CENG 3420
Computer Organization & Design

Lecture 07: Arithmetic and Logic Unit – 2

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(Textbook: Chapters 3.3 & 3.4)

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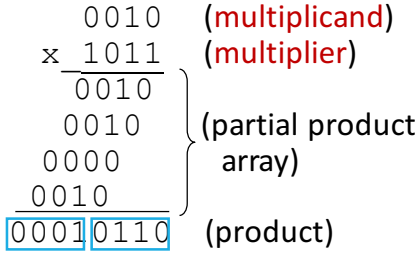
Multiplication & Division

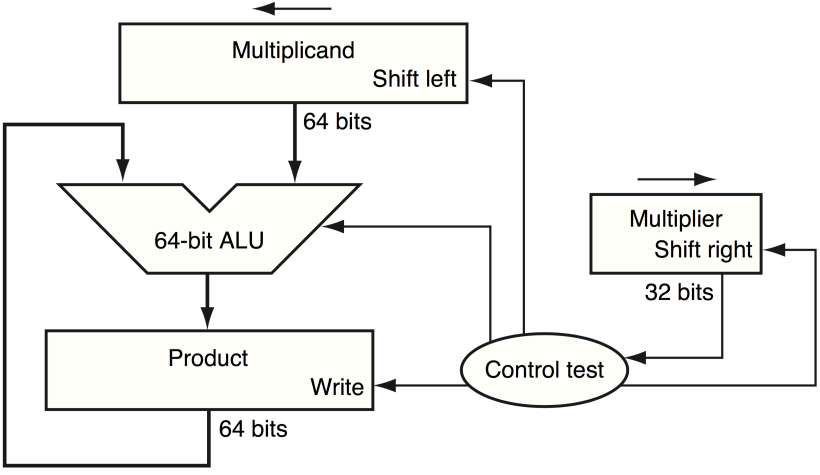
Multiplication

- More complicated than addition
- Can be accomplished via shifting and adding

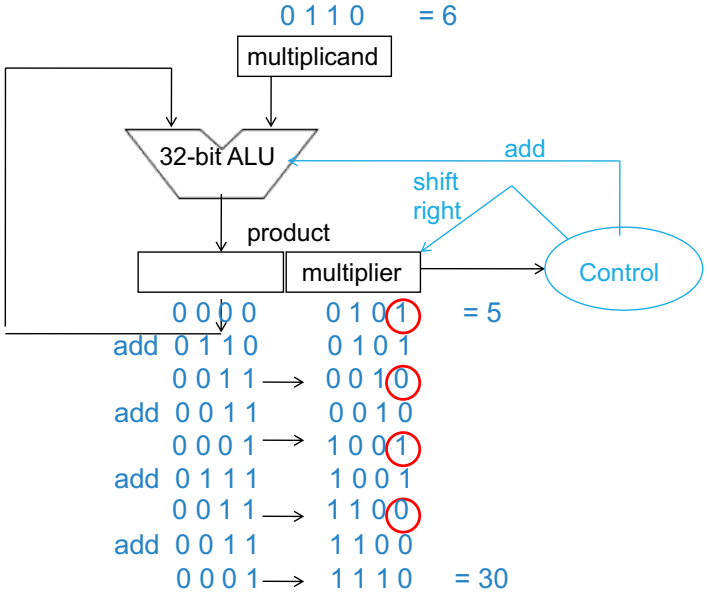


- Double precision product produced
- More time and more area to compute

First Version of Multiplication Hardware



Add and Right Shift Multiplier Hardware



RISC-V Multiply Instruction

- Multiply (`mult` and `multu`) produces a double precision product

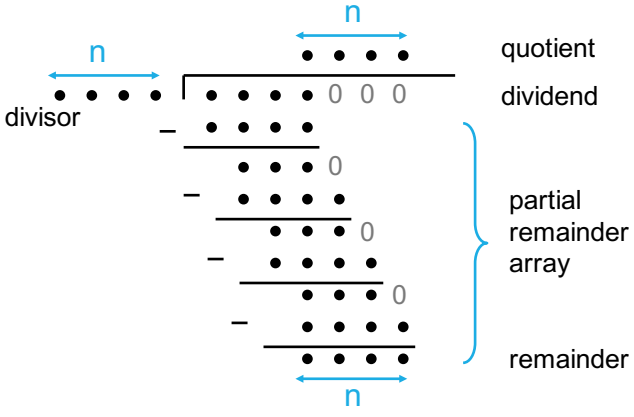
```
mul $rd, $s0, $s1        # hi||lo = $s0 * $s1
```

0	16	17	0	0	0x18

- Low-order word of the product is left in processor register `lo` and the high-order word is left in register `hi`
- Instructions `mfhi rd` and `mflo rd` are provided to move the product to (user accessible) registers in the register file
- Multiplies are usually done by fast, dedicated hardware and are much more complex (and slower) than adders

Division

- Division is just a bunch of quotient digit guesses and left shifts and subtracts



Question: Division

Dividing 1001010 by 1000

RISC-V Divide Instruction

- Divide generates the reminder in `hi` and the quotient in `lo`

```
div $rd, $s0, $s1       # lo = $s0 / $s1
                        # hi = $s0 mod $s1
```

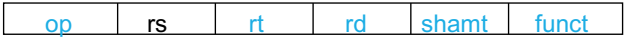
- Instructions `mflo rd` and `mfhi rd` are provided to move the quotient and reminder to (user accessible) registers in the register file
- As with multiply, divide ignores overflow so software must determine if the quotient is too large.
- Software must also check the divisor to avoid division by 0.

Shift

Shift Operations

- Shifts move all the bits in a word left or right

```
sll  $t2, $s0, 8 #$t2 = $s0 << 8 bits
srl  $t2, $s0, 8 #$t2 = $s0 >> 8 bits
sra  $t2, $s0, 8 #$t2 = $s0 >> 8 bits
```

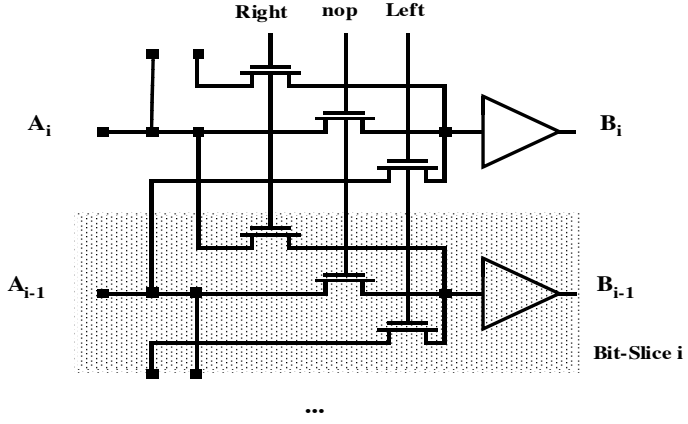


- Notice that a 5-bit `shamt` field is enough to shift a 32-bit value $2^5 - 1$ or 31 bit positions
- Logical shifts fill with zeros, arithmetic left shifts fill with the sign bit

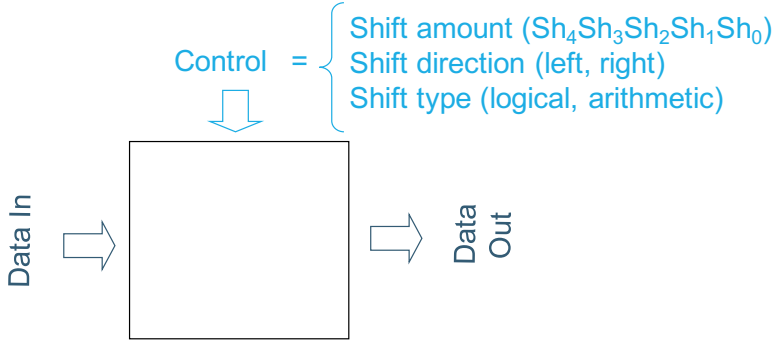
The shift operation is implemented by hardware separate from the ALU

Using a barrel shifter, which would takes lots of gates in discrete logic, but is pretty easy to implement in VLSI

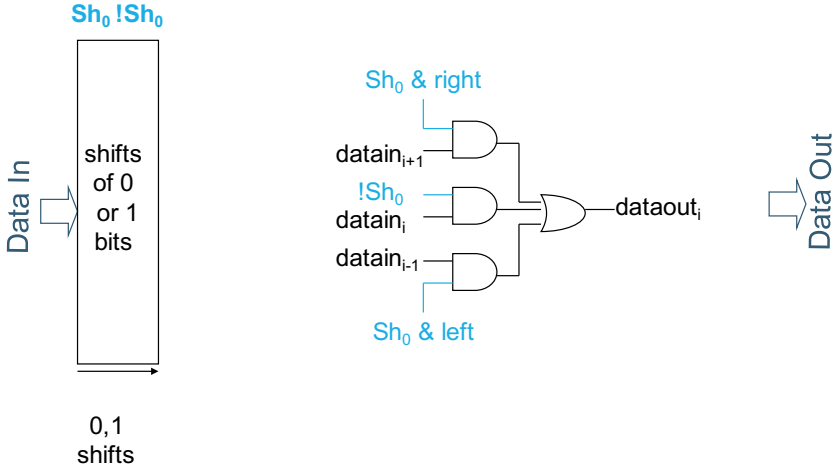
A Simple Shifter



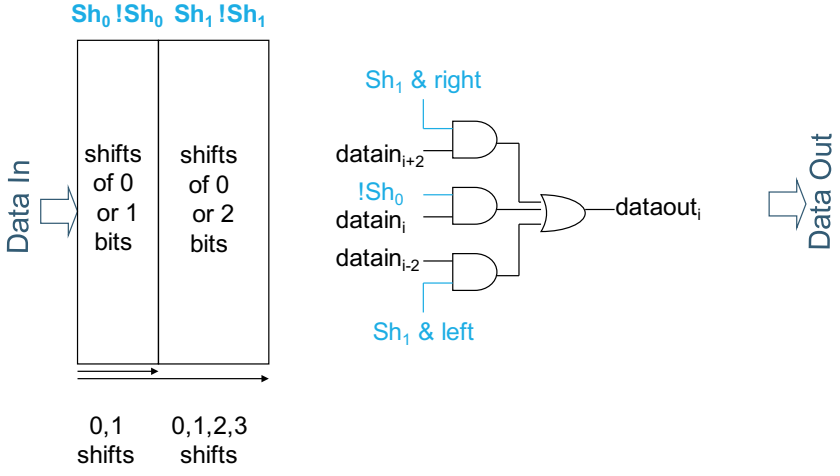
Parallel Programmable Shifters



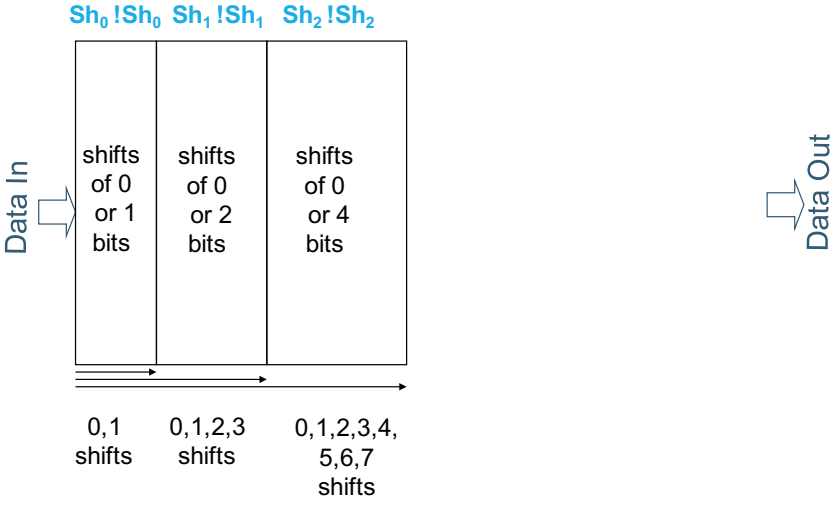
Logarithmic Shifter Structure



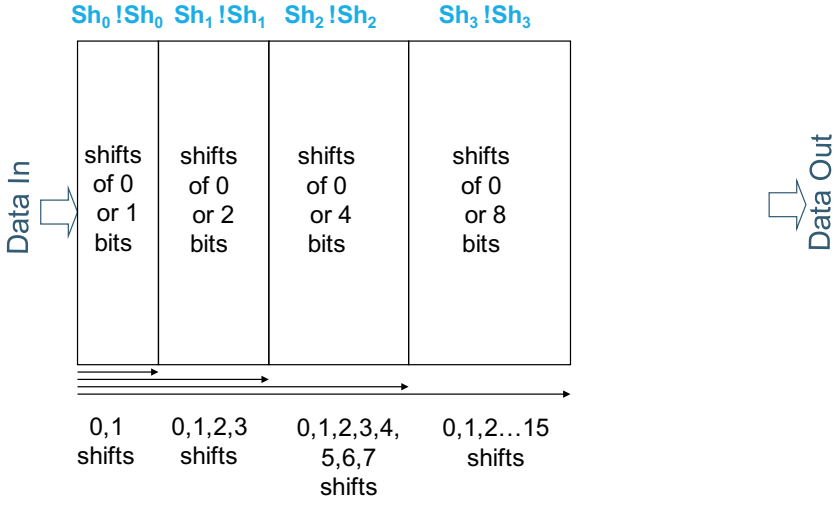
Logarithmic Shifter Structure



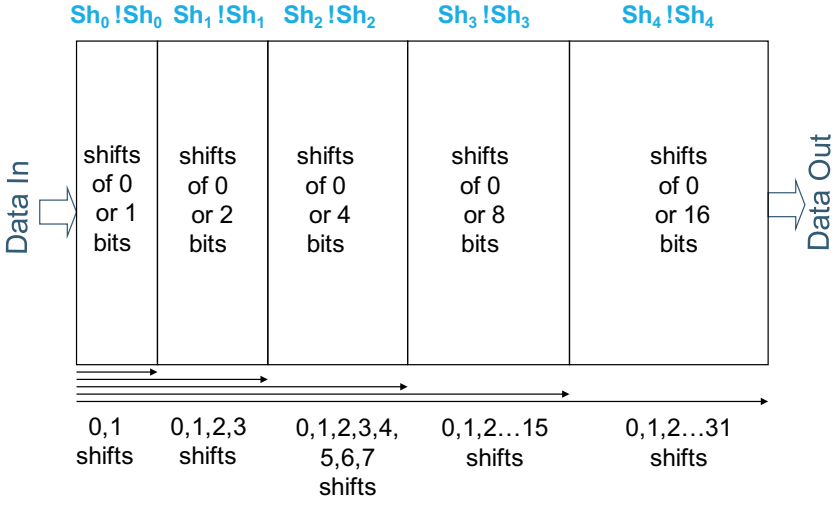
Logarithmic Shifter Structure



Logarithmic Shifter Structure



Logarithmic Shifter Structure



Logarithmic Shifter Structure