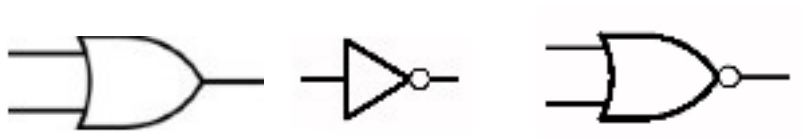
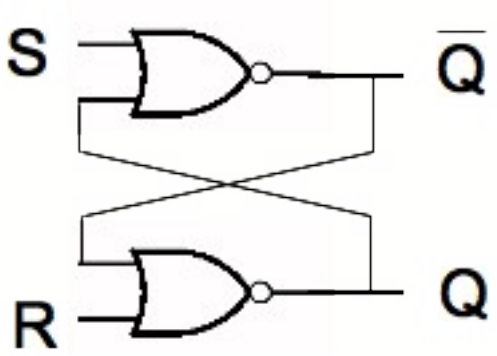
A 1-Bit Memory

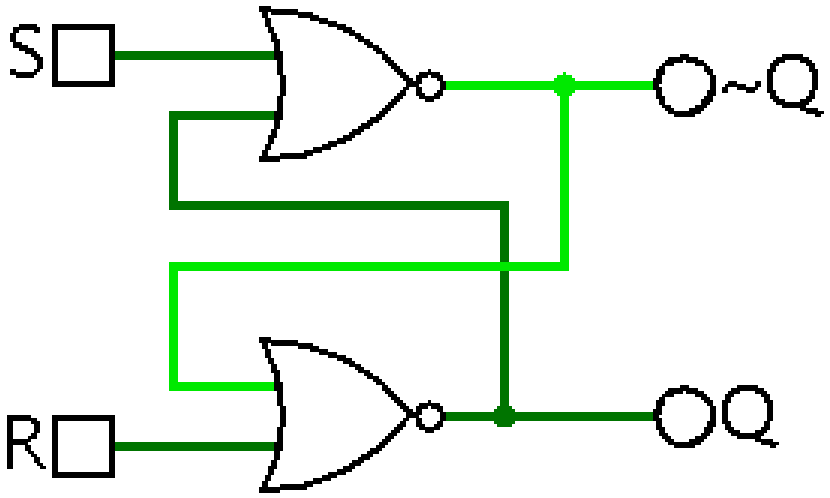
This stuff is truly unforgettable!



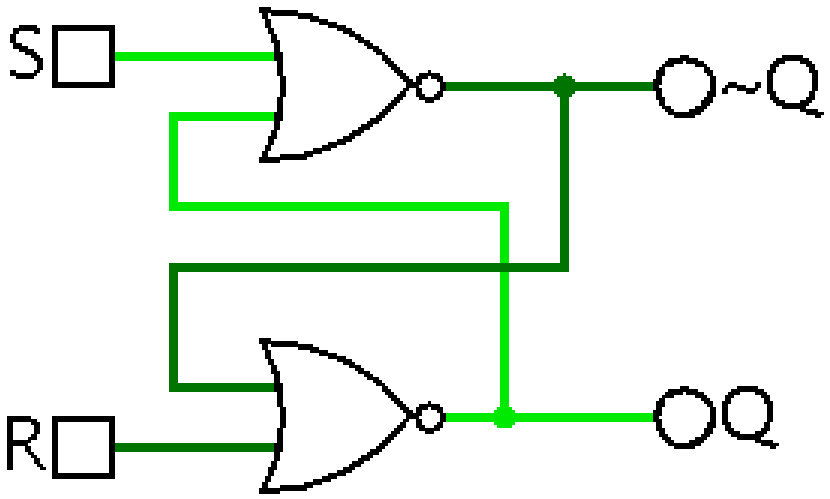
OR + NOT = NOR



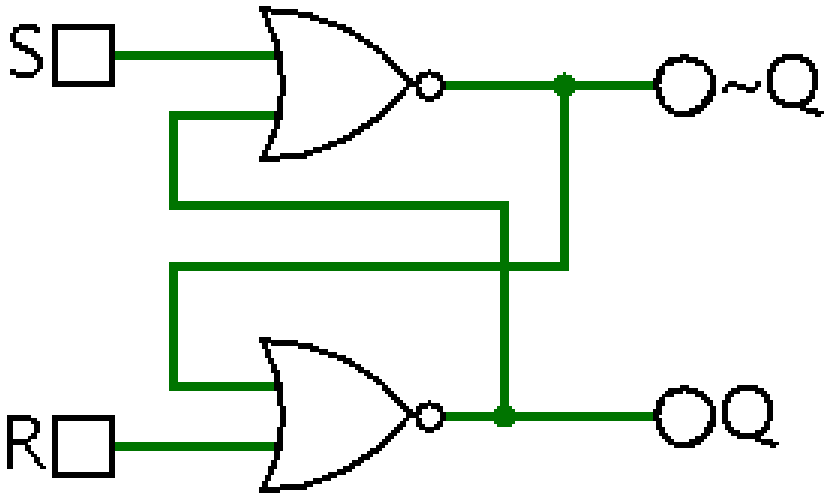
A 1-Bit Memory



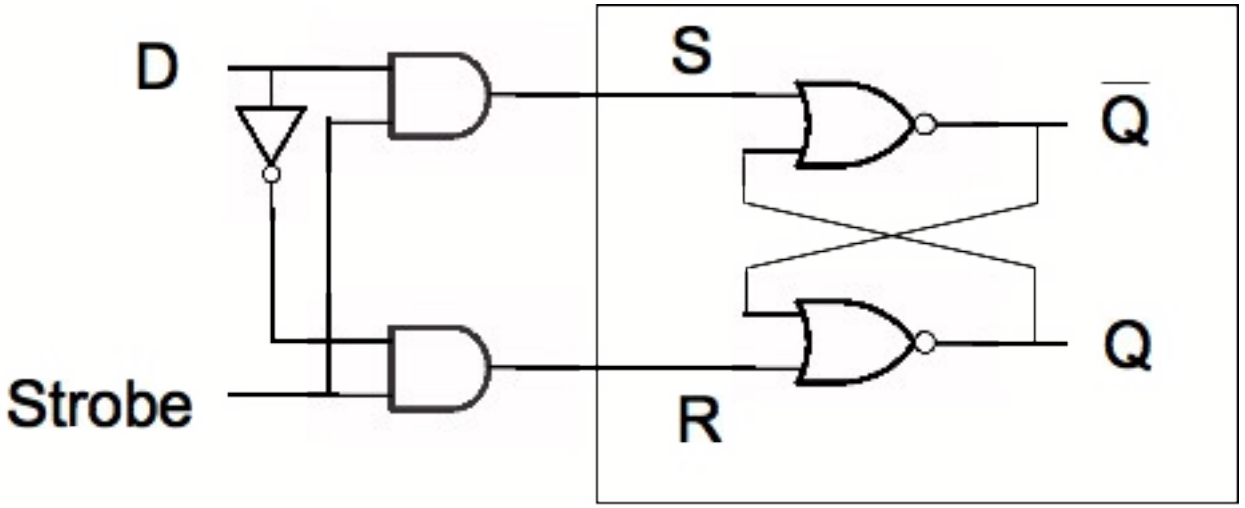
Setting a 1-Bit Memory

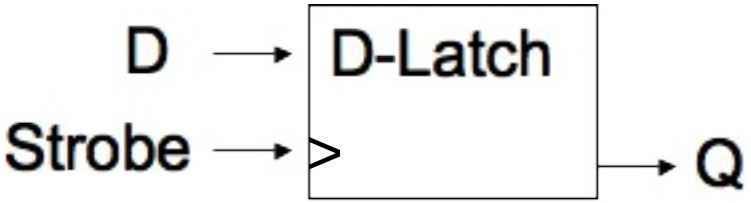


Initializing a 1-Bit Memory



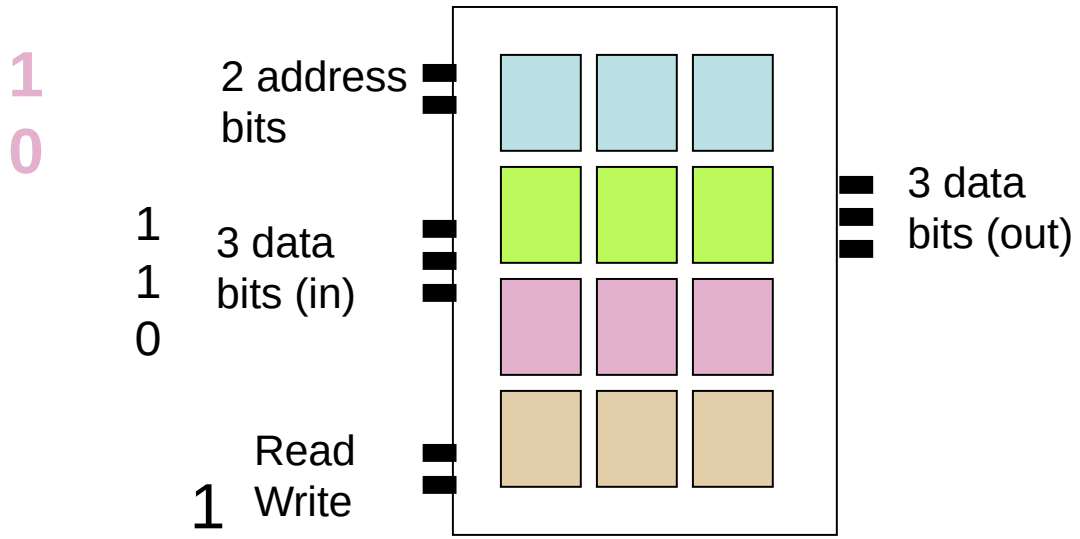
From S-R Latches to D-Latches



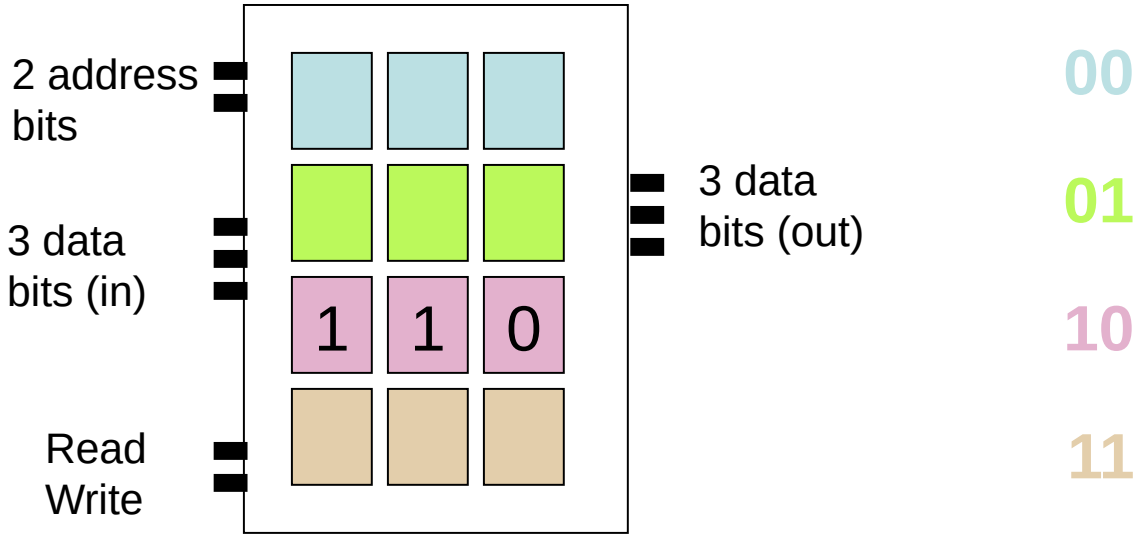


Worksheet!

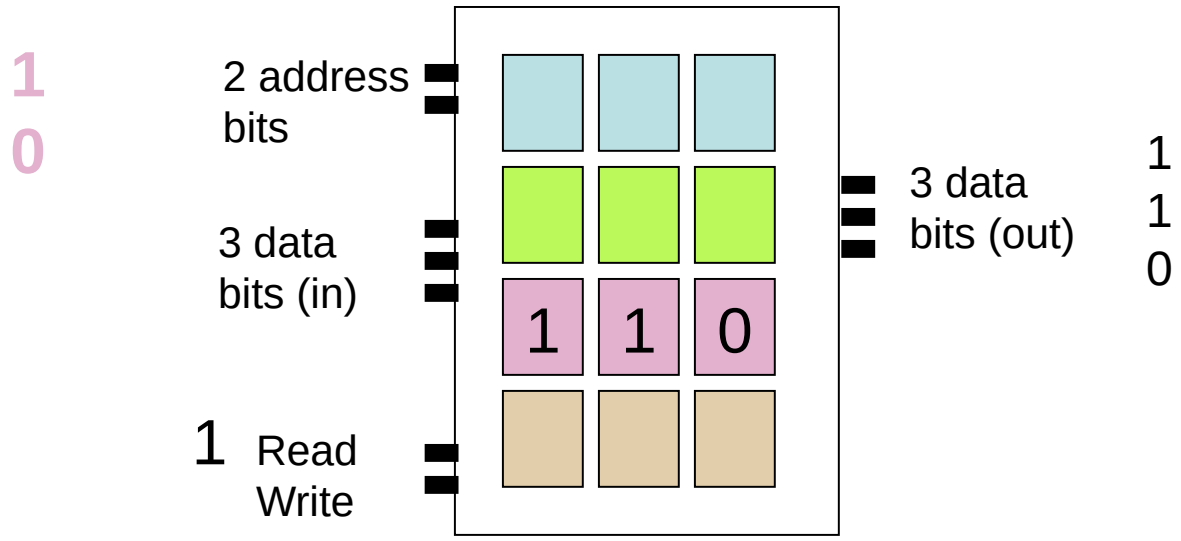
A Random Access Memory (RAM)



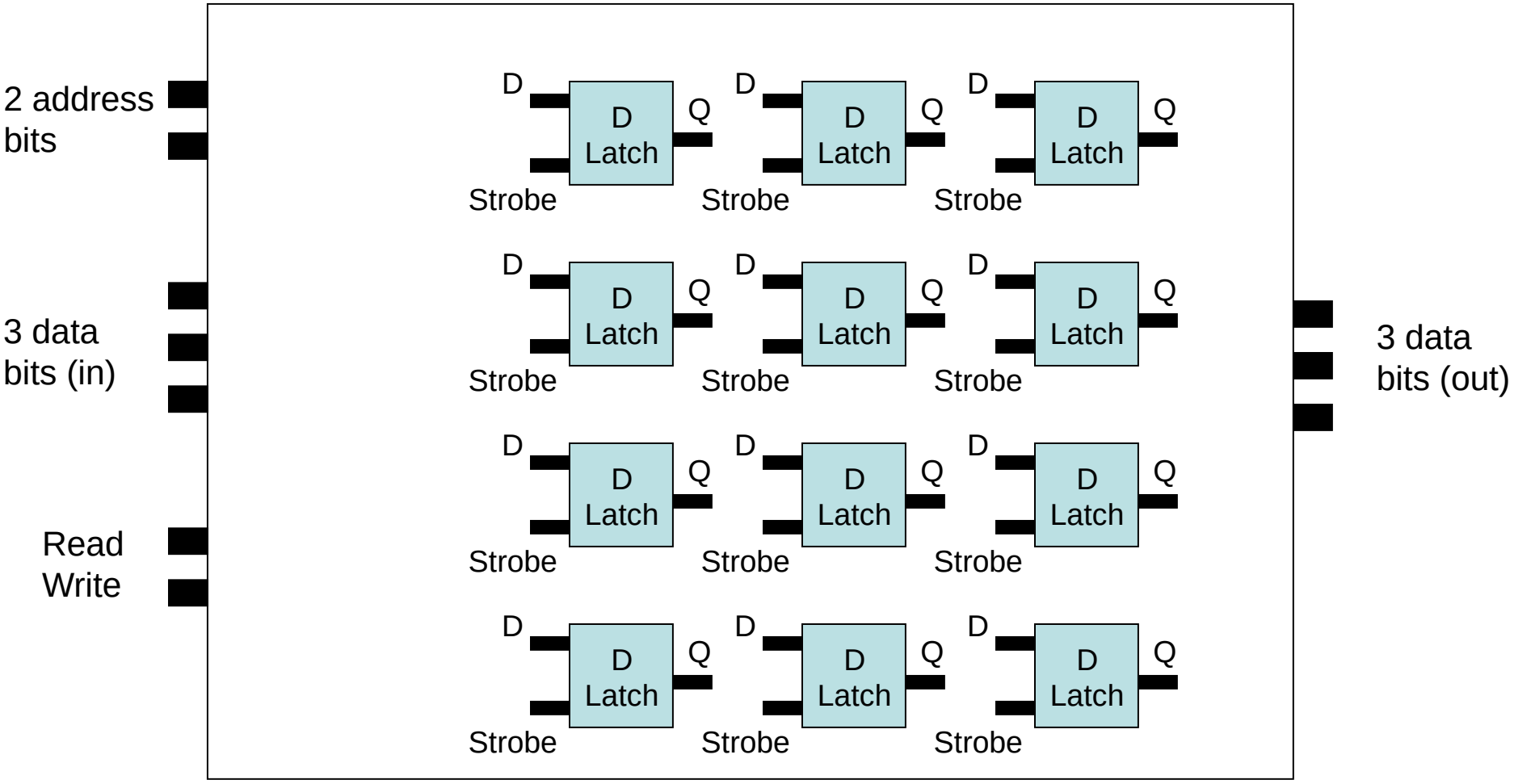
A Random Access Memory (RAM)



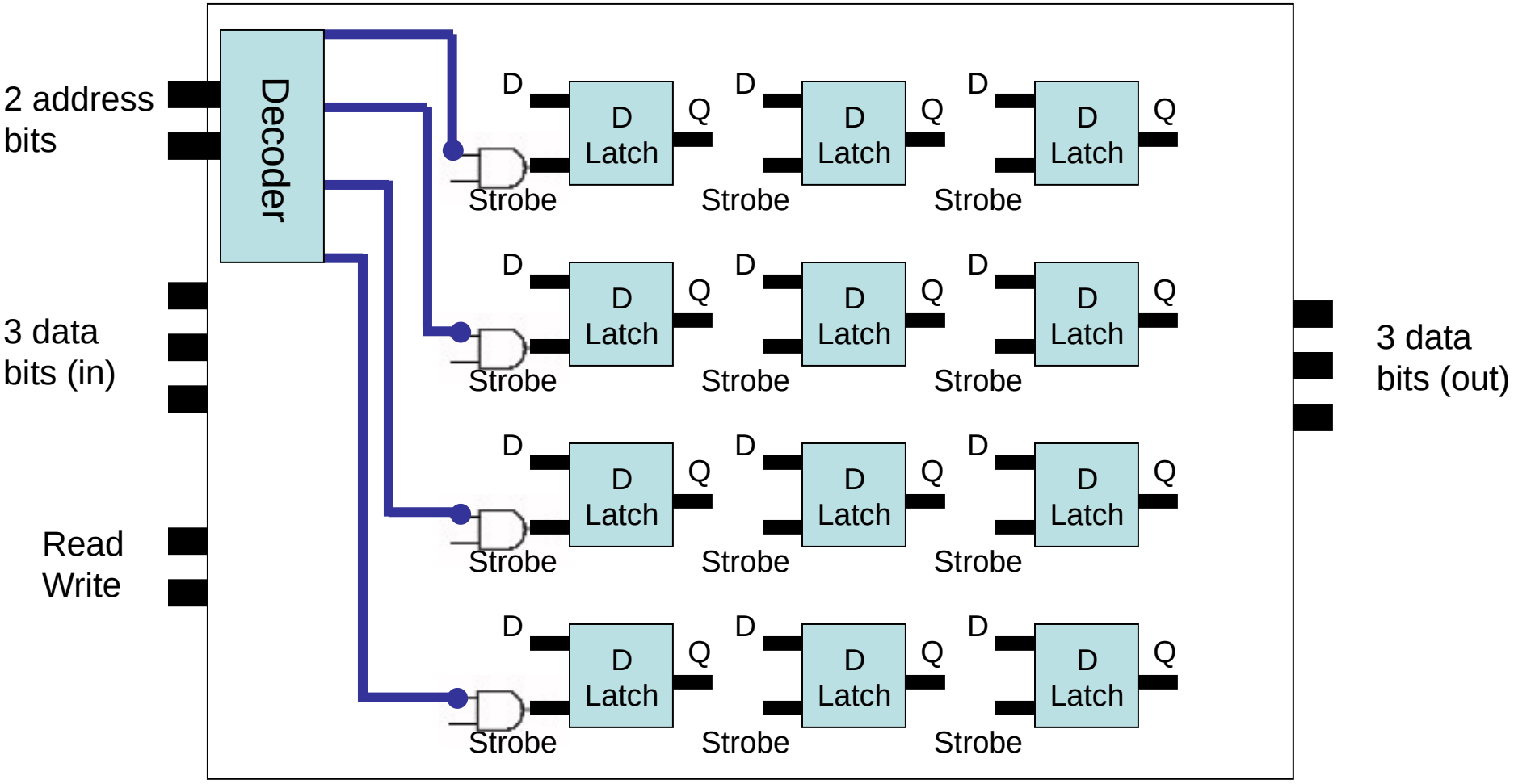
A Random Access Memory (RAM)



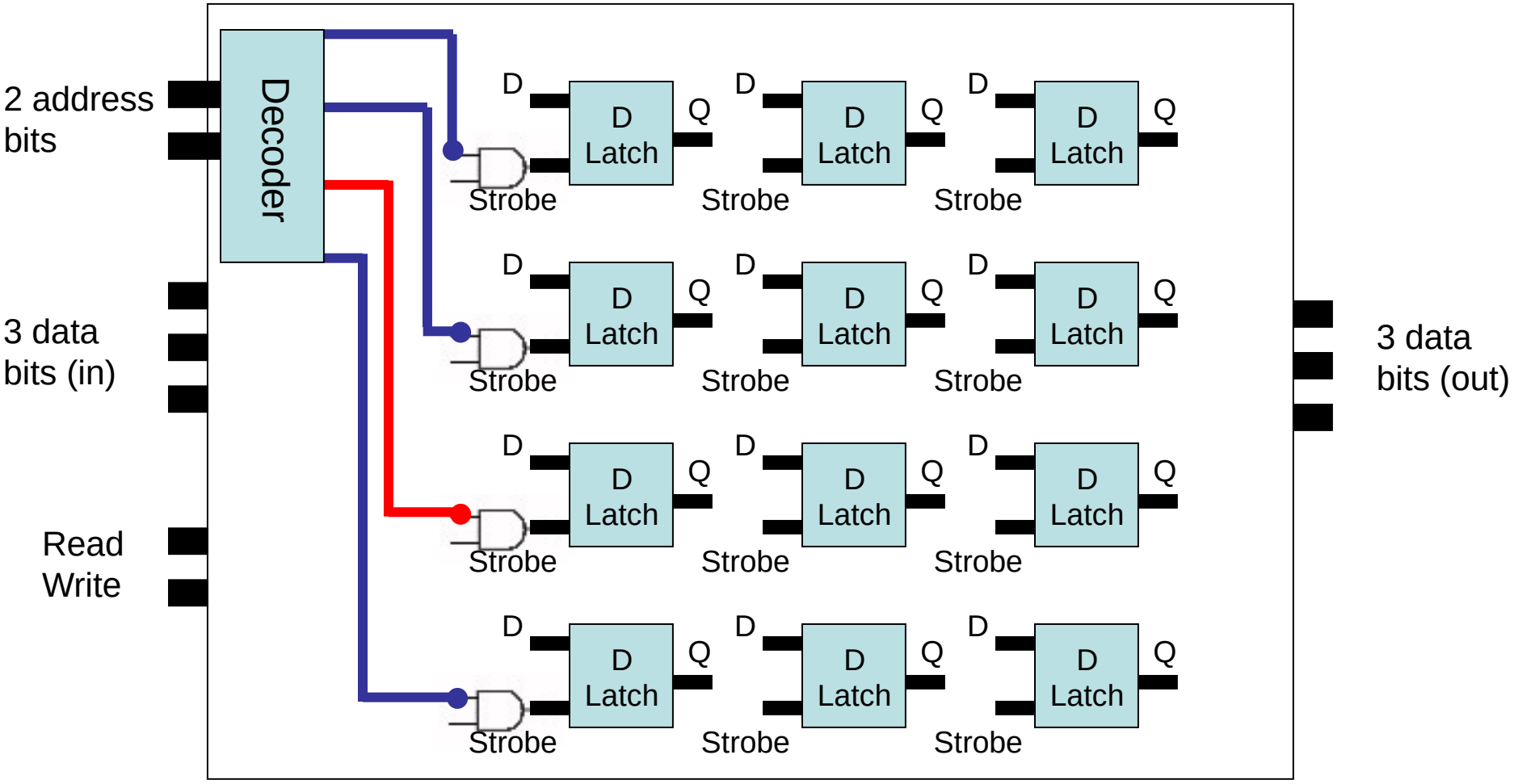
A Random Access Memory (RAM)



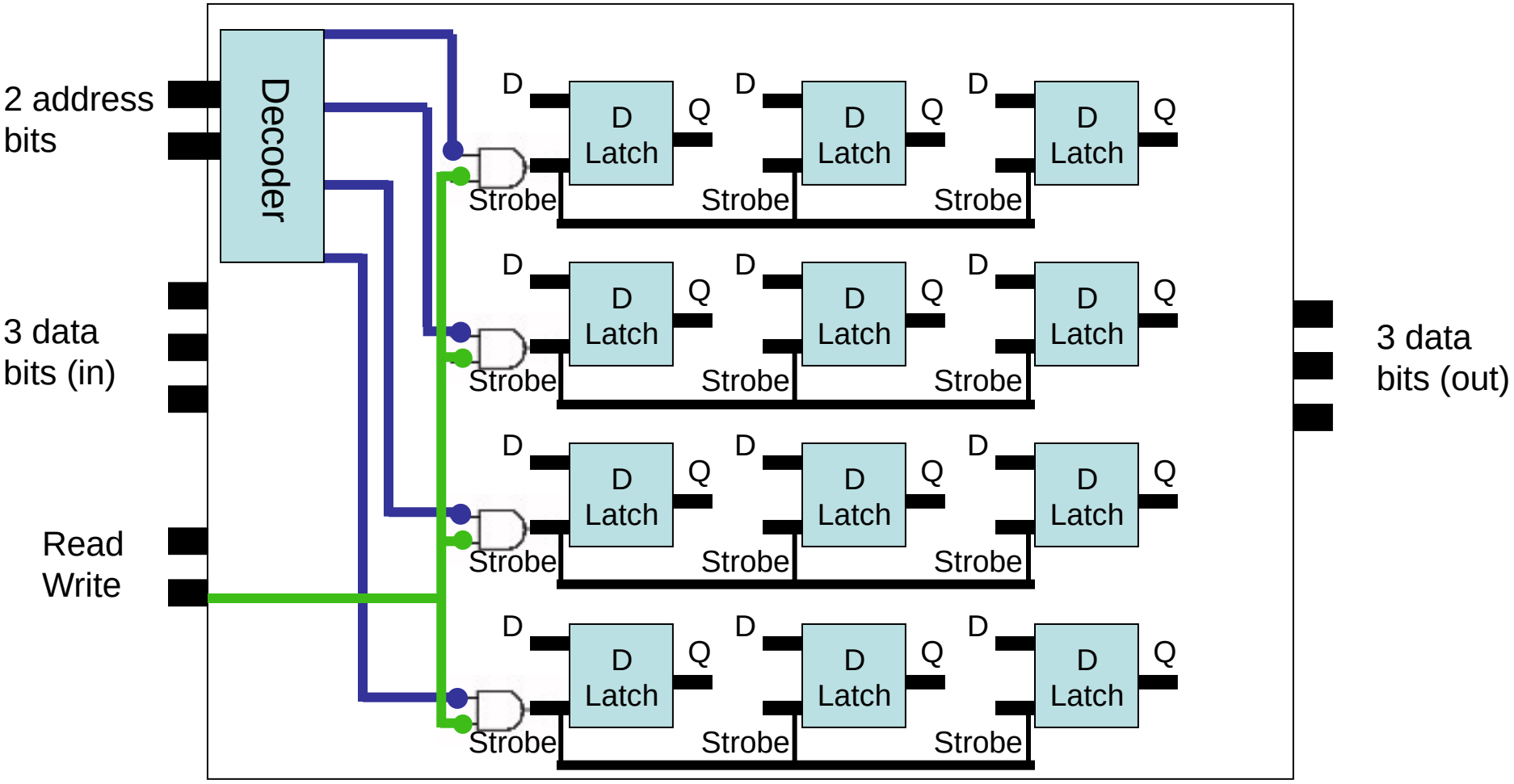
A Random Access Memory (RAM)



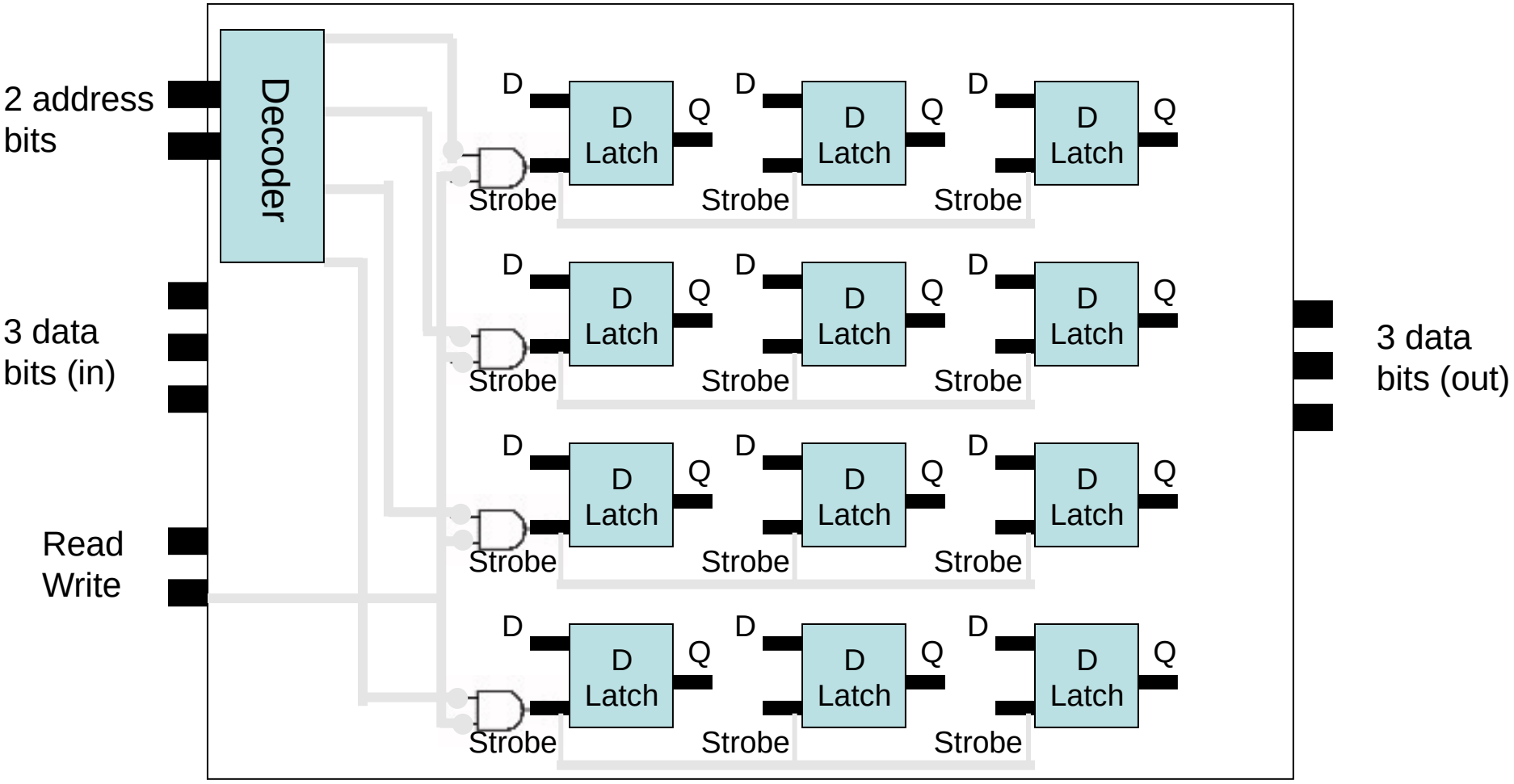
A Random Access Memory (RAM)



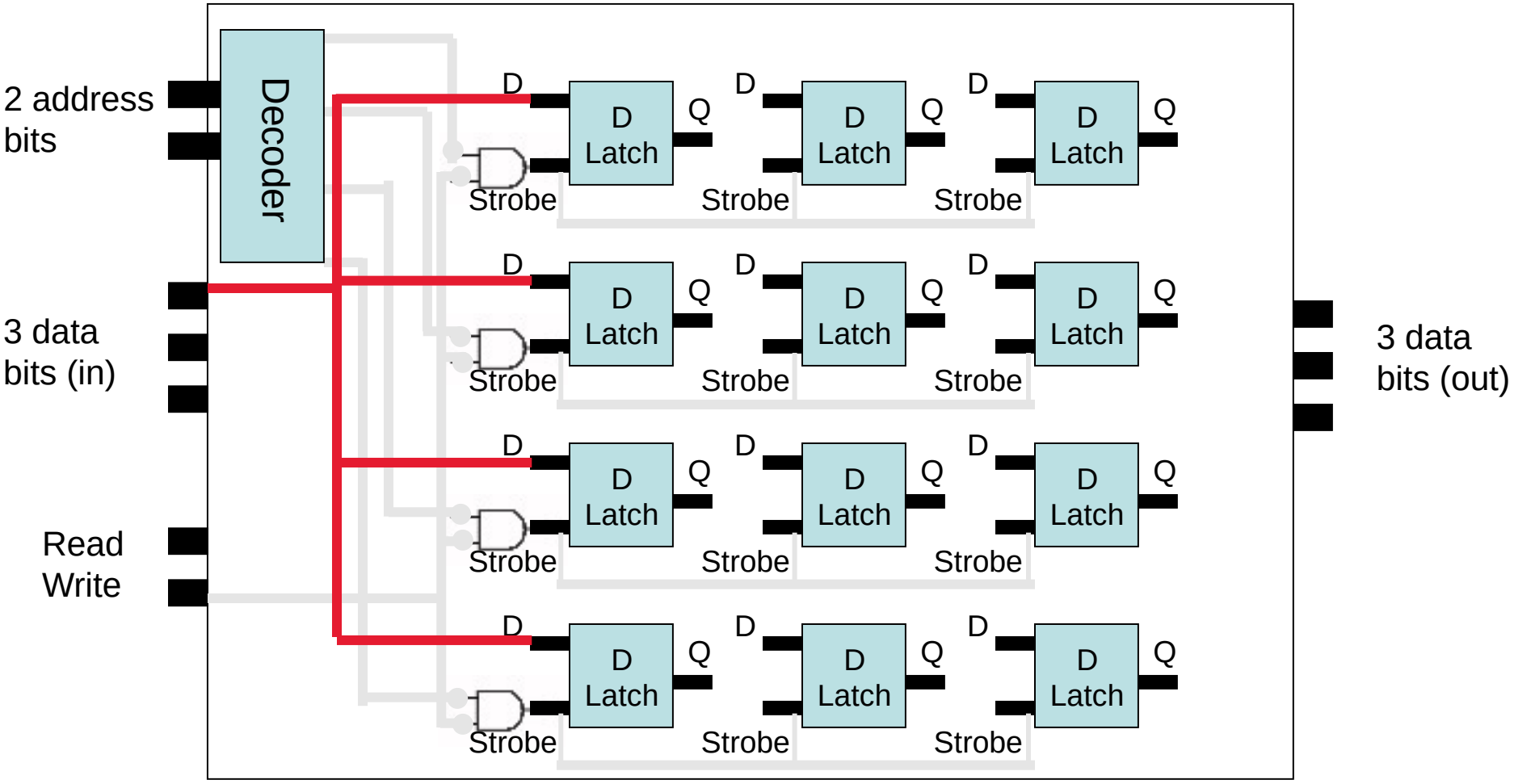
A Random Access Memory (RAM)



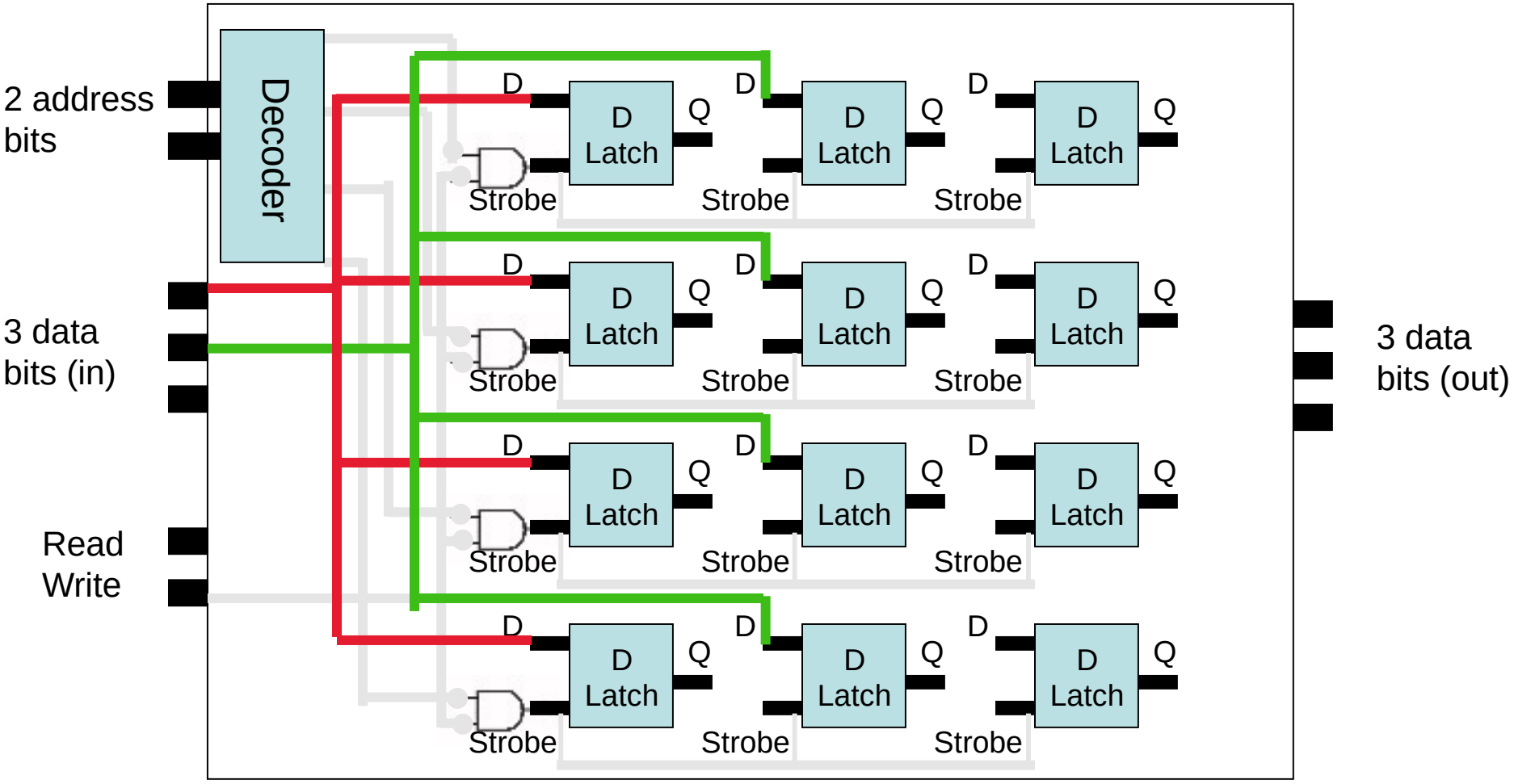
A Random Access Memory (RAM)



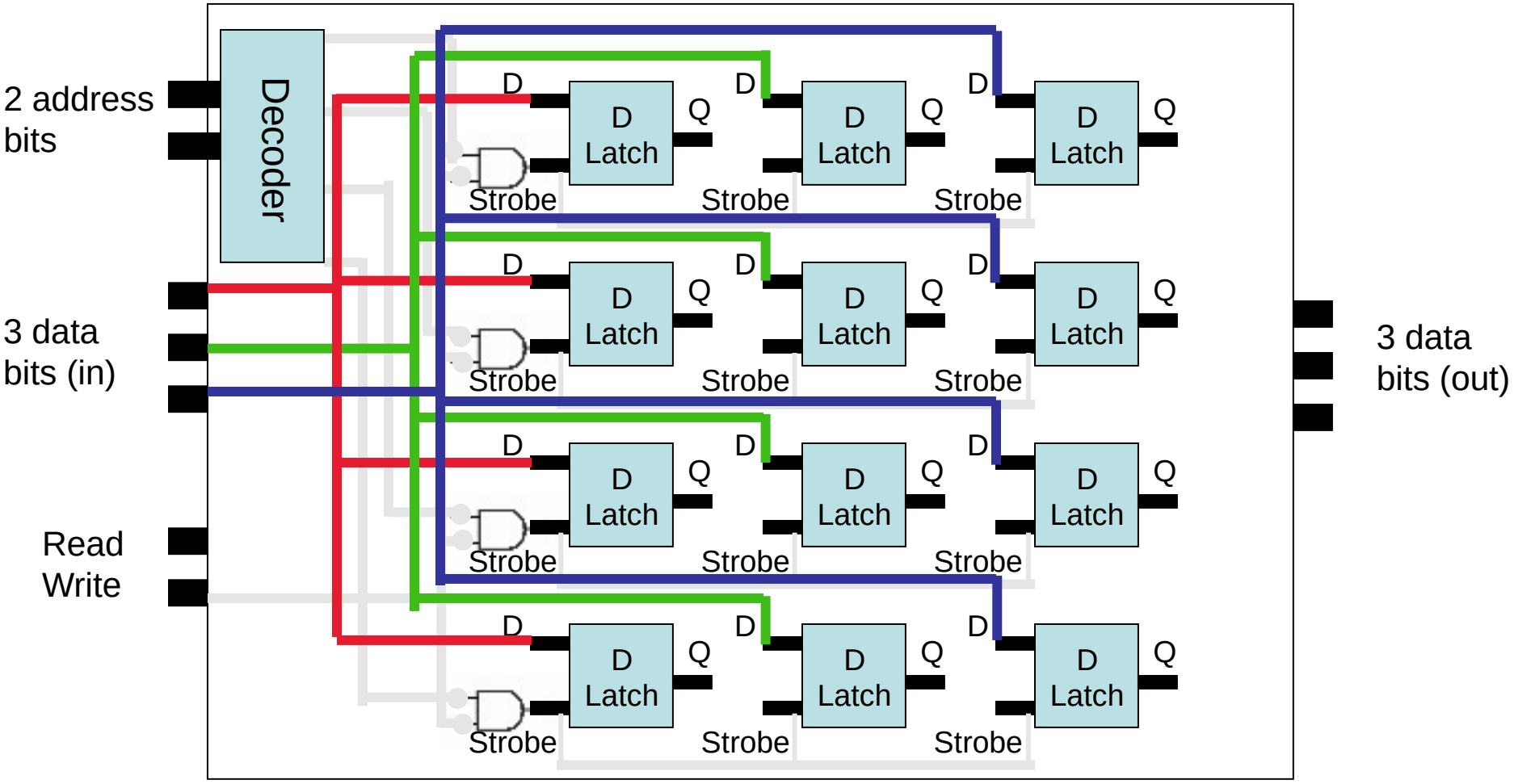
A Random Access Memory (RAM)



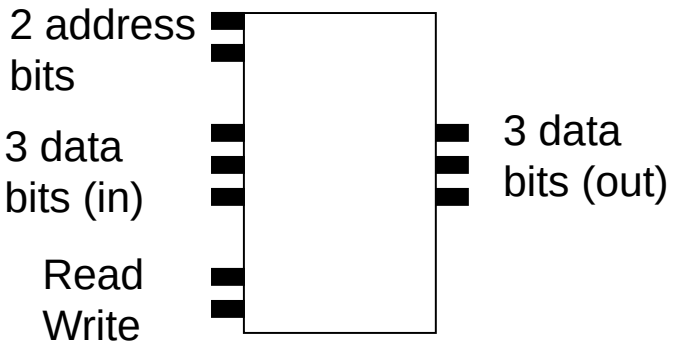
A Random Access Memory (RAM)

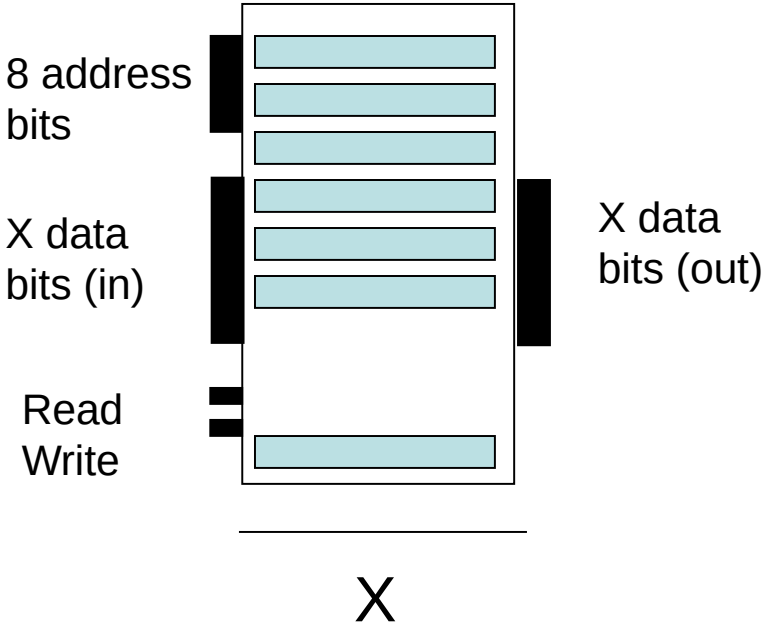


A Random Access Memory (RAM)

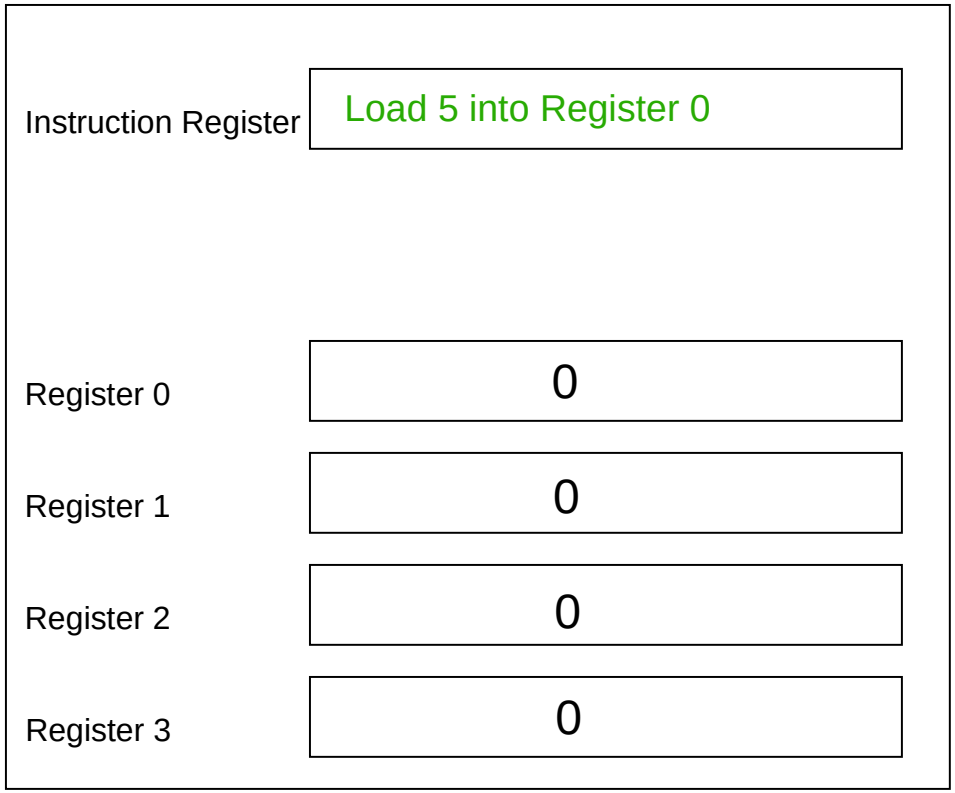


Small Memory, “Big” Memory…

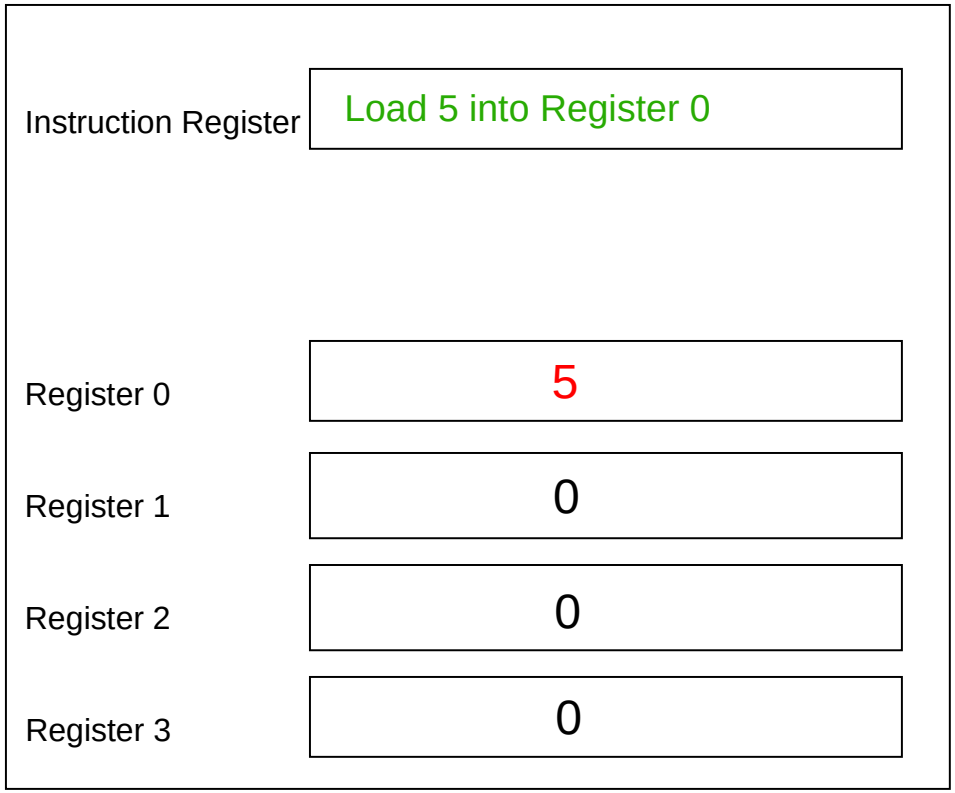




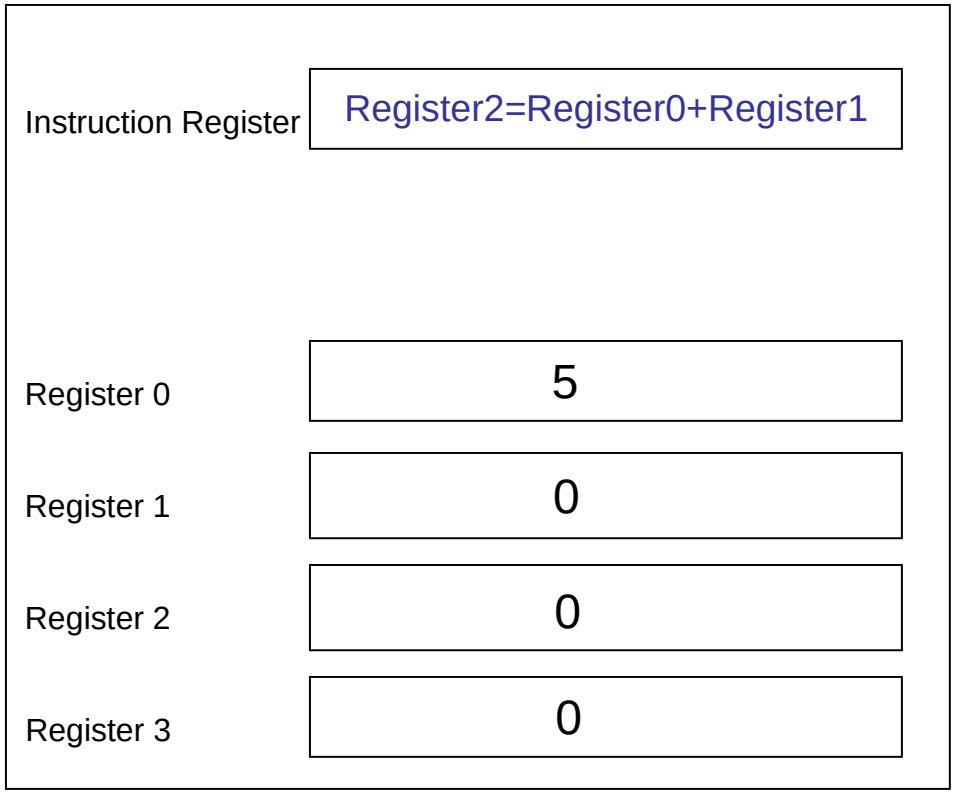
A “Calculator”



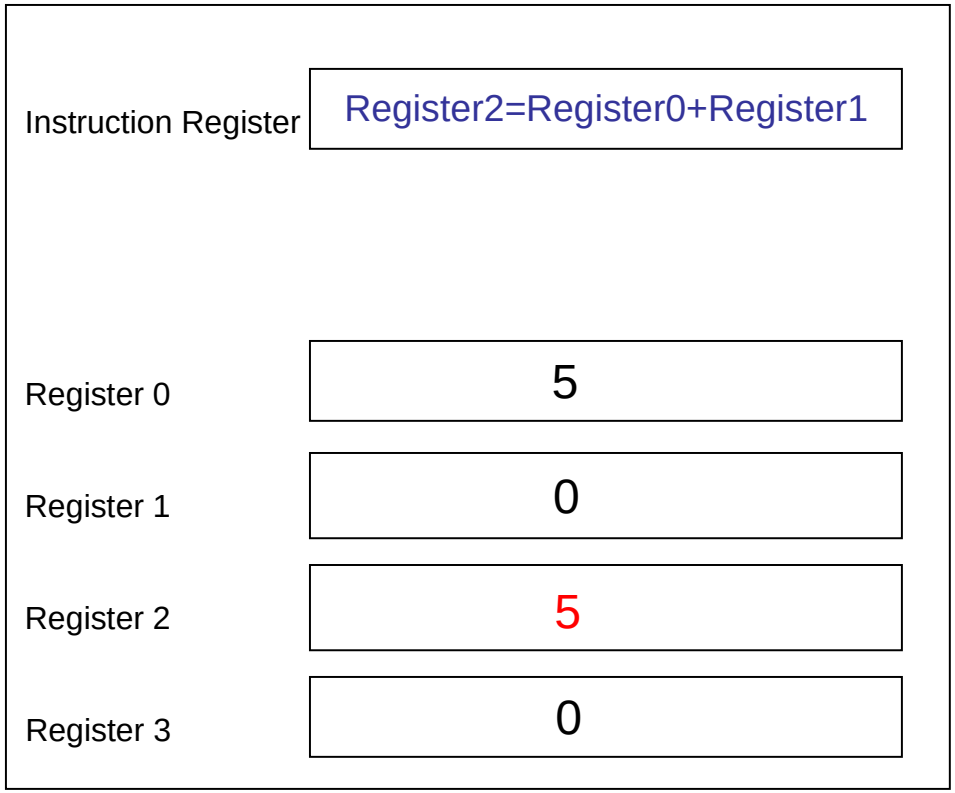
A “Calculator”



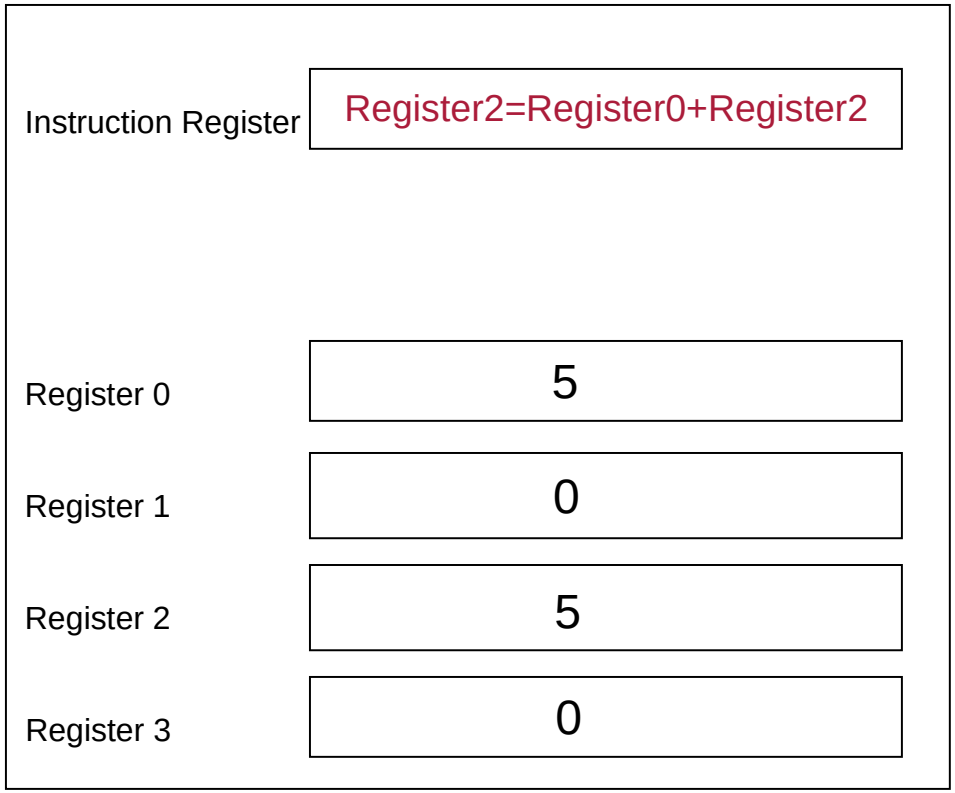
A “Calculator”



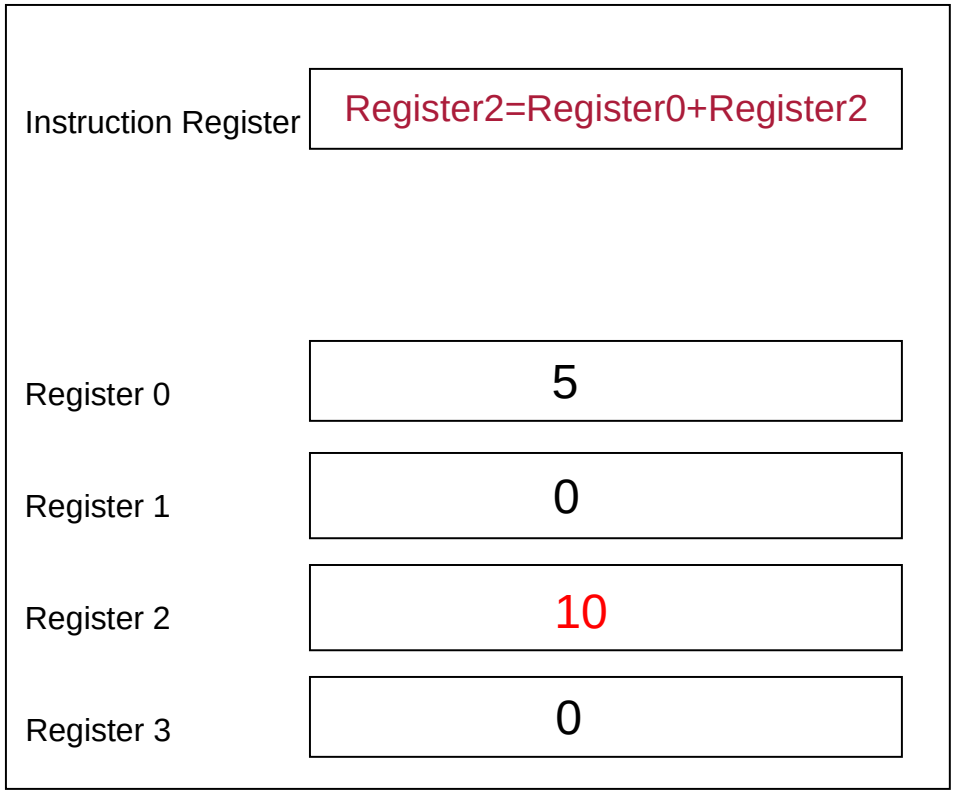
A “Calculator”



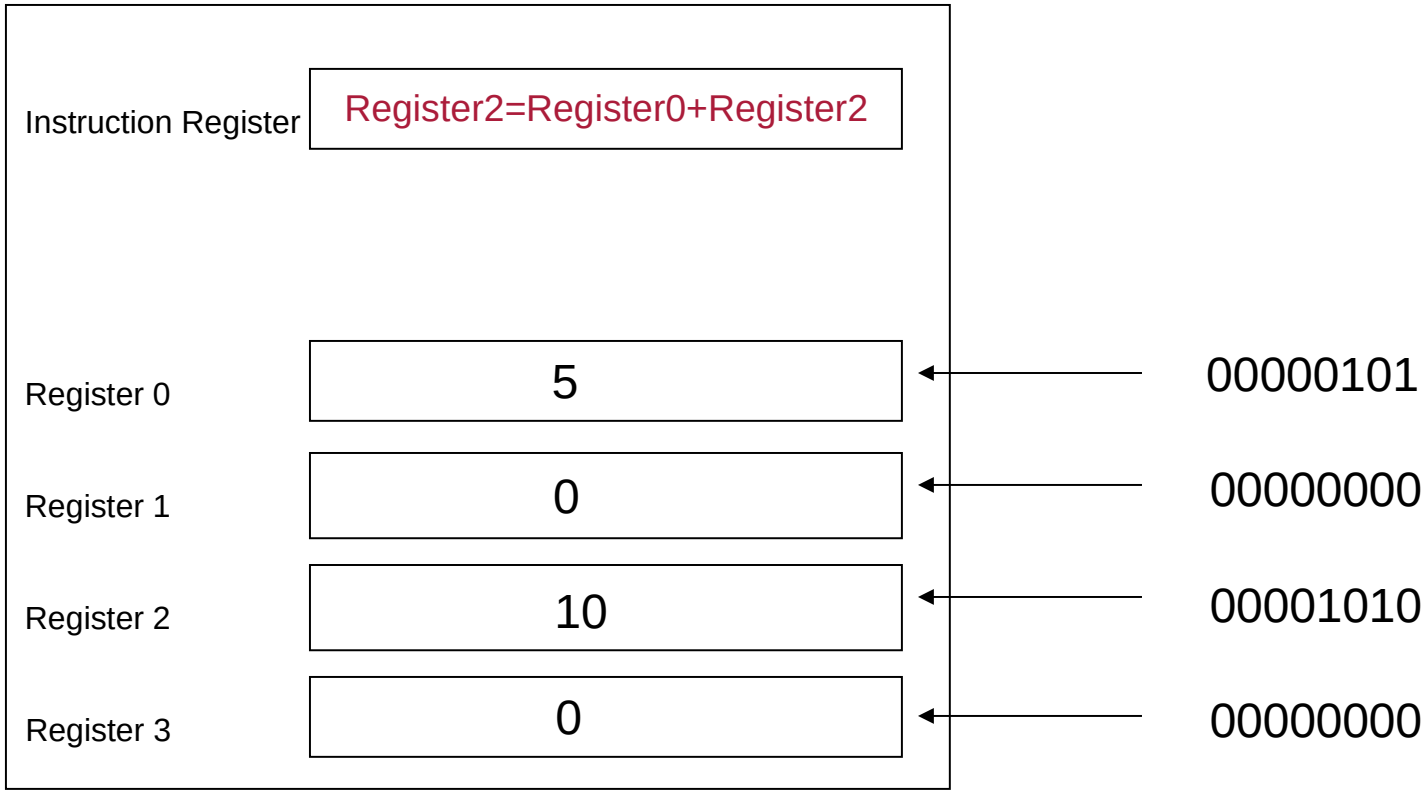
A “Calculator”



A “Calculator”

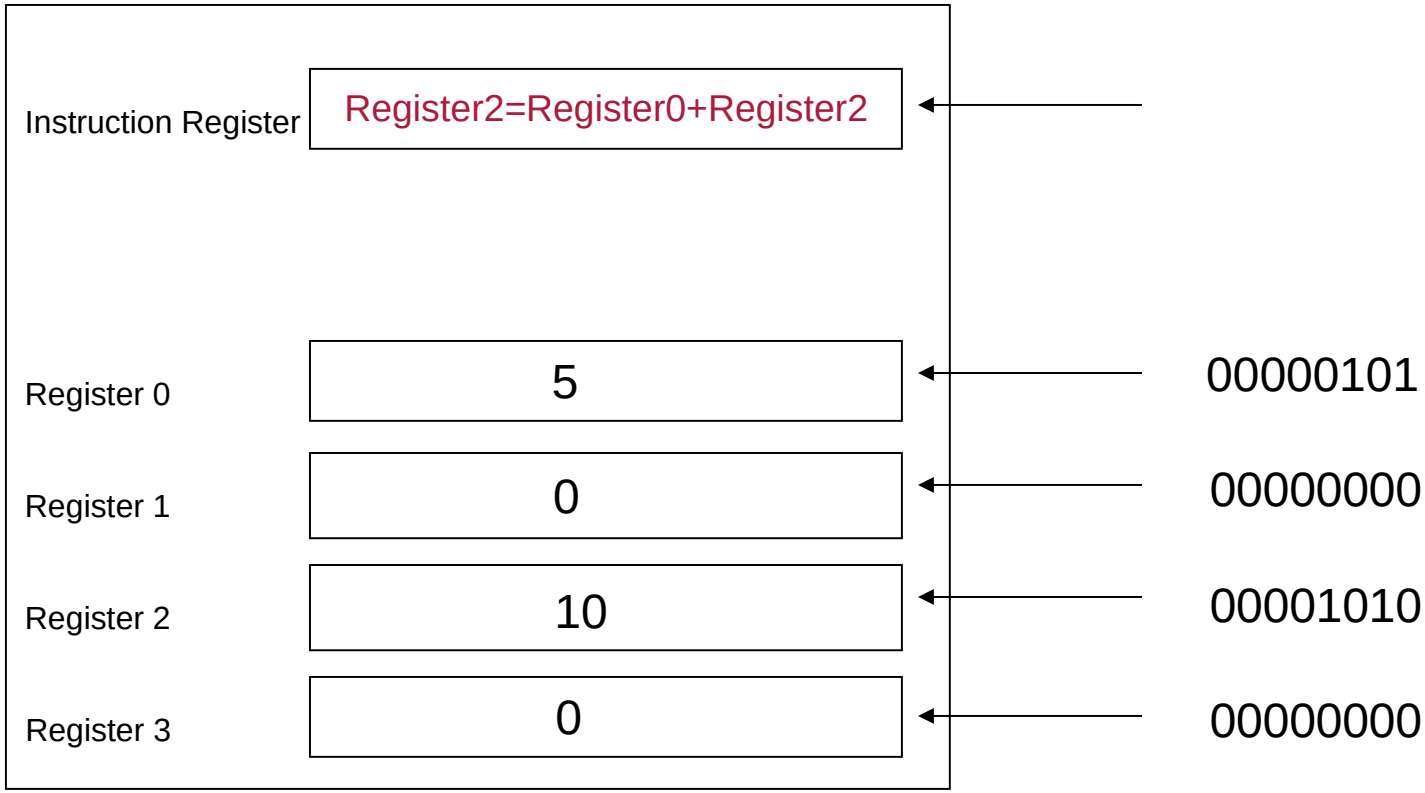


A “Calculator”



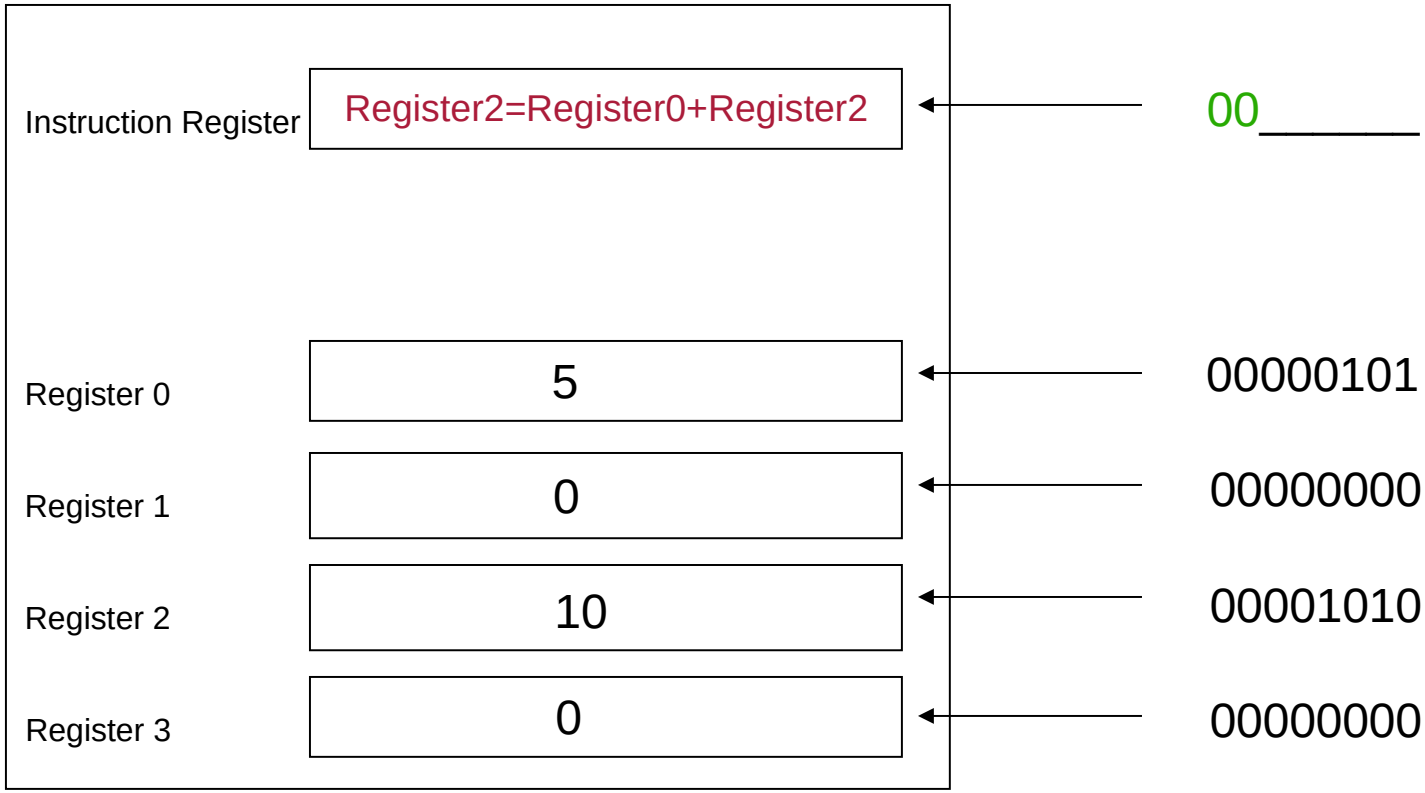
A “Calculator”

00	add
01	subtract
10	multiply
11	divide



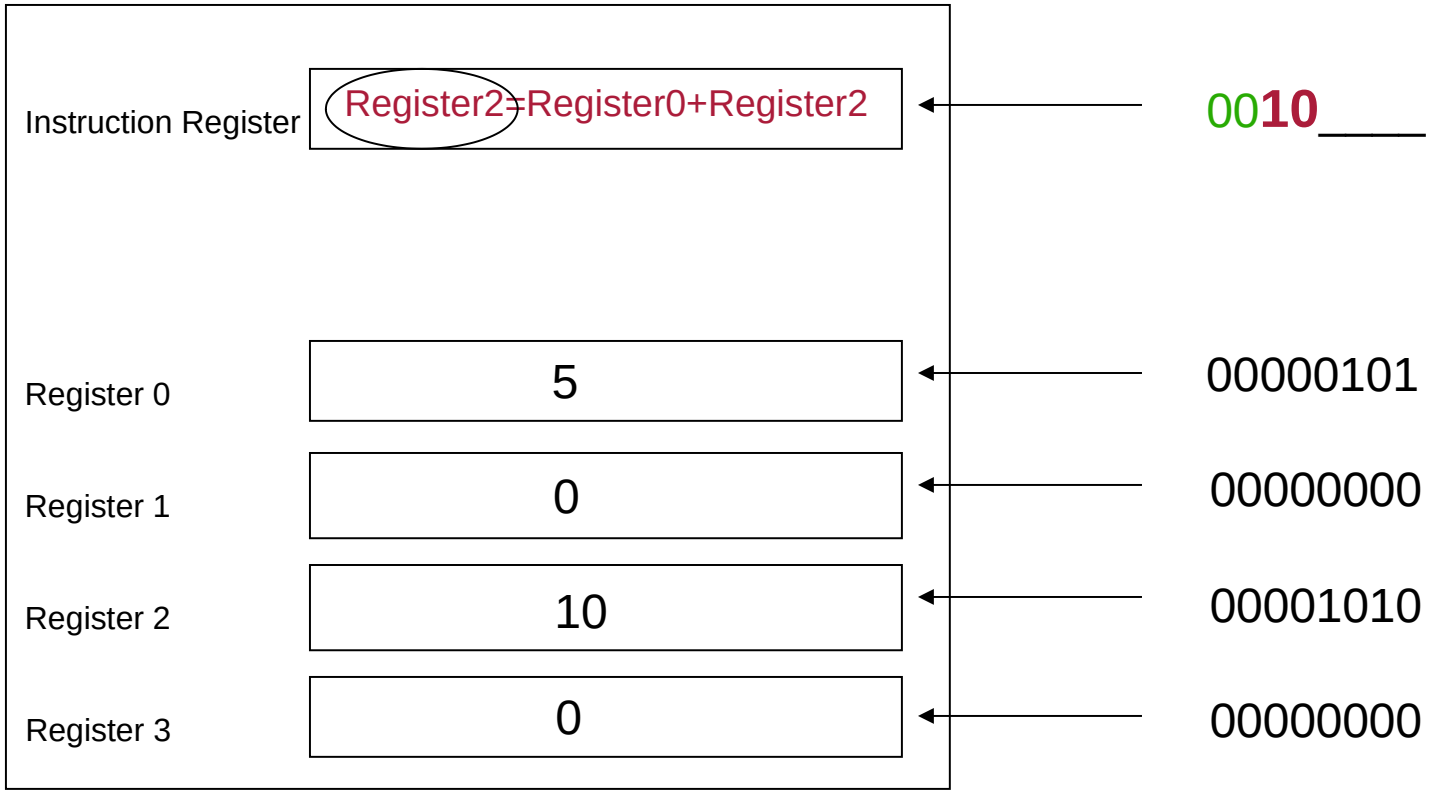
00	add
01	subtract
10	multiply
11	divide

A “Calculator”



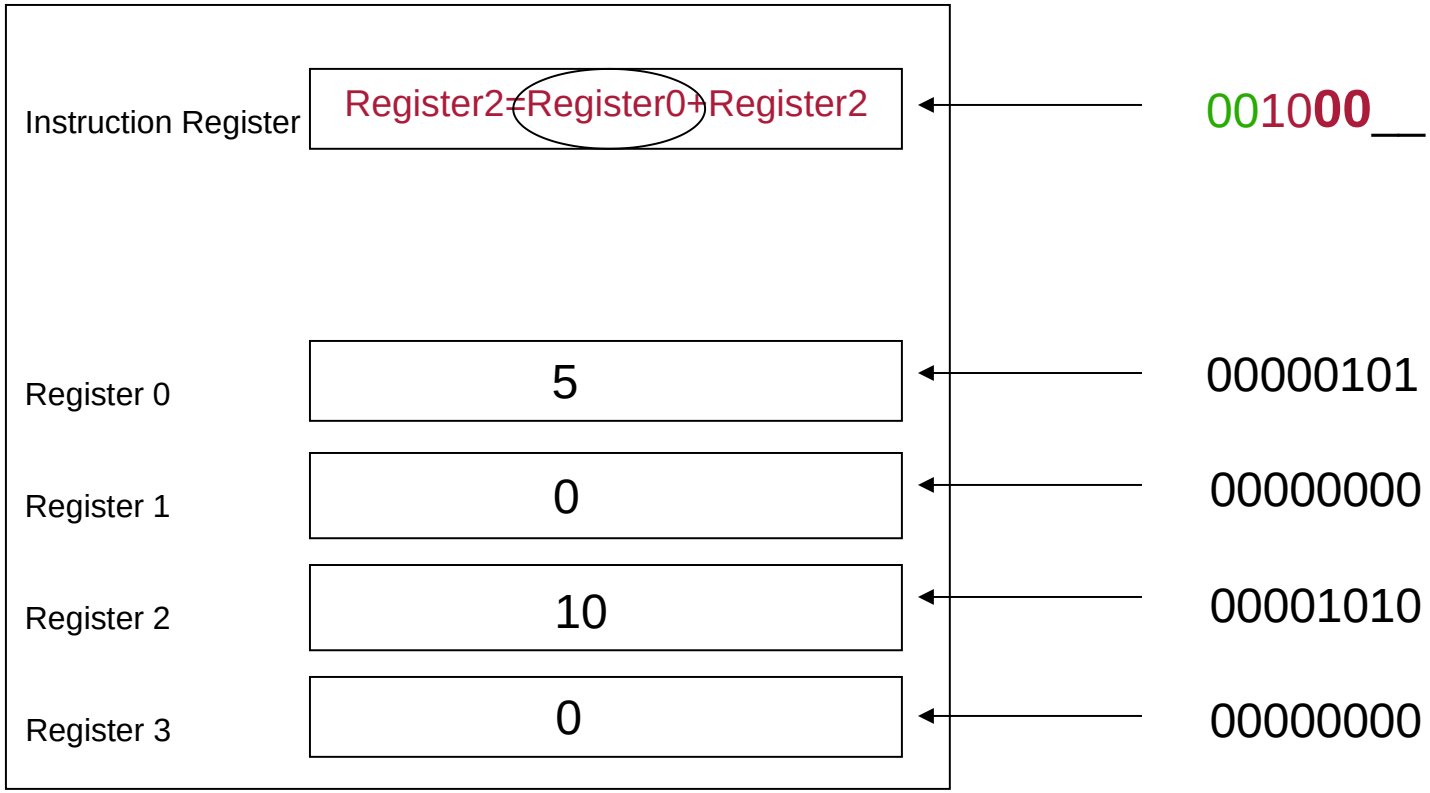
00	add
01	subtract
10	multiply
11	divide

A “Calculator”



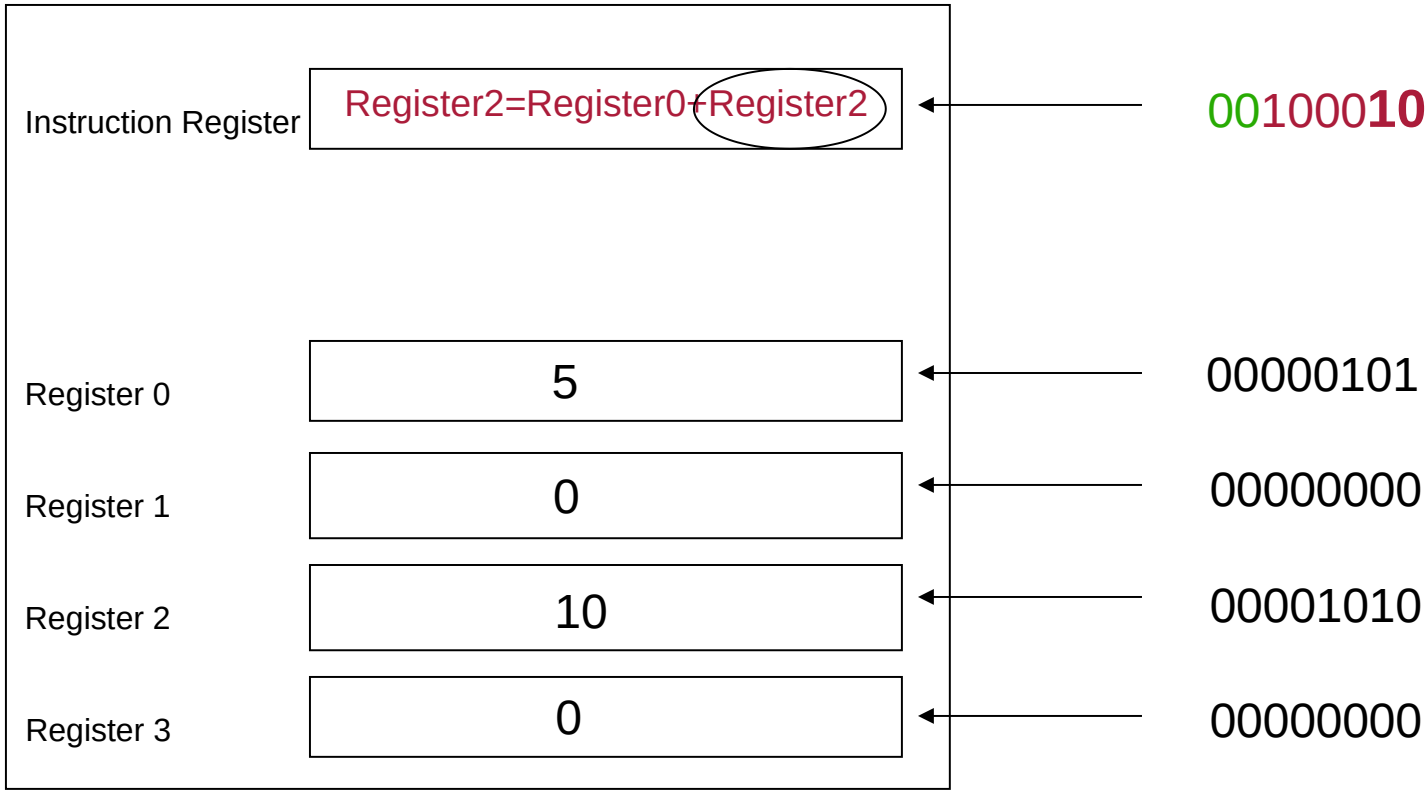
00	add
01	subtract
10	multiply
11	divide

A “Calculator”



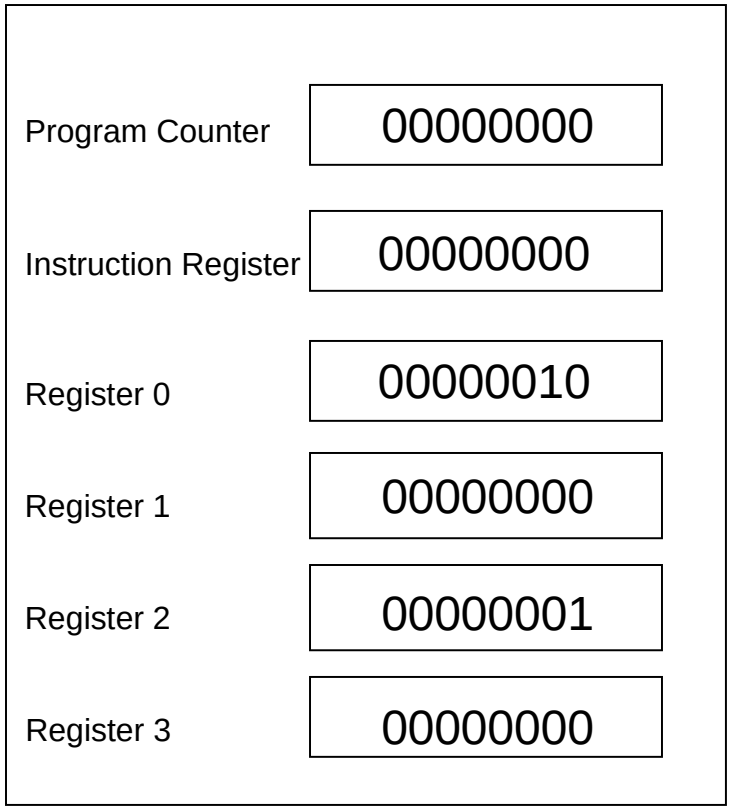
A “Calculator”

00	add
01	subtract
10	multiply
11	divide

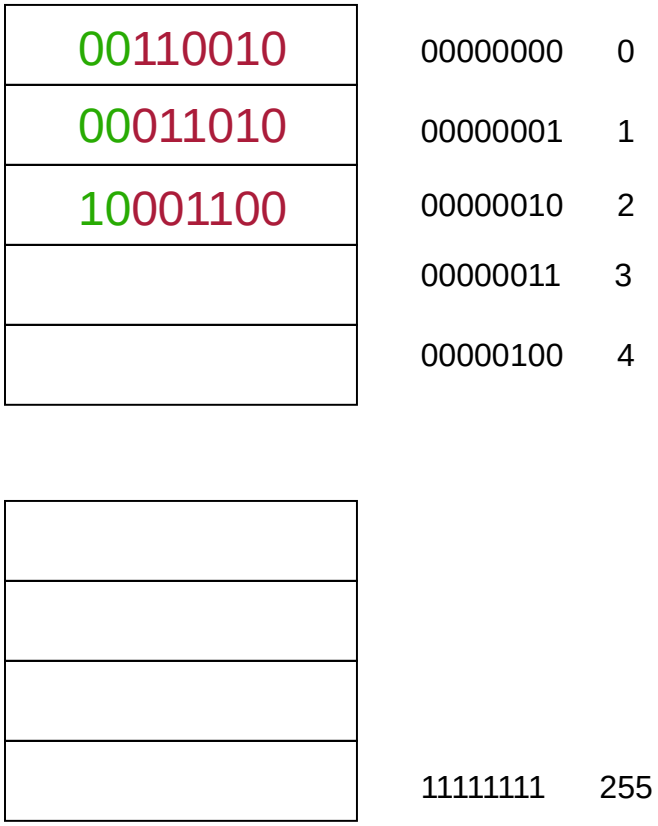


00	add
01	subtract
10	multiply
11	divide

A Computer!



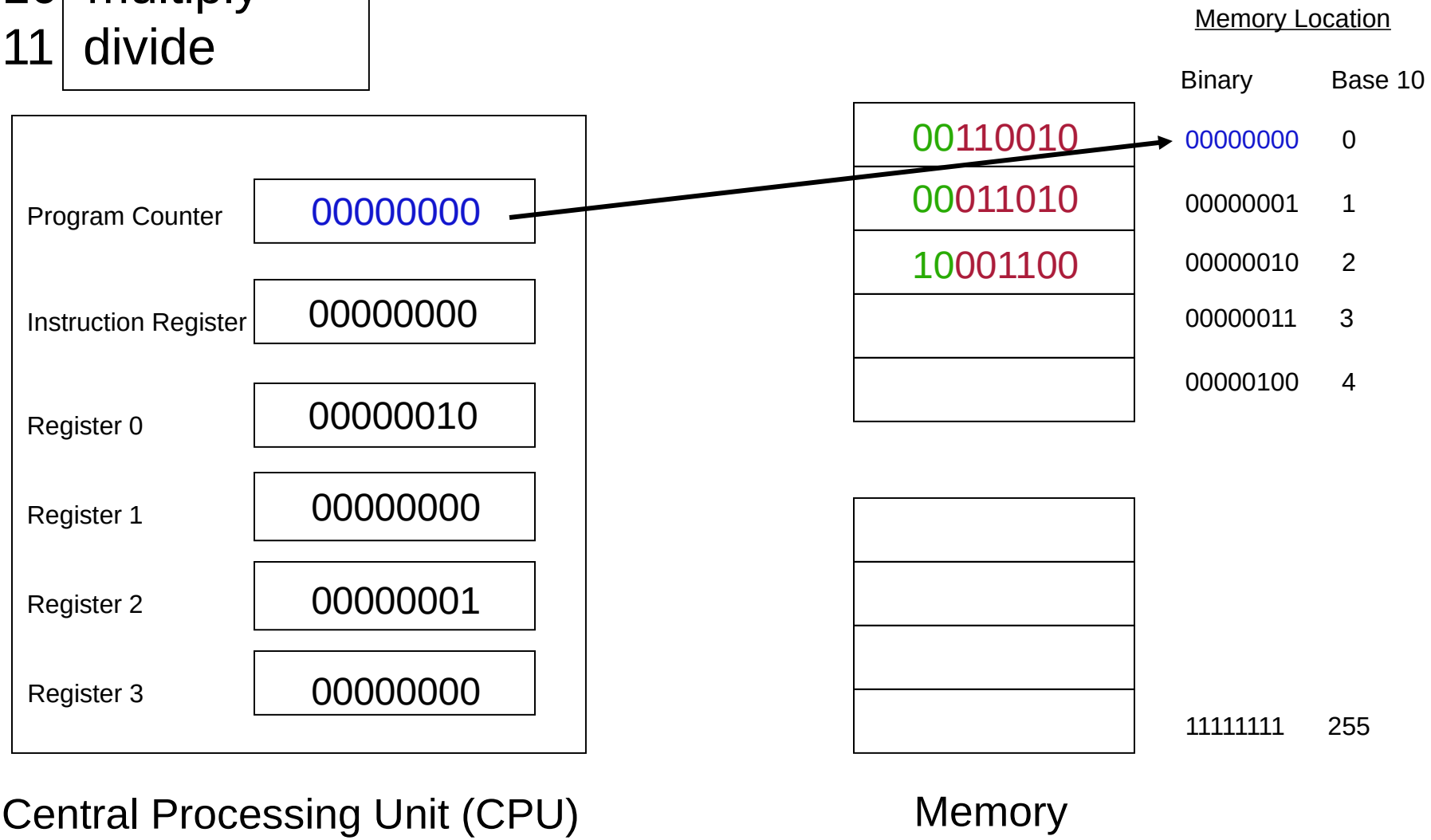
Central Processing Unit (CPU)



Memory

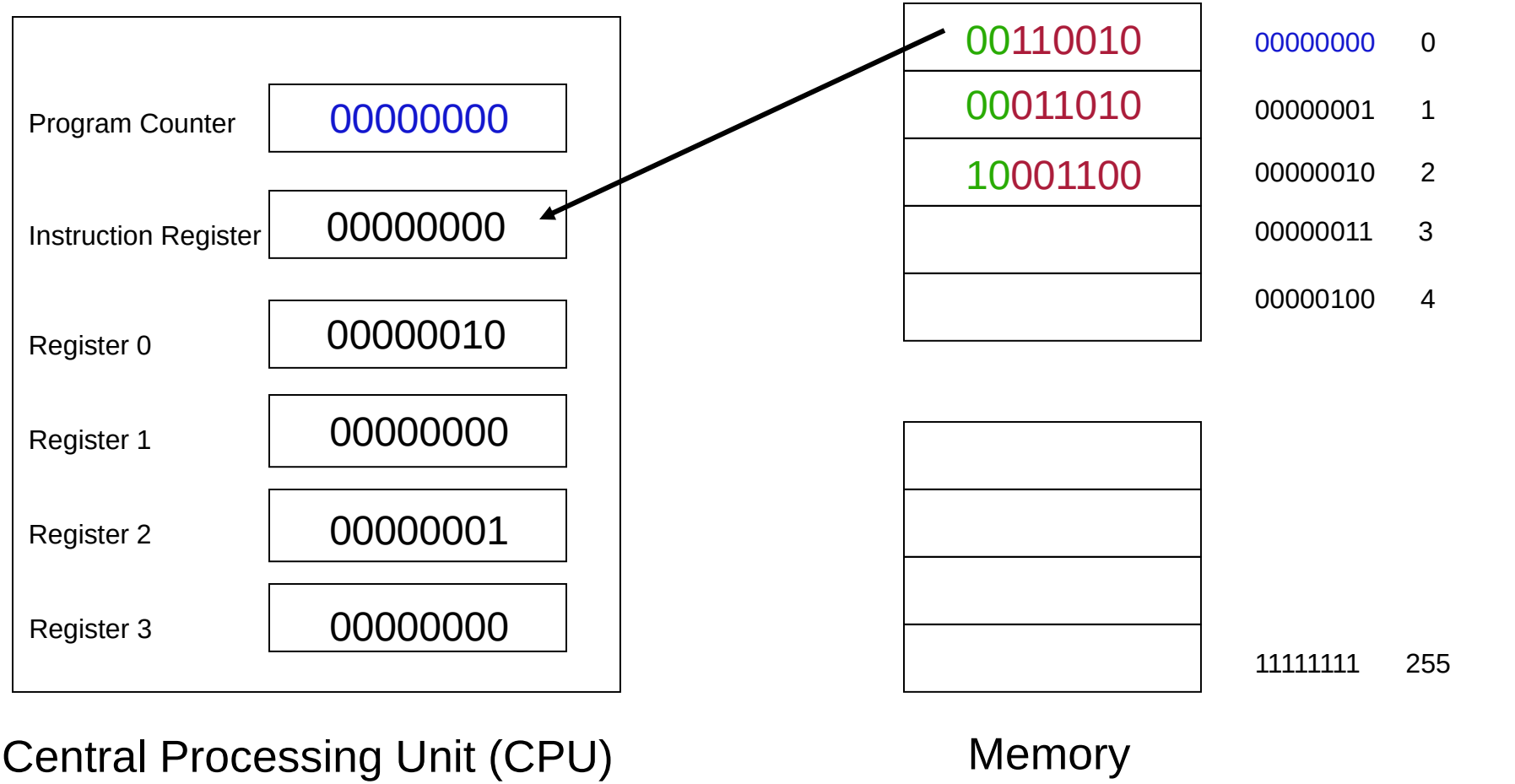
00	add
01	subtract
10	multiply
11	divide

A Computer!



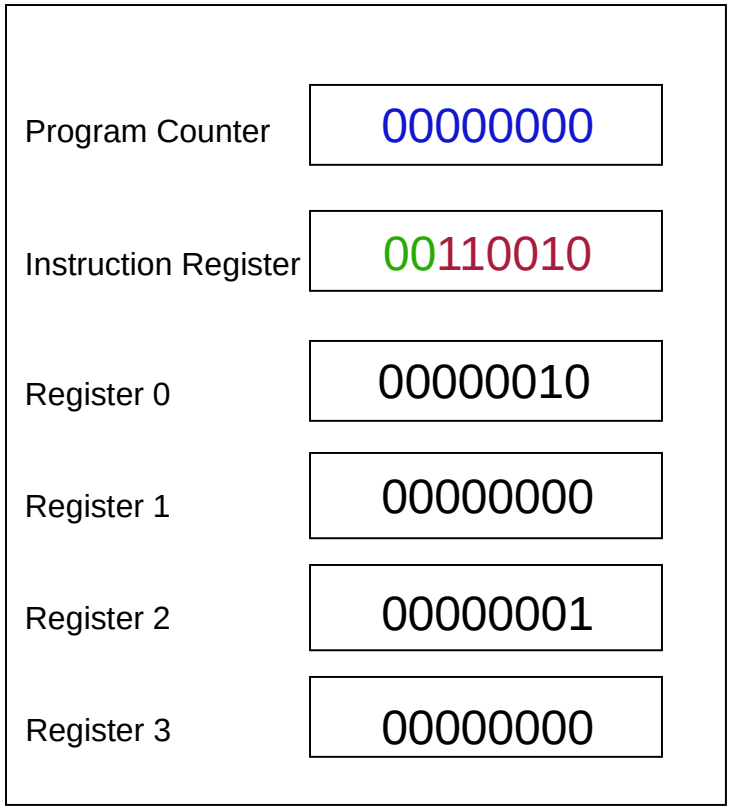
00	add
01	subtract
10	multiply
11	divide

A Computer!

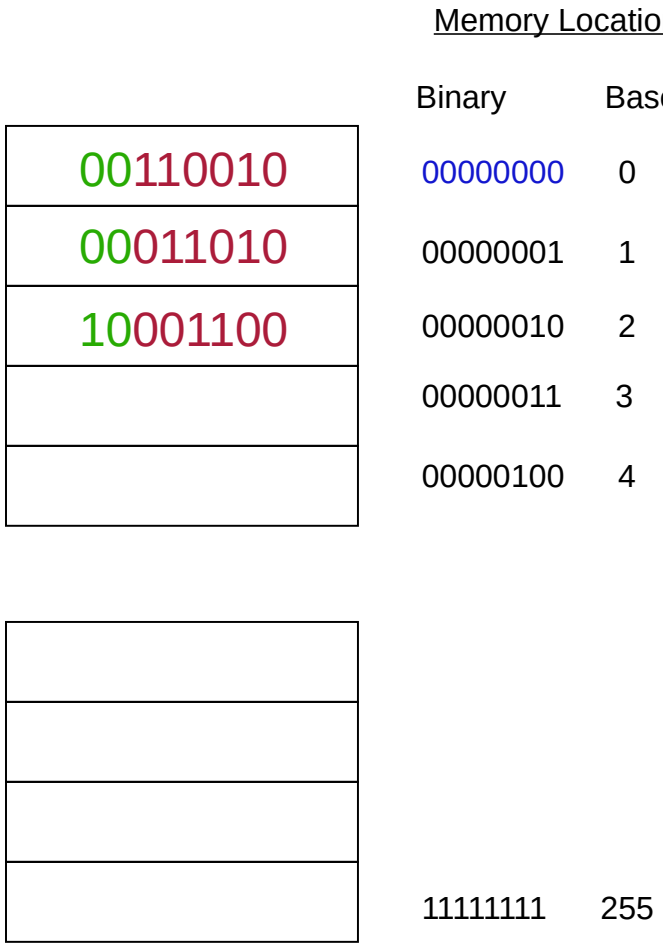


00	add
01	subtract
10	multiply
11	divide

A Computer!



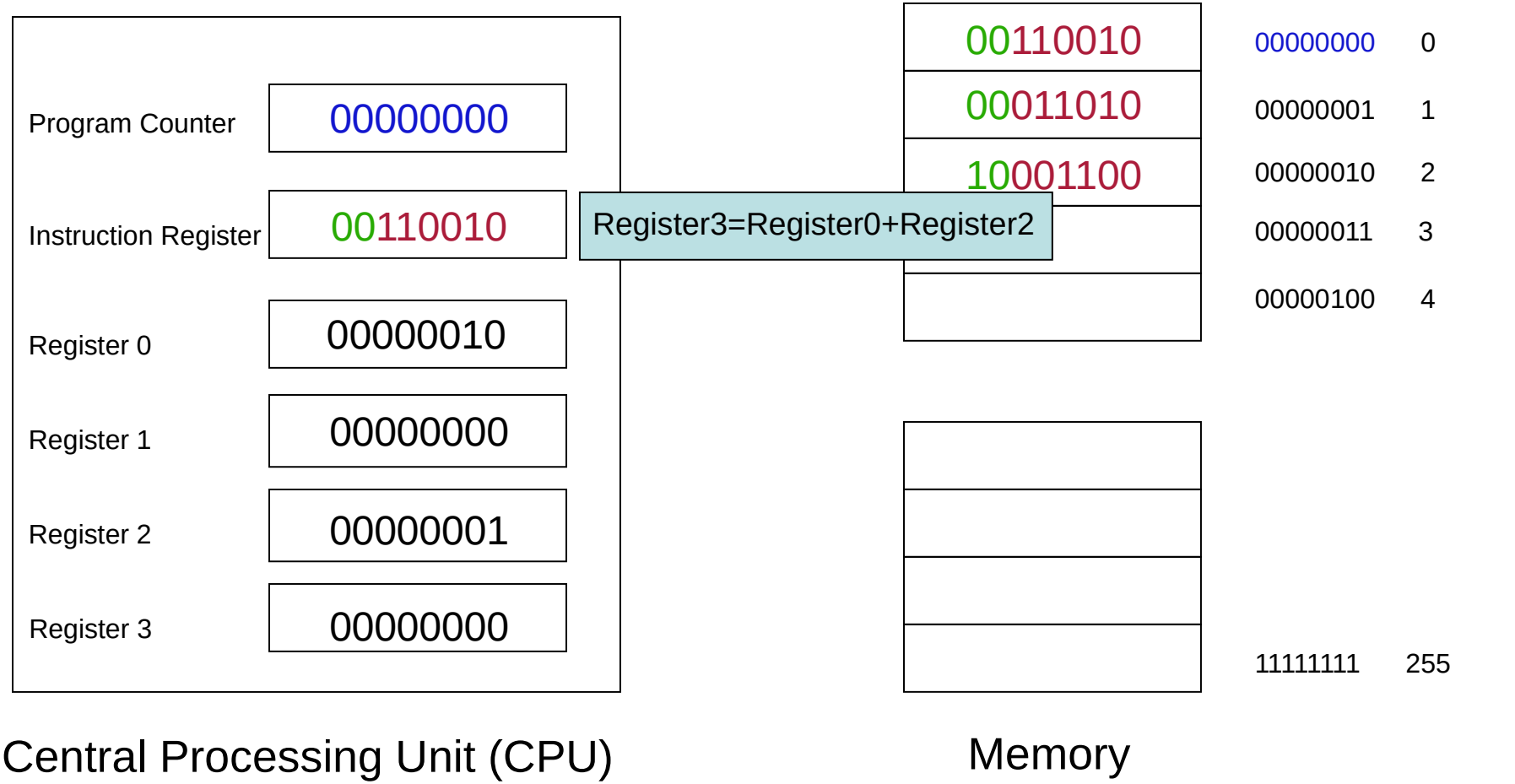
Central Processing Unit (CPU)



Memory

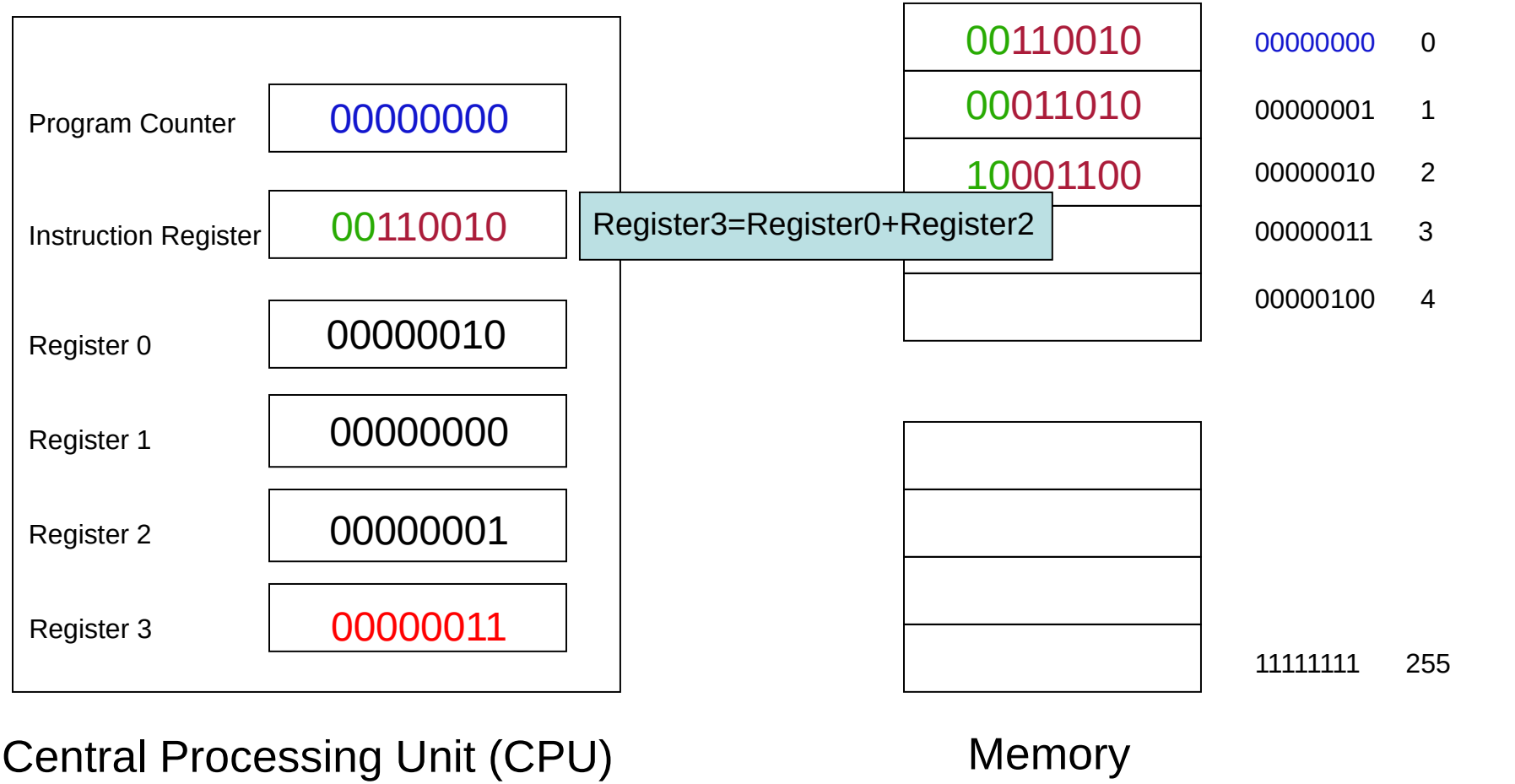
A Computer!

00	add
01	subtract
10	multiply
11	divide



A Computer!

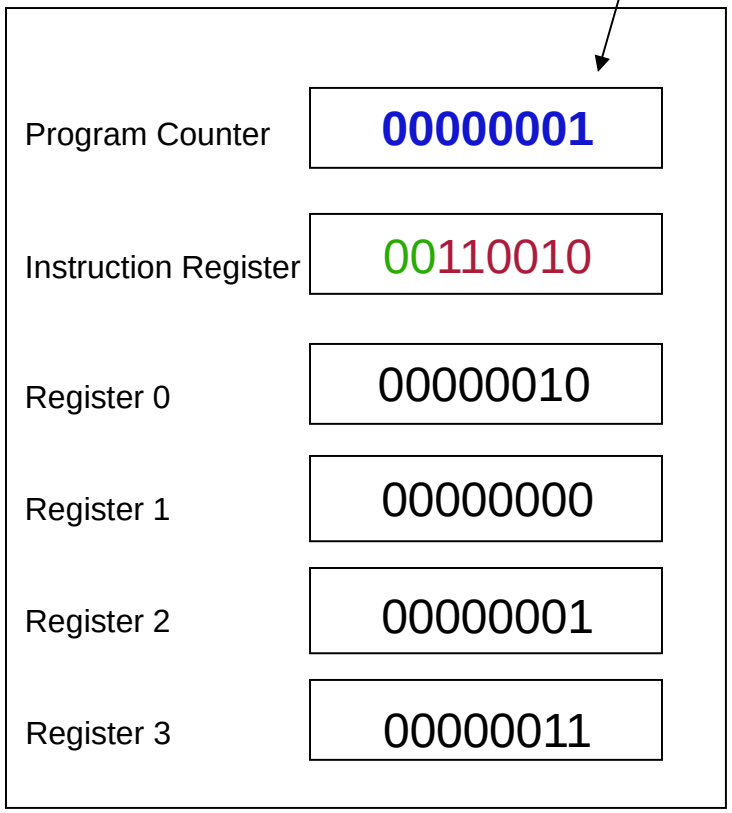
00	add
01	subtract
10	multiply
11	divide



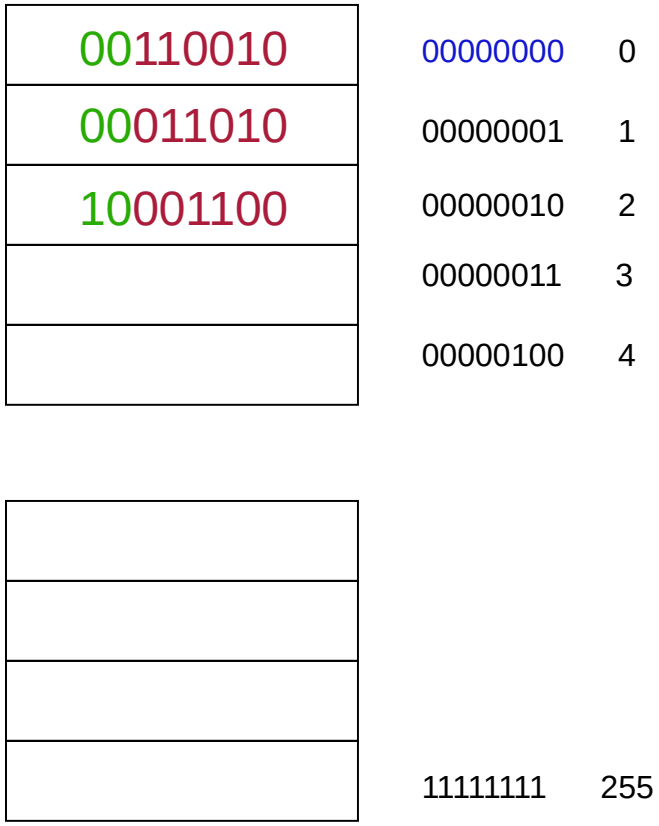
00	add
01	subtract
10	multiply
11	divide

A Computer!

Program Counter Incremented



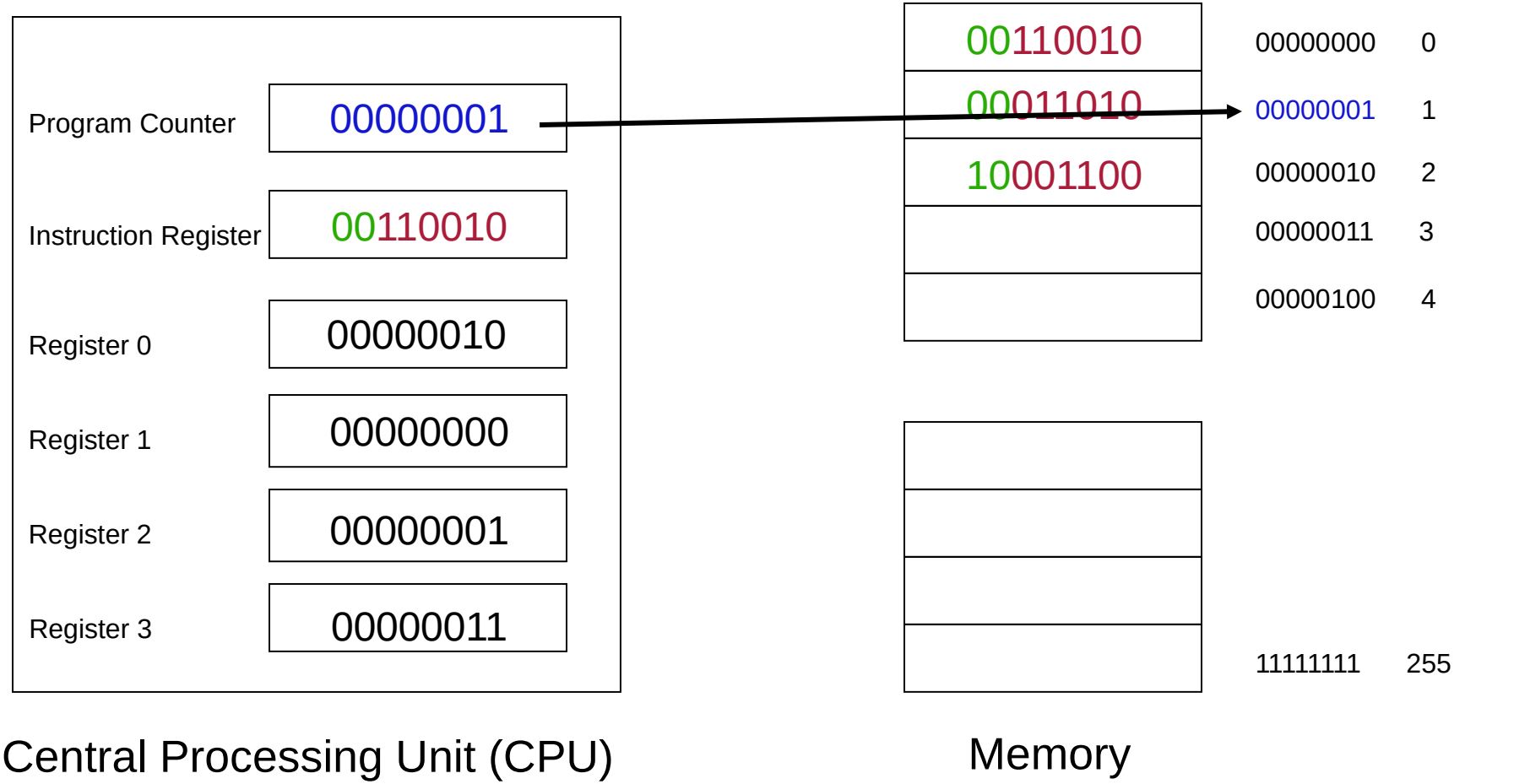
Central Processing Unit (CPU)



Memory

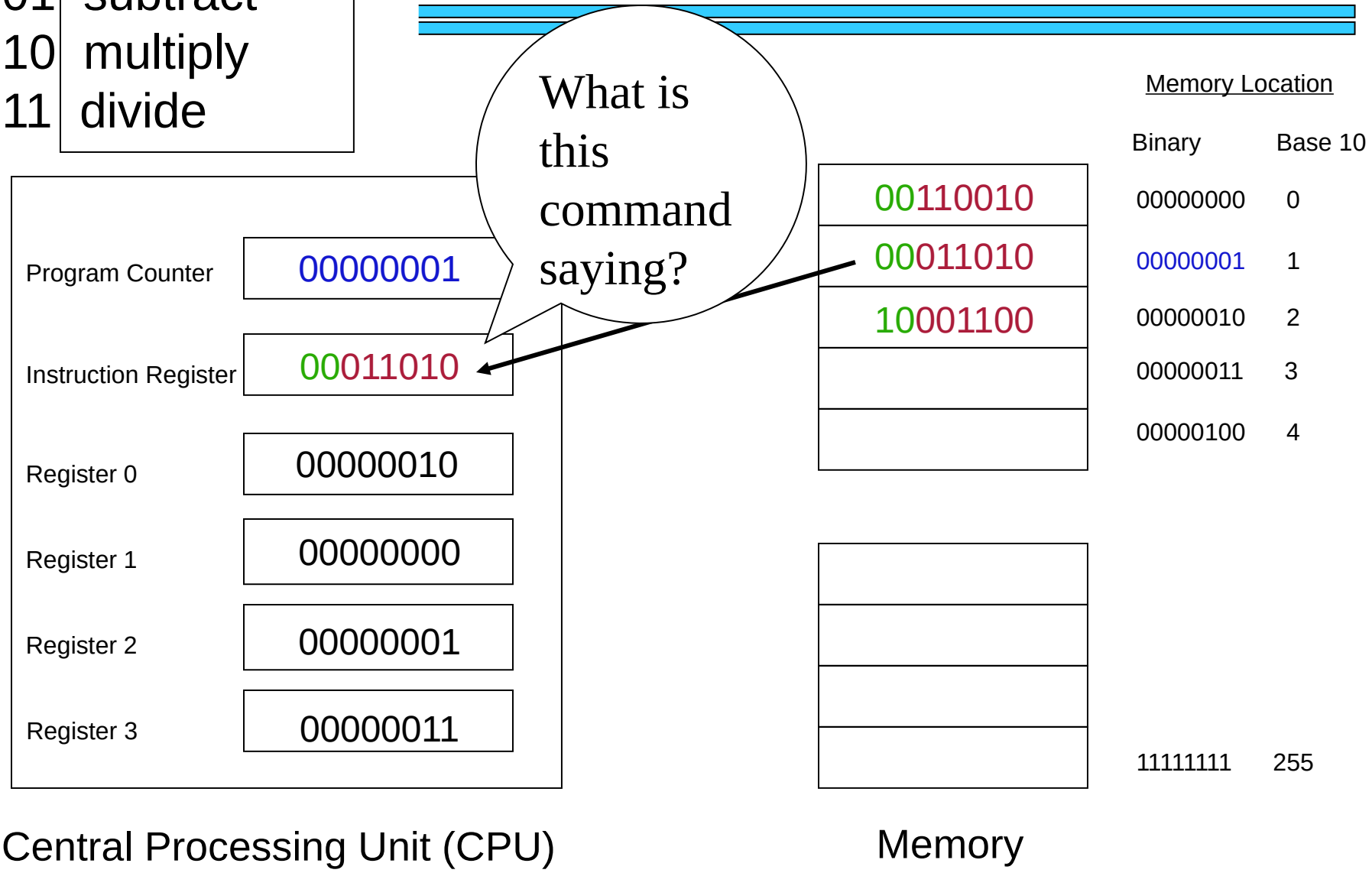
00	add
01	subtract
10	multiply
11	divide

A Computer!



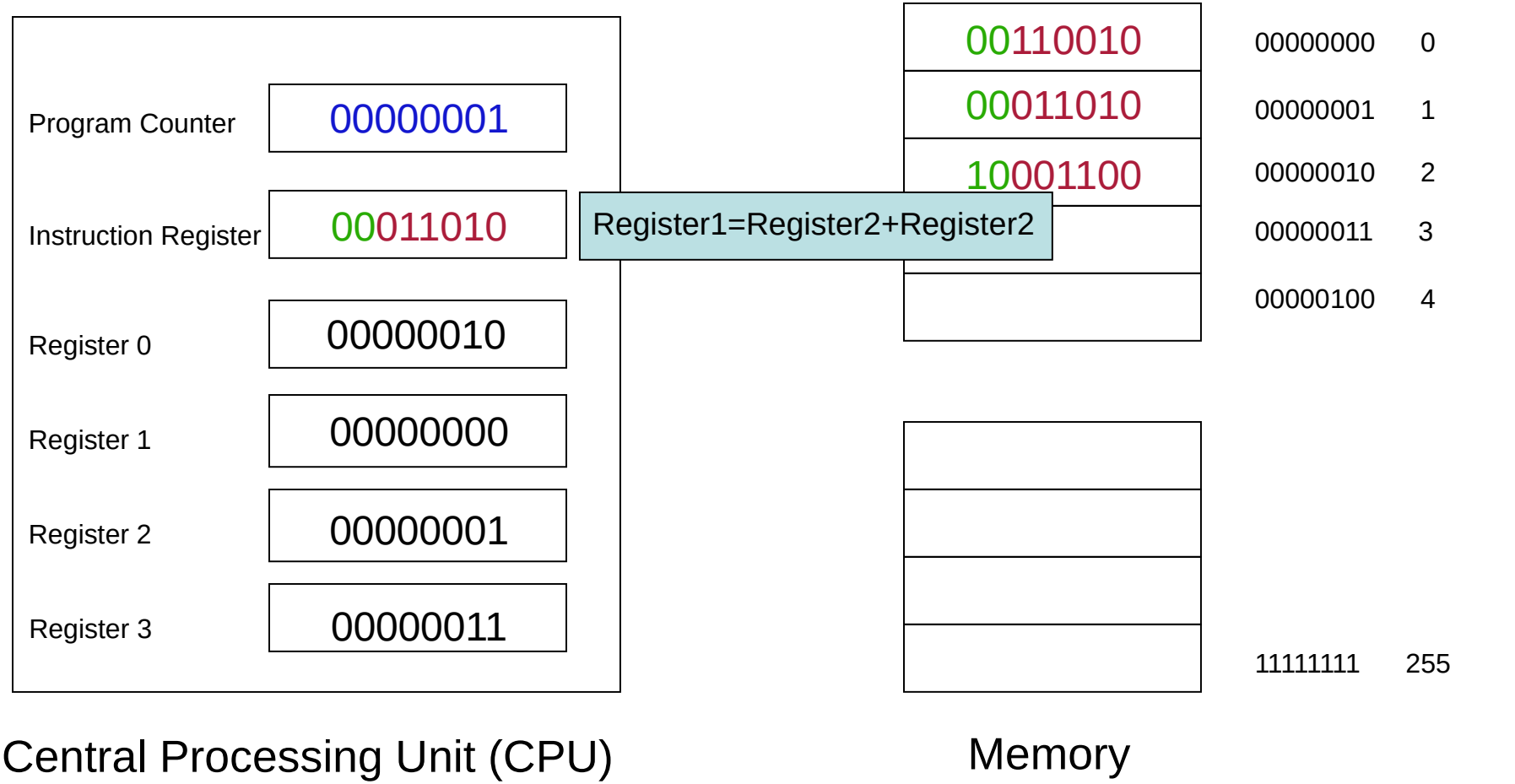
A Computer!

00	add
01	subtract
10	multiply
11	divide



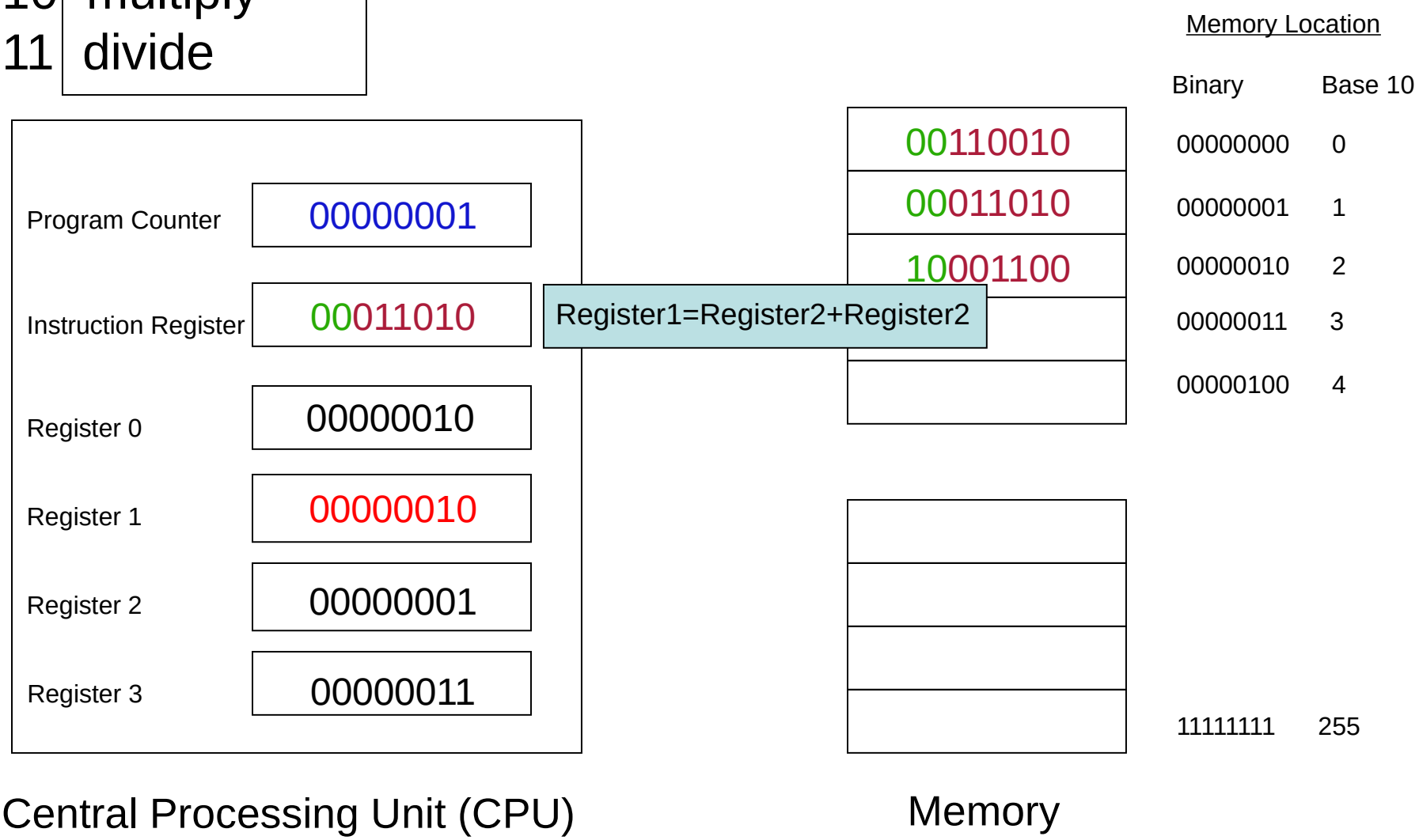
A Computer!

00	add
01	subtract
10	multiply
11	divide



00	add
01	subtract
10	multiply
11	divide

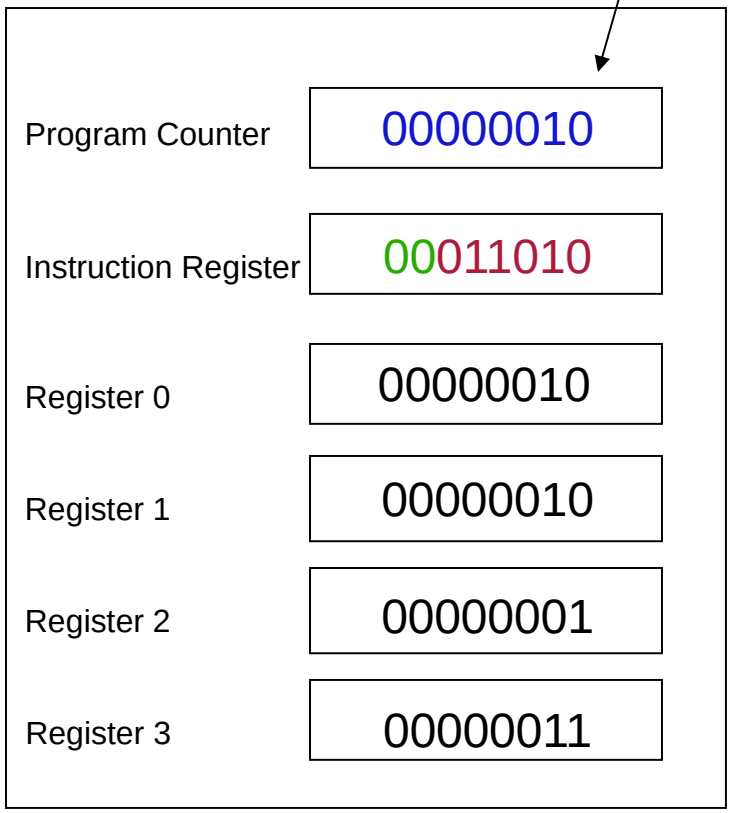
A Computer!



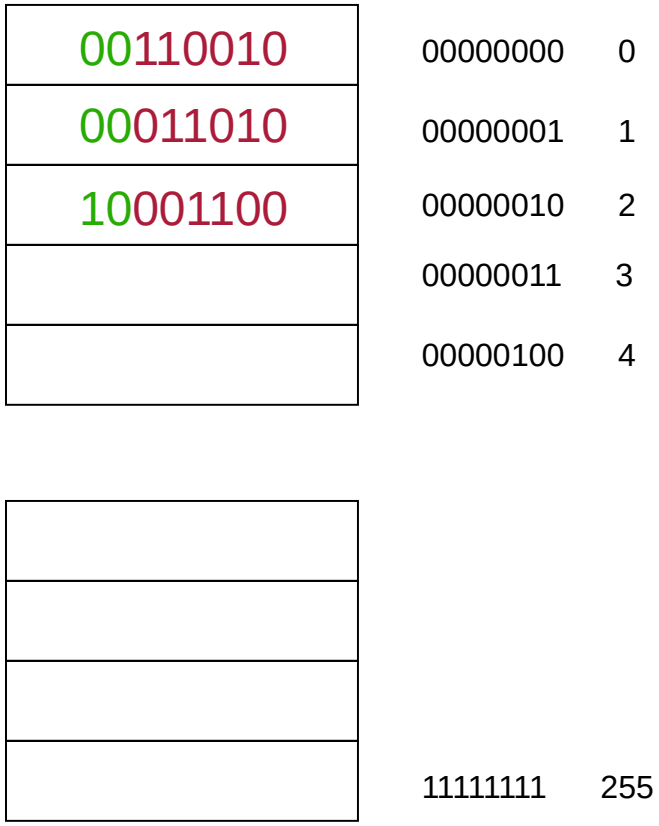
A Computer!

00	add
01	subtract
10	multiply
11	divide

Program Counter Incremented



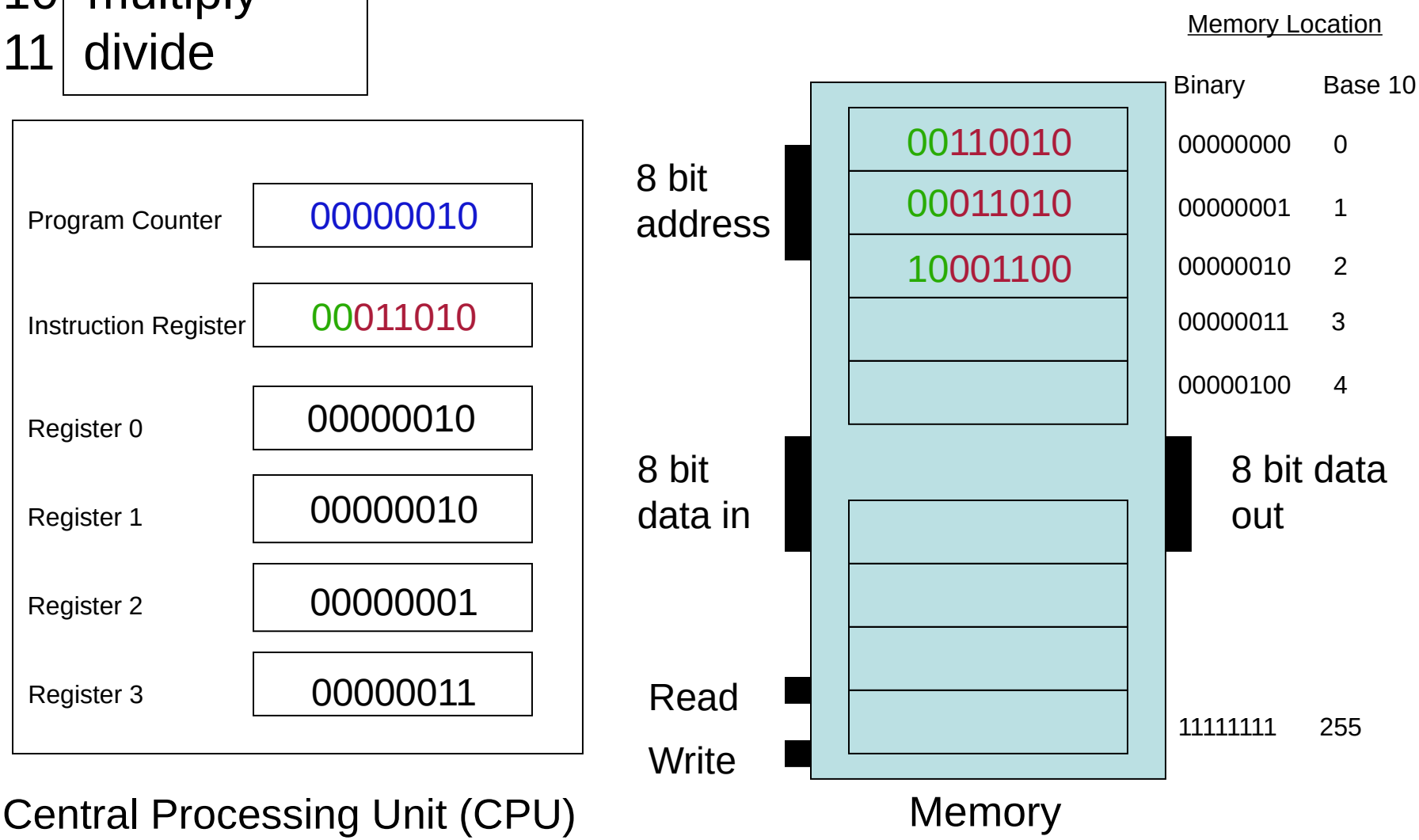
Central Processing Unit (CPU)



Memory

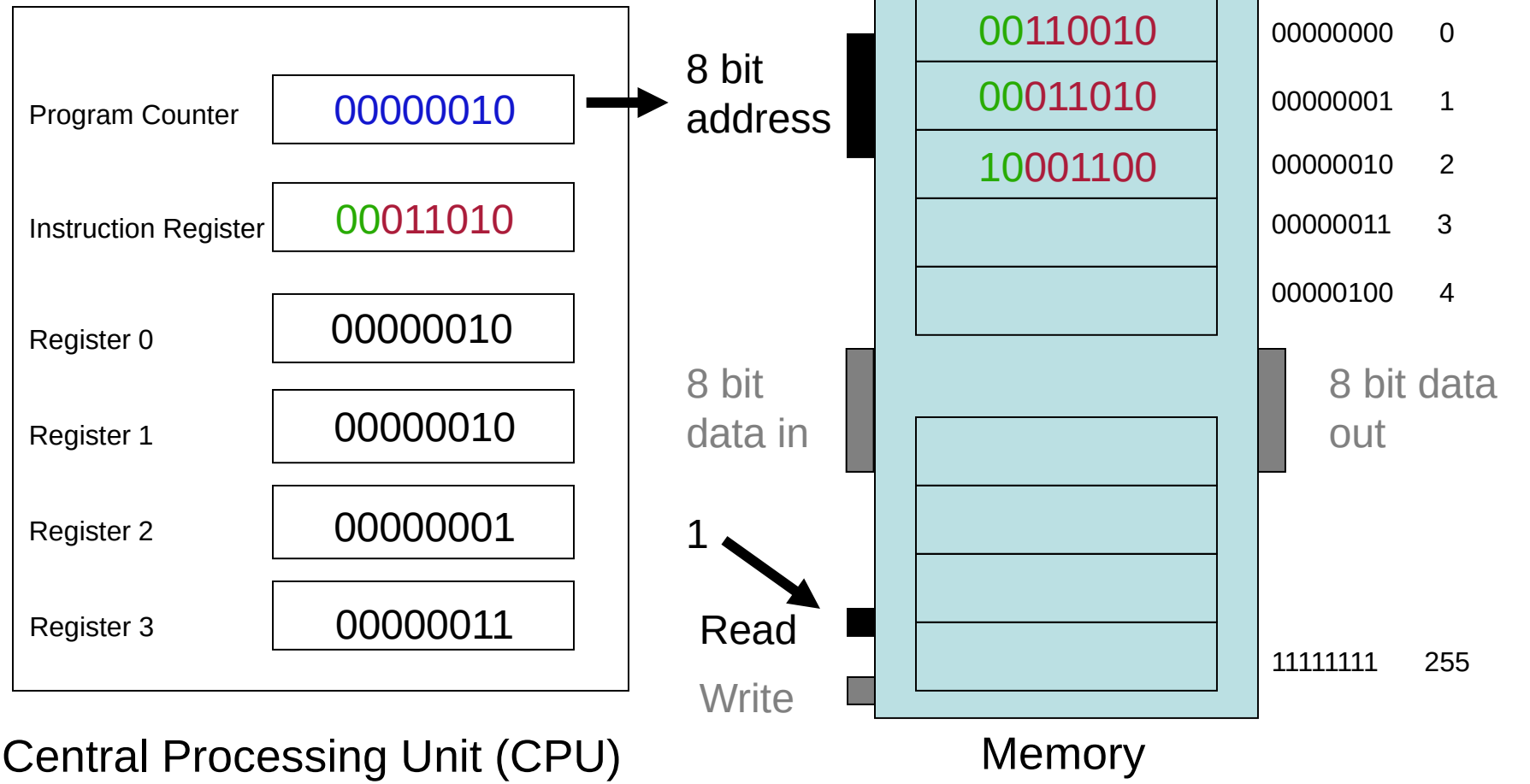
00	add
01	subtract
10	multiply
11	divide

A Computer!



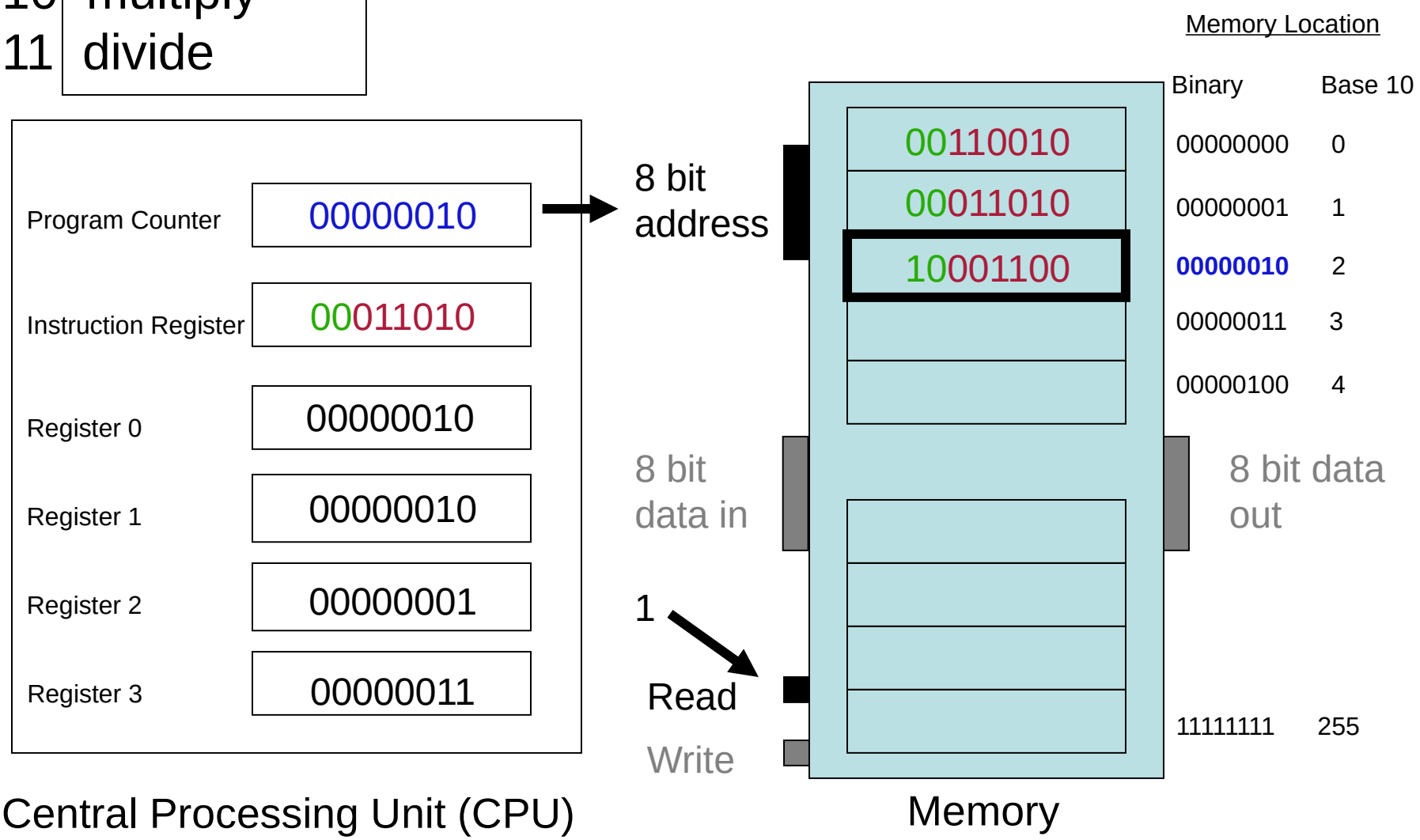
A Computer!

00	add
01	subtract
10	multiply
11	divide



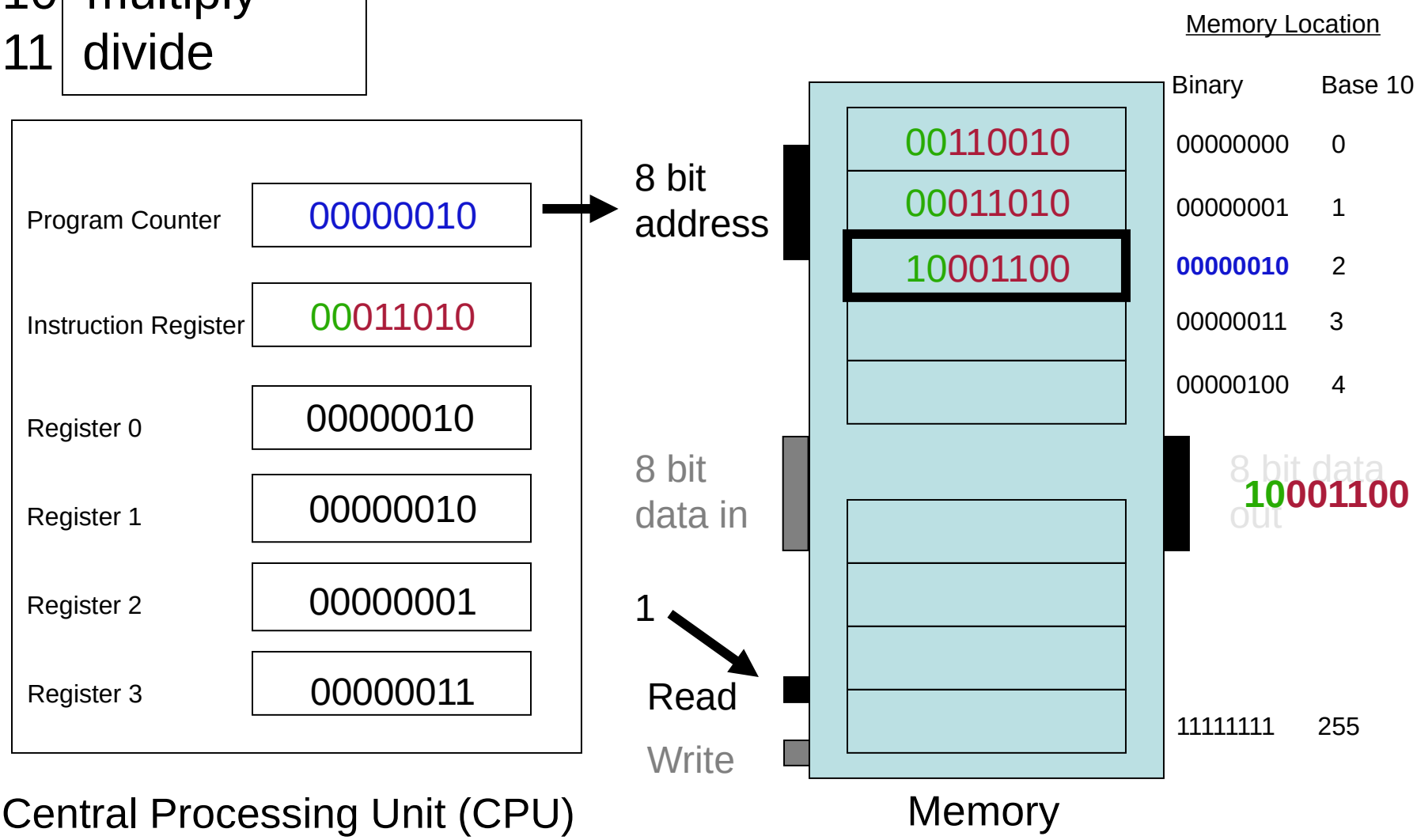
00	add
01	subtract
10	multiply
11	divide

A Computer!



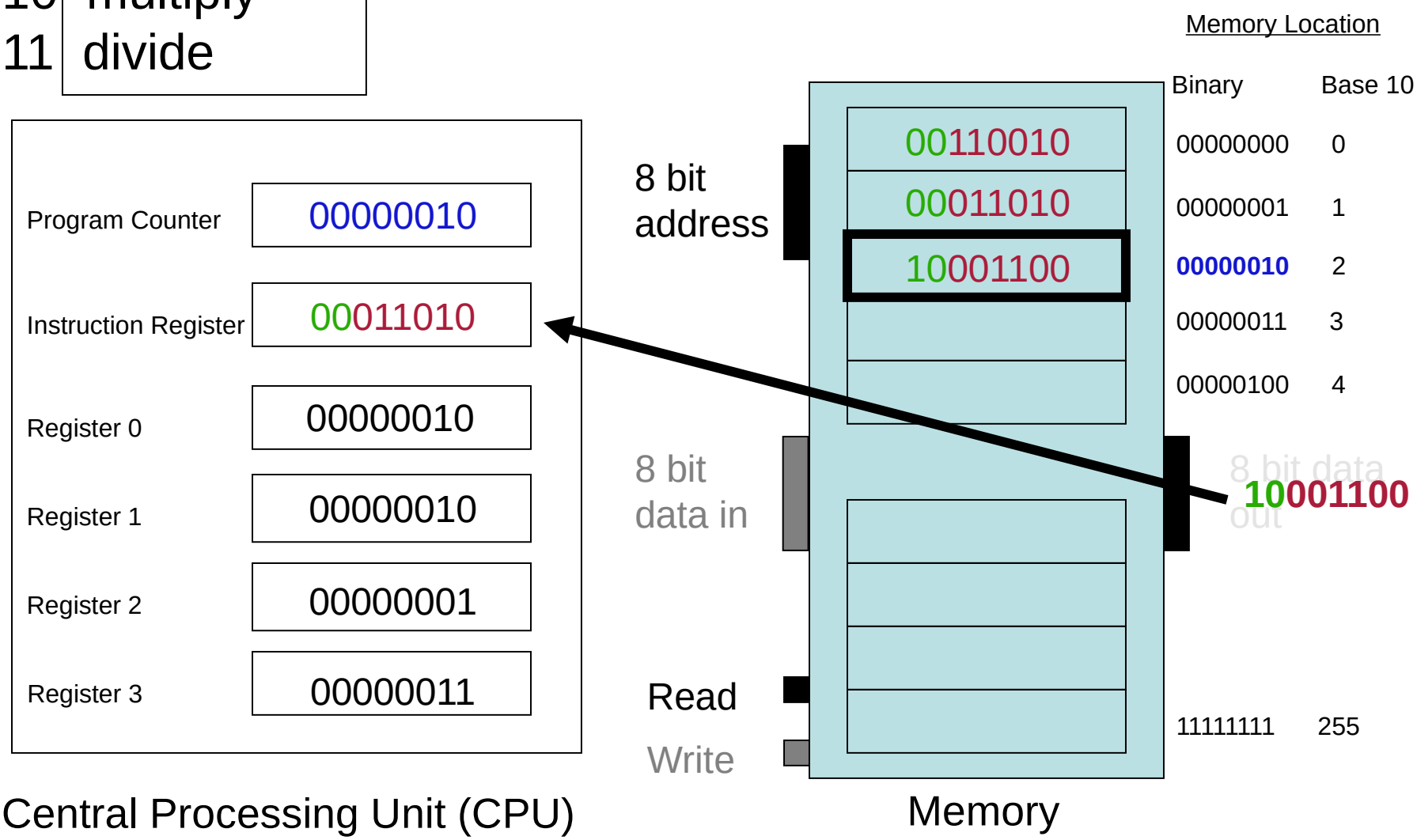
A Computer!

00	add
01	subtract
10	multiply
11	divide



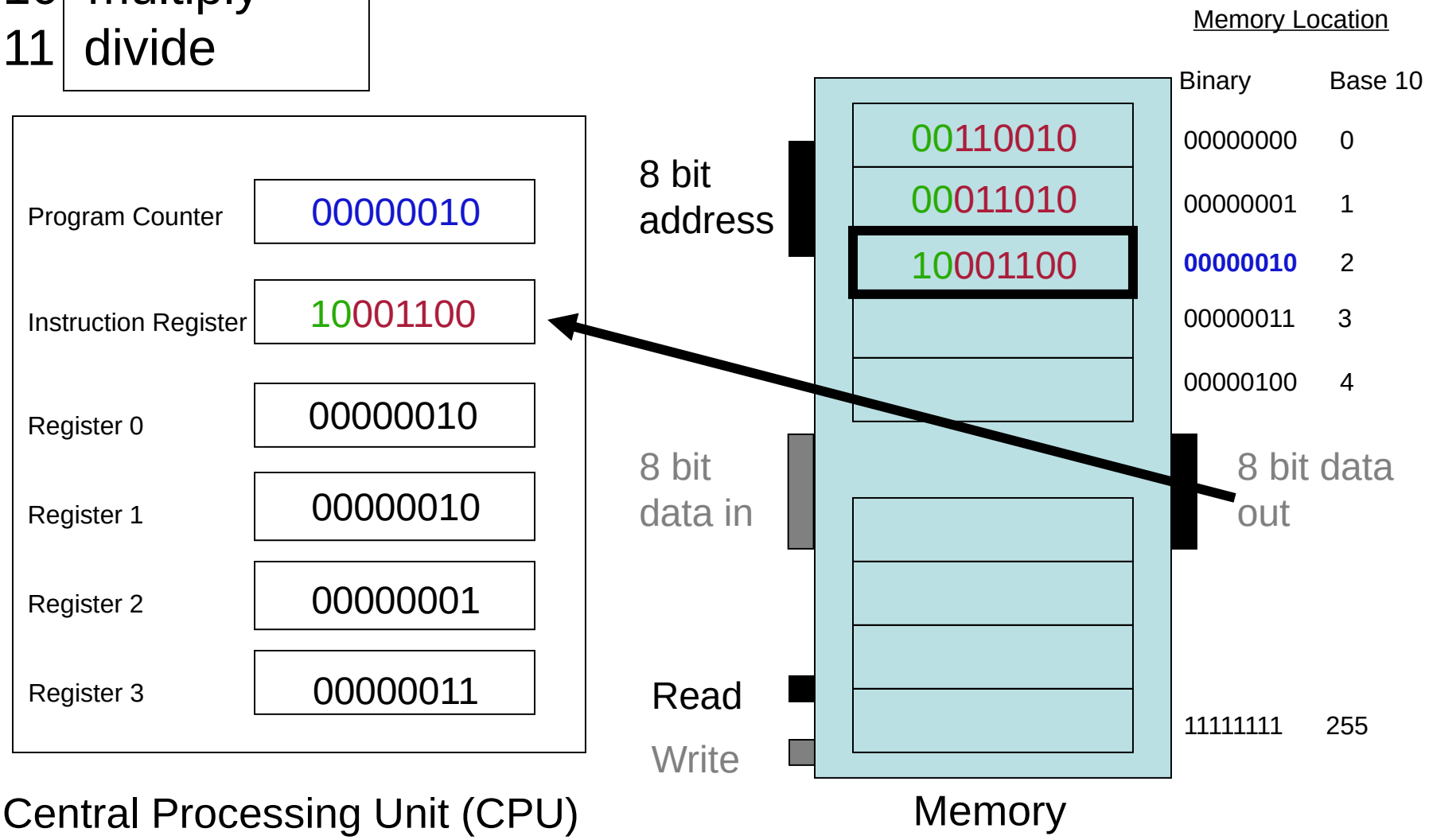
A Computer!

00	add
01	subtract
10	multiply
11	divide



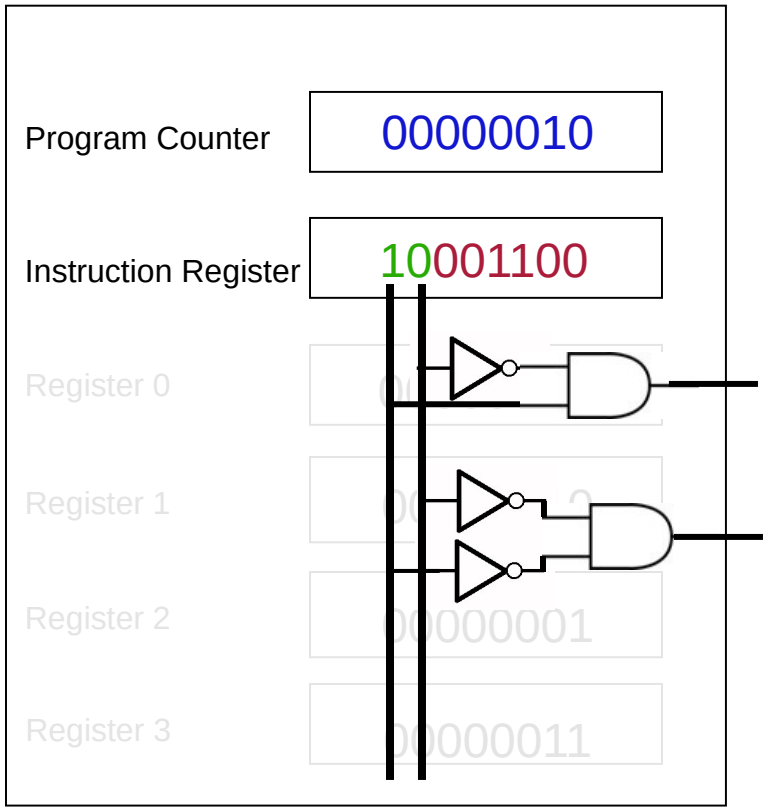
00 add
01 subtract
10 multiply
11 divide

A Computer!

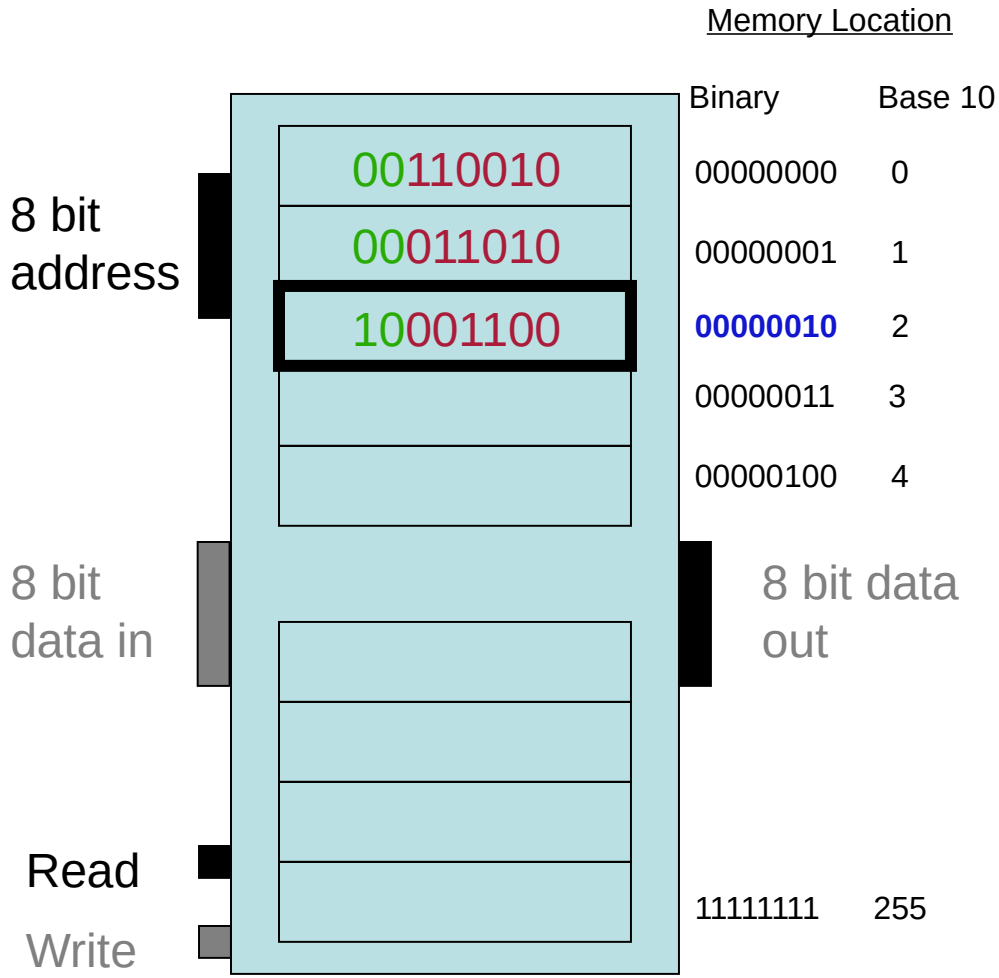


00 add
01 subtract
10 multiply
11 divide

A Computer!



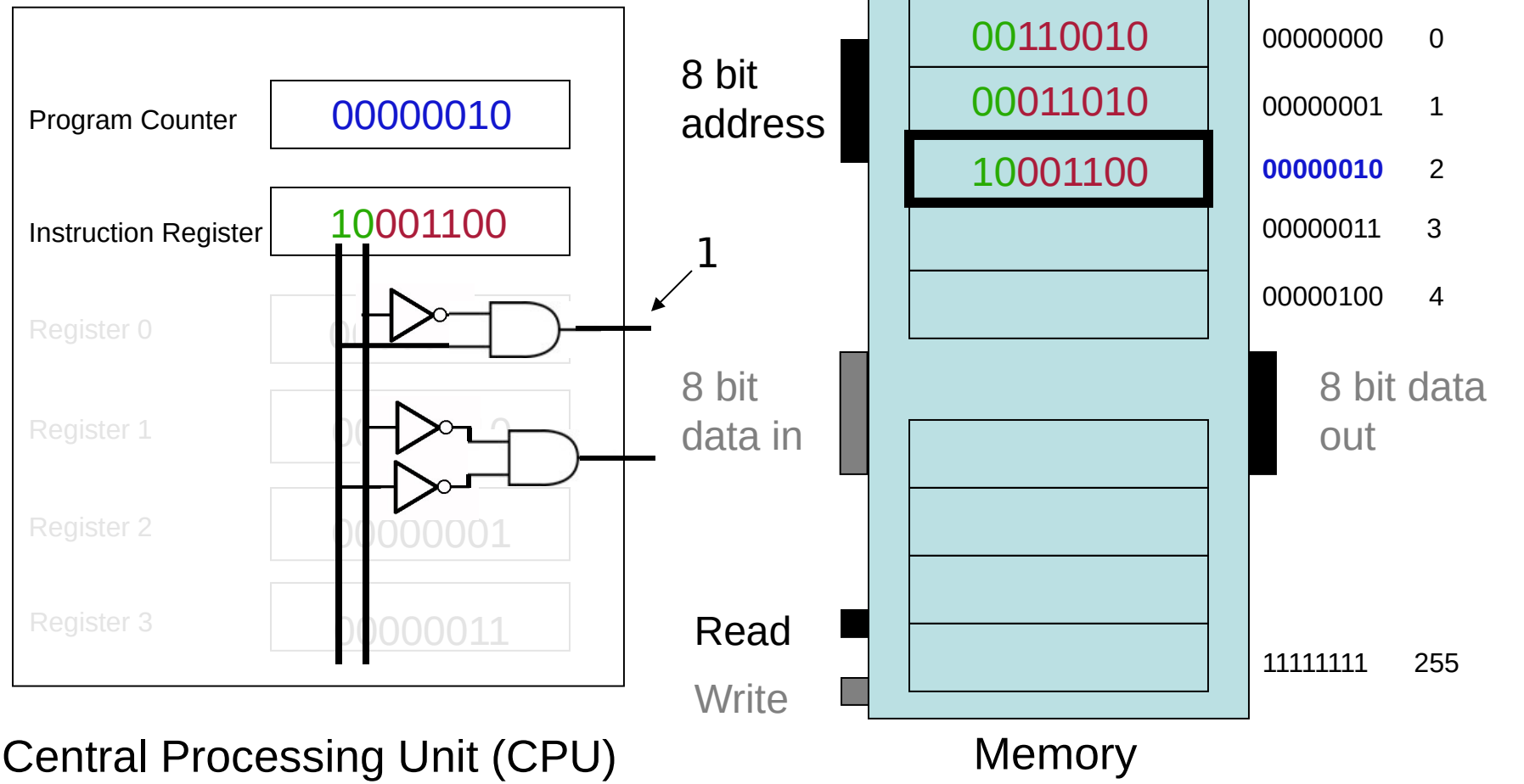
Central Processing Unit (CPU)



Memory

A Computer!

00	add
01	subtract
10	multiply
11	divide

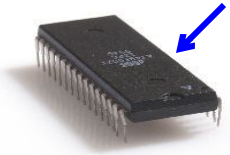


The von Neumann “Architecture”

John von Neumann

Ripple-carry adder
Multiplier,
Registers, etc.

Lots of latches!



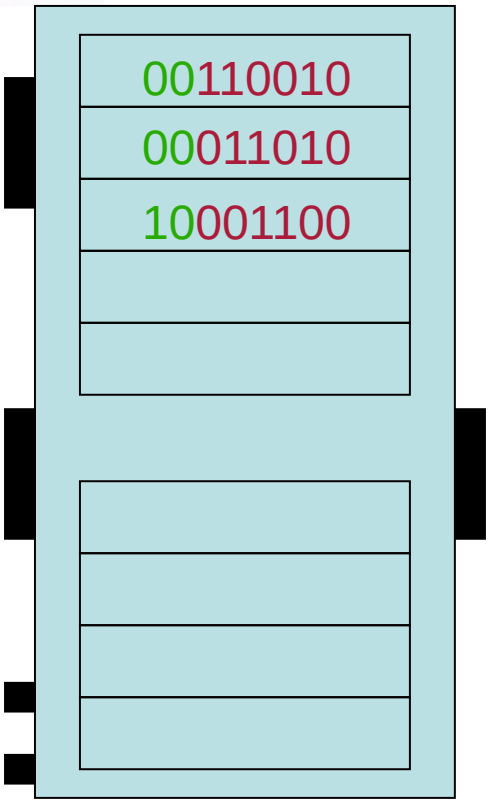
CPU

central processing unit

RAM

random access memory

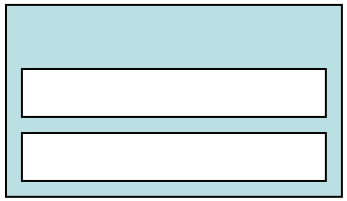
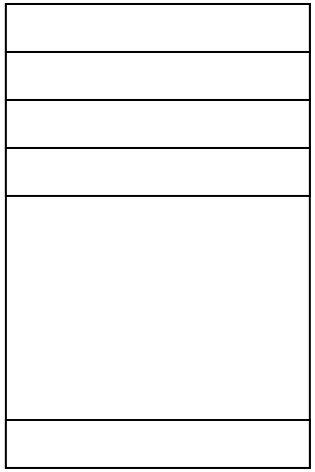
A few fast registers



Large but slow memory

2006
Intel Core 2 Duo
3 GHz clock
64-bit processor
291 million transistors
65 nm wires

A Short Aside…

	CPU	Main Memory (RAM)	Disk Drive
			
	16 Registers (“Bytes”)	10^9 “Bytes” of memory	10^{12} “Bytes” of memory
	1 cycle	200 cycles	? cycles
Actual time:	$<10^{-9}$ sec	$<10^{-7}$ sec	$<10^{-2}$ sec
If “cycle” = 1 sec	1 sec		