits of binary information.

In addition to the flip-flops, a register may have combinational gates that perform certain data-processing tasks.

In its broadest definition, a register consists of a group of flip-flops together with gates that affect their operation.

The flip-flops hold the binary information, and the gates determine how the information is transferred into the register.
A counter is essentially a register that goes through a predetermined sequence of binary states.

The gates in the counter are connected in such a way as to produce the prescribed sequence of states.

Although counters are a special type of register, it is common to differentiate them by giving them a different name.
The common clock input triggers all flip-flops on the positive edge of each pulse, and the binary data available at the four inputs are transferred into the register.

The value of \((I_3, I_2, I_1, I_0)\) immediately before the clock edge determines the value of \((A_3, A_2, A_1, A_0)\) after the clock edge.
Four-bit register with parallel load

The additional gates implement a two-channel mux whose output drives the input to the register with either the data bus or the output of the register. The load input to the register determines the action to be taken with each clock pulse. When the load input is 1, the data at the four external inputs are transferred into the register with the next positive edge of the clock. When the load input is 0, the outputs of the flip-flops are connected to their respective inputs. The feed-back connection from output to input is necessary because a D flip-flop does not have a “no change” condition.
The clock could be inhibited from reaching the register by controlling the clock input signal with an enabling gate.

Inserting gates into the clock path is ill advised because it means that logic is performed with clock pulses. The insertion of logic gates produces uneven propagation delays between the master clock and the inputs of flip-flops.

To fully synchronize the system, we must ensure that all clock pulses arrive at the same time anywhere in the system, so that all flip-flops trigger simultaneously.

Performing logic with clock pulses inserts variable delays and may cause the system to go out of synchronism.

For this reason, it is advisable to control the operation of the register with the D inputs, rather than controlling the clock in the C inputs of the flip-flops. This creates the effect of a gated clock, but without affecting the clock path of the circuit.
Sometimes it is necessary to control the shift so that it occurs only with certain pulses, but not with others.

This is best done by recirculating the output of each register cell back through a two-channel mux whose output is connected to the input of the cell.
Serial Transfer

<table>
<thead>
<tr>
<th>Timing Pulse</th>
<th>Shift Register A</th>
<th>Shift Register B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial value</td>
<td>1 0 1 1</td>
<td>0 0 1 0</td>
</tr>
<tr>
<td>After $T_1$</td>
<td>1 1 0 1</td>
<td>1 0 0 1</td>
</tr>
<tr>
<td>After $T_2$</td>
<td>1 1 1 0</td>
<td>1 1 0 0</td>
</tr>
<tr>
<td>After $T_3$</td>
<td>0 1 1 1</td>
<td>0 1 1 0</td>
</tr>
<tr>
<td>After $T_4$</td>
<td>1 0 1 1</td>
<td>1 0 1 1</td>
</tr>
</tbody>
</table>

the control unit that supervises the transfer of data must be designed in such a way that it enables the shift registers, through the shift control signal, for a fixed time of four clock pulses in order to pass an entire word.
The two binary numbers to be added serially are stored in two shift registers. Beginning with the least significant pair of bits, the circuit adds one pair at a time through a single full-adder (FA) circuit.

The carry out of the full adder is transferred to a D flip-flop, the output of which is then used as the carry input for the next pair of significant bits. The sum bit from the S output of the full adder could be transferred into a third shift register.
Universal Shift Register

The most general shift register has the following capabilities:
1. A clear control to clear the register to 0.
2. A clock input to synchronize the operations.
3. A shift-right control to enable the shift-right operation and the serial input and output lines associated with the shift right.
4. A shift-left control to enable the shift-left operation and the serial input and output lines associated with the shift left.
5. A parallel-load control to enable a parallel transfer and the n input lines associated with the parallel transfer.
6. n parallel output lines.
7. A control state that leaves the information in the register unchanged in response to the clock.

Other shift registers may have only some of the preceding functions, with at least one shift operation.
**Mode Control**

<table>
<thead>
<tr>
<th>$s_1$</th>
<th>$s_0$</th>
<th>Register Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>No change</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Shift right</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Shift left</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Parallel load</td>
</tr>
</tbody>
</table>
The four multiplexers have two common selection inputs \( s_1 \) and \( s_0 \).

Input 0 in each multiplexer is selected when \( s_1 s_0 = 00 \), input 1 is selected when \( s_1 s_0 = 01 \), and similarly for the other two inputs.

When \( s_1 s_0 = 00 \),
the present value of the register is applied to the D inputs of the flip-flops.

This condition forms a path from the output of each flip-flop into the input of the same flip-flop, so that
the output recirculates to the input in this mode of operation.

The next clock edge transfers into each flip-flop the binary value it held previously, and no change of state occurs.
When \( s_1 s_0 = 01 \), terminal 1 of the multiplexer inputs has a path to the D inputs of the flip-flops. This causes a shift-right operation, with the serial input transferred into flip-flop A 3.

When \( s_1 s_0 = 10 \), a shift-left operation results, with the other serial input going into flip-flop A 0.

Finally, when \( s_1 s_0 = 11 \), the binary information on the parallel input lines is transferred into the register simultaneously during the next clock edge.

Note that data enters MSB_in for a shift-right operation and enters LSB_in for a shift-left operation.

Clear_b is an active-low signal that clears all of the flip-flops.
module Shift_Register_4_beh ( // V2001, 2005
output reg [3: 0] A_par, // Register output
input [3: 0] l_par, // Parallel input
input s1, s0, // Select inputs
MSB_in, LSB_in, // Serial inputs
CLK, Clear_b // Clock and Clear
);

always @ (posedge CLK, negedge Clear_b) // V2001, 2005
if (Clear_b == 0) A_par <= 4'b0000;
else
case ({s1, s0})
  2'b00: A_par <= A_par; // No change
  2'b01: A_par <= {MSB_in, A_par[3: 1]}; // Shift right
  2'b10: A_par <= {A_par[2: 0], LSB_in}; // Shift left
  2'b11: A_par <= l_par; // Parallel load of input
endcase
endmodule