B38DB: Digital Design and Programming
Datapath Components – ALU and Register File

Mustafa Suphi Erden

Heriot-Watt University
School of Engineering & Physical Sciences
Electrical, Electronic and Computer Engineering
Room: EM 2.01
Phone: 0131-4514159
E-mail: m.s.erden@hw.ac.uk

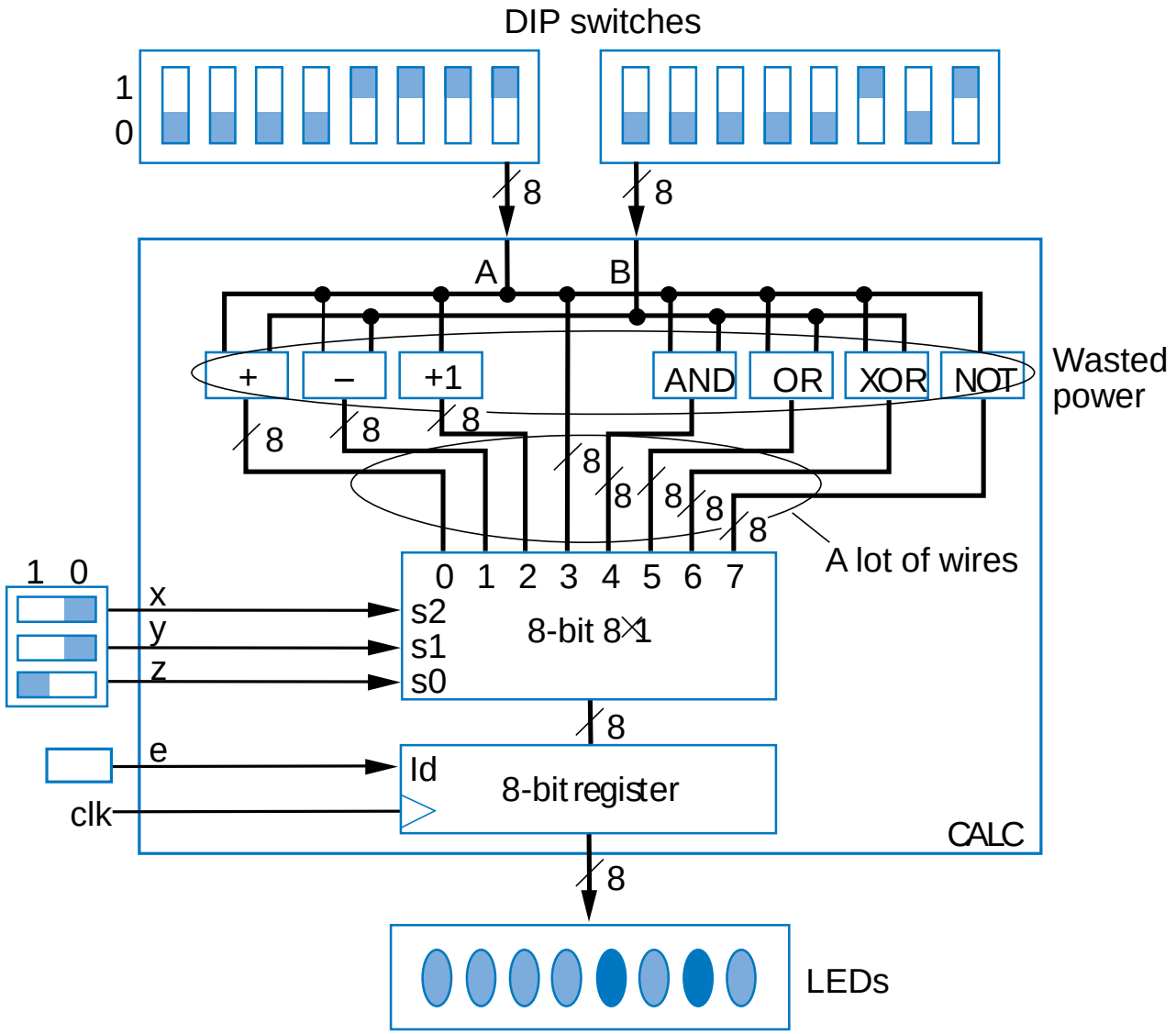
Arithmetic-Logic Unit: ALU

- ***ALU***: The component that can perform any of various arithmetic (add, subtract, increment, etc.) and logic (AND, OR, etc.) operations, based on control inputs.

Desired calculator operations

Inputs			Operation	Sample output if A=00001111, B=00000101
x	y	z		
0	0	0	S = A + B	S=00010100
0	0	1	S = A - B	S=00001010
0	1	0	S = A + 1	S=00010000
0	1	1	S = A	S=00001111
1	0	0	S = A AND B (bitwise AND)	S=00000101
1	0	1	S = A OR B (bitwise OR)	S=00001111
1	1	0	S = A XOR B (bitwise XOR)	S=00001010
1	1	1	S = NOT A (bitwise complement)	S=11110000

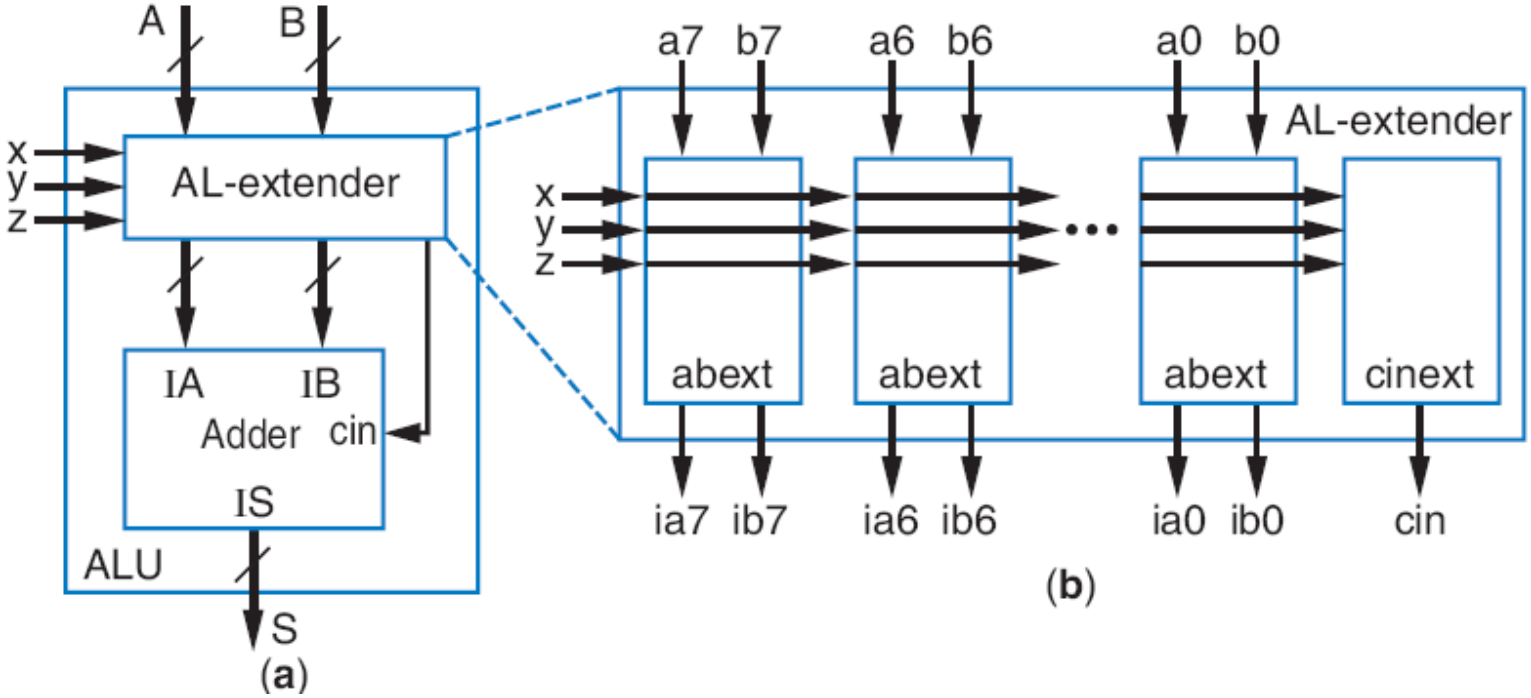
Multifunction Calculator without an ALU



- Separate components for each operation, and muxes
- But too many wires and waste of computing-power when at any time you only use one of the results

ALU

- More efficient design uses ALU

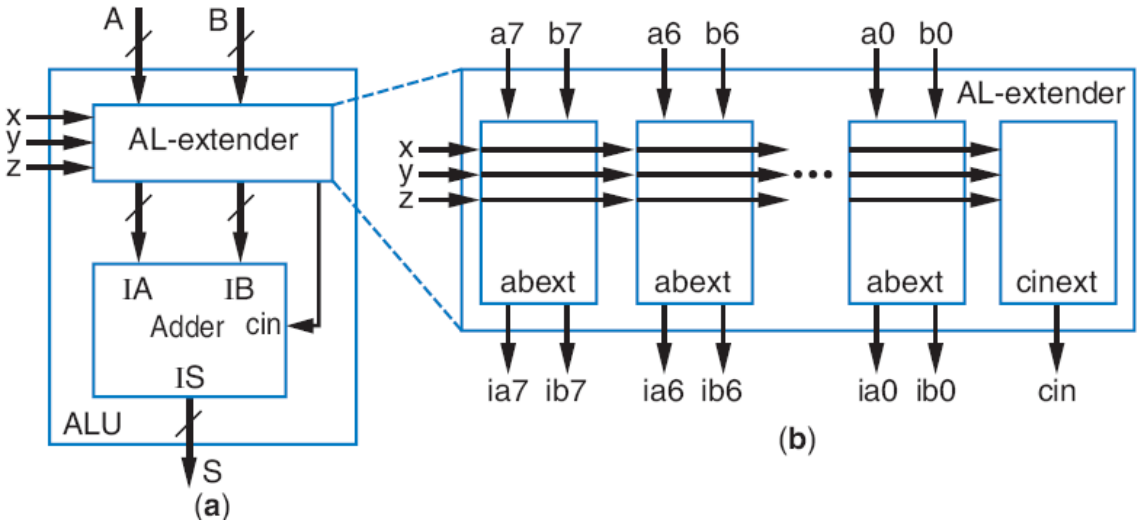


- ALU design uses single adder, plus logic gates in front of the adder's A and B inputs
  - Logic gates in the front is called an **arithmetic-logic extender**
- The extender modifies the A and B inputs such that the desired operation will appear at the output of the adder

Arithmetic-Logic Extender in Front of ALU

TABLE 4.2 Desired calculator operations

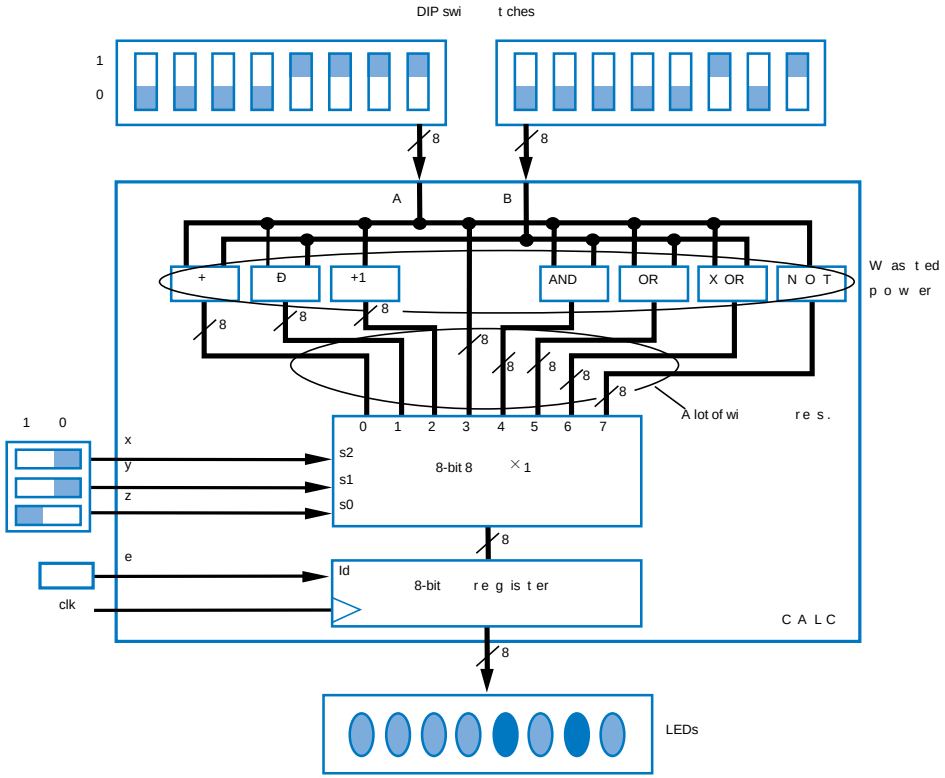
Inputs x	y	z	Operation	Sample output if A=00001111, B=00000101
0	0	0	S = A + B	S=00010100
0	0	1	S = A - B	S=00001010
0	1	0	S = A + 1	S=00010000
0	1	1	S = A	S=00001111
1	0	0	S = A AND B (bitwise AND)	S=00000101
1	0	1	S = A OR B (bitwise OR)	S=00001111
1	1	0	S = A XOR B (bitwise XOR)	S=00001010
1	1	1	S = NOT A (bitwise complement)	S=11110000

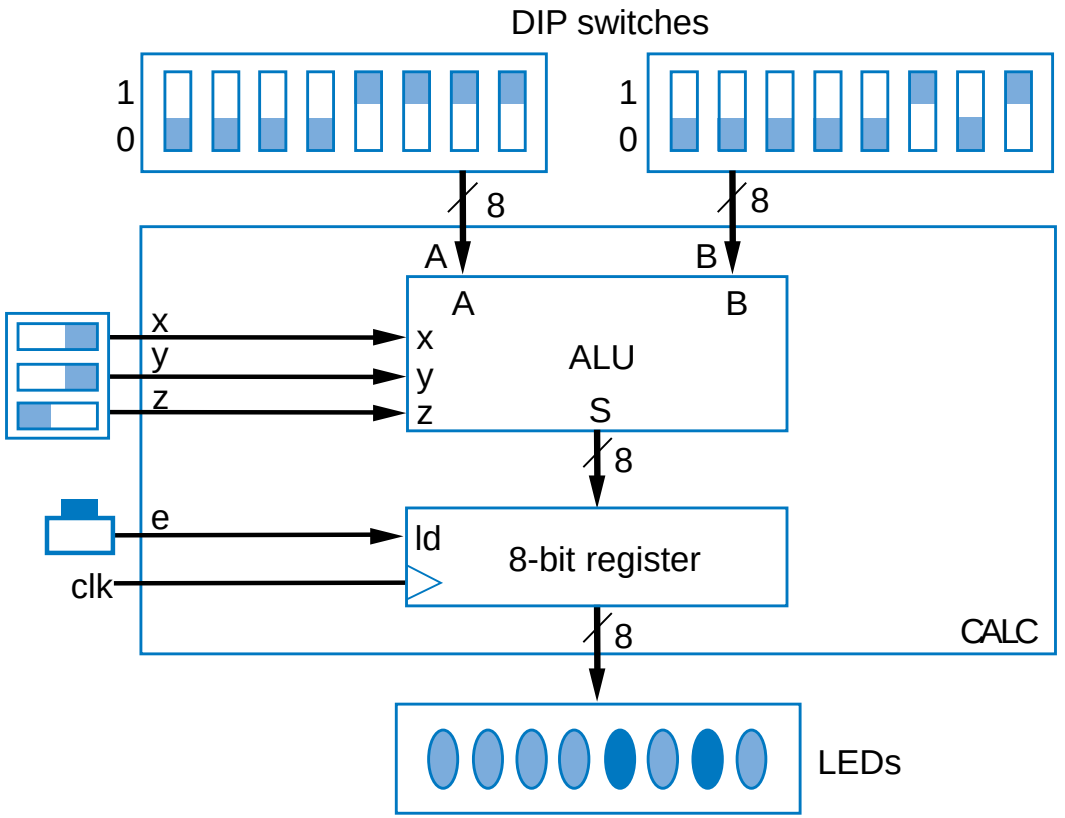


- xyz=000: S=A+B → just pass **a** to **ia**, **b** to **ib**, and set **cin**=0
- xyz=001: S=A-B → pass **a** to **ia**, **b'** to **ib**, and set **cin**=1
- xyz=010: S=A+1 → pass **a** to **ia**, set **ib**=0, and set **cin**=1
- xyz=011: S=A → pass **a** to **ia**, set **ib**=0, and set **cin**=0
- xyz=100: S=A AND B → set **ia**=**a***b, **b**=0, and **cin**=0
- others: likewise
- Based on above, create the logic for **ia**(x,y,z,a,b) and **ib**(x,y,z,a,b) for each *abext*, and create logic for **cin**(x,y,z), to complete the design of the AL-extender component

ALU Example: Multifunction Calculator

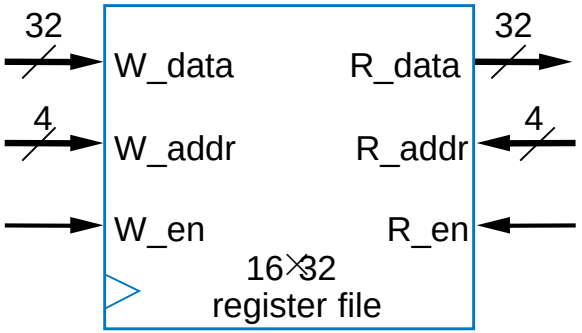
- Design using ALU is elegant and efficient
  - No mass of wires
  - No big waste of power

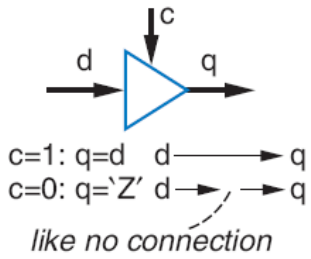


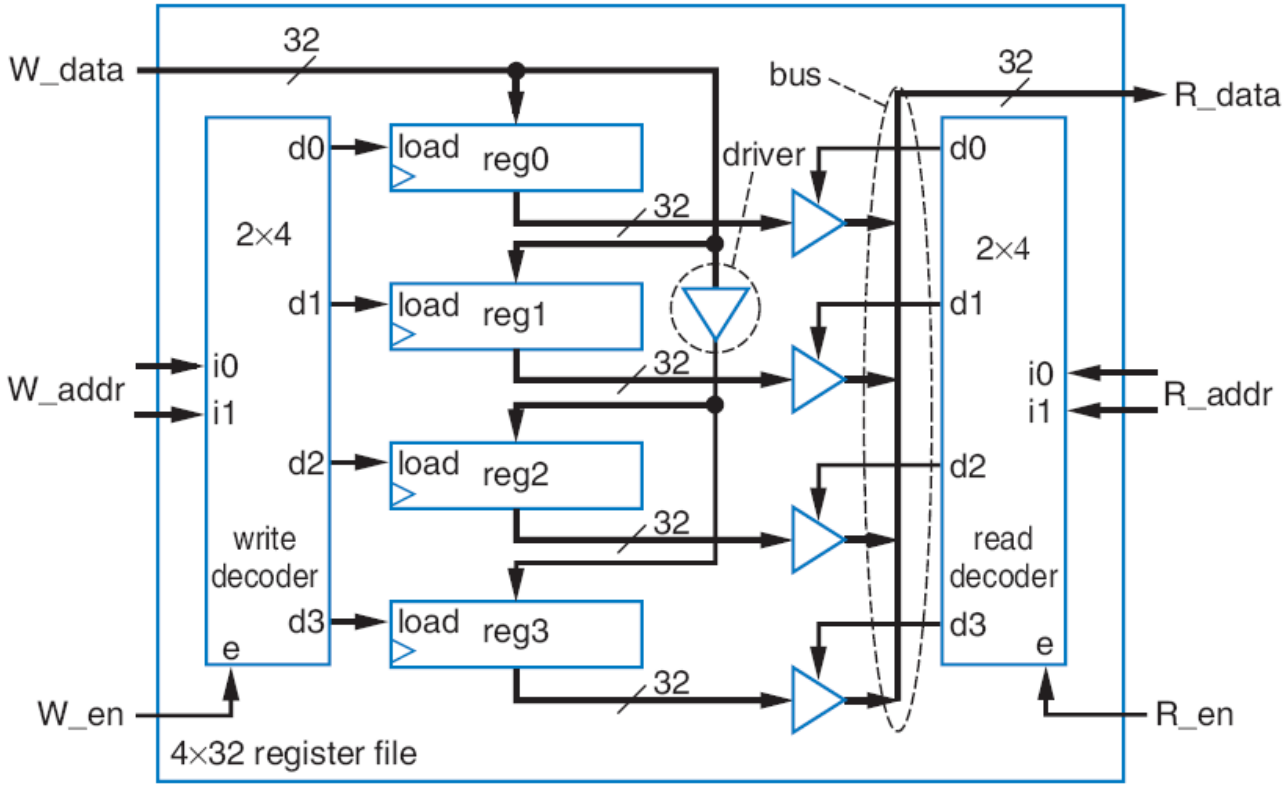


Register File

- ***MxN register file:*** a component that has one data input and one data output, and allows specifying which internal register to write and which to read







Register-File Example: Above-Mirror Display

- Register file hides complexity internally
  - Because only one register needs to be written and/or read at a time, internal design is simple.