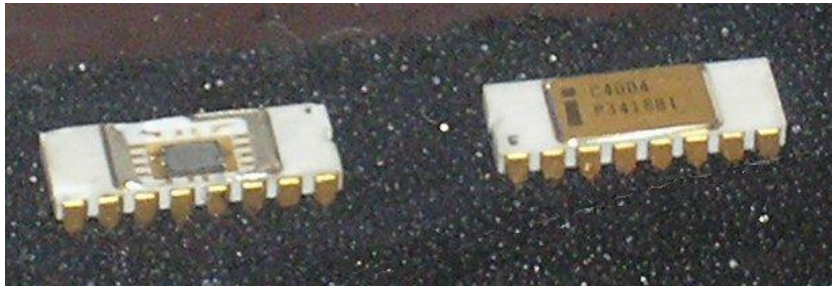
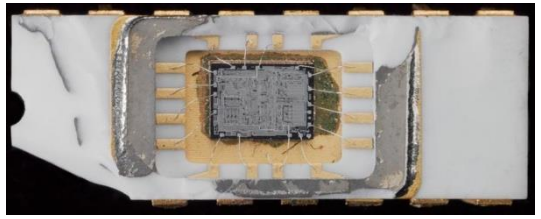
CSCI 210: Computer Architecture
Lecture 25: Data Path 2

Stephen Checkoway

Slides from Cynthia Taylor

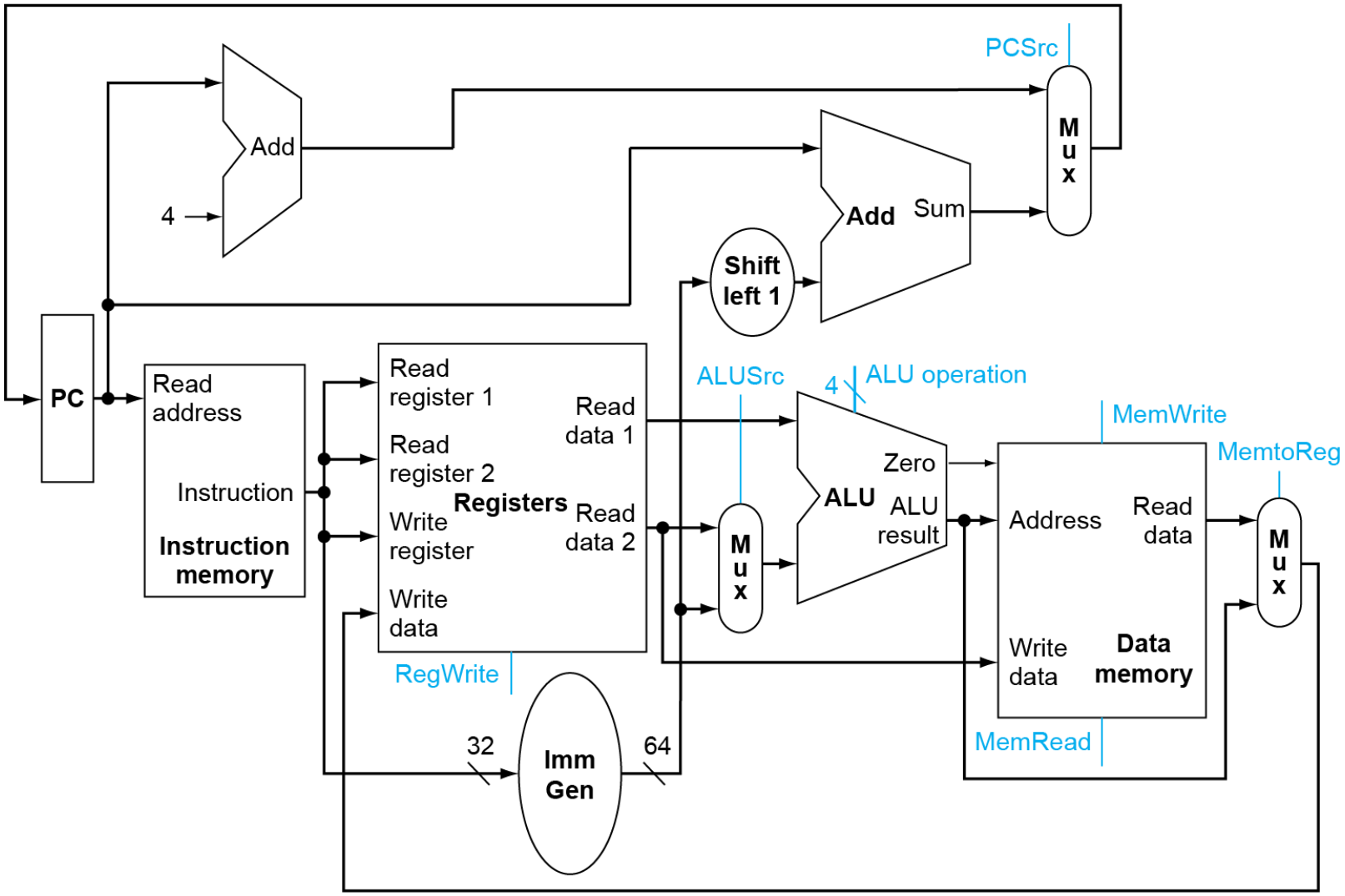
CS History: Intel 4004





- First commercially available microprocessor (single chip with both data processing logic and control)
- Released in 1971
- Had 12-bit addresses, 8-bit instructions, and 4-bit data words
- 16 4-bit registers
- Designed for Binary-Coded Decimal, in which every decimal digit is stored as a 4-bit value
  - Support for BCD is still present in x86

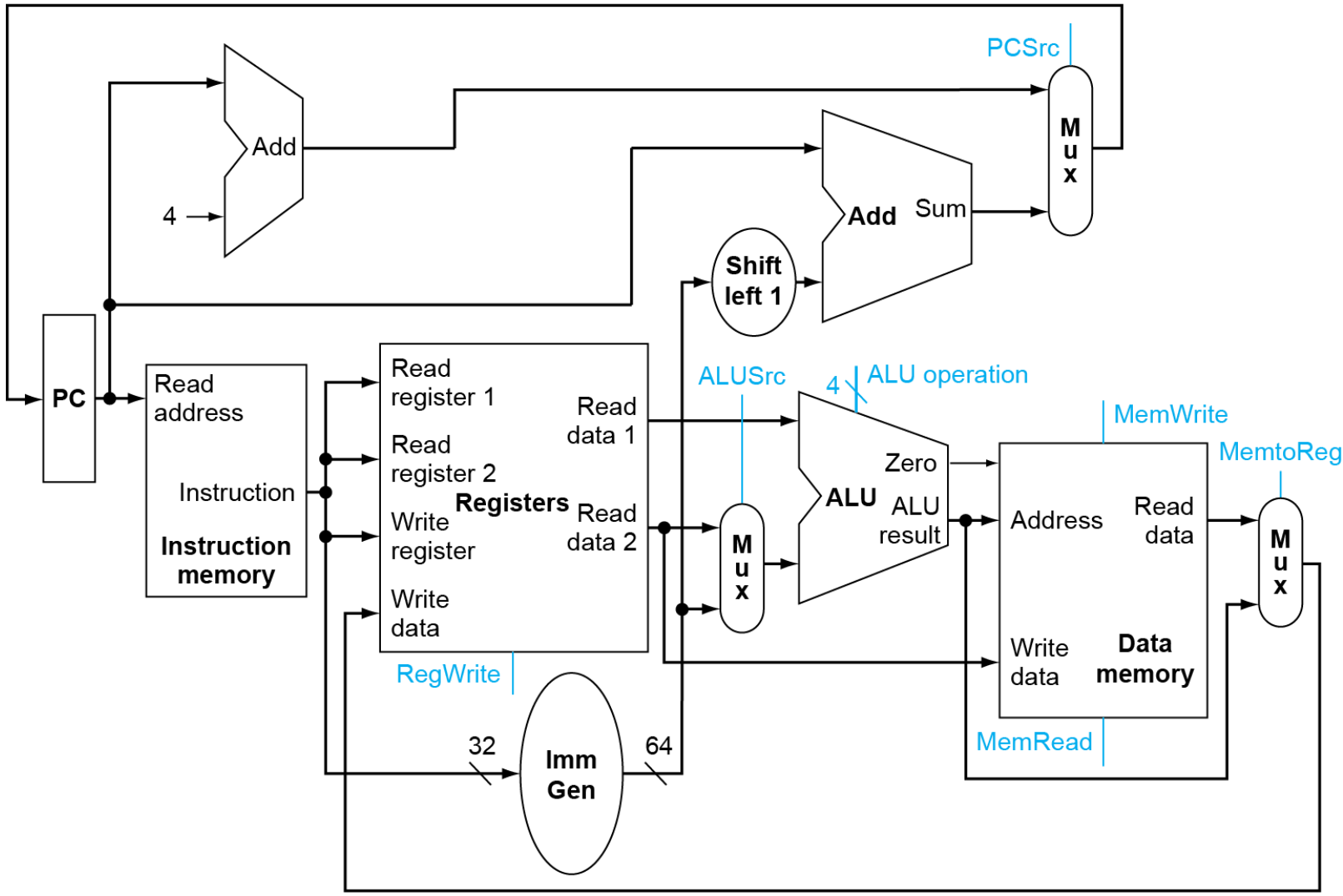
Datapath (still simplified a bit)



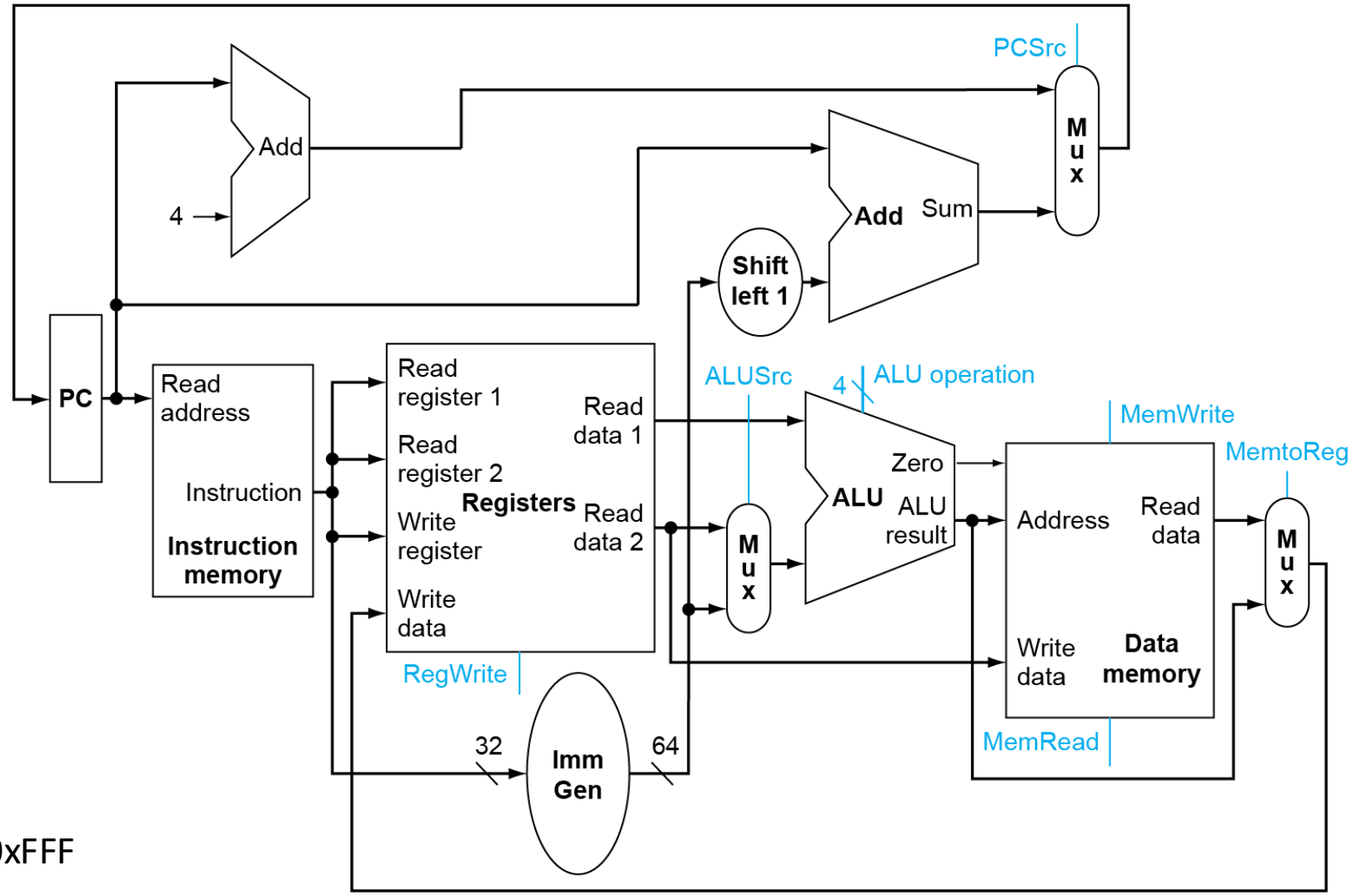
Adding support for immediate instructions

To support addi, subi, andi, and ori

- Immediate Generation Unit sign-extends immediate field
- ALUSrc mux selects the immediate value



addi x11, x10, -1



x10 holds 10

12-bit immediate: 0xFFF

RISC-V immediate arithmetic/logical instructions have a 12-bit sign-extended immediate. If t1 has value 5, what value does t0 have after

```
ori t0, t1, 0x803
```

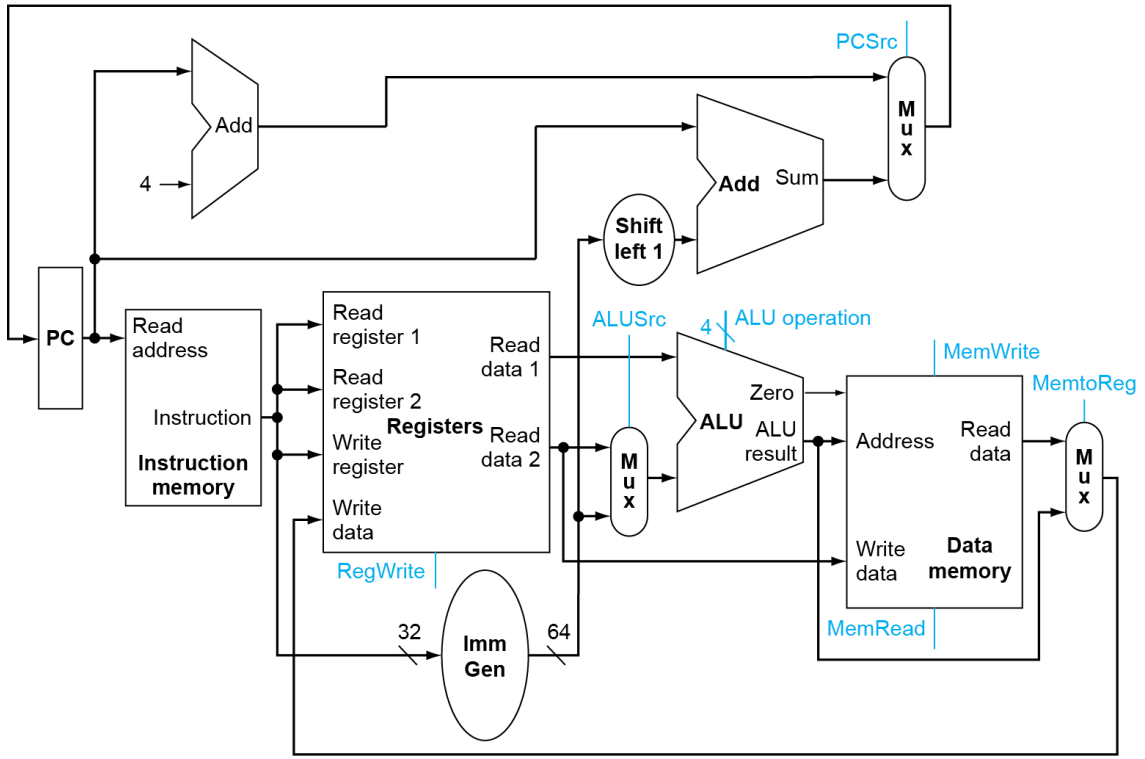
A. 0x0000000000000805

B. 0x0000000000000807

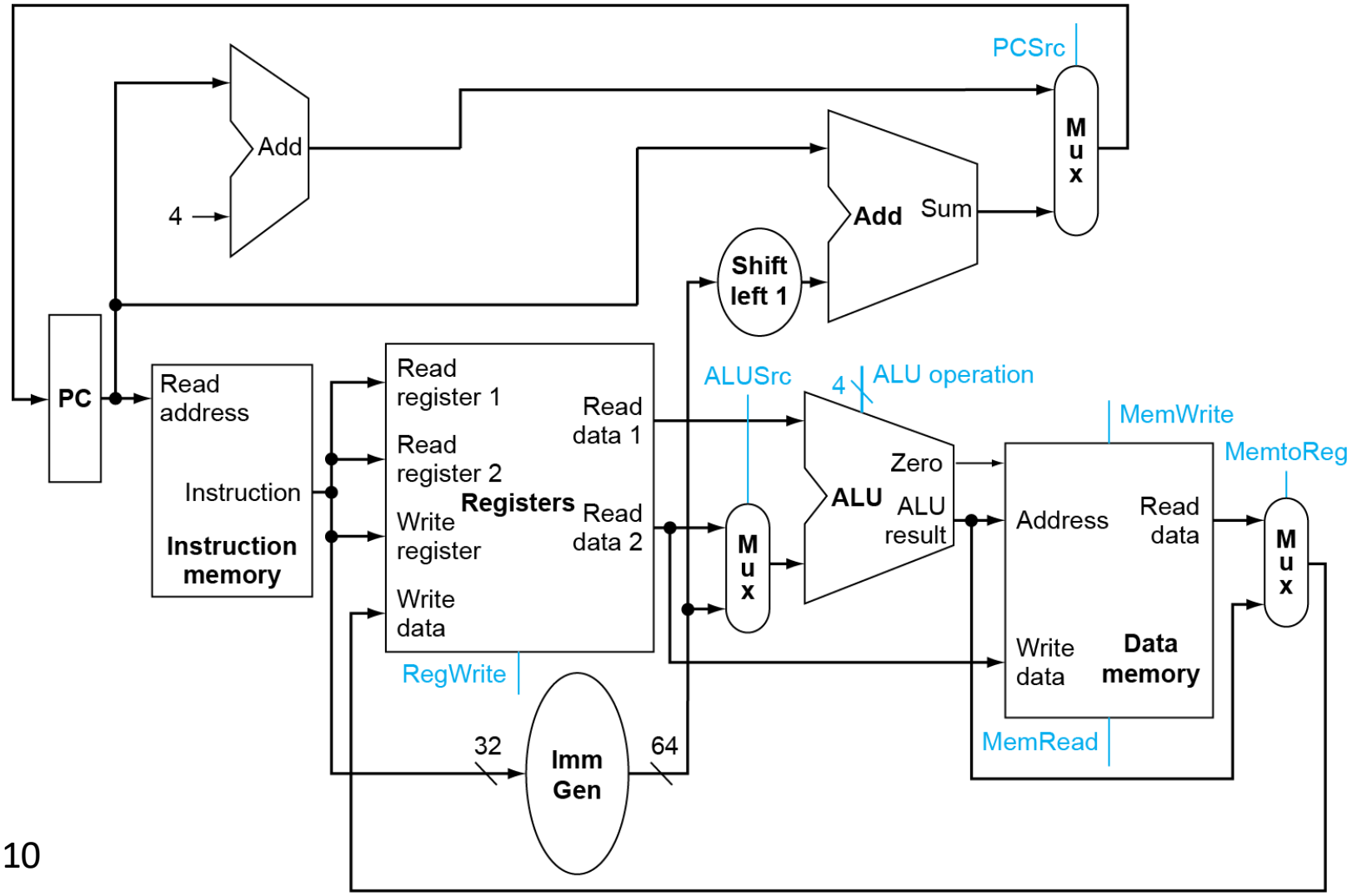
C. 0x8888888888888807

D. 0x8000000000000805

E. 0xFFFFFFFFFFFFF807

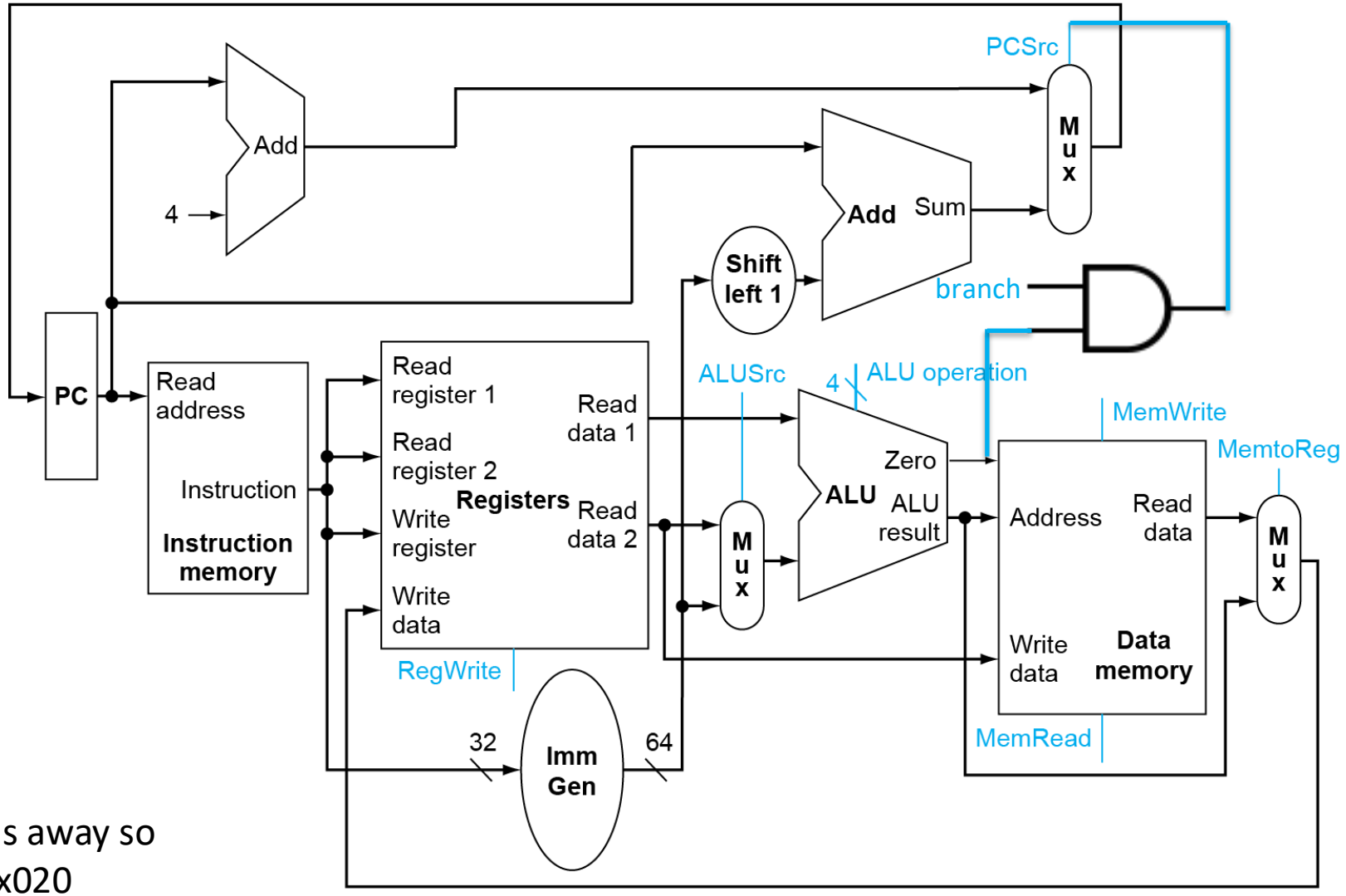


sd x11, 8(x10)



x10 holds 0x07AB8110
x11 holds 5
12-bit immediate: 0x008

beq x10, x20, label



x10 holds 10
x20 holds 10
label is 16 instructions away so
12-bit immediate = 0x020

Composing the Elements

- Data path executes one instruction in one clock cycle
  - Each data path element can only do one function at a time
  - Hence, we need separate instruction and data memories, ALU and adders, etc
- Use multiplexers where alternative data sources are used for different instructions
  - Each multiplexer will need select inputs to choose which input to use as the output

Key Points

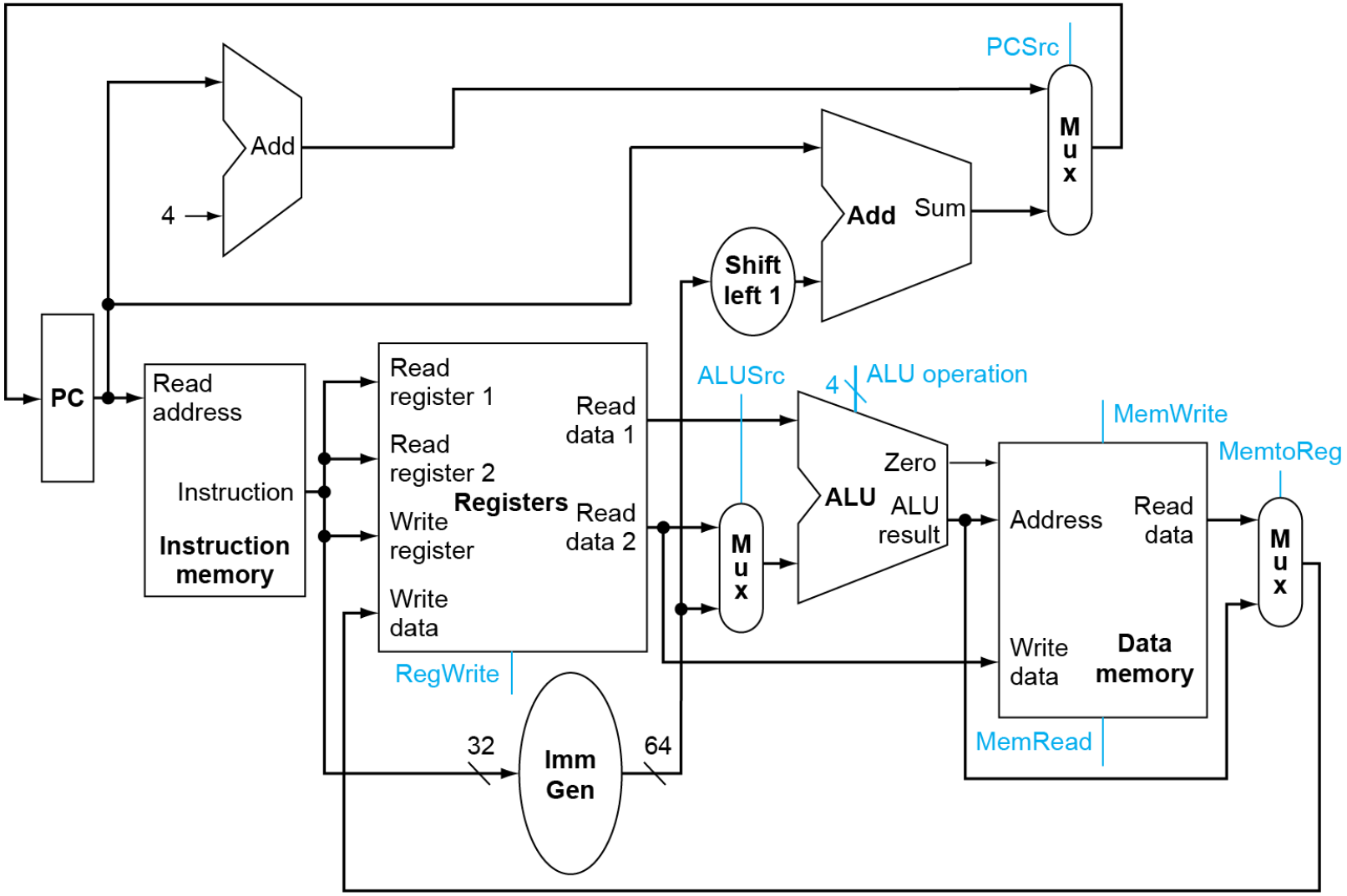
- CPU is just a collection of state and combinational logic
- We just designed a very rich processor, at least in terms of functionality
- ET = IC * CPI * Cycle Time
  - Where cycle time is determined by how much work the processor has to do each clock cycle for one iteration of fetch, decode, execute

What's next?

All of those blue inputs are **control** signals

They control how the data flows through the data path

Each instruction (opcode + function fields) determines the control signals



Reading

- Next lecture: Control Path
  - Section 5.4