**How to implement multibit shift in hardware?**

Let us illustrate the process for a 4-bit number B = (b3, b2, b1, b0). You can extend the idea for 8-bit or 32-bit numbers in the future.

1. **Consider logical right shift**

Shift by 0: B = (b3, b2, b1, b0) 🡪 B0 = (b3, b2, b1, b0)

Shift by 1: B = (b3, b2, b1, b0) 🡪 B1 = (0, b3, b2, b1)

Shift by 2: B = (b3, b2, b1, b0) 🡪 B2 = (0, 0, b3, b2)

Shift by 3: B = (b3, b2, b1, b0) 🡪 B3 = (0, 0, 0, b3)

Consider a multiplexer circuit as shown below.

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Shift amount (2 bits)

B0

B3

B2

B1

Actually, there are four 4-to-1 multiplexers. To generate B0, B1, B2 and B3, you do not need any extra circuits; just some wiring. This circuit can generate shifted data by any desired amount.

1. **Consider arithmetic right shift**

Shift by 0: B = (b3, b2, b1, b0) 🡪 B0 = (b3, b2, b1, b0)

Shift by 1: B = (b3, b2, b1, b0) 🡪 B1 = (b3, b3, b2, b1)

Shift by 2: B = (b3, b2, b1, b0) 🡪 B2 = (b3, b3, b3, b2)

Shift by 3: B = (b3, b2, b1, b0) 🡪 B3 = (b3, b3, b3, b3)

This can again be implemented using multiplexers.

1. **Consider shift left**

Shift by 0: B = (b3, b2, b1, b0) 🡪 B0 = (b3, b2, b1, b0)

Shift by 1: B = (b3, b2, b1, b0) 🡪 B1 = (b2, b1, b0, 0)

Shift by 2: B = (b3, b2, b1, b0) 🡪 B2 = (b1, b0, 0, 0)

Shift by 3: B = (b3, b2, b1, b0) 🡪 B3 = (b0, 0, 0, 0)

This can again be implemented using multiplexers.

For 8-bit data, you will need eight 8-to-1 multiplexers. For 32-bit data, you will need 32 32-to-1 multiplexers.

**How to count number of 1’s in an 8-bit data word?**

Let the data word be denoted as B = (b7, b6, b5, b4, b3, b2, b1, b0). We have to add all the bits of the number using a combinational circuit. We are not allowed to use a shift register of a counter with multiple clock pulses to do this.

We can do this using a tree of adders of progressively larger sizes – 1-bit adder (same as a full adder, can add three bits), 2-bit adder, and 3-bit adder. One possible schematic is shown below.

B0

B1

B2

B3

B4

B5

B6

B7

FA

FA

2-bit Adder

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3-bit Adder