Last Time

- Storing information
- D flip-flops
- Sequential circuits

Flip-Flop Notes

- Means of storing 'bits' of data
- Have now seen two circuits that operate on sets of 'bits' (or binary numbers)
  - Counter
  - Shift register
    - What arithmetic operation does shifting perform?
- These are examples of operations that are performed by the "Arithmetic Logical Unit"

Today

- Microprocessor Basics

- (getting ready to program microcontrollers)

Components of a Microprocessor

Components of a Microprocessor

- Memory:
  - Storage of data
  - Storage of a program
  - Either can be temporary or “permanent” storage
- Registers: small, fast memories
  - General purpose: store arbitrary data
  - Special purpose: used to control the processor

Components of a Microprocessor

- Instruction decoder:
  - Translates current program instruction into a set of control signals
- Arithmetic logical unit:
  - Performs both arithmetic and logical operations on data
- Input/output control modules

Components of a Microprocessor

- Many of these components must exchange data with one-another
- It is common to use a ‘bus’ for this exchange

Buses

- In the simplest form, it is a single wire
- Many different components can be attached to the bus
- Any component can take input from the bus

Buses

- At most one component may write to the bus at any one time
- Which component is allowed to write is usually determined by the instruction decoder (in the microprocessor case)

Collections of Bits

- 8 bits: a “byte”
- 4 bits: a “nybble”

- “words”: can be 8, 16, or 32 bits (depending on the processor)

Collections of Bits

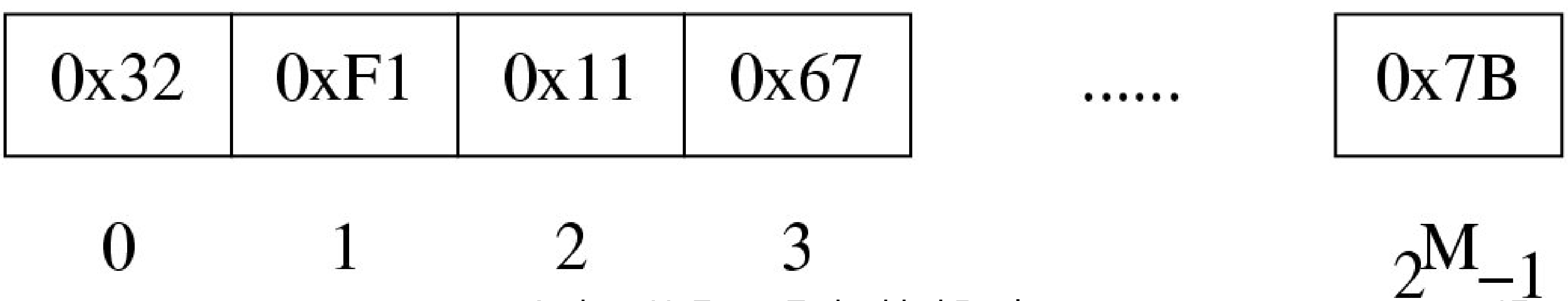
- A data bus typically captures a set of bits simultaneously
- Need one wire for each of these bits
- In the Atmel Mega8: the data bus is 8-bits "wide"
- In your home machines: 32 or 64 bits

Memory

What are the essential components of a memory?

A Memory Abstraction

- We think of memory as an array of elements – each with its own address
- Each element contains a value
  - It is most common for the values to by 8-bits wide (so a byte)



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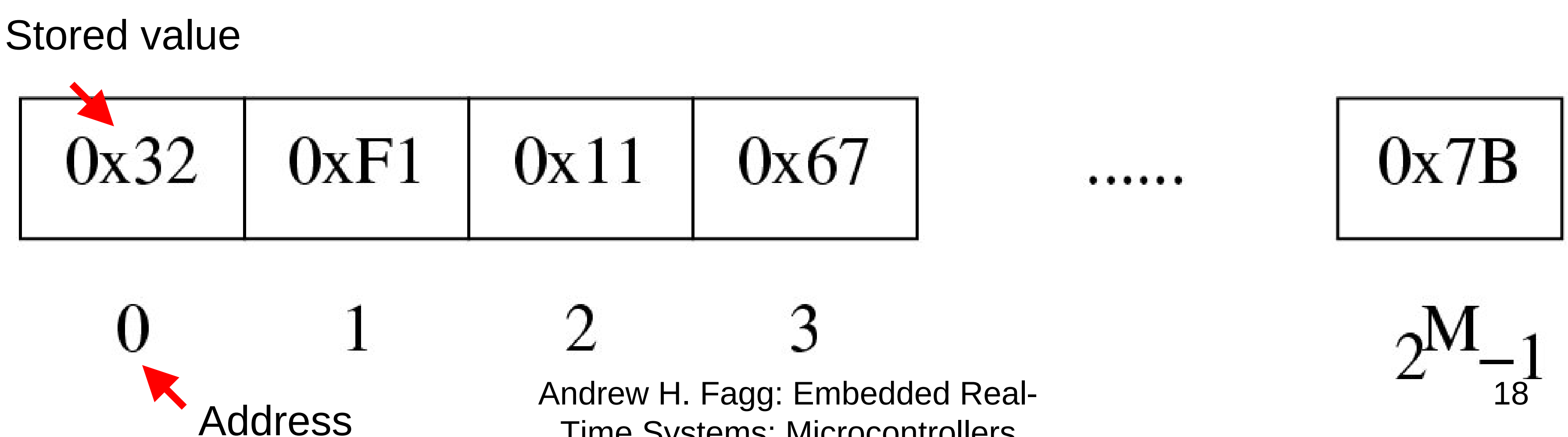


Memory Operations

Read

```
foo(A+5);
```

reads the value from the memory location referenced by the variable ‘A’ and adds the value to 5. The result is passed to a function called `foo();`

Memory Operations

Write

```
A = 5;
```

writes the value 5 into the memory location referenced by ‘A’

Types of Memory

Random Access Memory (RAM)

- Computer can change state of this memory at any time
- Once power is lost, we lose the contents of the memory

- This will be our data storage on our microcontrollers

Types of Memory

Read Only Memory (ROM)

- Computer **cannot** arbitrarily change state of this memory
- When power is lost, the contents are maintained

Types of Memory

Erasable/Programmable ROM (EPROM)

- State can be changed under very specific conditions (usually not when connected to a computer)

- Our microcontrollers have an Electrically Erasable/Programmable ROM (EEPROM) for program storage

Example: A Read/Write Memory Module

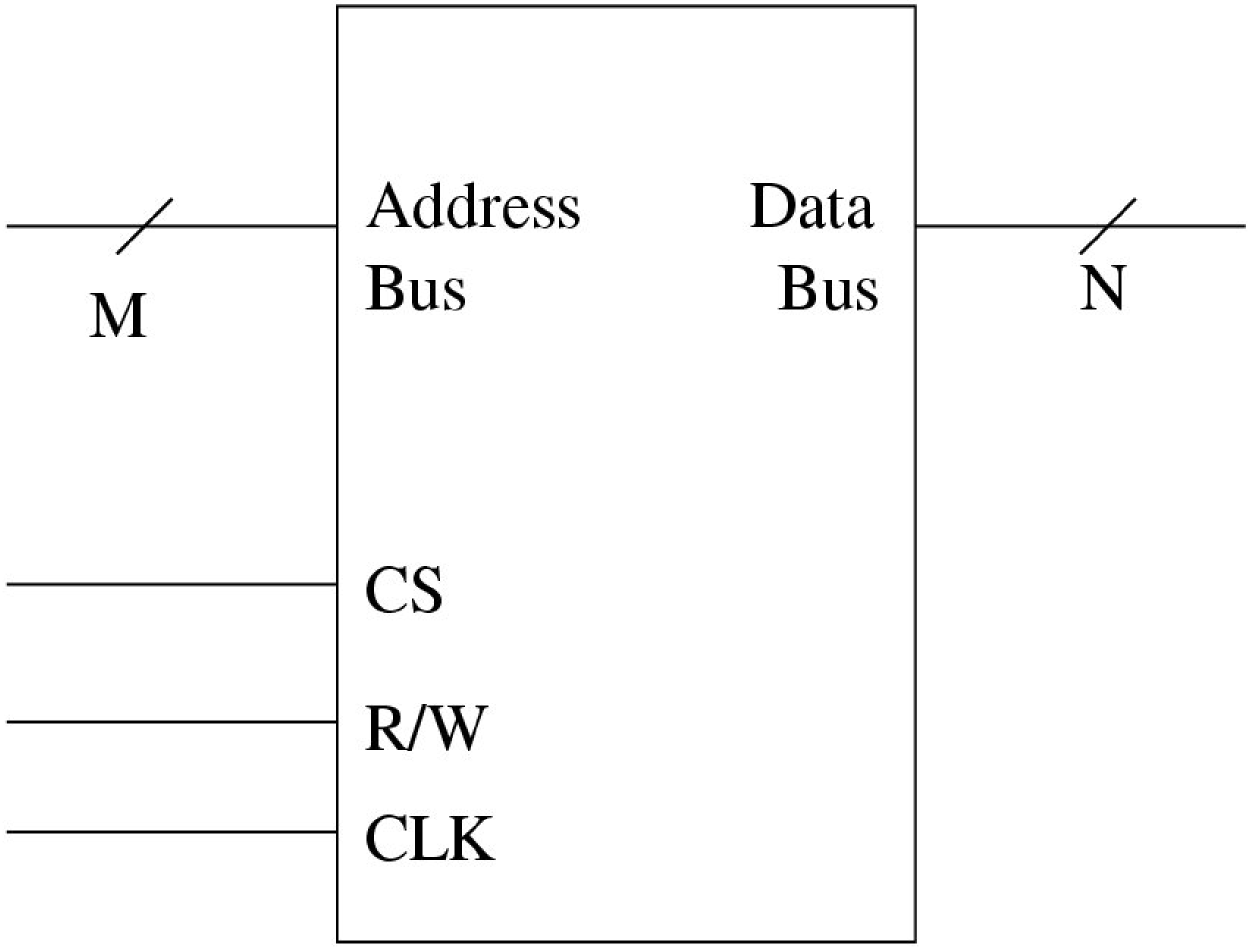
Inputs:

- 2 Address bits: A0 and A1
- 1 “chip select” (CS) bit
- 1 read/write bit (1 = read; 0 = write)
- 1 clock signal (CLK)

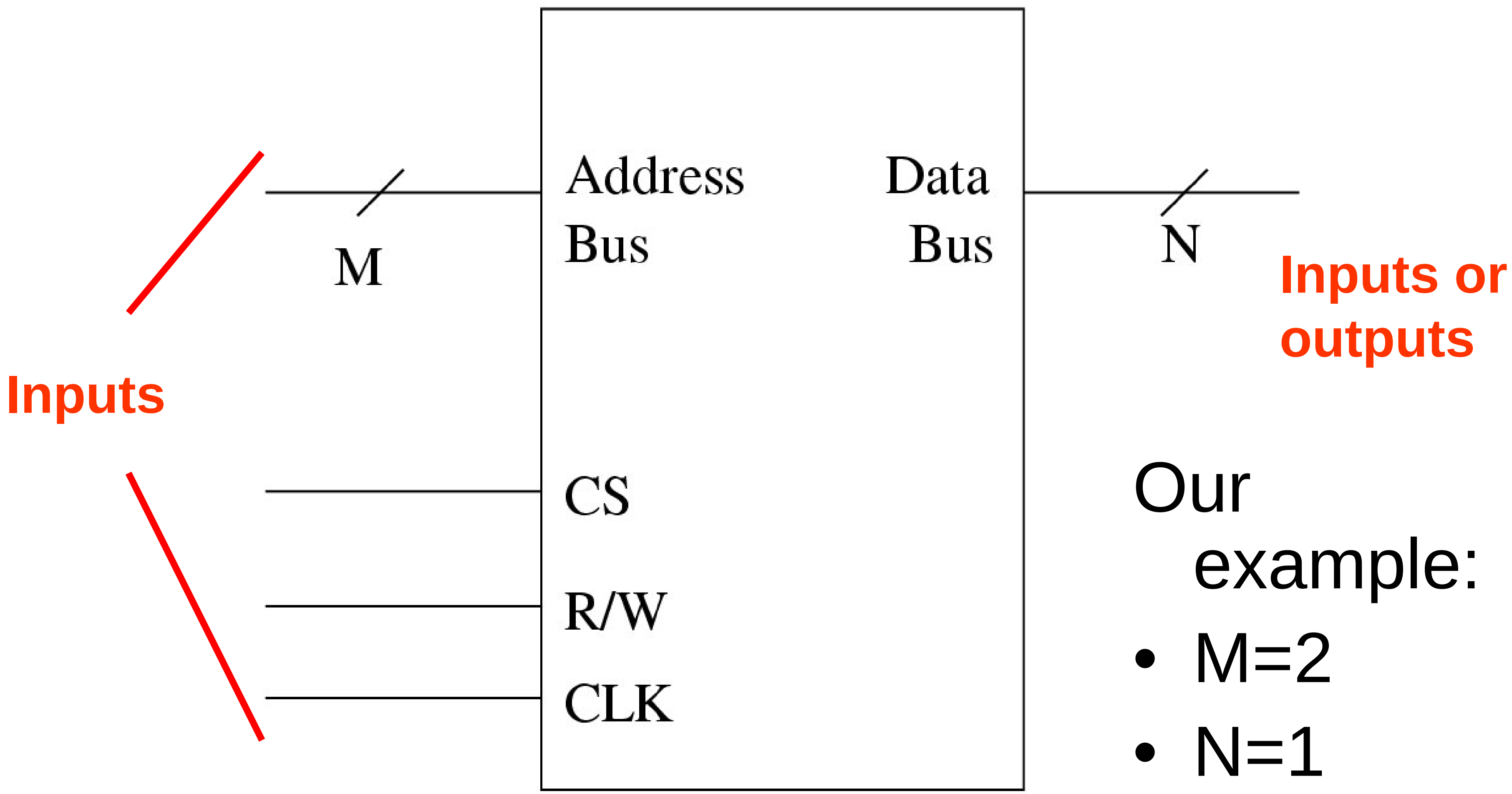
Input or Output:

- Data bit (connected to the “data bus”)

A Read/Write Memory Module



A Read/Write Memory Module



Our example:

- M=2
- N=1

Implementing A Read/Write Memory Module

With 2 address bits, how many memory elements can we address?

How could we implement each memory element?

Implementing A Read/Write Memory Module

With 2 address bits, how many memory elements can we address?

- 4 1-bit elements

How could we implement each memory element?

- With a D flip-flop

Memory Module Specification

“chip select” signal:

- Allows us to have multiple devices (e.g., memory modules) that can write to the bus
- But: only one device will ever be selected at one time

Memory Module Specification

When chip select is low:

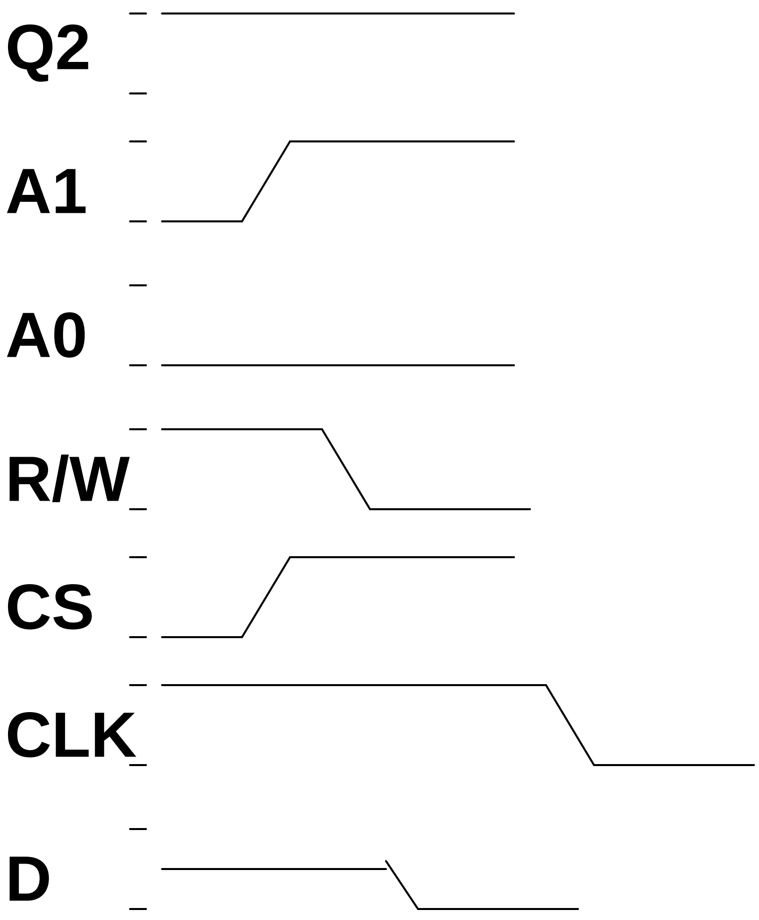
- No memory elements change state
- The memory does not drive the data bus

Memory Module Specification

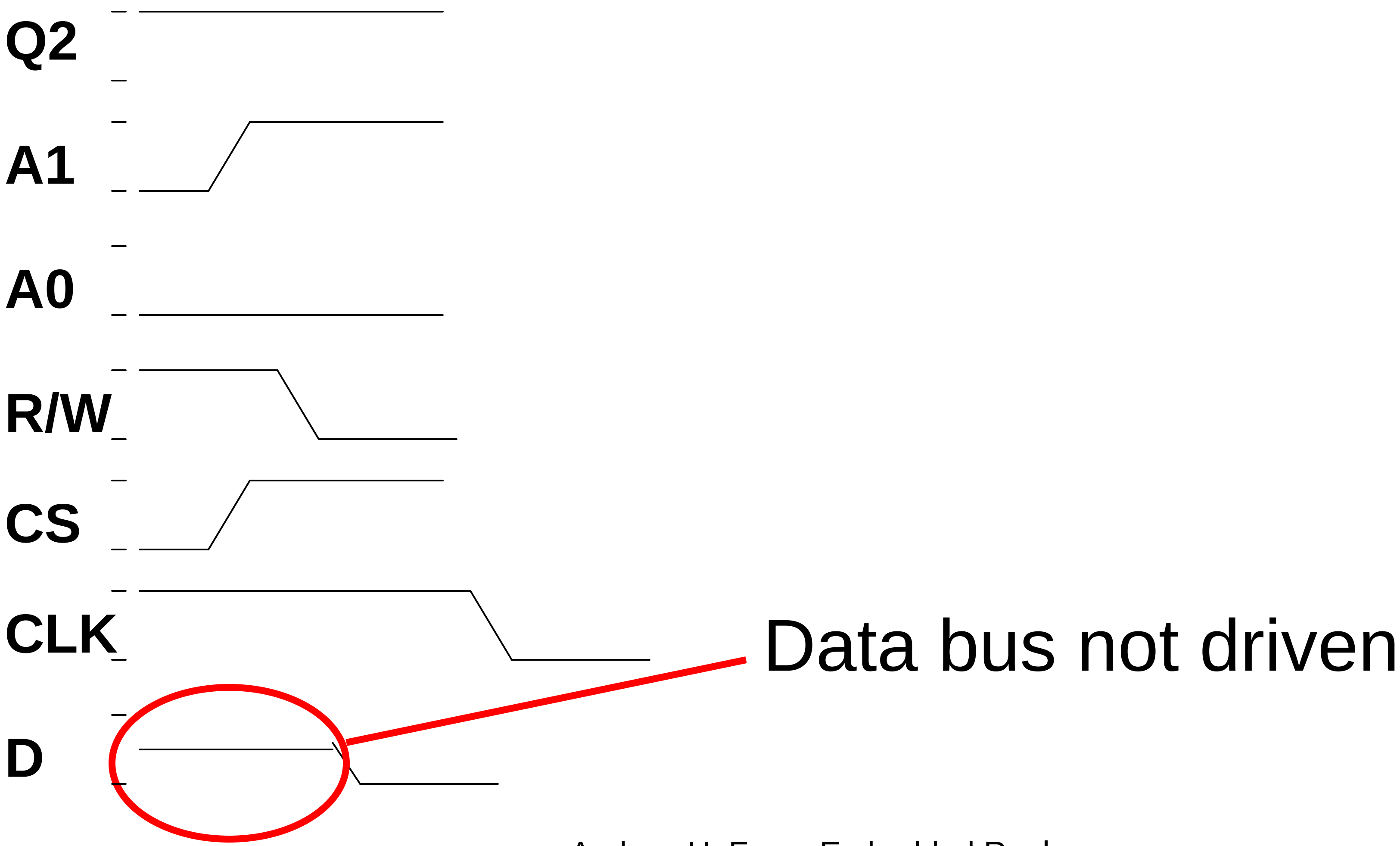
When chip select is high:

- If R/W is high:
  - Drive the data bus with the value that is stored in the element specified by A1, A0
- If R/W is low:
  - Store the value that is on the data bus in the element specified by A1, A0

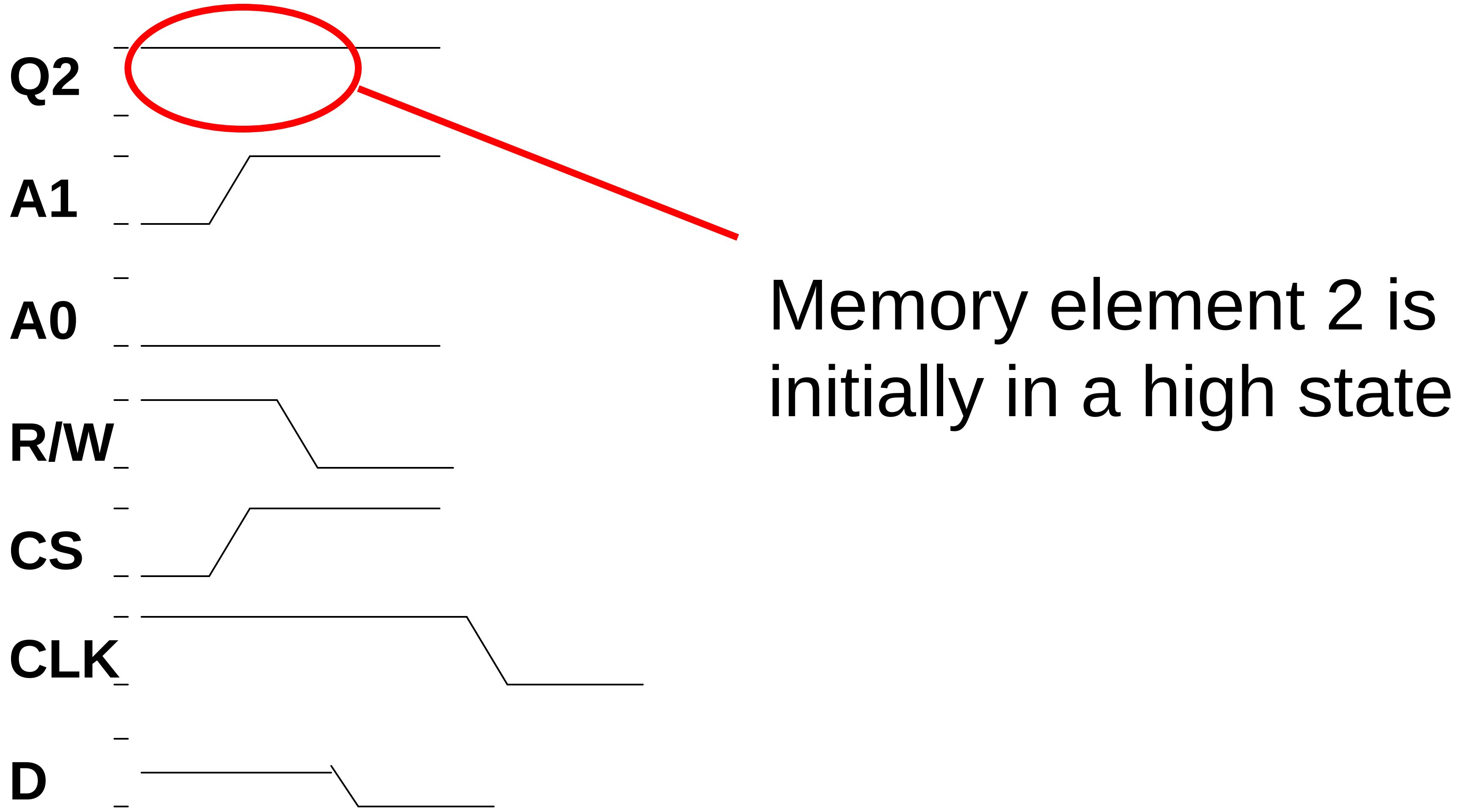
Memory Timing Diagram



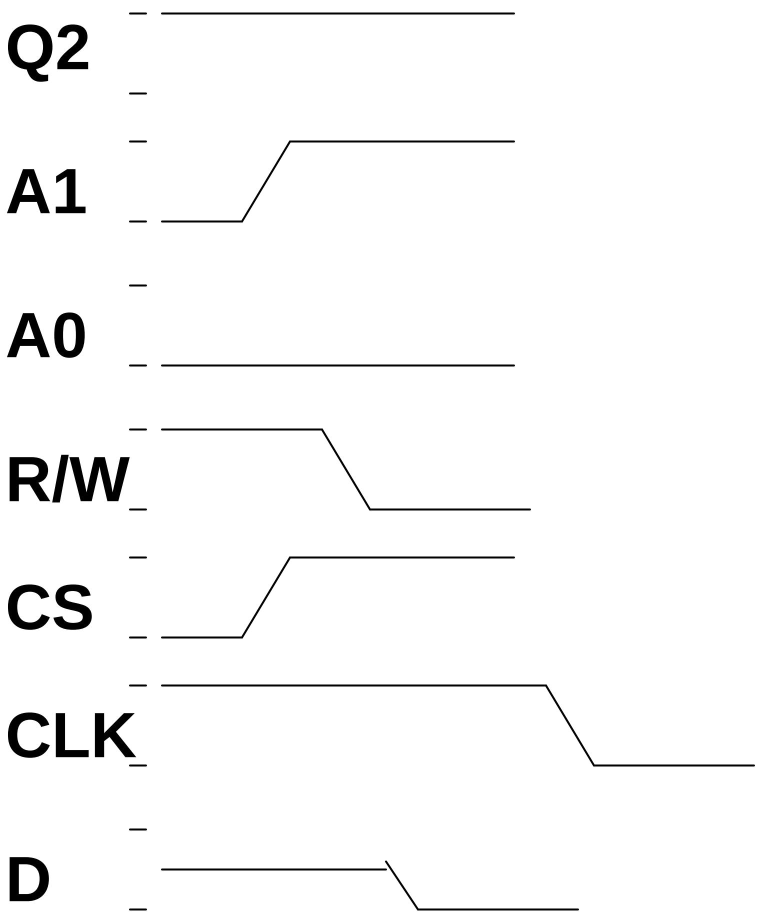
Memory Timing Diagram



Memory Timing Diagram

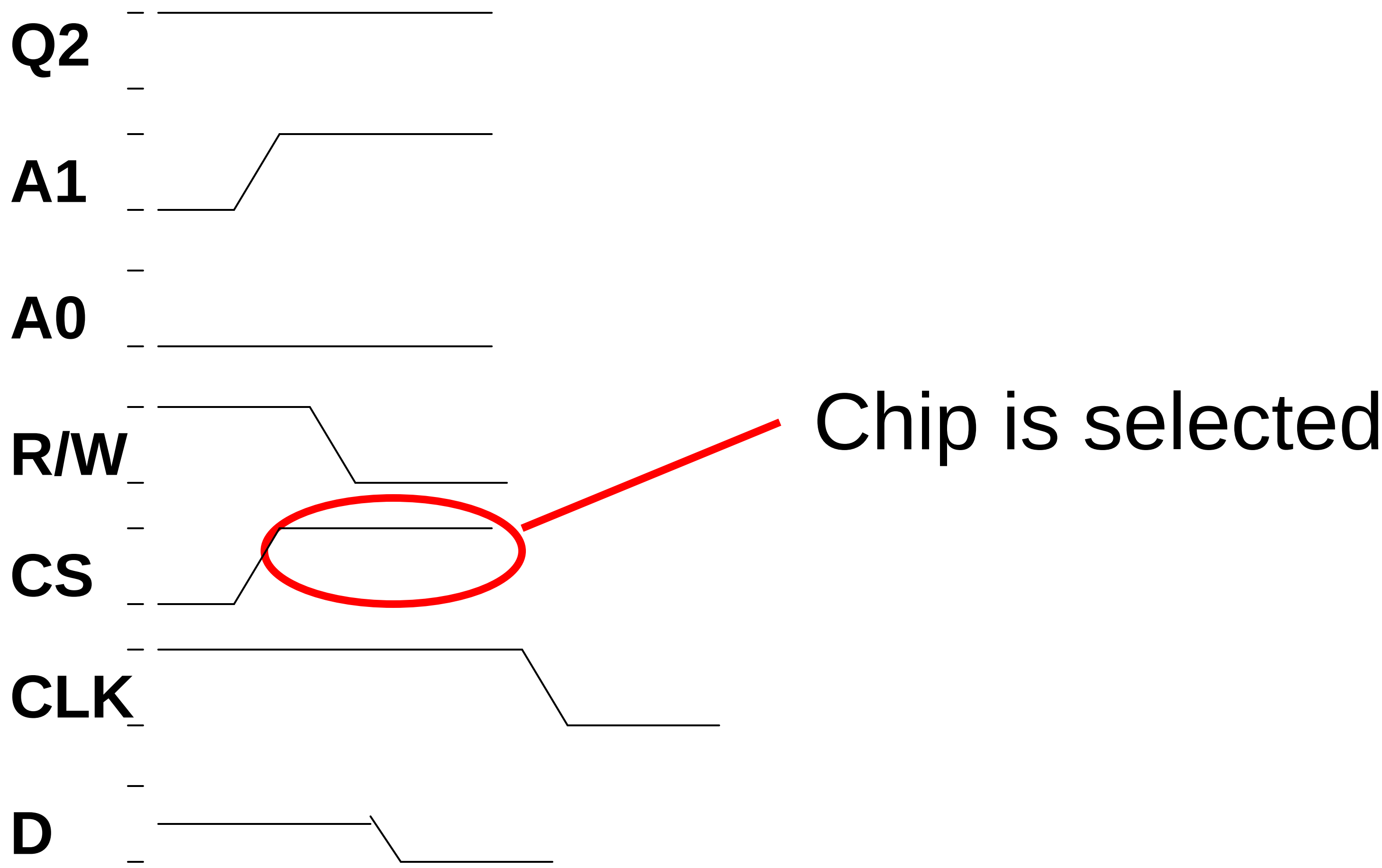


Memory Timing Diagram

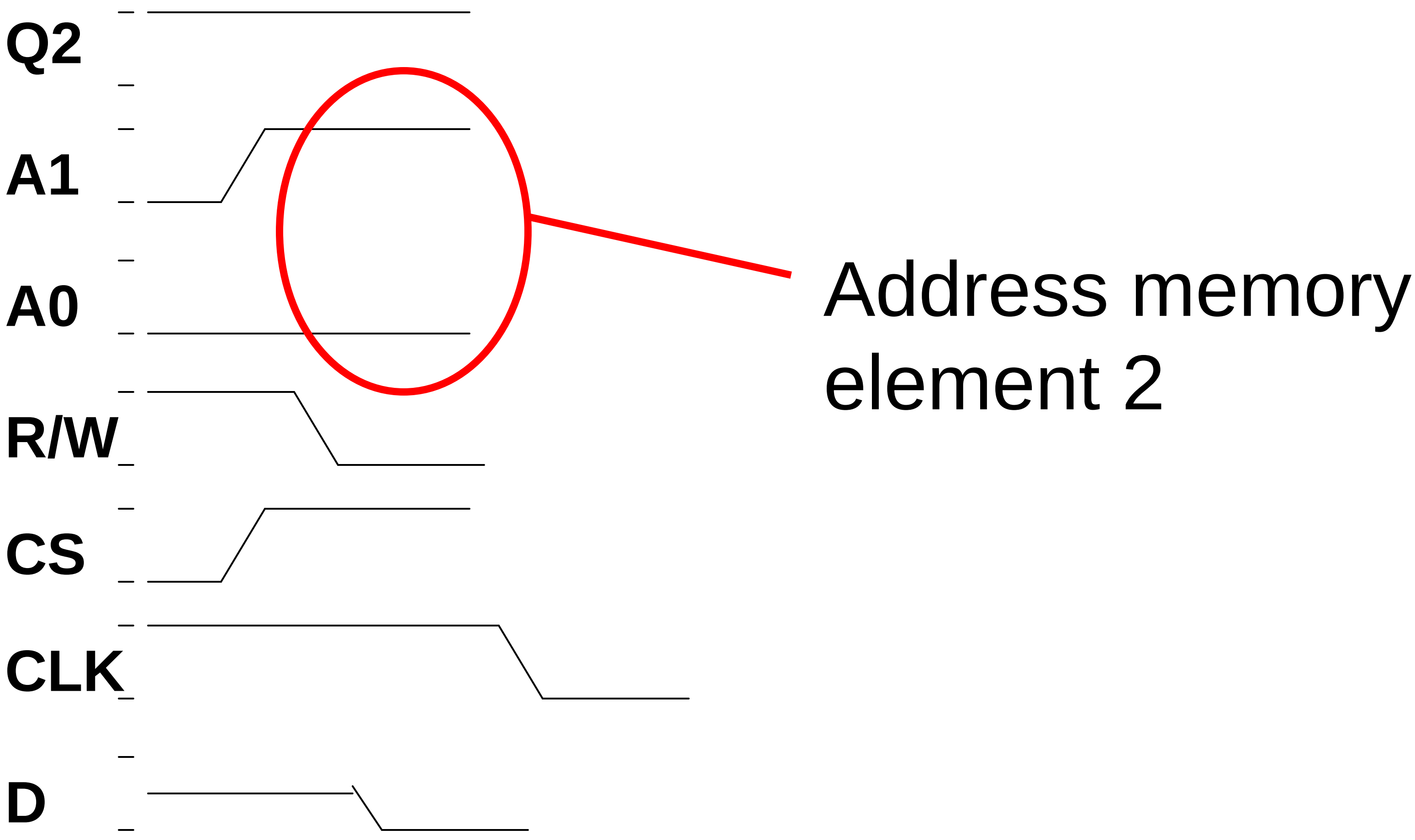


What happens next?

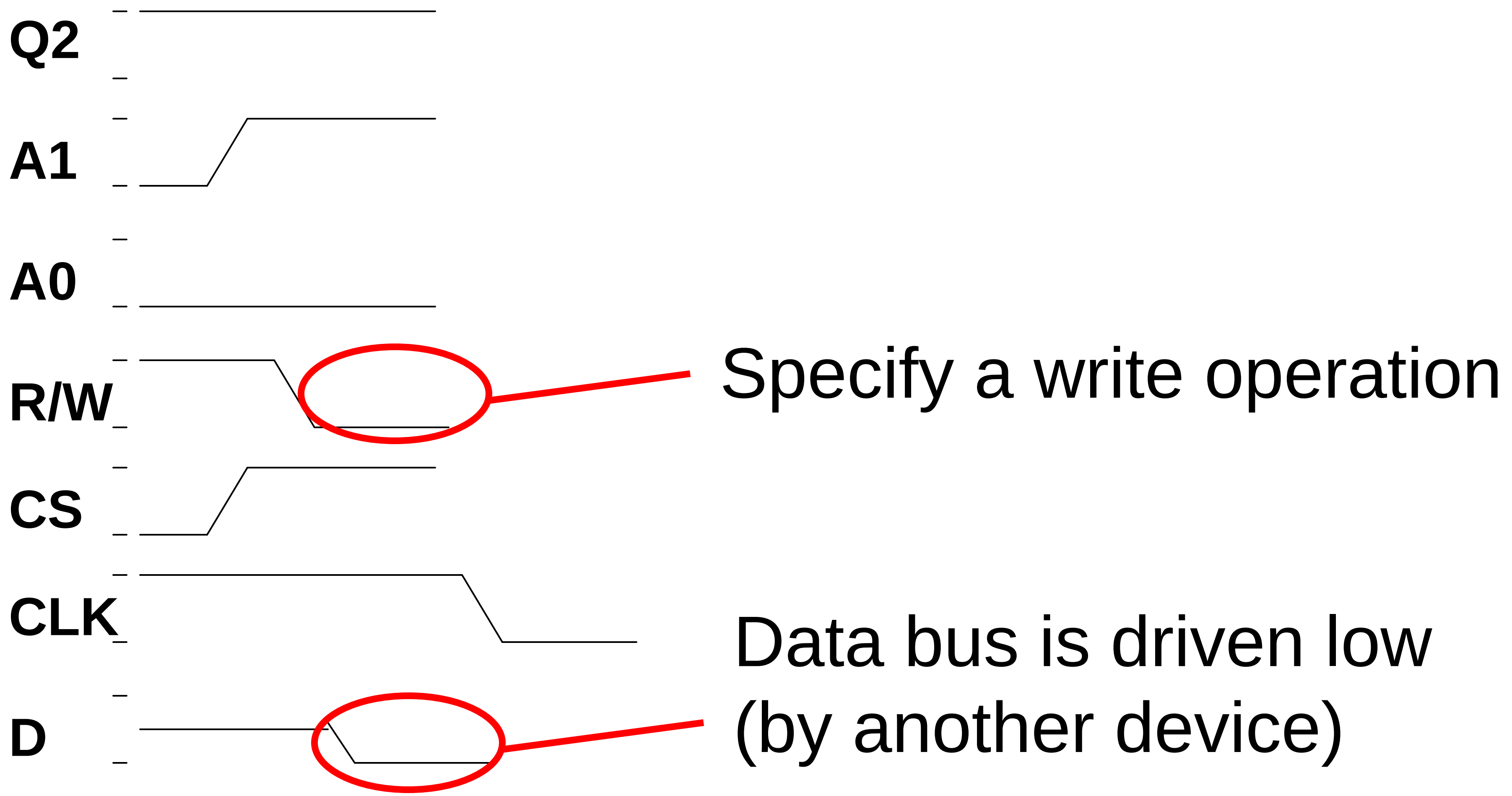
Memory Timing Diagram



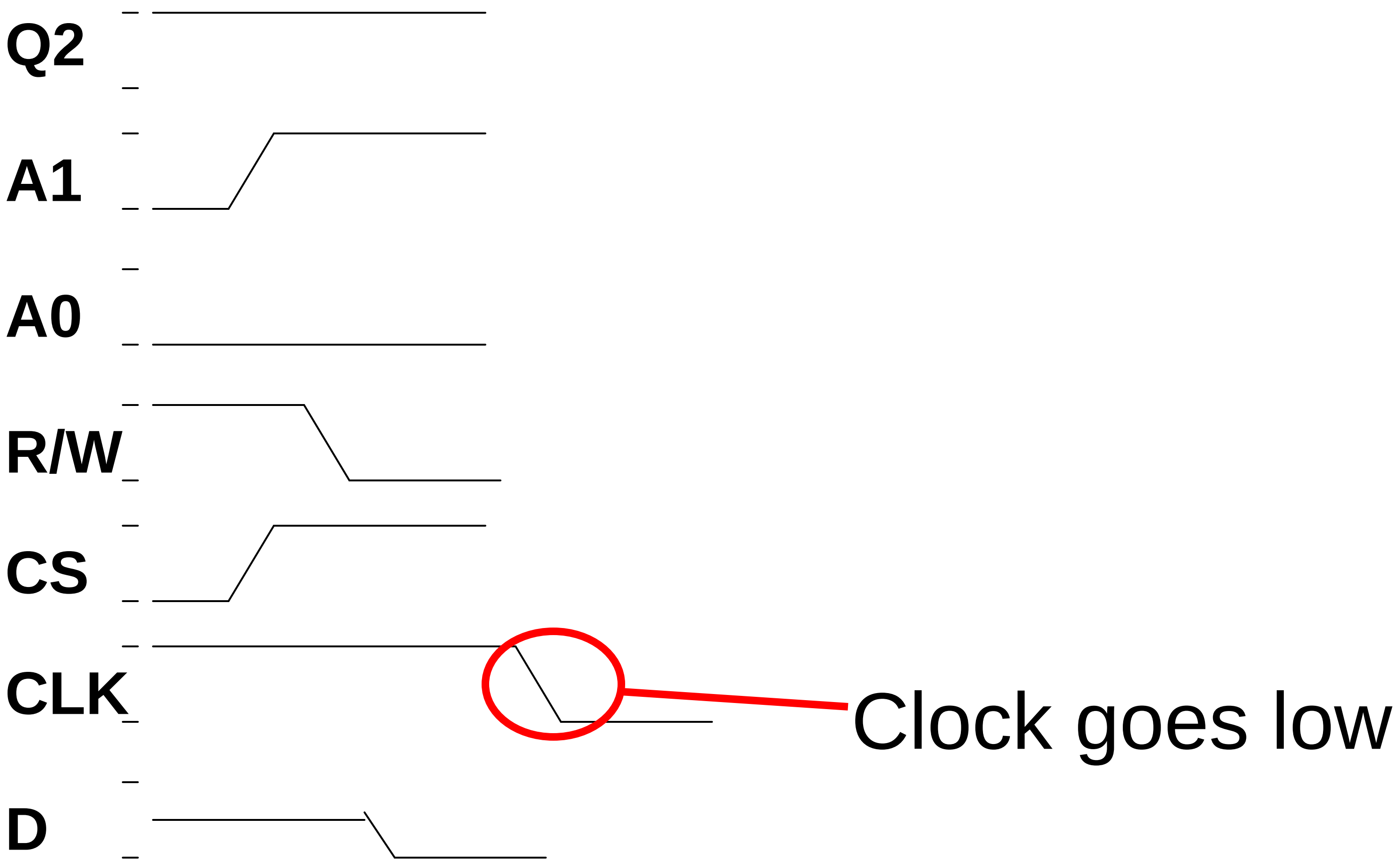
Memory Timing Diagram



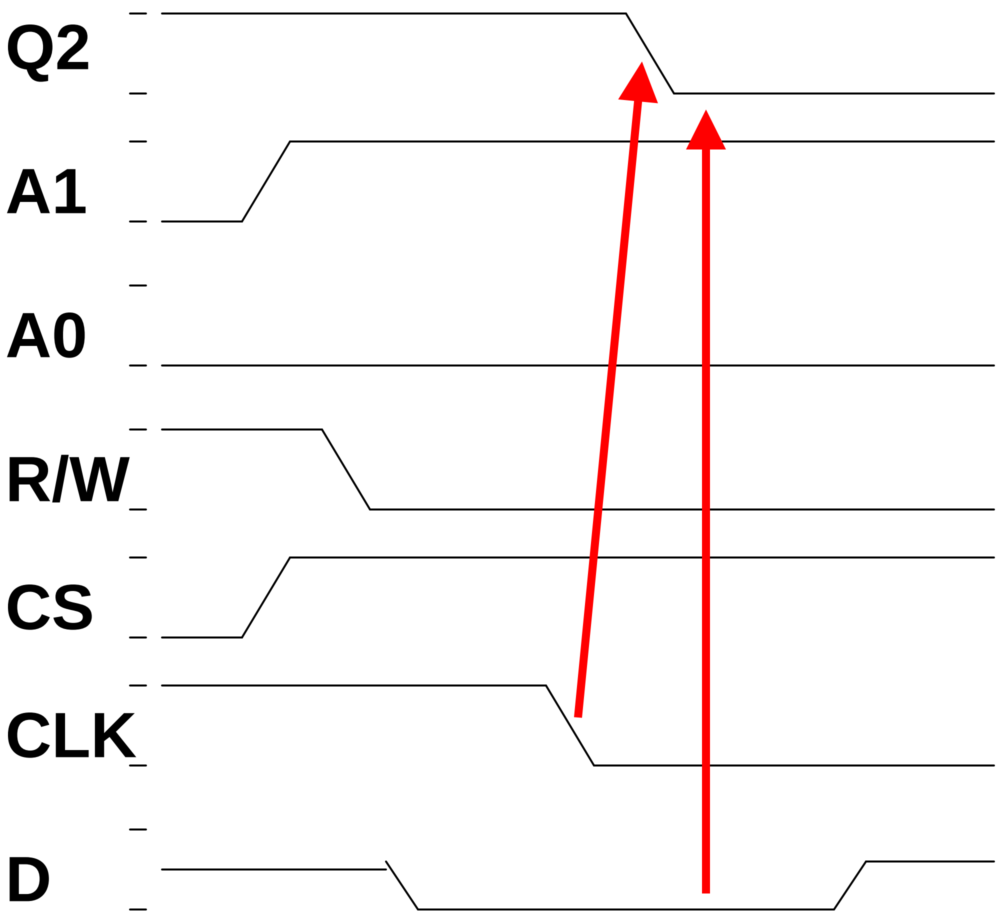
Memory Timing Diagram



Memory Timing Diagram

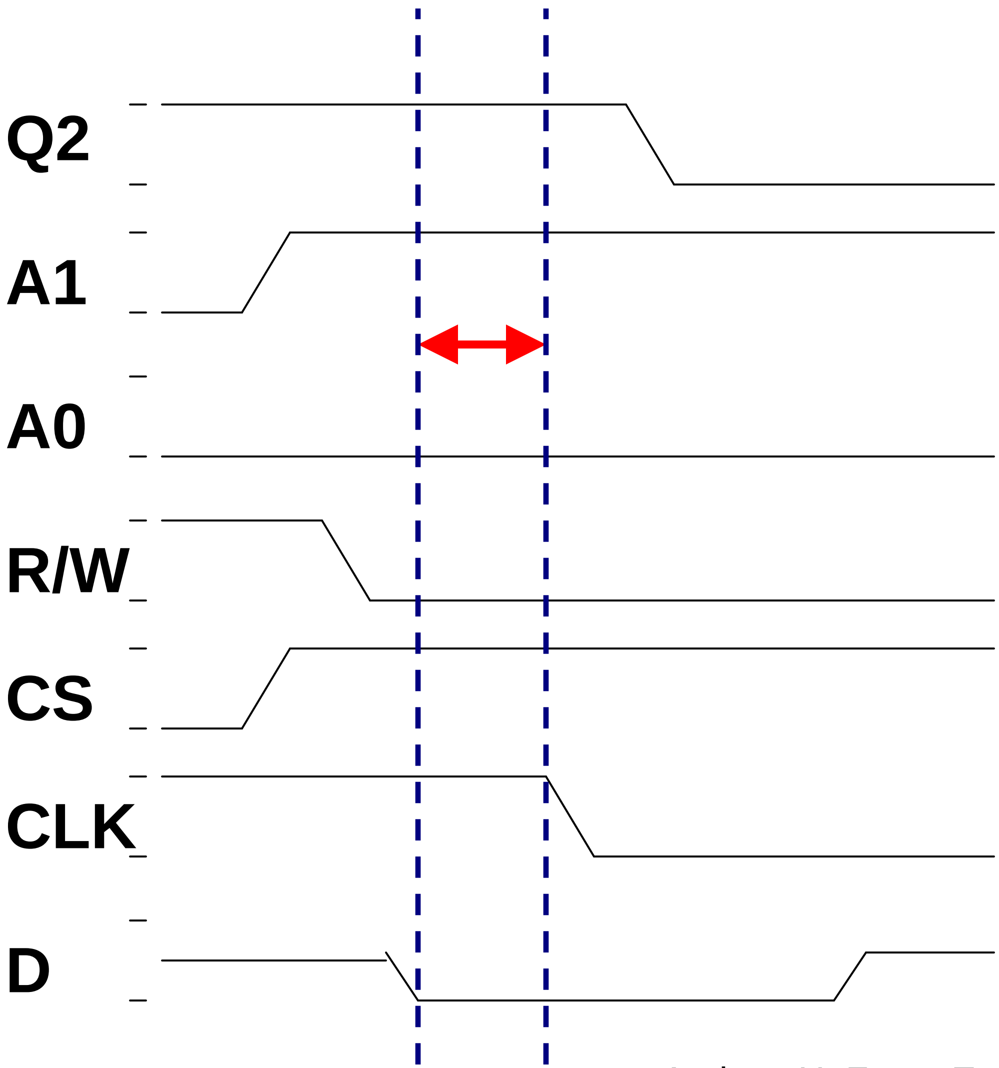


Memory Timing Diagram



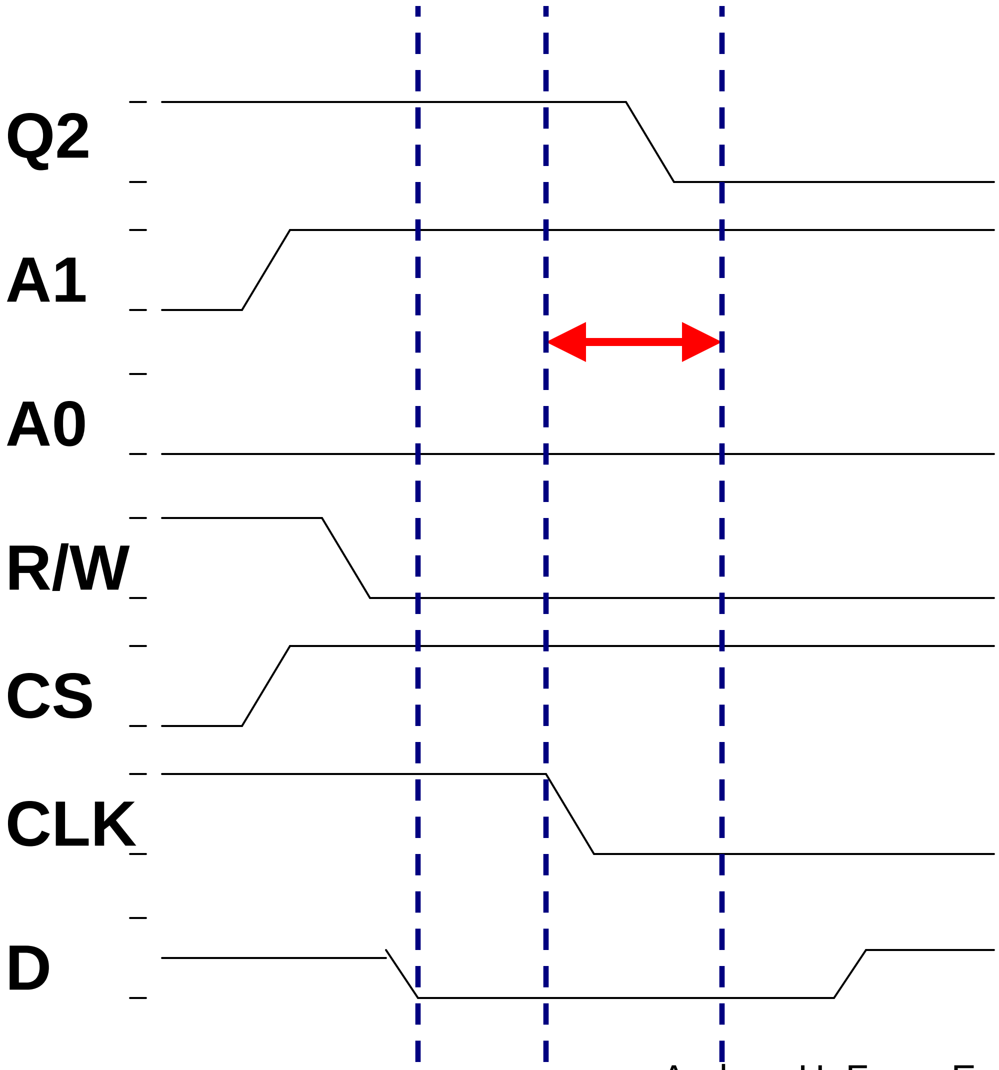
Memory element 2 changes state to low

Memory Timing Diagram



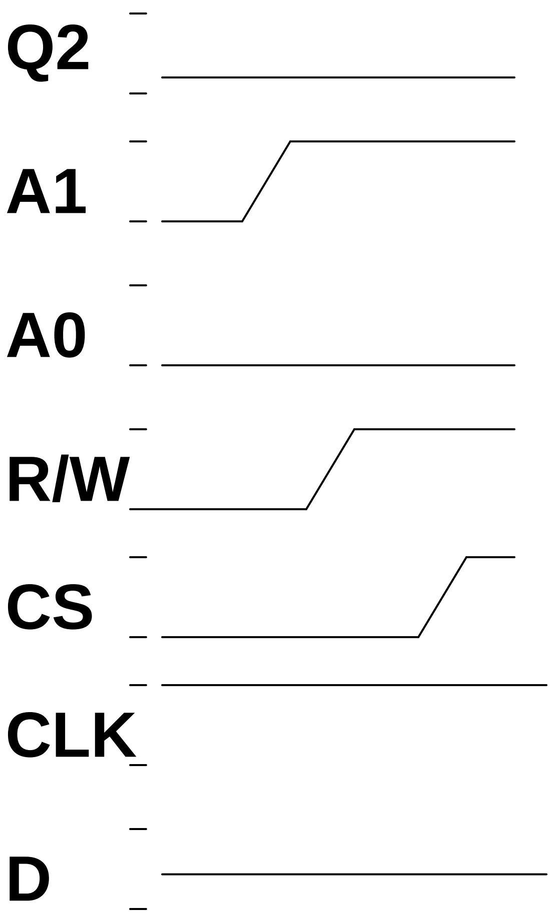
Setup time: all inputs must be valid during this time

Memory Timing Diagram

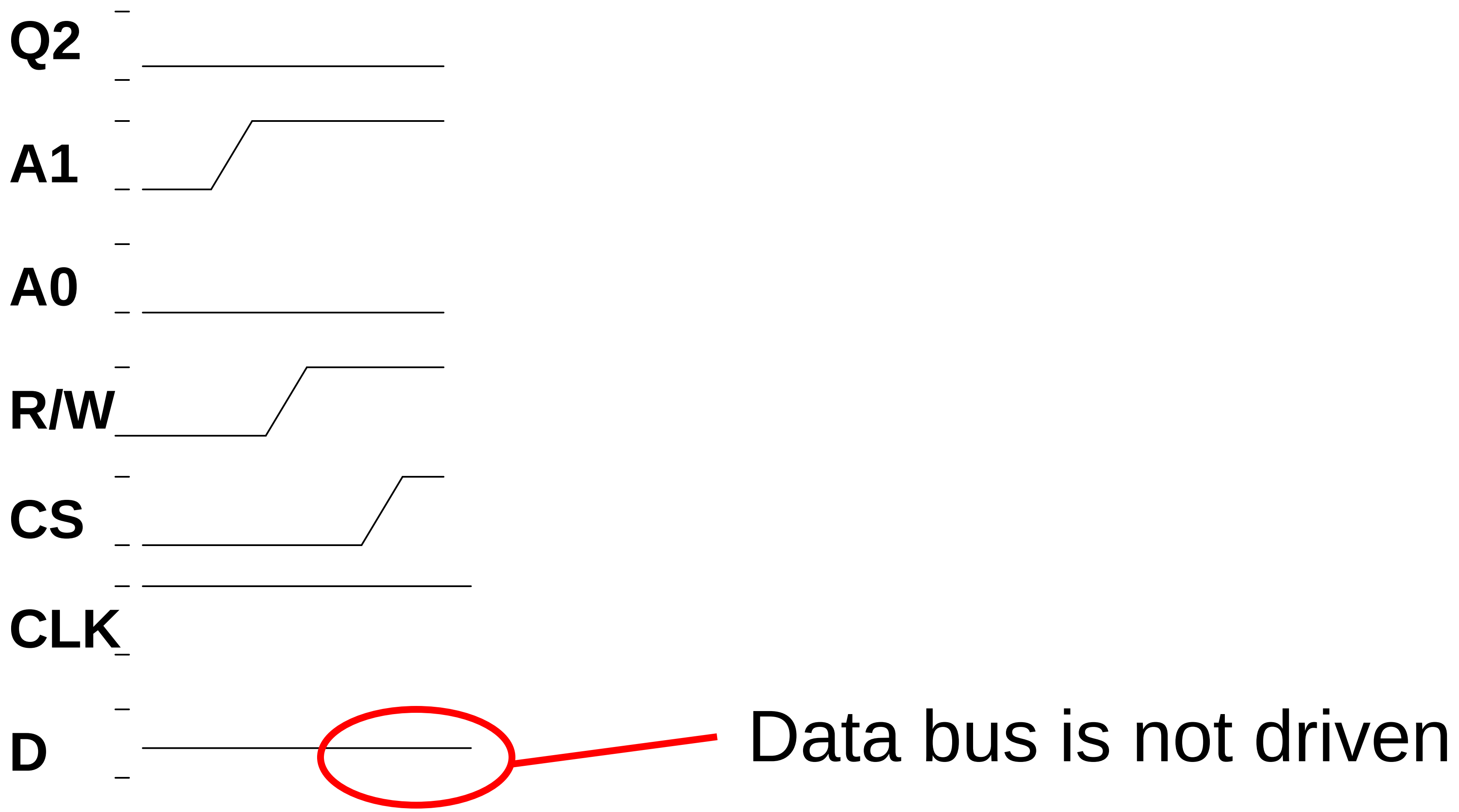


Hold time: all inputs must continue to be valid

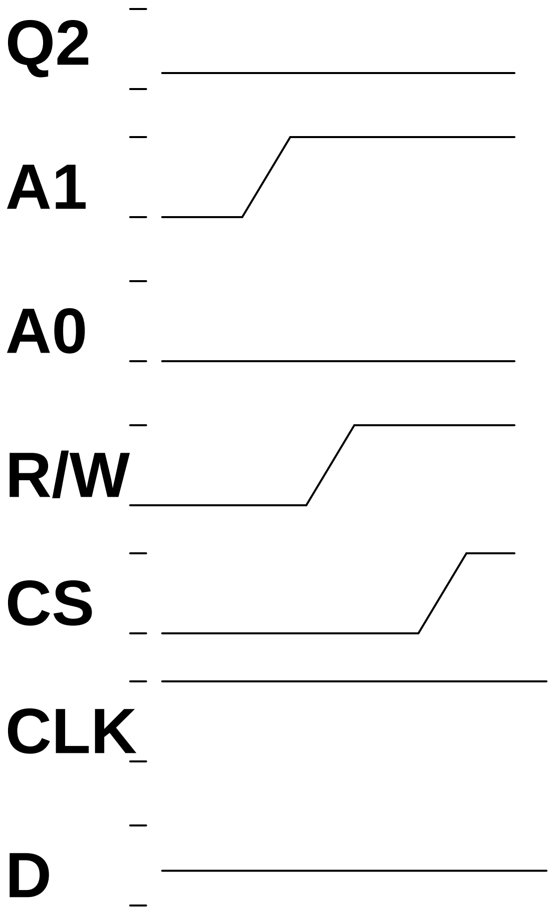
Memory Timing Diagram II



Memory Timing Diagram II

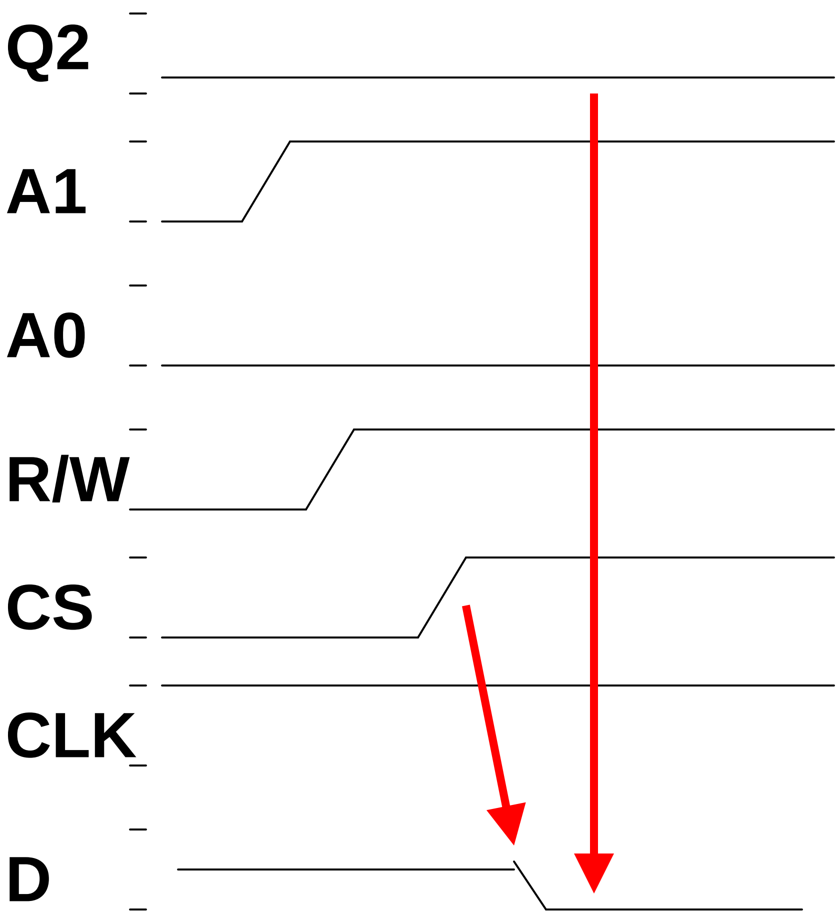


Memory Timing Diagram II



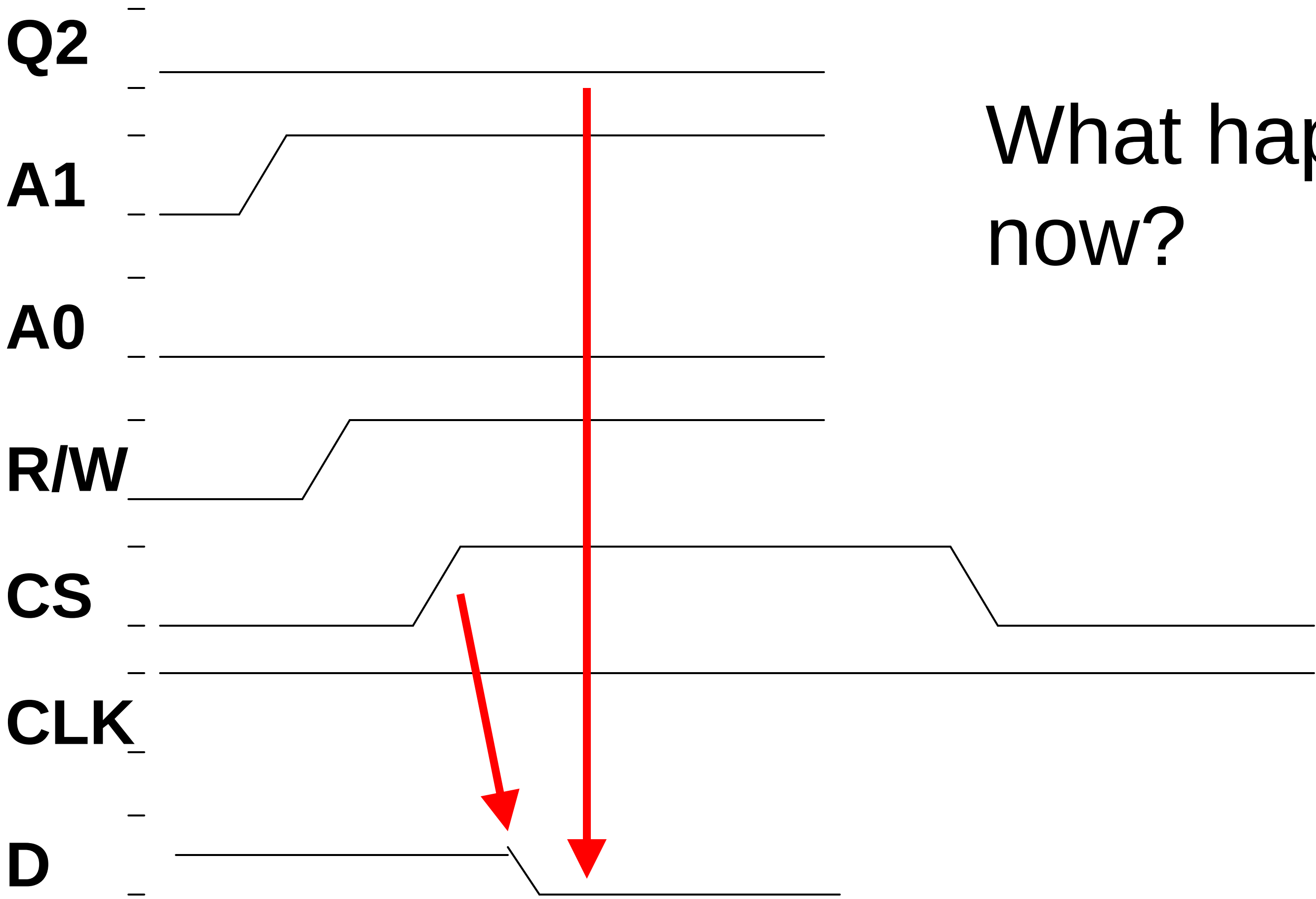
What happens next?

Memory Timing Diagram II



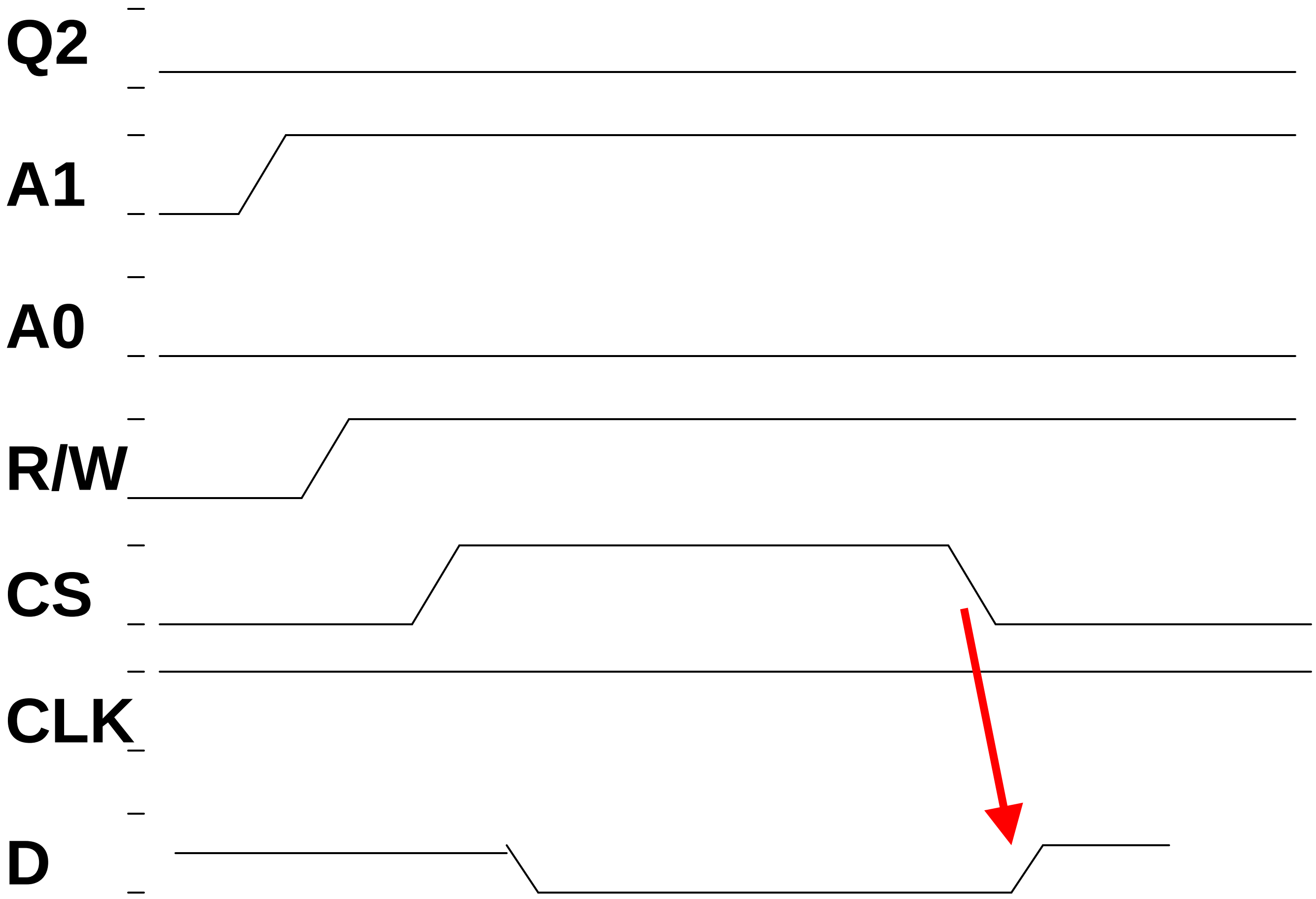
On chip select – drive data bus from Q2

Memory Timing Diagram II



What happens now?

Memory Timing Diagram II



Data bus returns to a non-driven state

Memory Summary

- Many independent storage elements
- Elements are typically organized into 8-bit bytes
- Each byte has its own address
- The value of each byte can be read
- In RAM: the value can also be changed quickly

Last Time

- Buses
  - Communication between devices
- Memory
  - Storage of information
  - Many individual storage “cells”
  - Each cell has a unique address
  - Types of memory: RAM vs ROM

Today

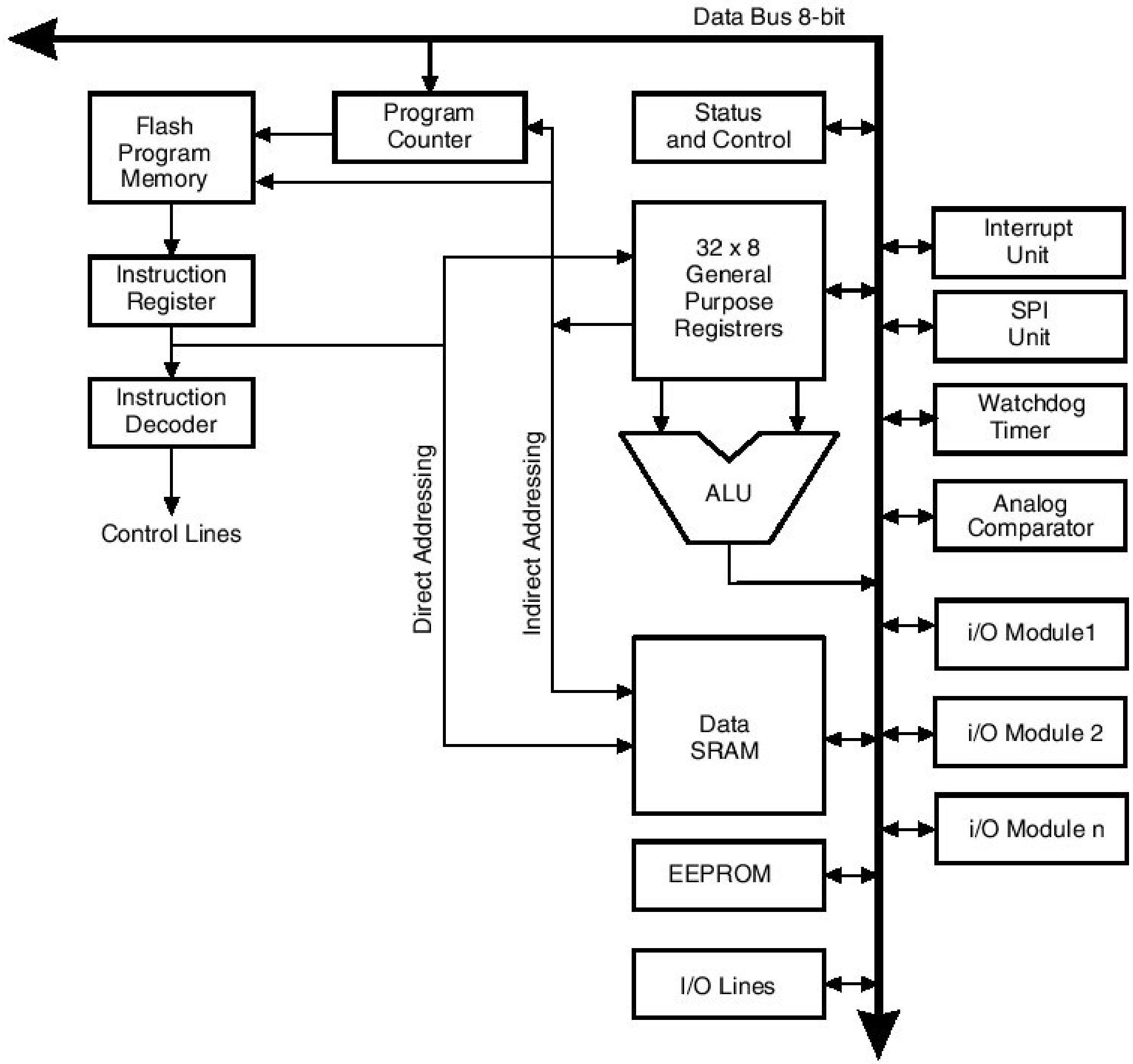
Atmel Mega8 microcontroller

- High-level components
- A hint of assembly language
- Digital I/O

Next Time

- In-class programming exercise
  - Bring laptops
  - Before class: install the Atmel software (instructions linked to from D2L)
- Project 1

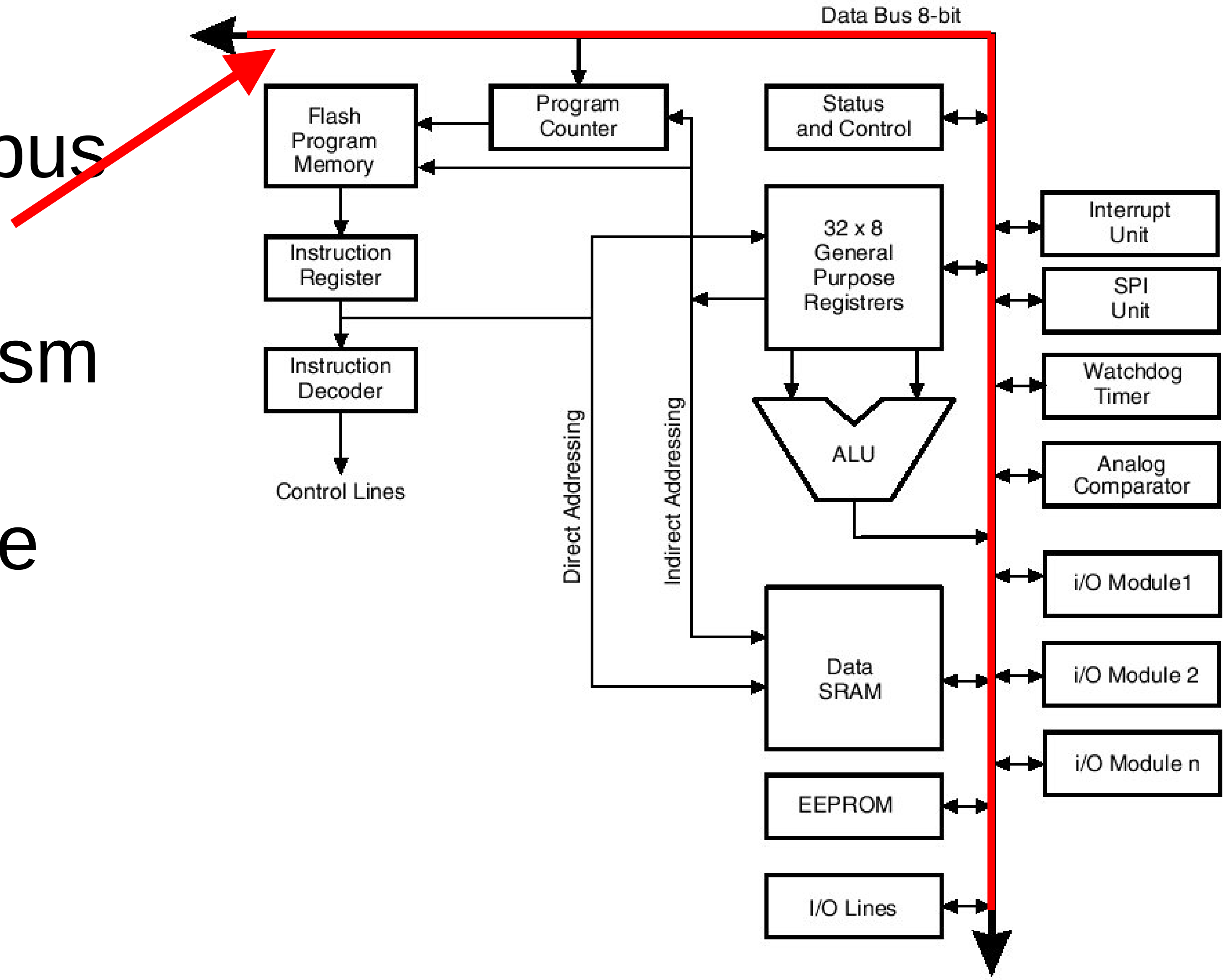
An Example: the Atmel Mega8



Atmel Mega8

8-bit data bus

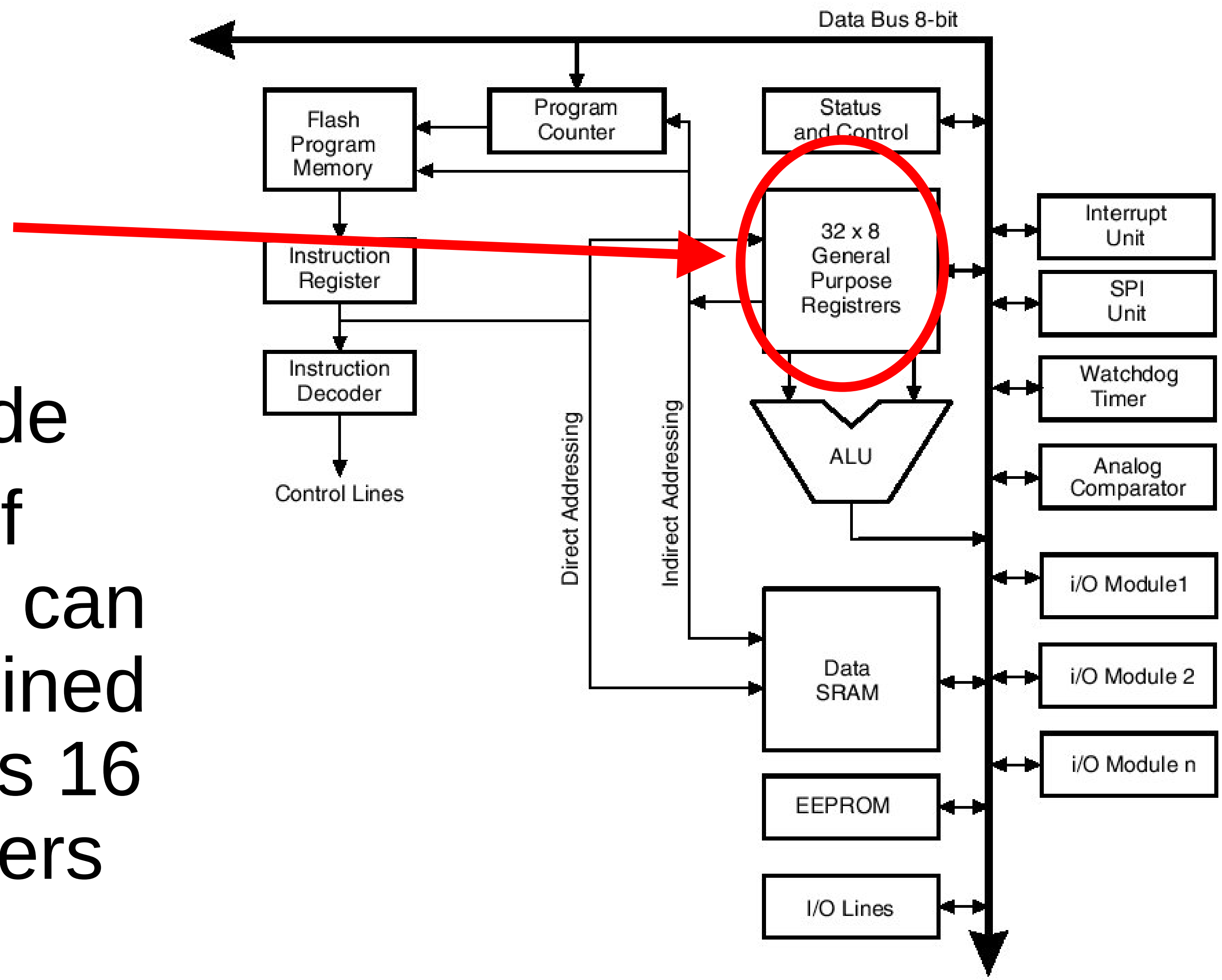
- Primary mechanism for data exchange



Atmel Mega8

32 general purpose registers

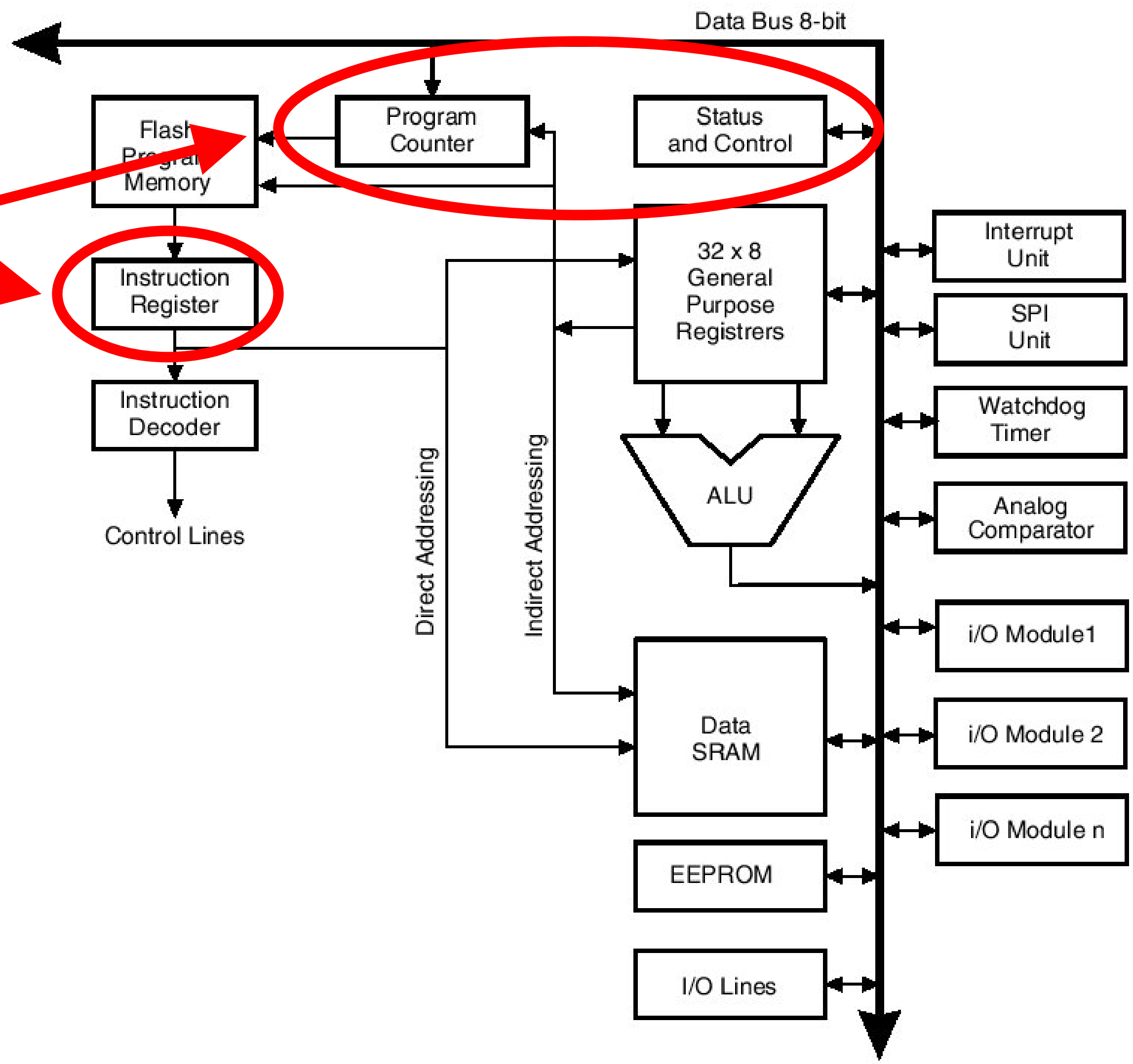
- 8 bits wide
- 3 pairs of registers can be combined to give us 16 bit registers



Atmel Mega8

Special purpose registers

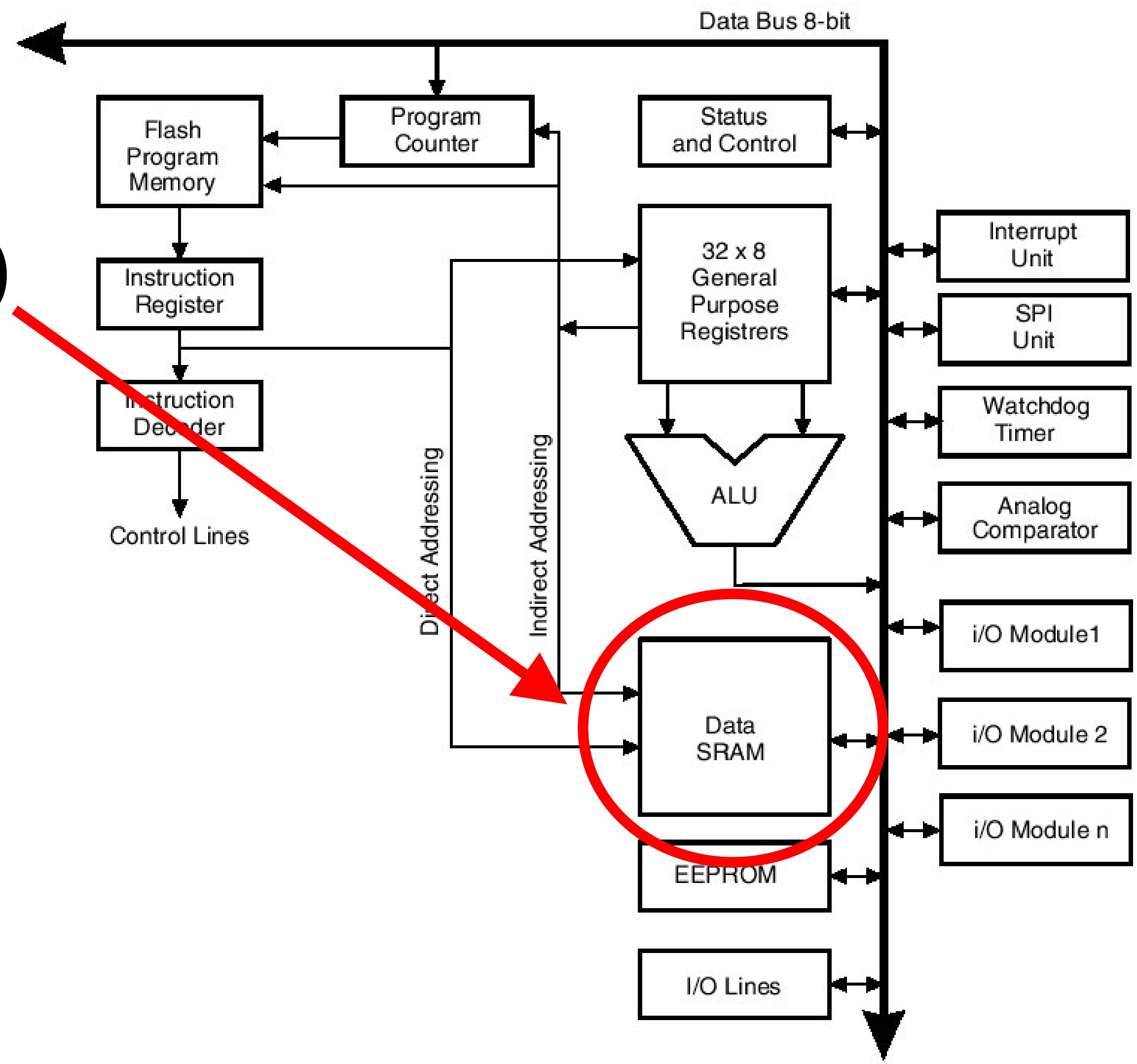
- Control of the internals of the processor



Atmel Mega8

Random Access Memory (RAM)

- 1 KByte in size

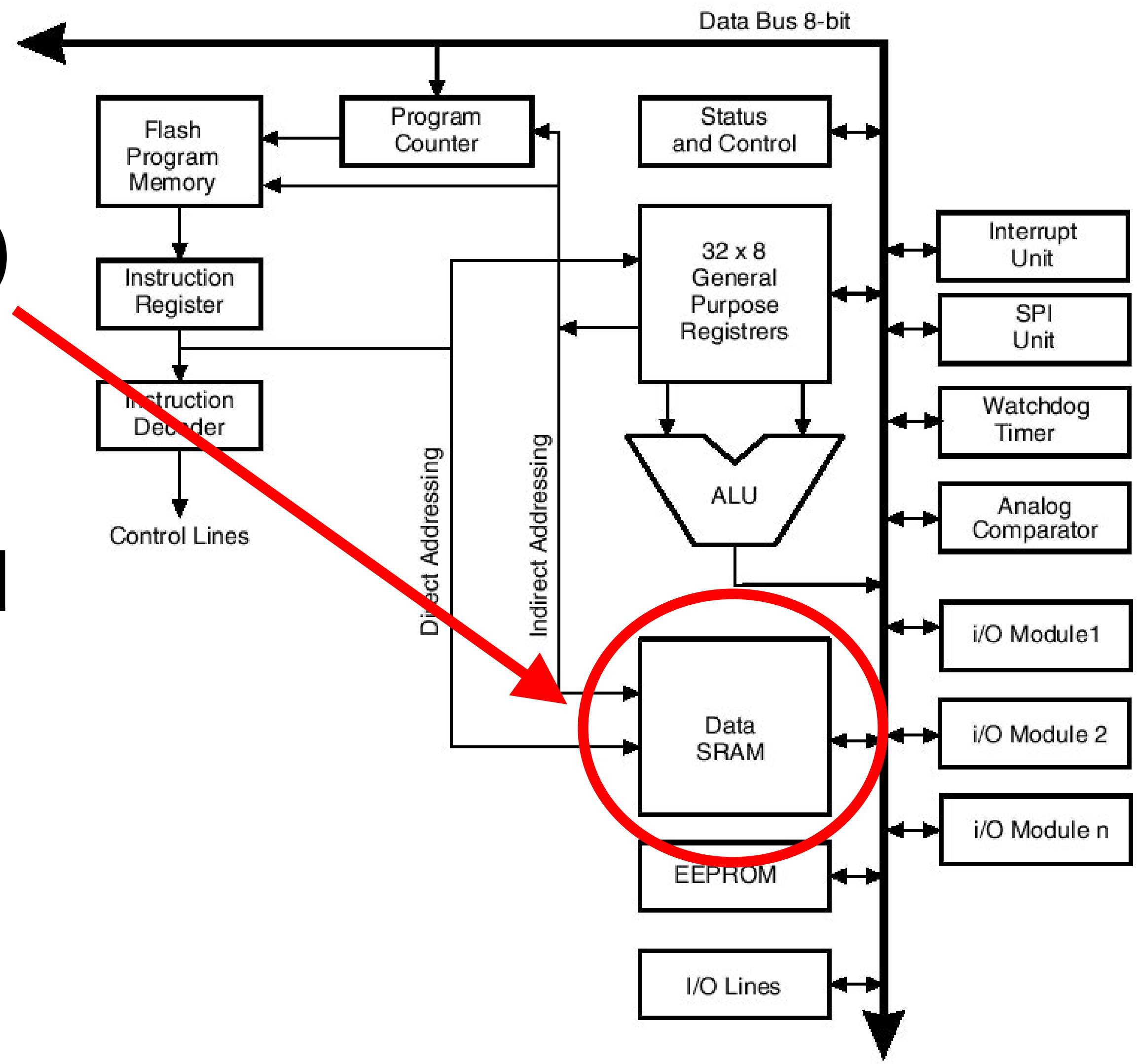


Atmel Mega8

Random Access Memory (RAM)

- 1 KByte in size

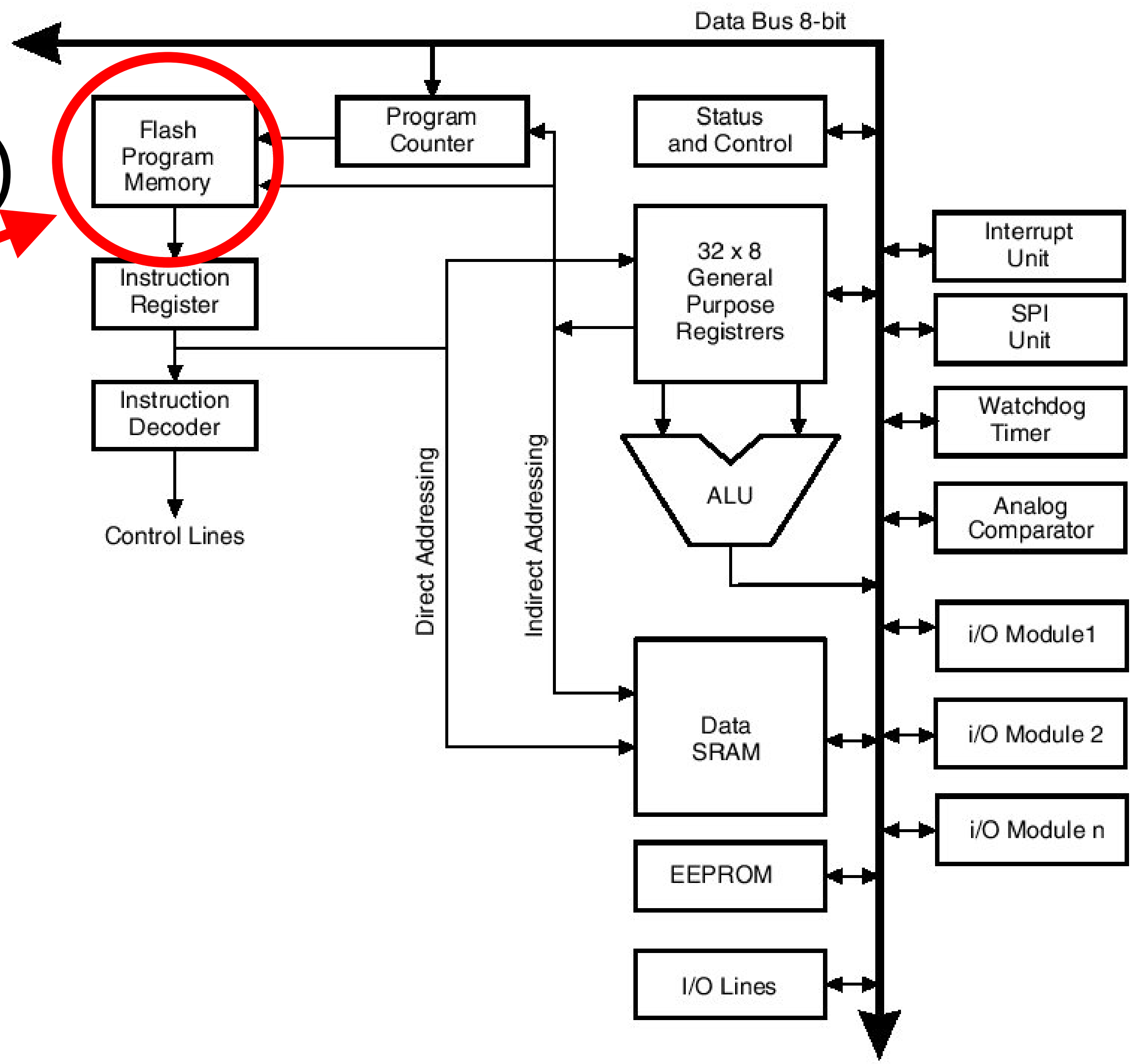
Note: in high-end processors, RAM is a separate component



Atmel Mega8

Flash (EEPROM)

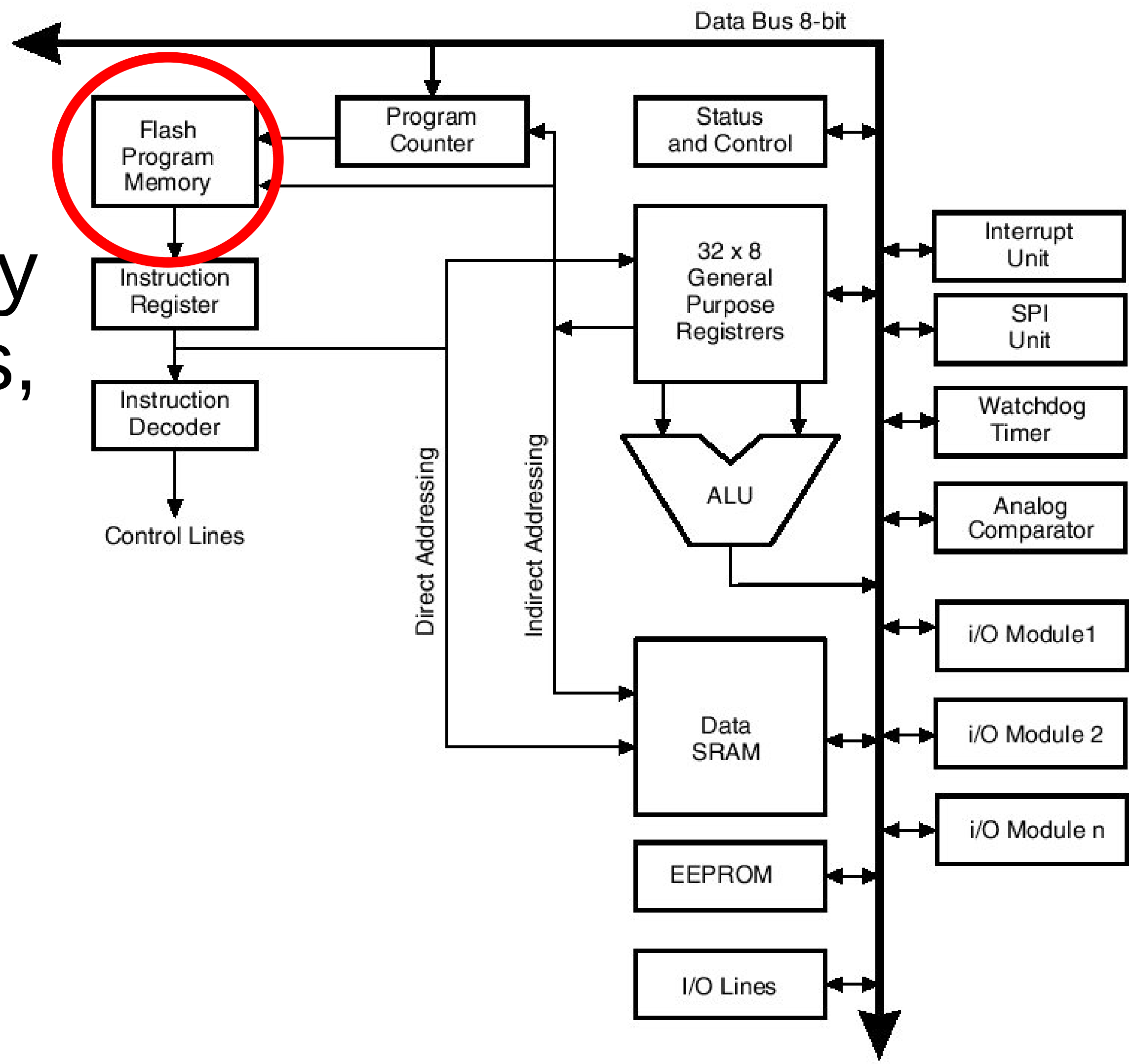
- Program storage
- 8 KByte in size



Atmel Mega8

Flash (EEPROM)

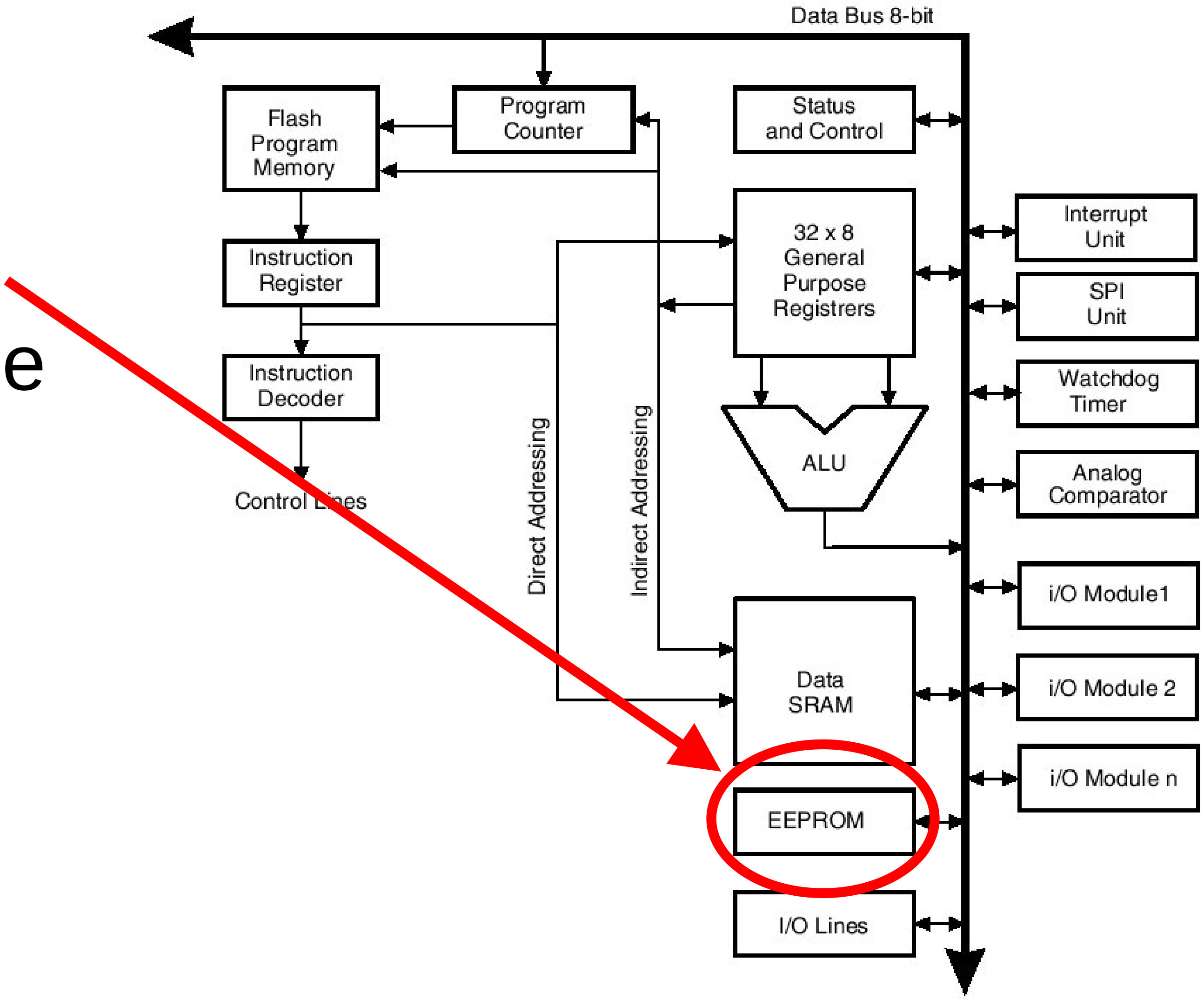
- In this and many microcontrollers, program and data storage is separate
- Not the case in our general purpose computers



Atmel Mega8

EEPROM

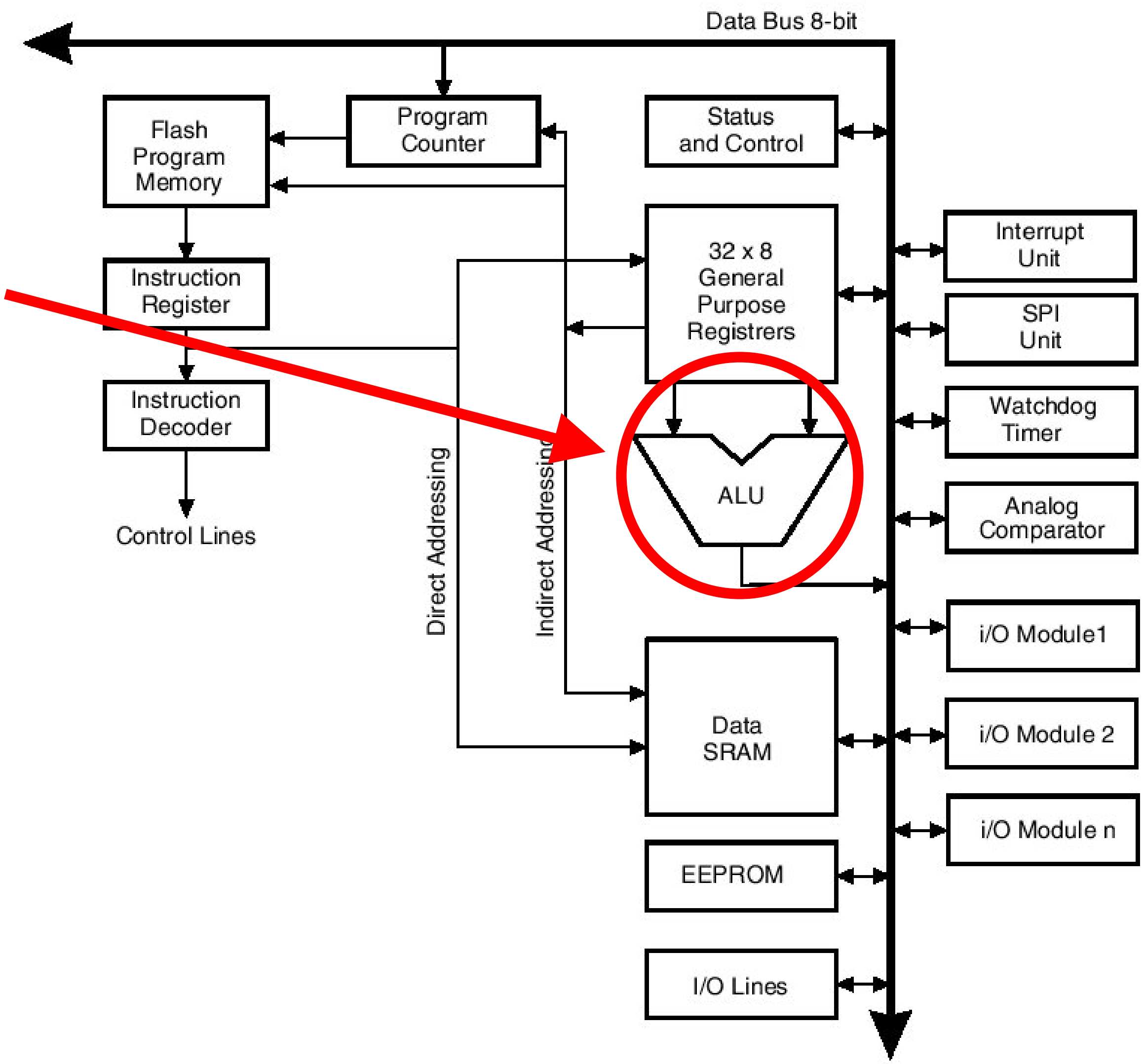
- Permanent data storage



Atmel Mega8

Arithmetic Logical Unit

- Data inputs from registers
- Control inputs not shown (derived from instruction decoder)



Machine-Level Programs

Machine-level programs are stored as sequences of *atomic* machine instructions

- Stored in program memory
- Execution is generally sequential (instructions are executed in order)
- But – with occasional “jumps” to other locations in memory

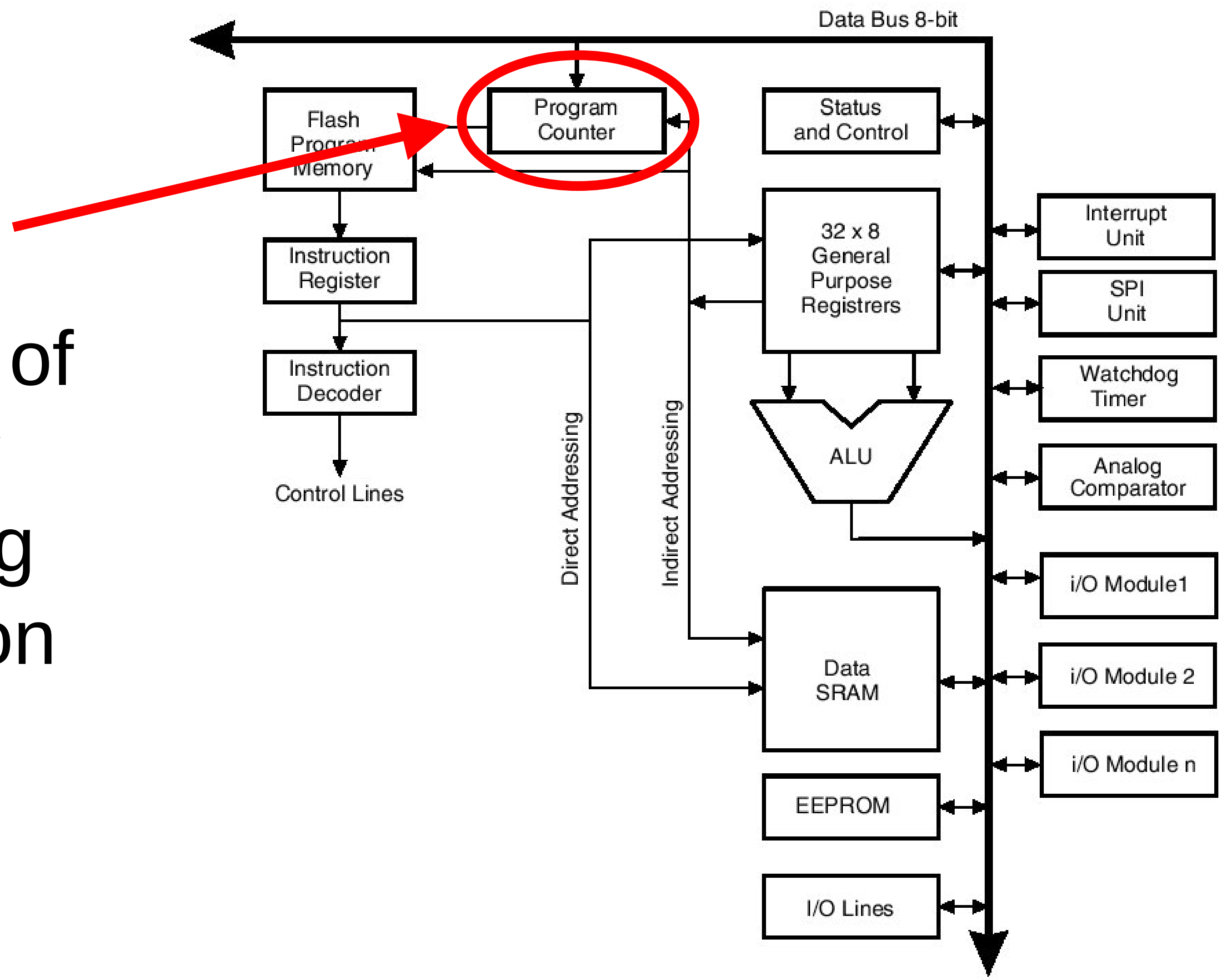
Types of Instructions

- Memory operations: transfer data values between memory and the internal registers
- Mathematical operations: ADD, SUBTRACT, MULT, AND, etc.
- Tests: value == 0, value > 0, etc.
- Program flow: jump to a new location, jump conditionally (e.g., if the last test was true)

Atmel Mega8: Decoding Instructions

Program counter

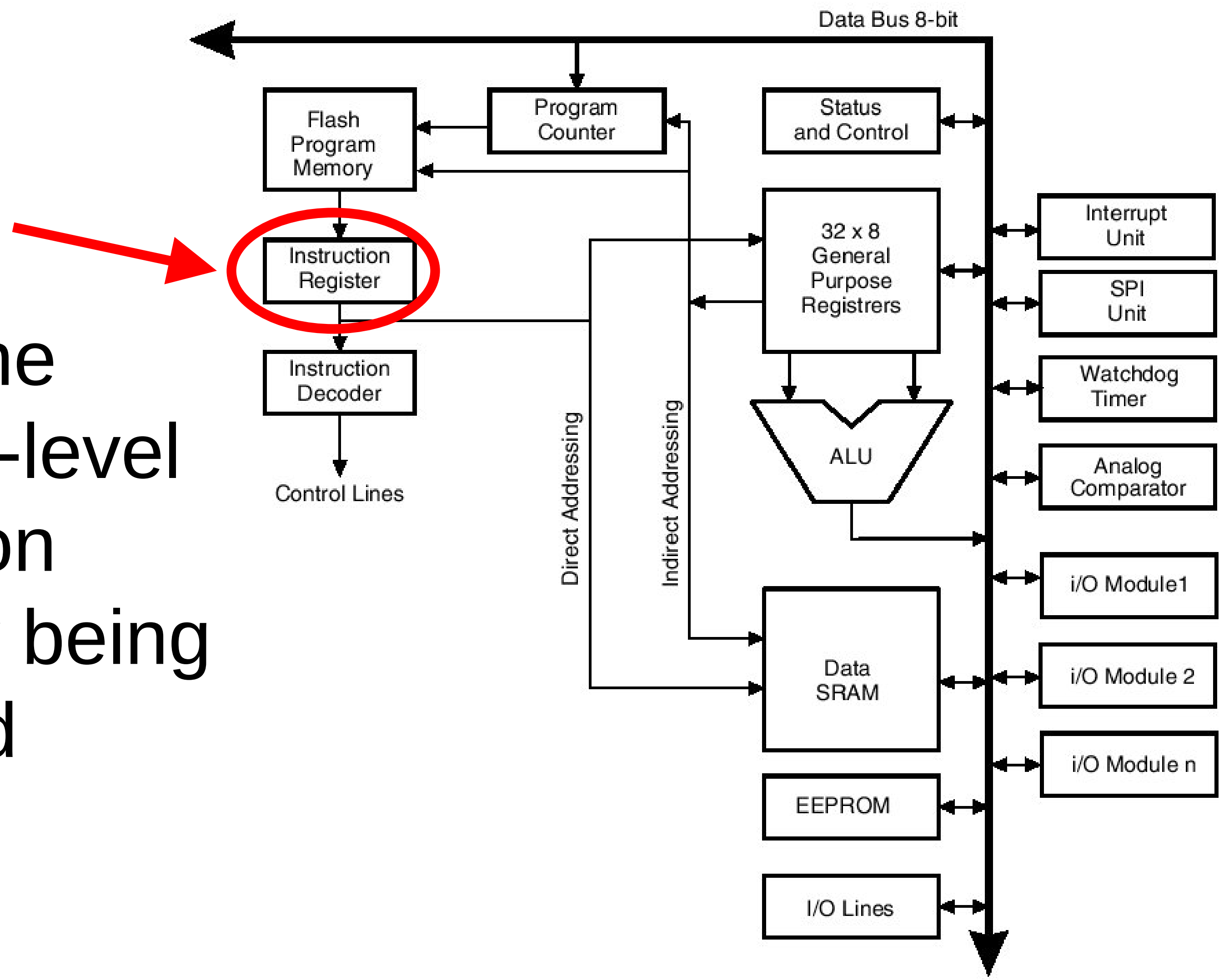
- Address of currently executing instruction



Atmel Mega8: Decoding Instructions

Instruction register

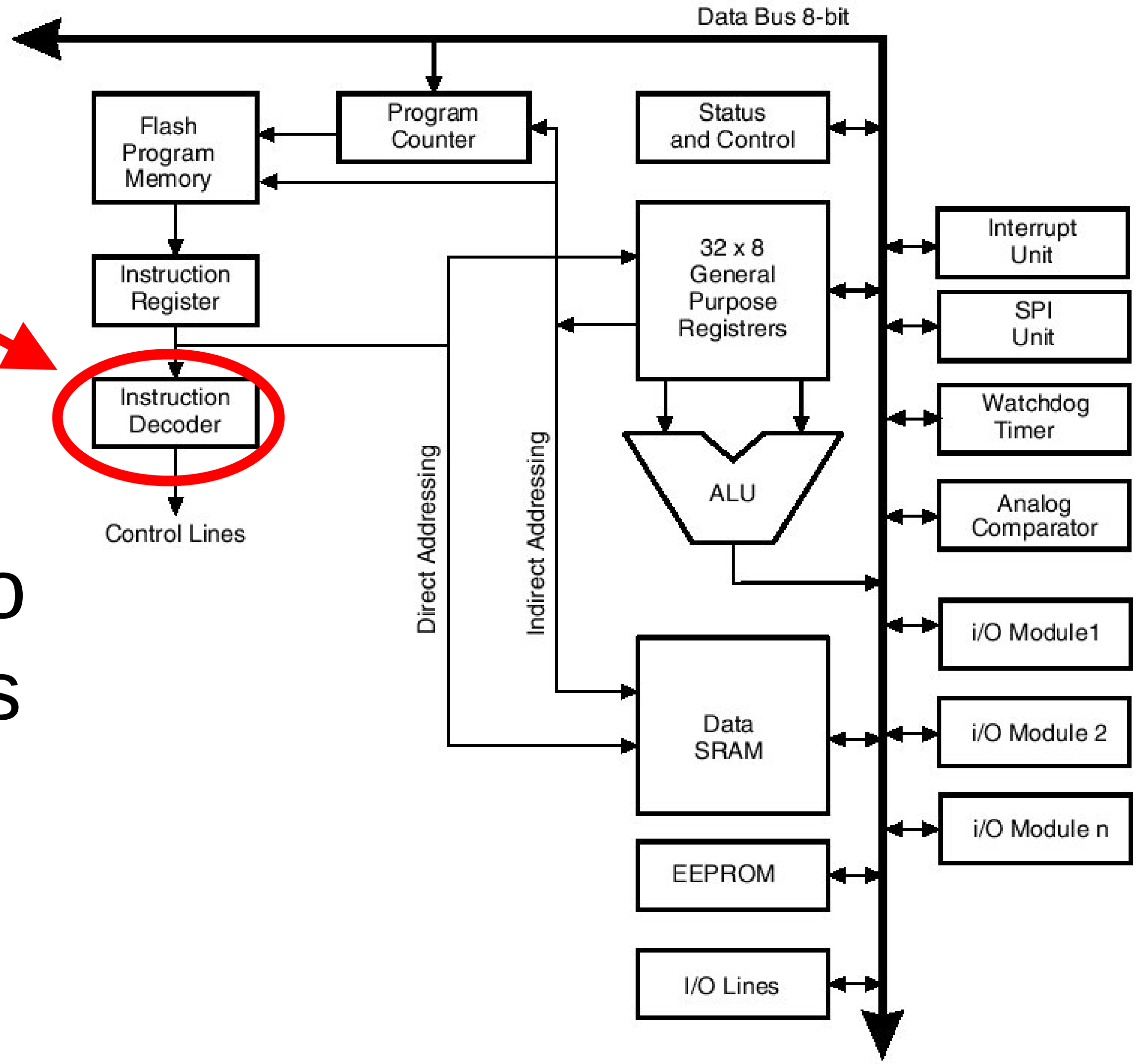
- Stores the machine-level instruction currently being executed



Atmel Mega8

Instruction decoder

- Translates current instruction into control signals for the rest of the processor



Some Mega8 Memory Operations

We refer to this as "Assembly Language"

LDS Rd, k

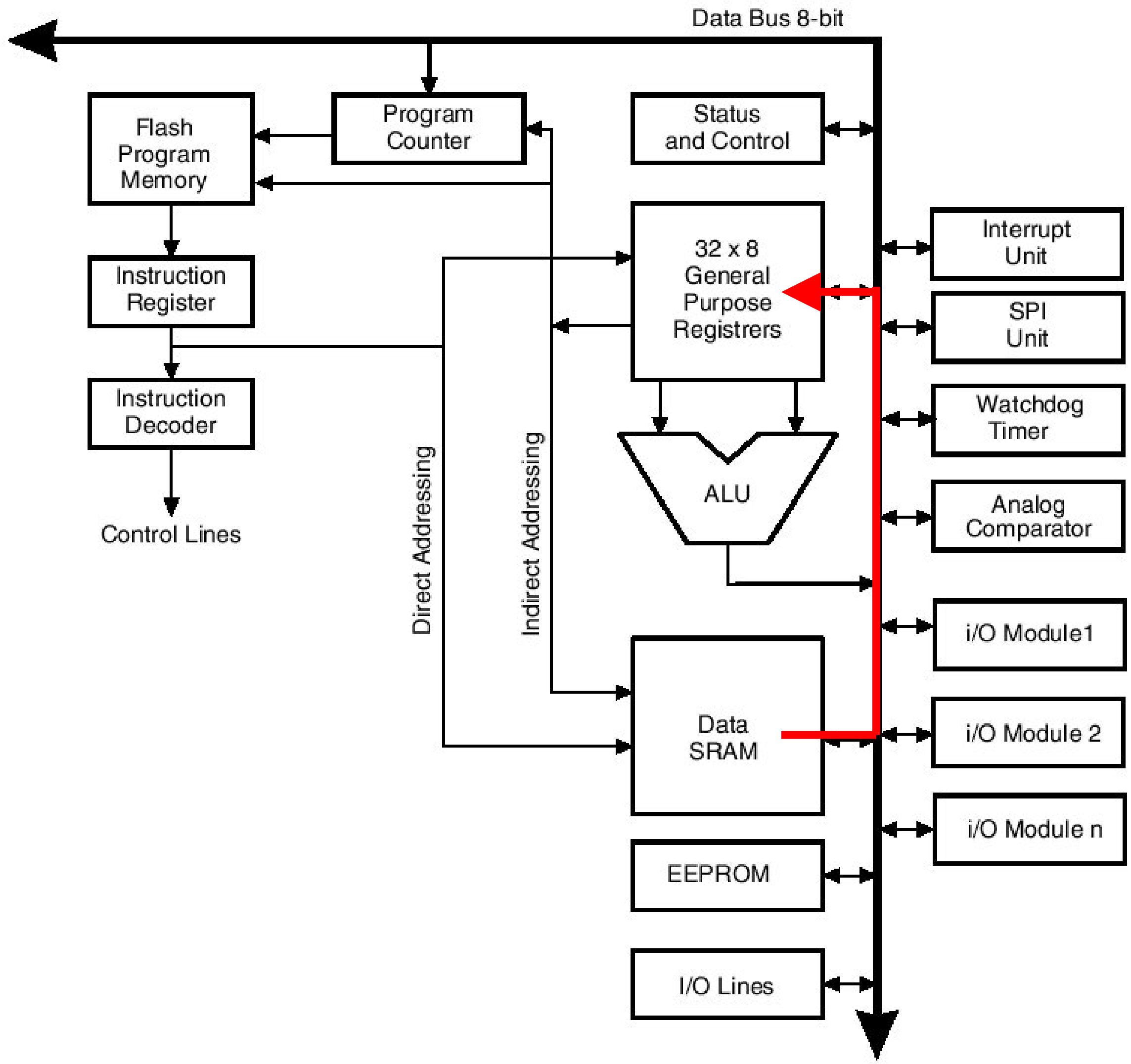
- Load SRAM memory location k into register Rd
- Rd <- (k)

STS Rd, k

- Store value of Rd into SRAM location k
- (k) <- Rd

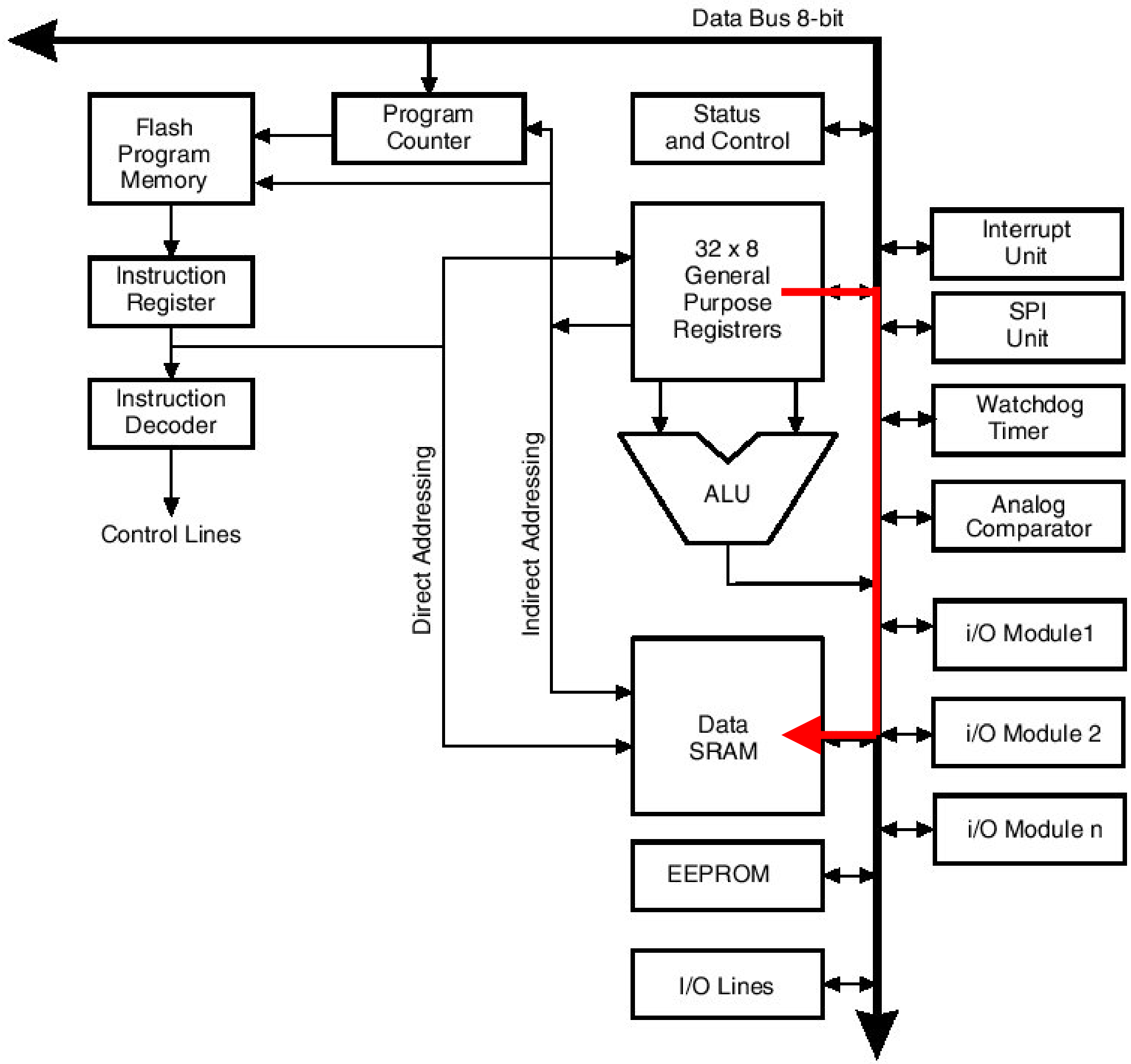
Load SRAM Value to Register

LDS Rd, k



Store Register Value to SRAM

STS Rd, k



Some Mega8 Arithmetic and Logical Instructions

ADD Rd, Rr

- Rd and Rr are registers
- Operation: Rd <- Rd + Rr
- Also affects status register (zero, carry, etc.)

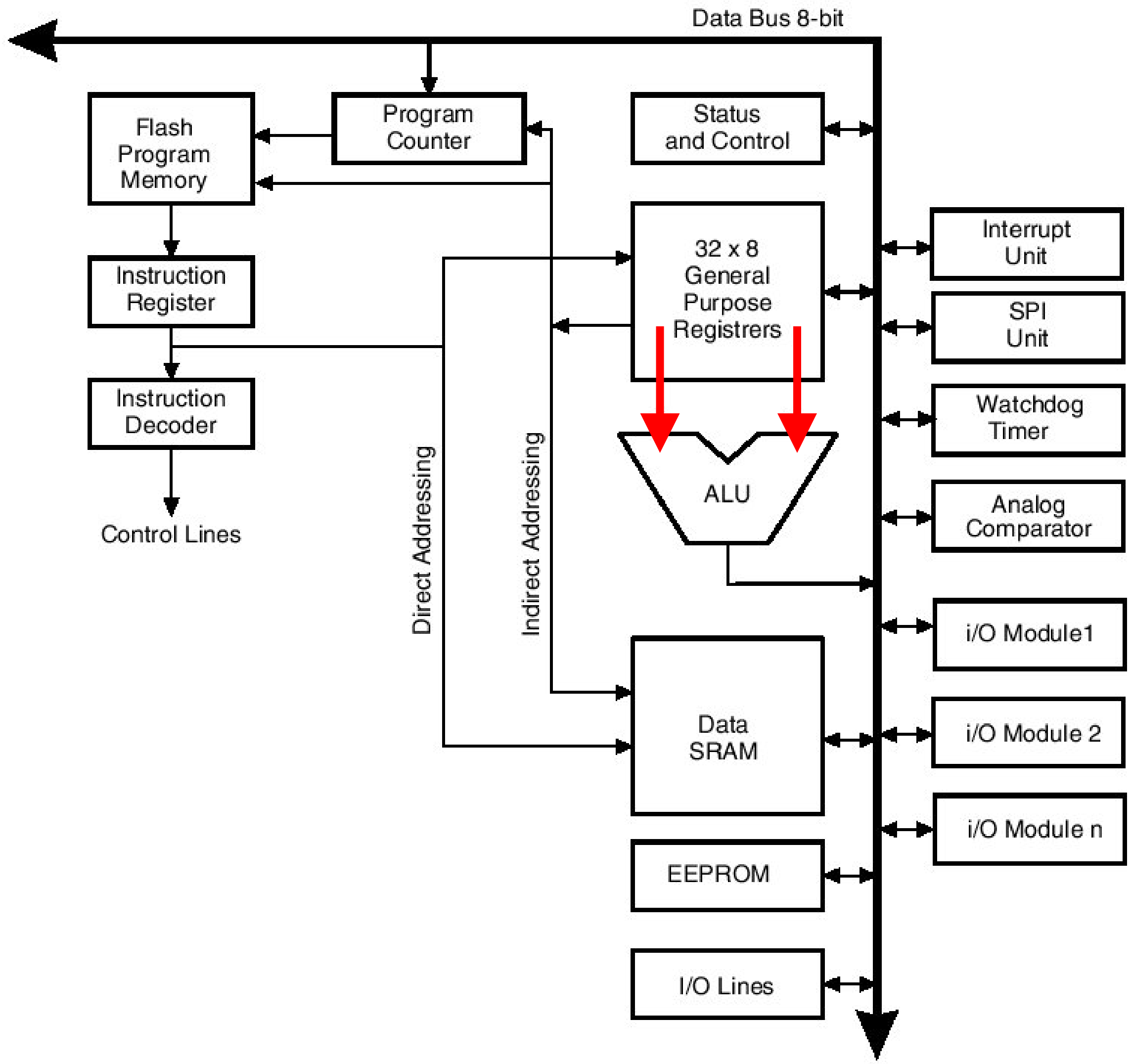
ADC Rd, Rr

- Add with carry
- Rd <- Rd + Rr + C

Add Two Register Values

ADD Rd, Rr

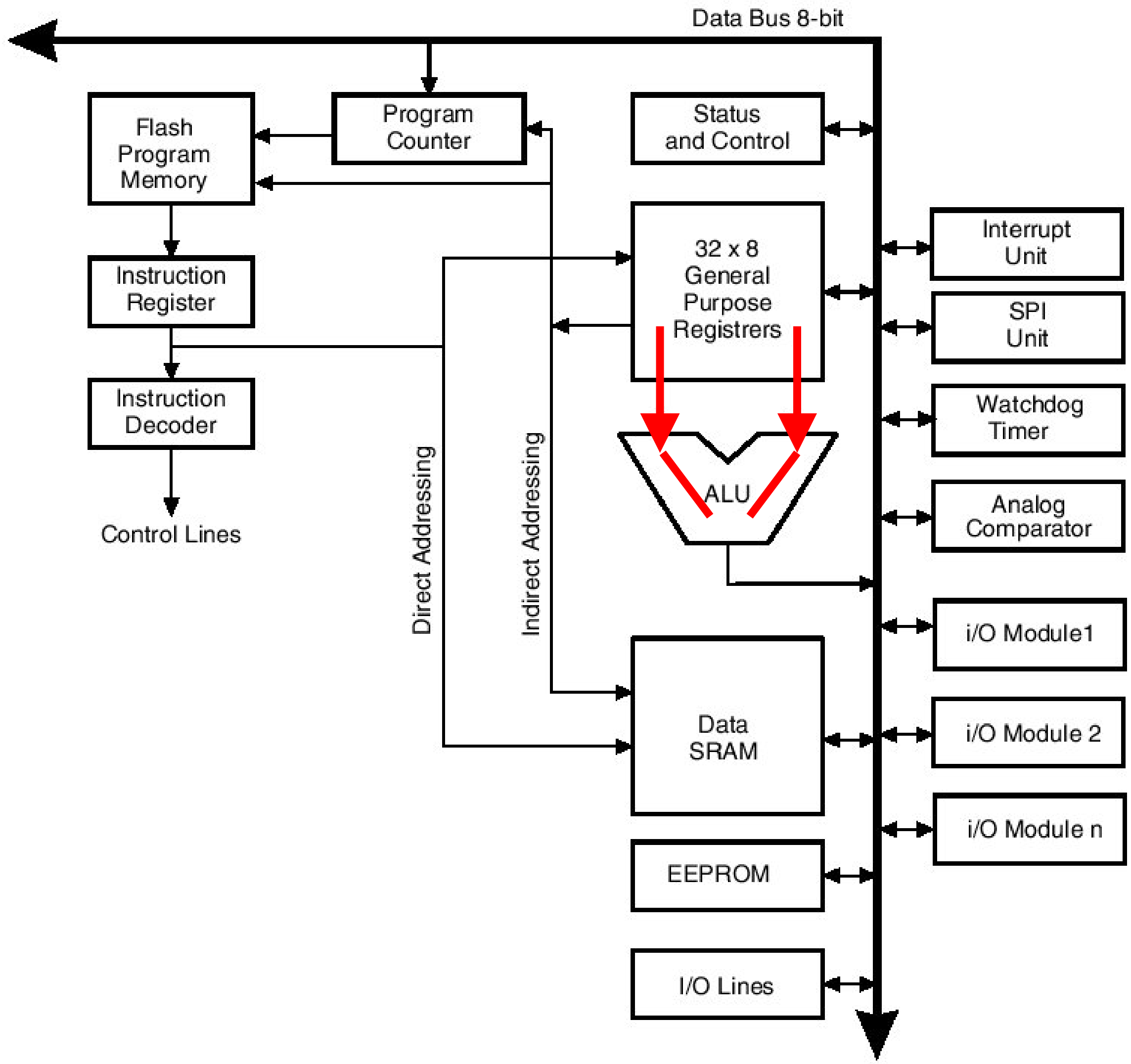
- Fetch register values



Add Two Register Values

ADD Rd, Rr

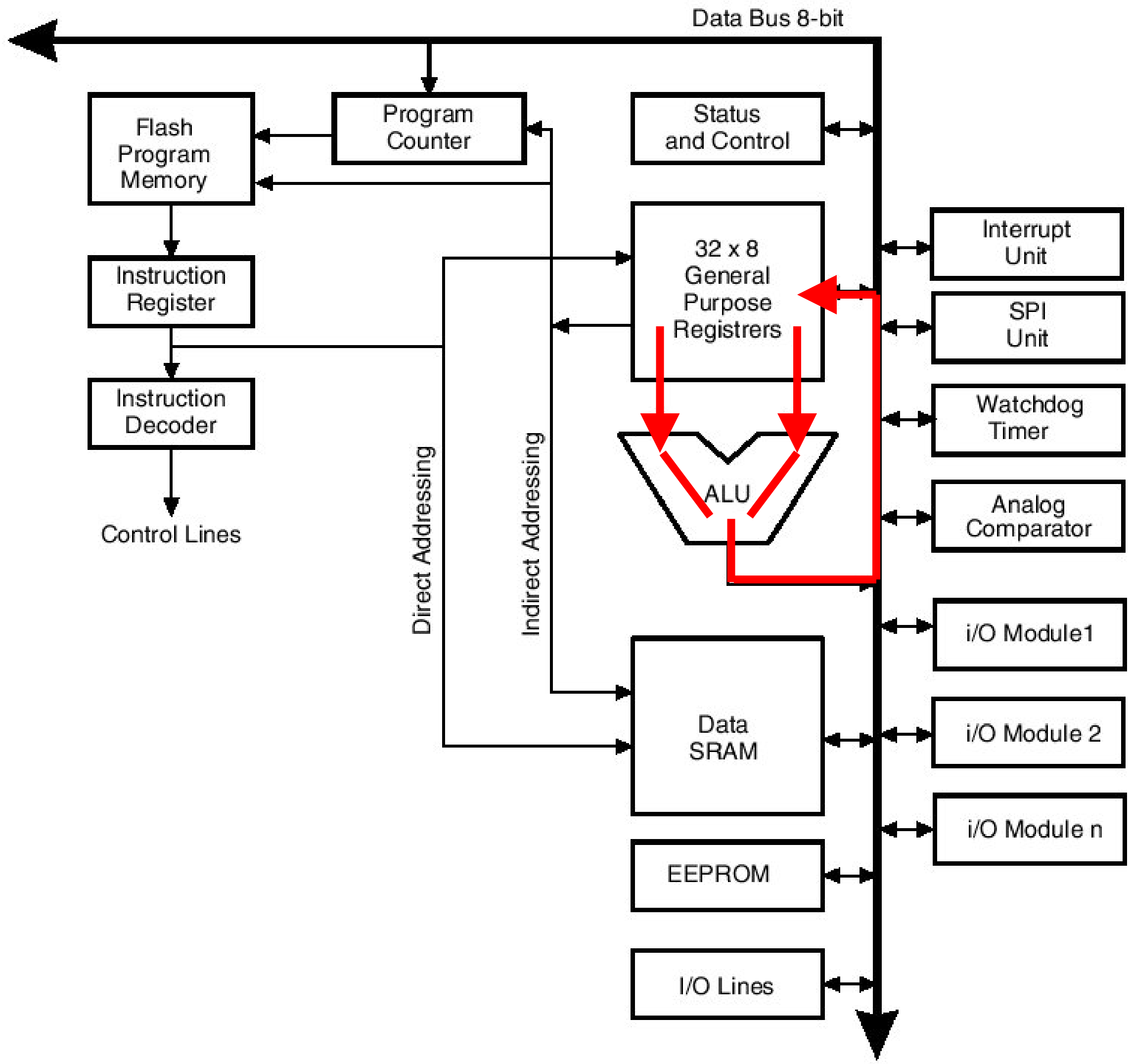
- Fetch register values
- ALU performs ADD



Add Two Register Values

ADD Rd, Rr

- Fetch register values
- ALU performs ADD
- Result is written back to register via the data bus



Some Mega8 Test Instructions

CP Rd, Rr

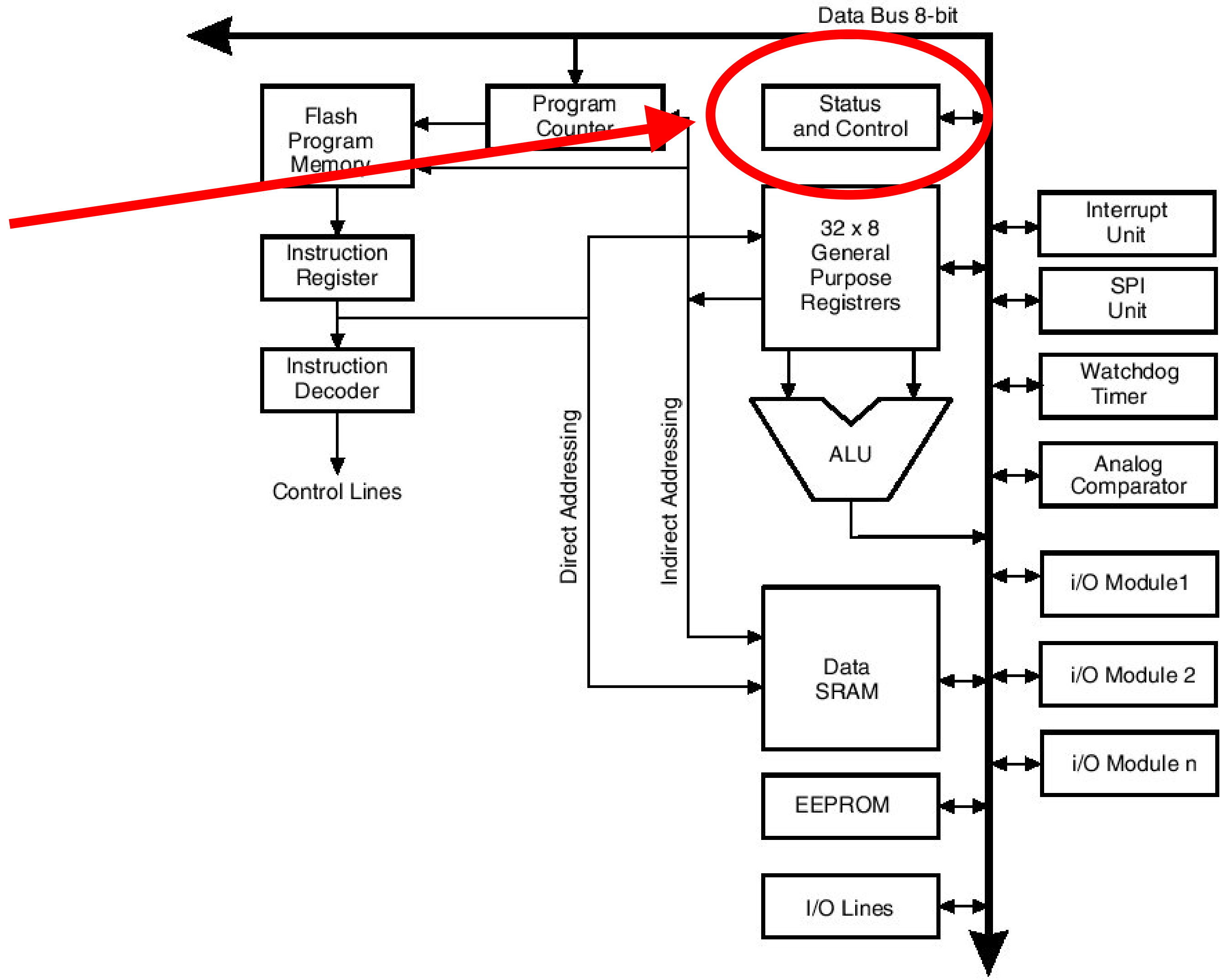
- Compare Rd with Rr
- Alters the status register

TST Rd

- Test for zero or minus
- Alters the status register

Some Mega8 Test Instructions

Modify the status register



Some Program Flow Instructions

RJMP k

- Change the program counter by k+1
- PC <- PC + k + 1

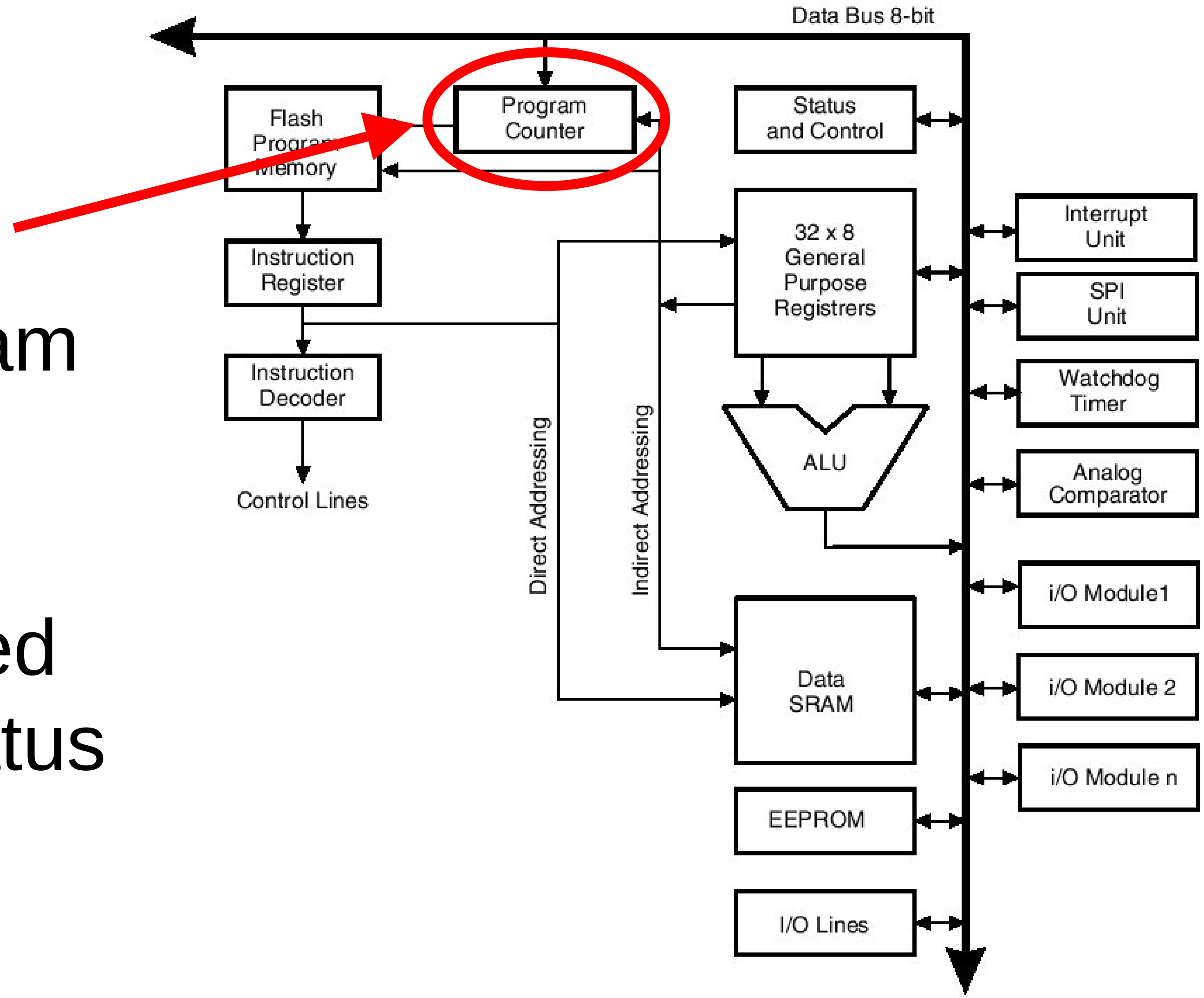
BRCS k

- Branch if carry set
- If C==1 then PC <- PC + k + 1

Atmel Mega8: Decoding Instructions

Results in a change to the program counter

- May be conditioned on the status register



Connecting Assembly Language to C

- Our C compiler is responsible for translating our code into Assembly Language
- Today, we rarely program in Assembly Language
  – Embedded systems are a common exception
  – Also: it is useful in some cases to view the assembly code generated by the compiler

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3

……..
```

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Load the contents of memory location A into register 1

The Assembly :

```
LDS R1 (A)      ← PC
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Load the contents of memory location B into register 2

The Assembly :

```
LDS R1 (A)
LDS R2 (B)     ← PC
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Compare the contents of register 2 with those of register 1

This results in a change to the status register

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1      <- PC
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3        ← PC
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

Branch If Greater Than or Equal To: jump ahead 3 instructions if true

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Branch if greater than or equal to will jump ahead 3 instructions if true

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

if true

PC

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Not true: execute the next instruction

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3
……..
```

if not true

PC

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Load the contents of memory location D into register 3

The Assembly :

LDS R1 (A)

LDS R2 (B)

CP R2, R1

BRGE 3

LDS R3 (D) ← **PC**

ADD R3, R1

STS (D), R3

……..

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Add the values in registers 1 and 3 and store the result in register 3

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1   ← PC
STS (D), R3
……..
```

An Example

A C code snippet:

```
if(B < A) {
    D += A;
}
```

Store the value in register 3 back to memory location D

The Assembly :

```
LDS R1 (A)
LDS R2 (B)
CP R2, R1
BRGE 3
LDS R3 (D)
ADD R3, R1
STS (D), R3      ← PC
……..
```

Summary

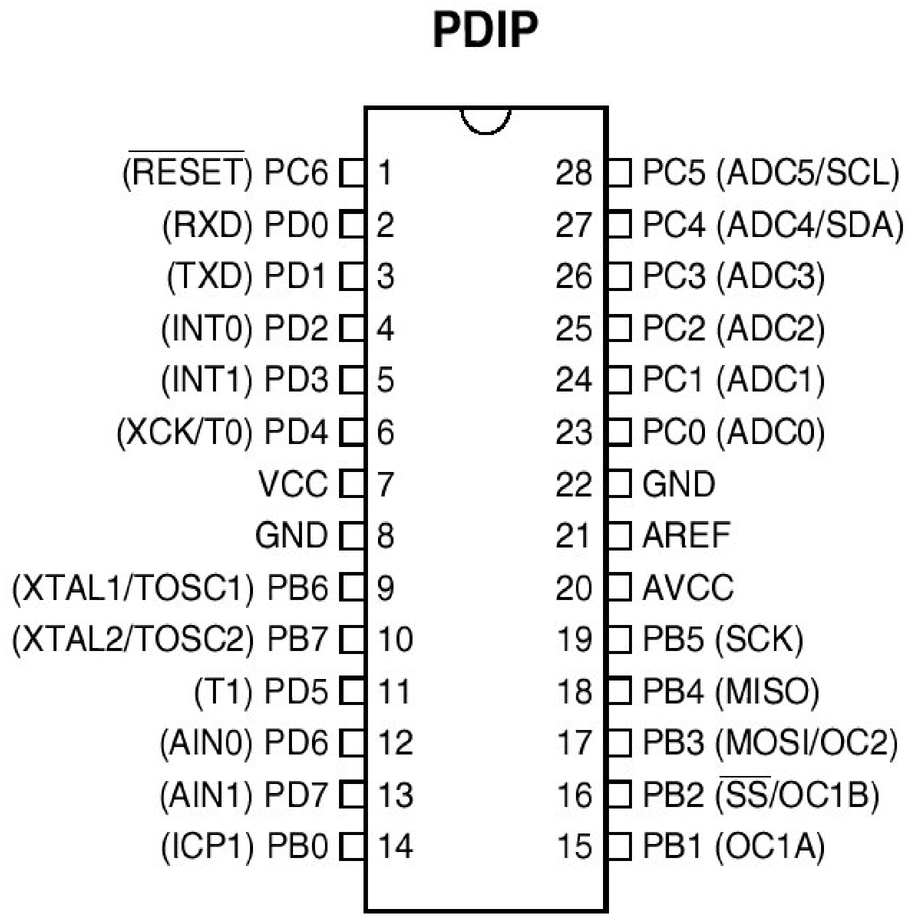
Instructions are the “atomic” actions that are taken by the processor

- One line of C code typically translates to a sequence of several instructions
- In the mega 8, most instructions are executed in a single clock cycle

The high-level view is important here: don’t worry about the details of specific instructions

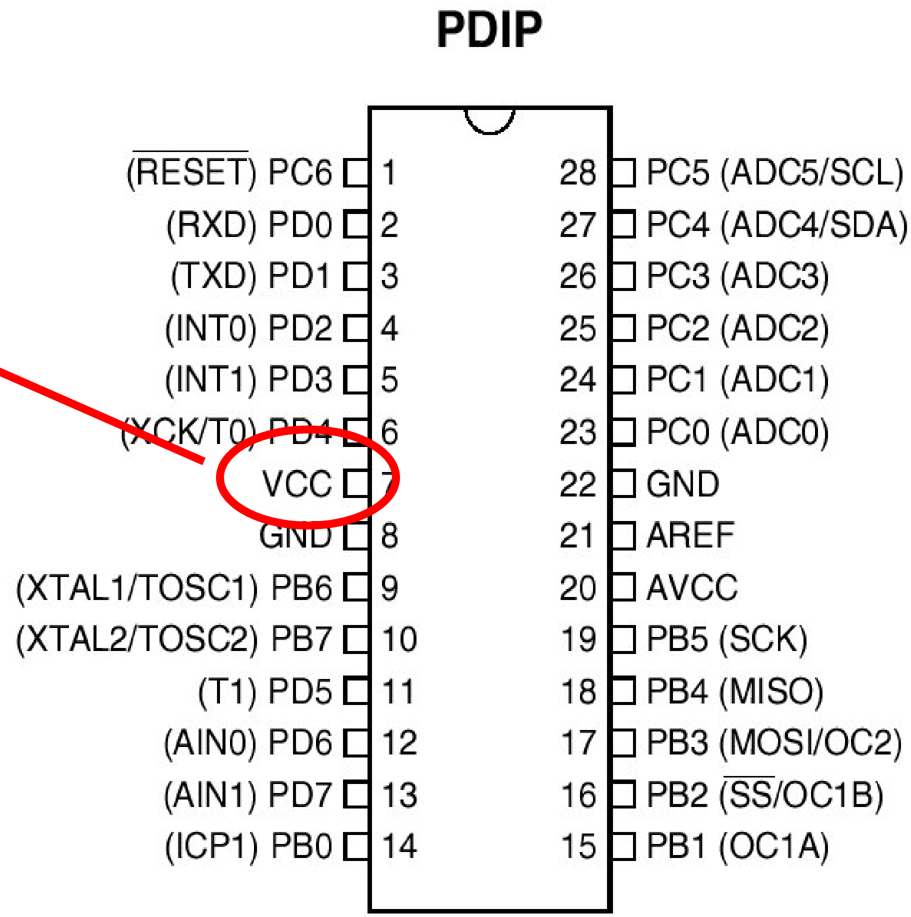
Atmel Mega8 Basics

- Complete, stand-alone computer
- Ours is a 28-pin package
- Most pins:
  - Are used for input/output
  - How they are used is configurable



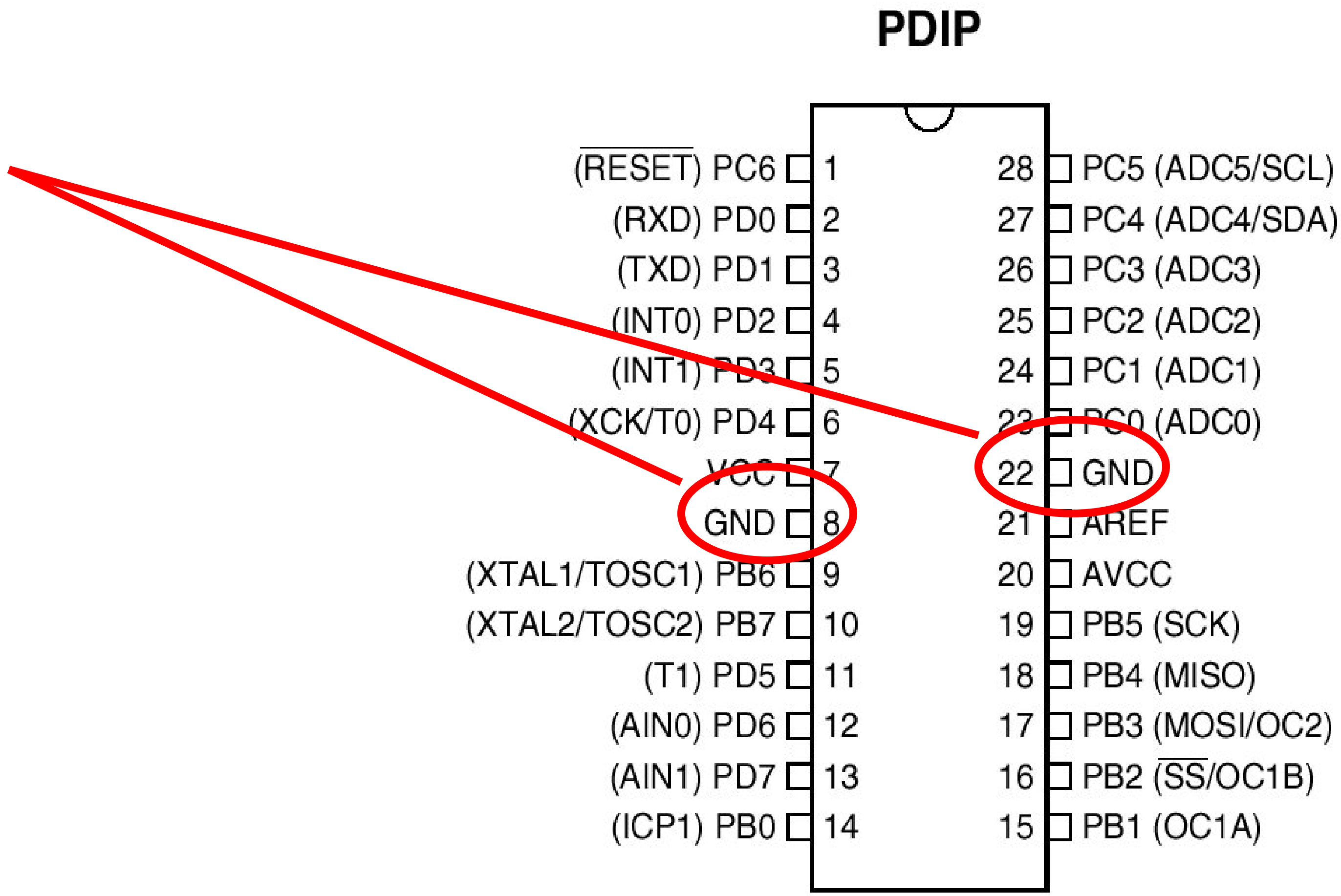
Atmel Mega8 Basics

Power (we will use +5V)



Atmel Mega8 Basics

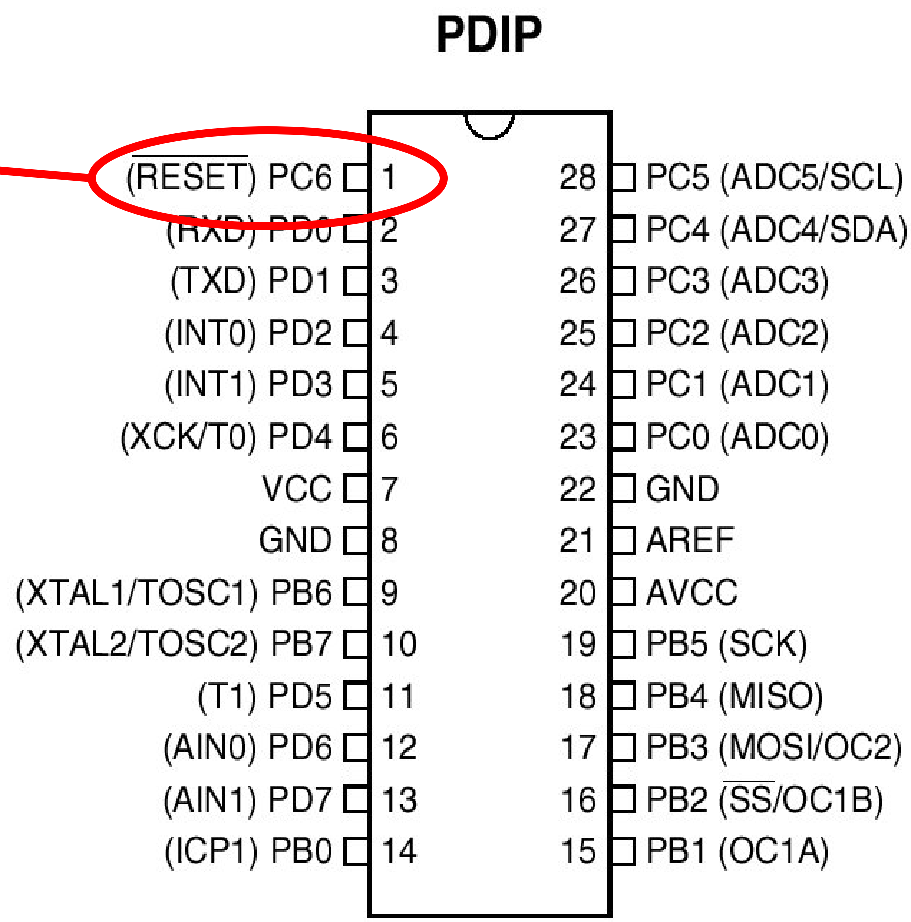
Ground



Atmel Mega8 Basics

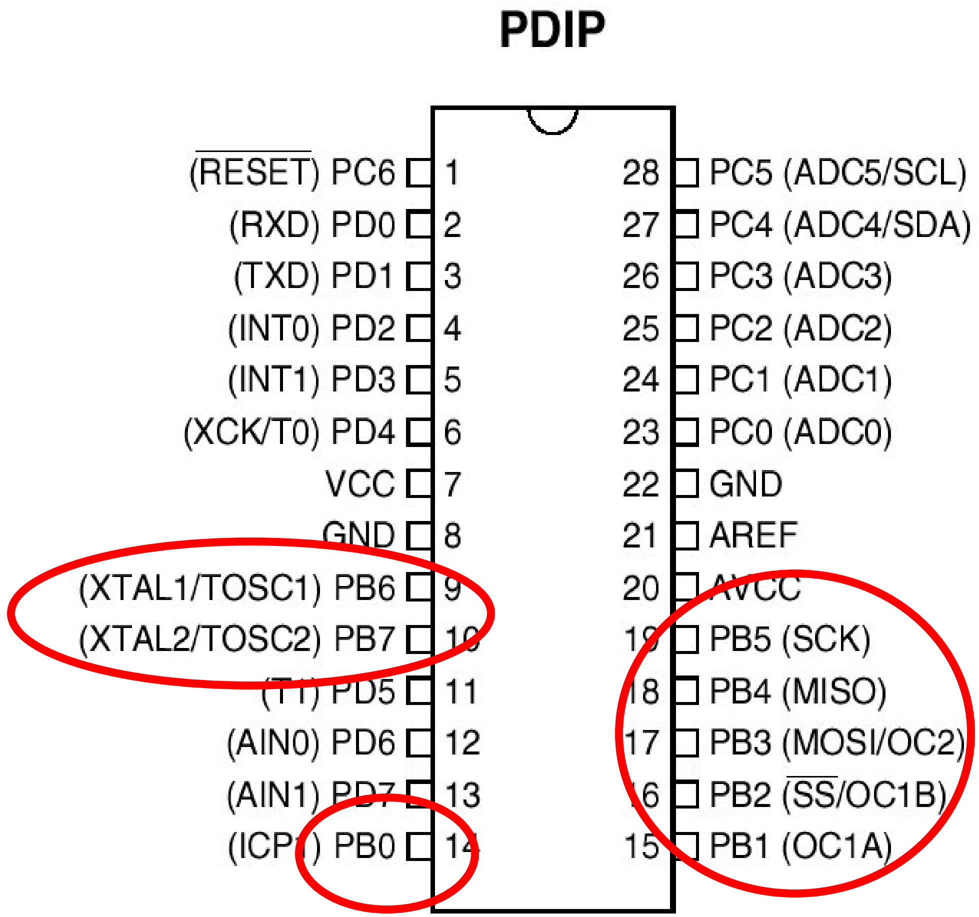
Reset

- Bring low to reset the processor
- In general, we will tie this pin to high through a pull-up resistor (10K ohm)



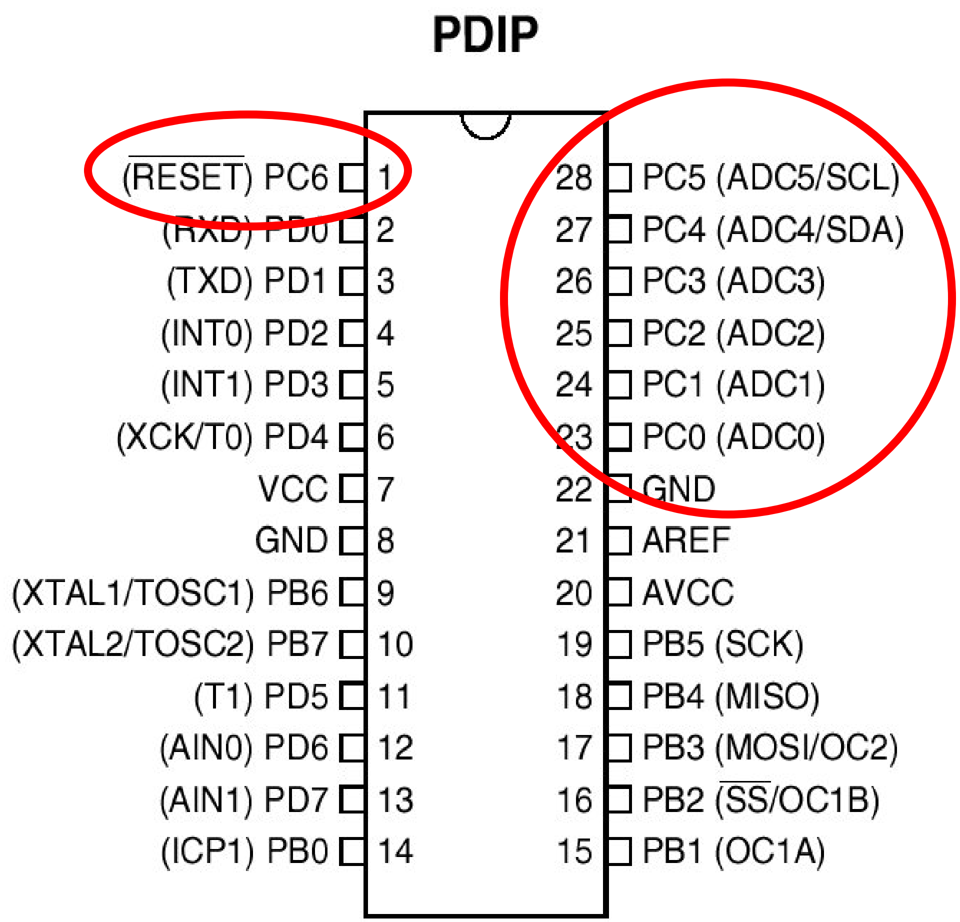
Atmel Mega8 Basics

PORT B



Atmel Mega8 Basics

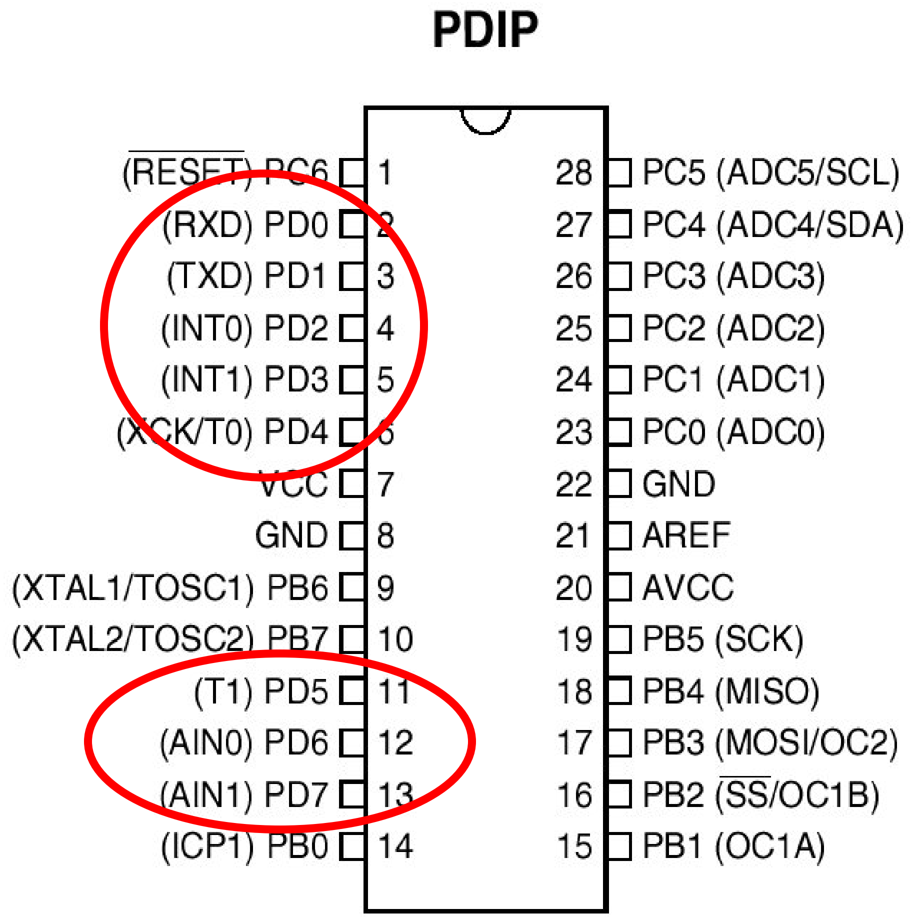
PORT C



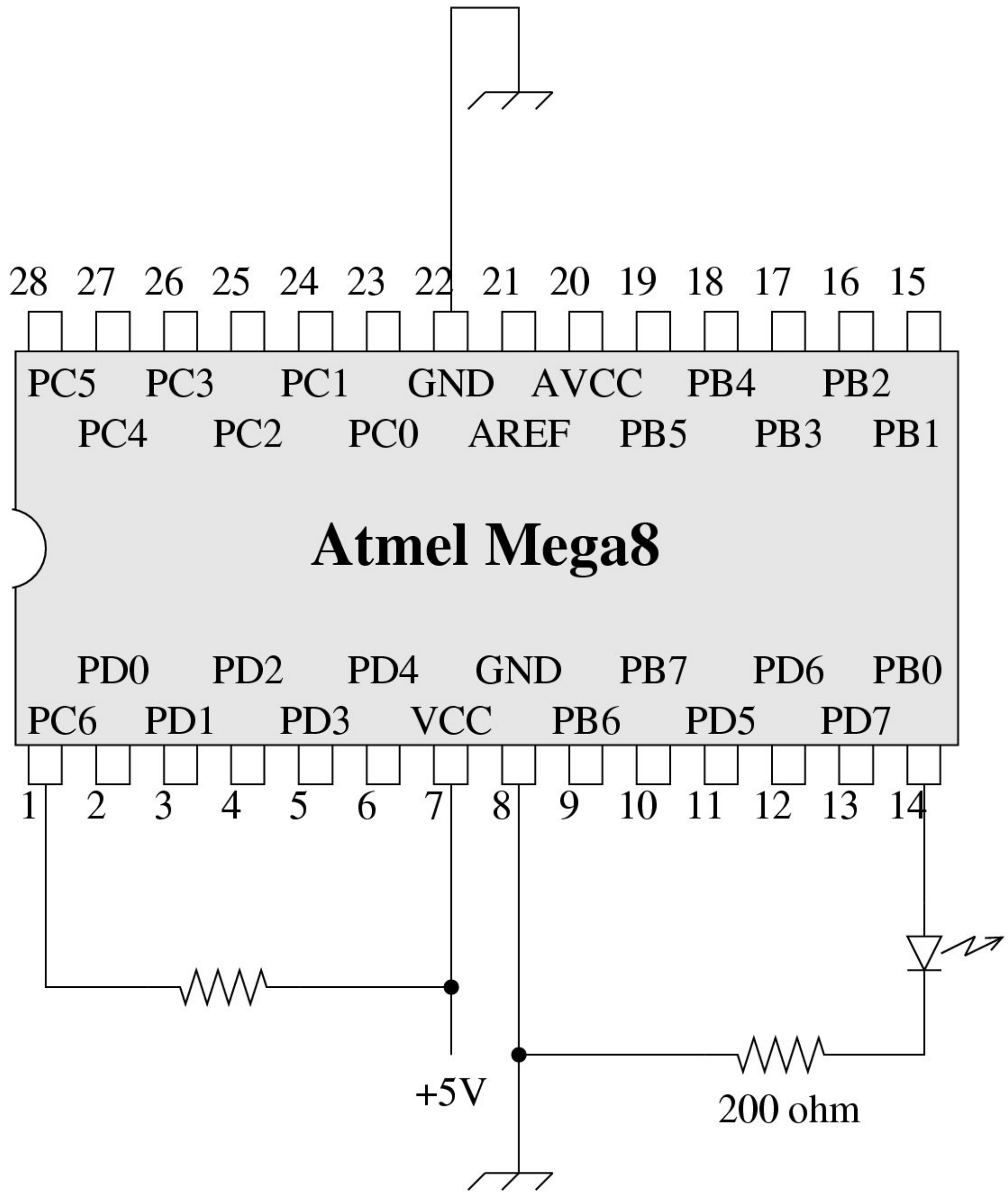
Atmel Mega8 Basics

PORT D

(all 8 bits are available)



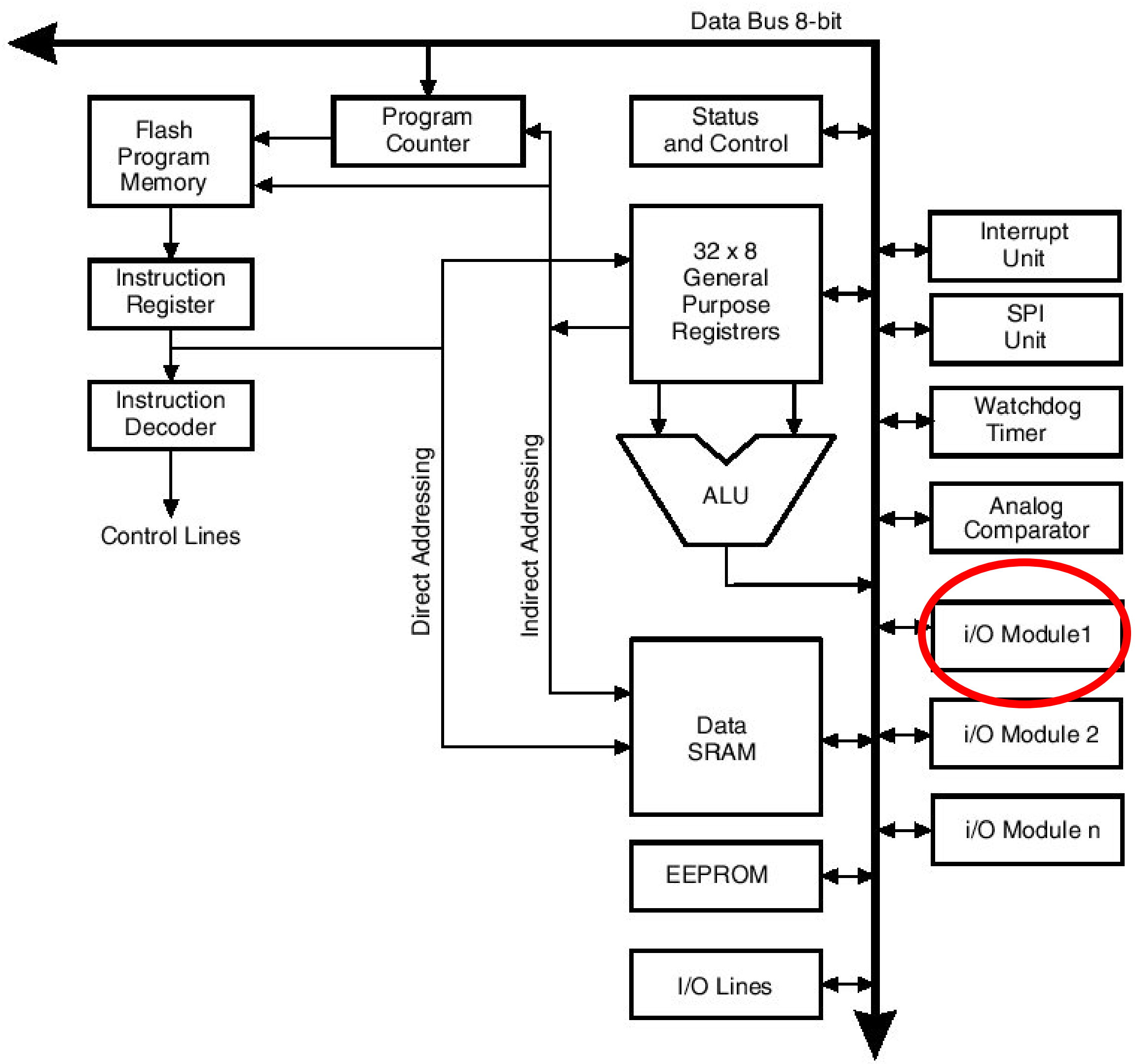
A First Circuit



Atmel Mega8

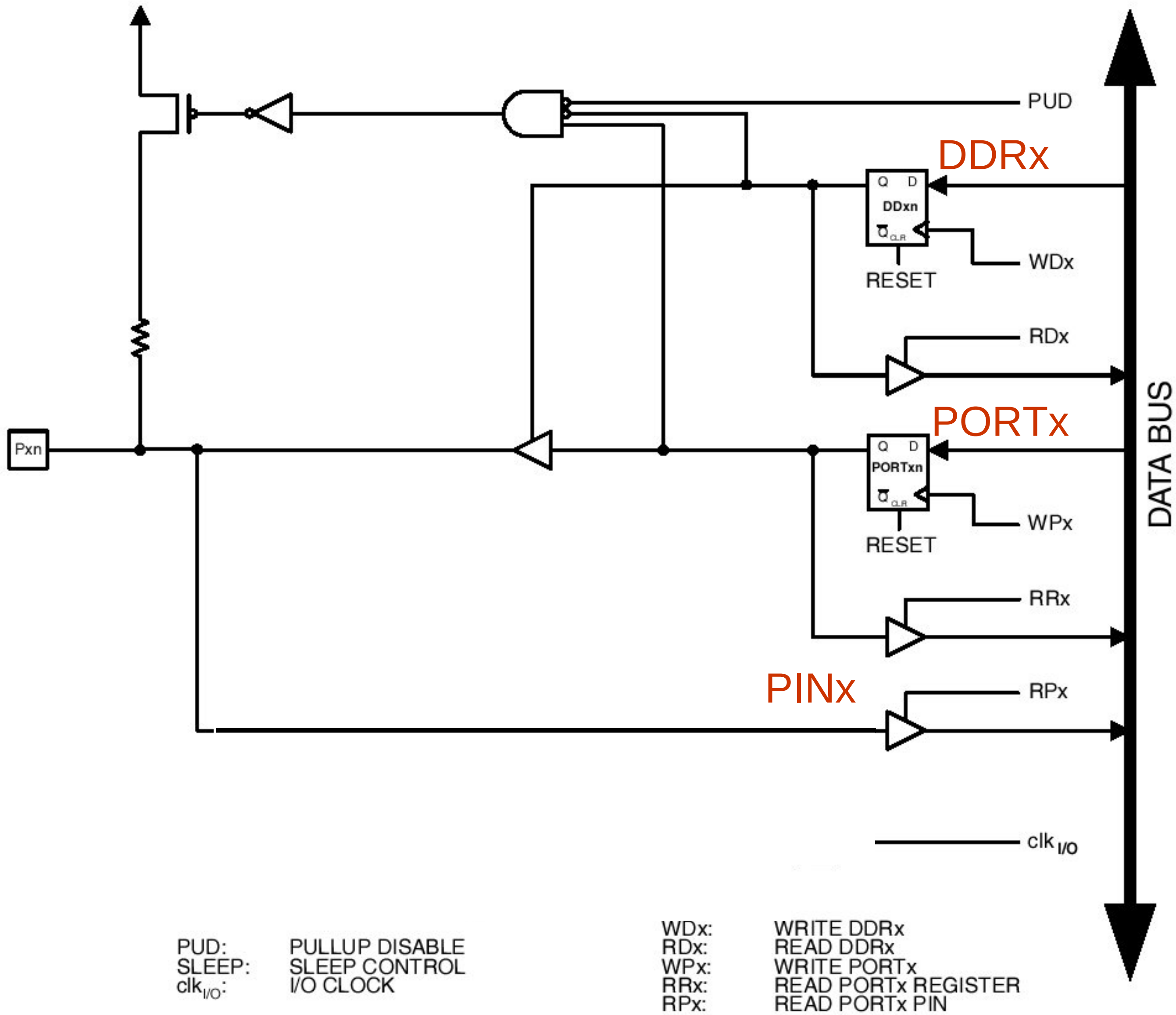
Control the pins through the I/O modules

- At the heart, these are registers … that are implemented using D flip-flops!



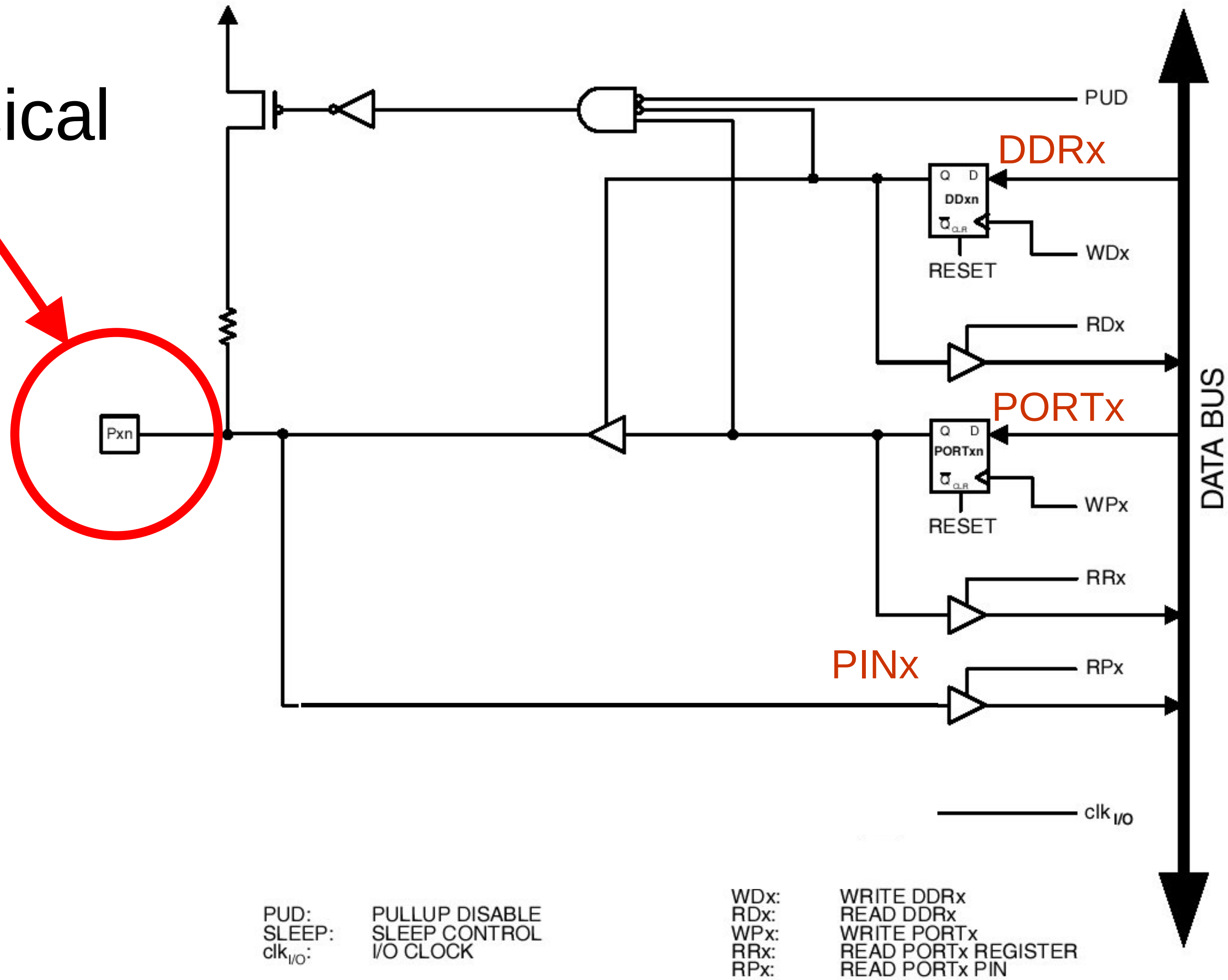
I/O Pin Implementation

Single bit of
PORT B



I/O Pin Implementation

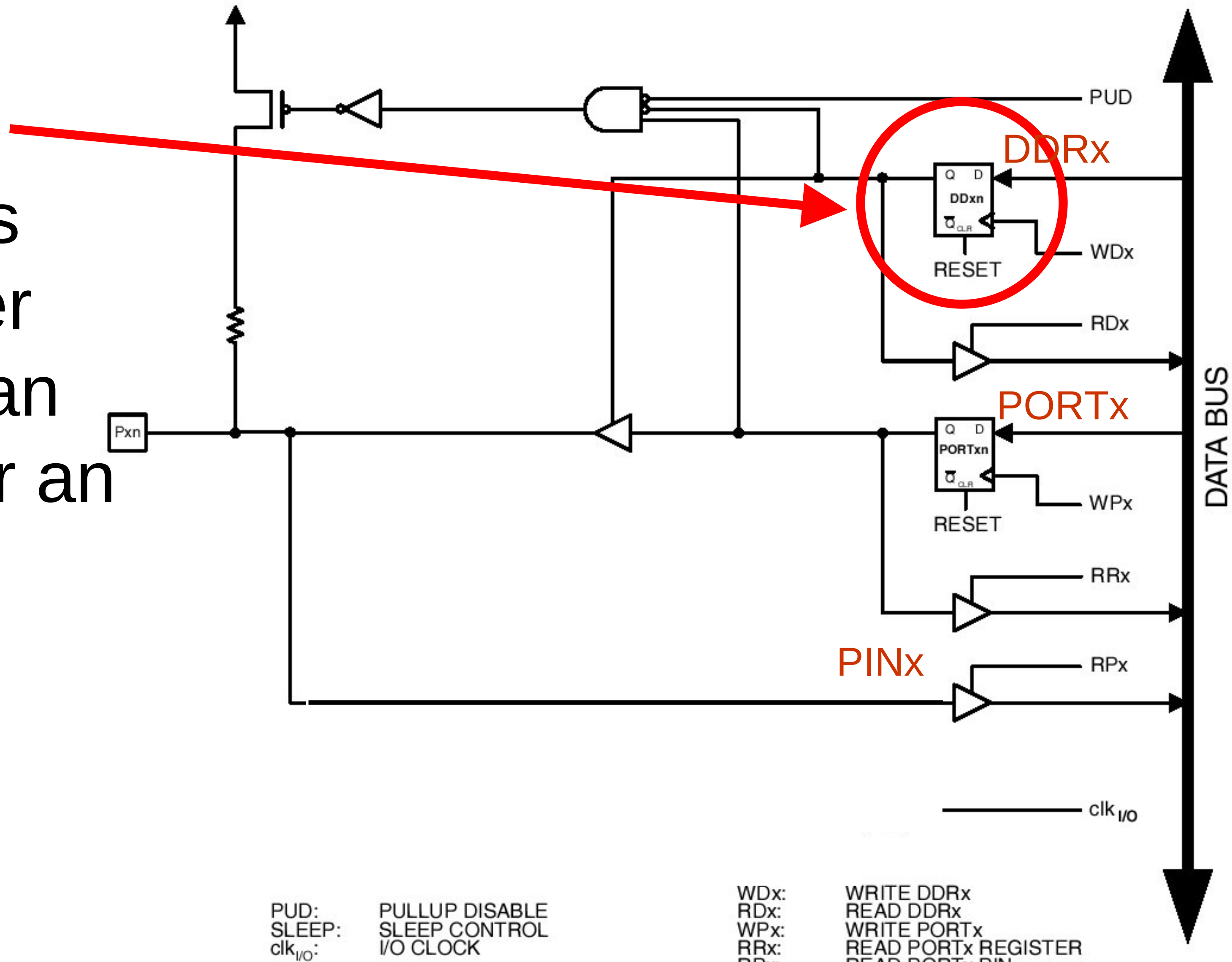
The physical pin



I/O Pin Implementation

DDRB

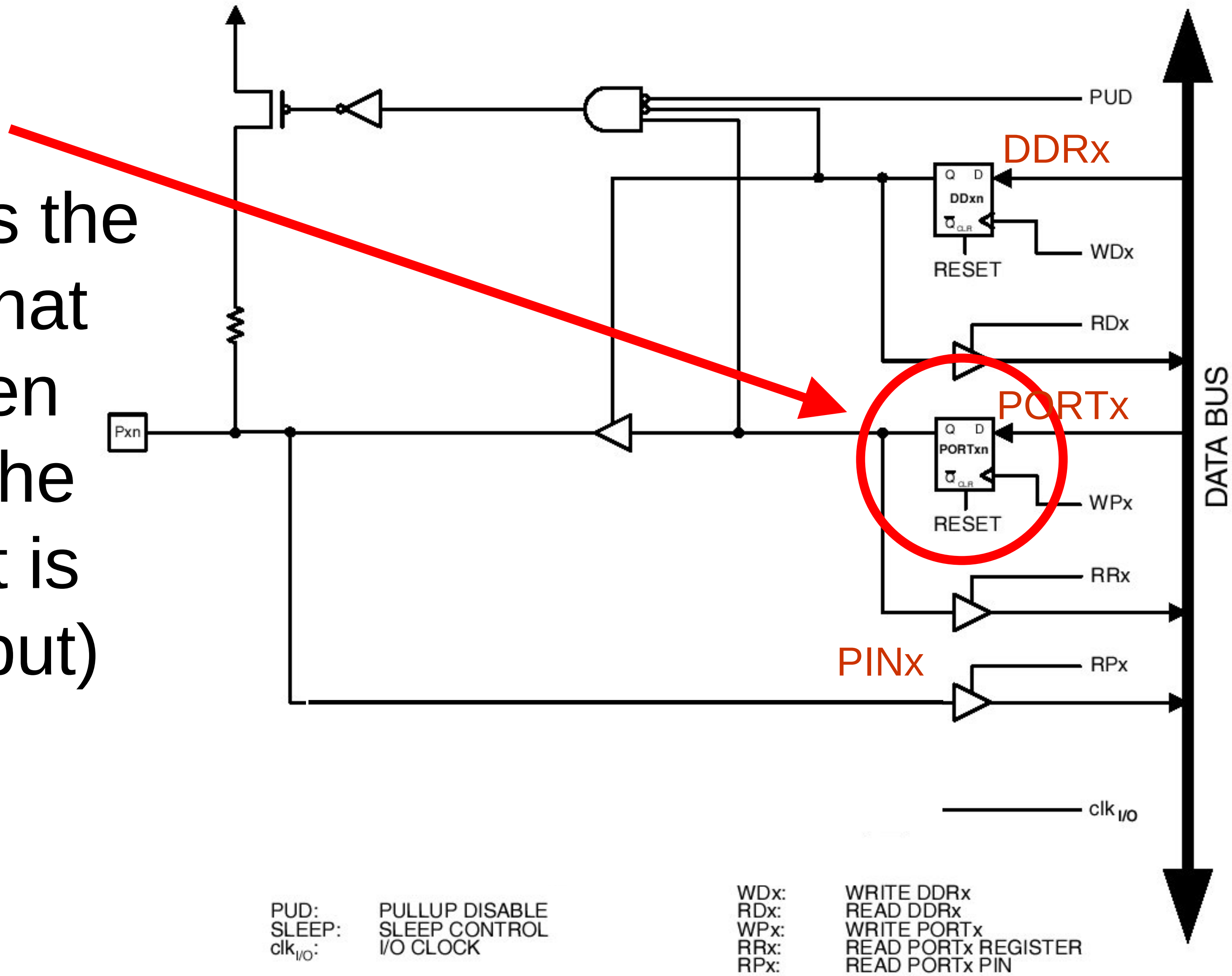
- Defines whether this is an input or an output



I/O Pin Implementation

PORTB

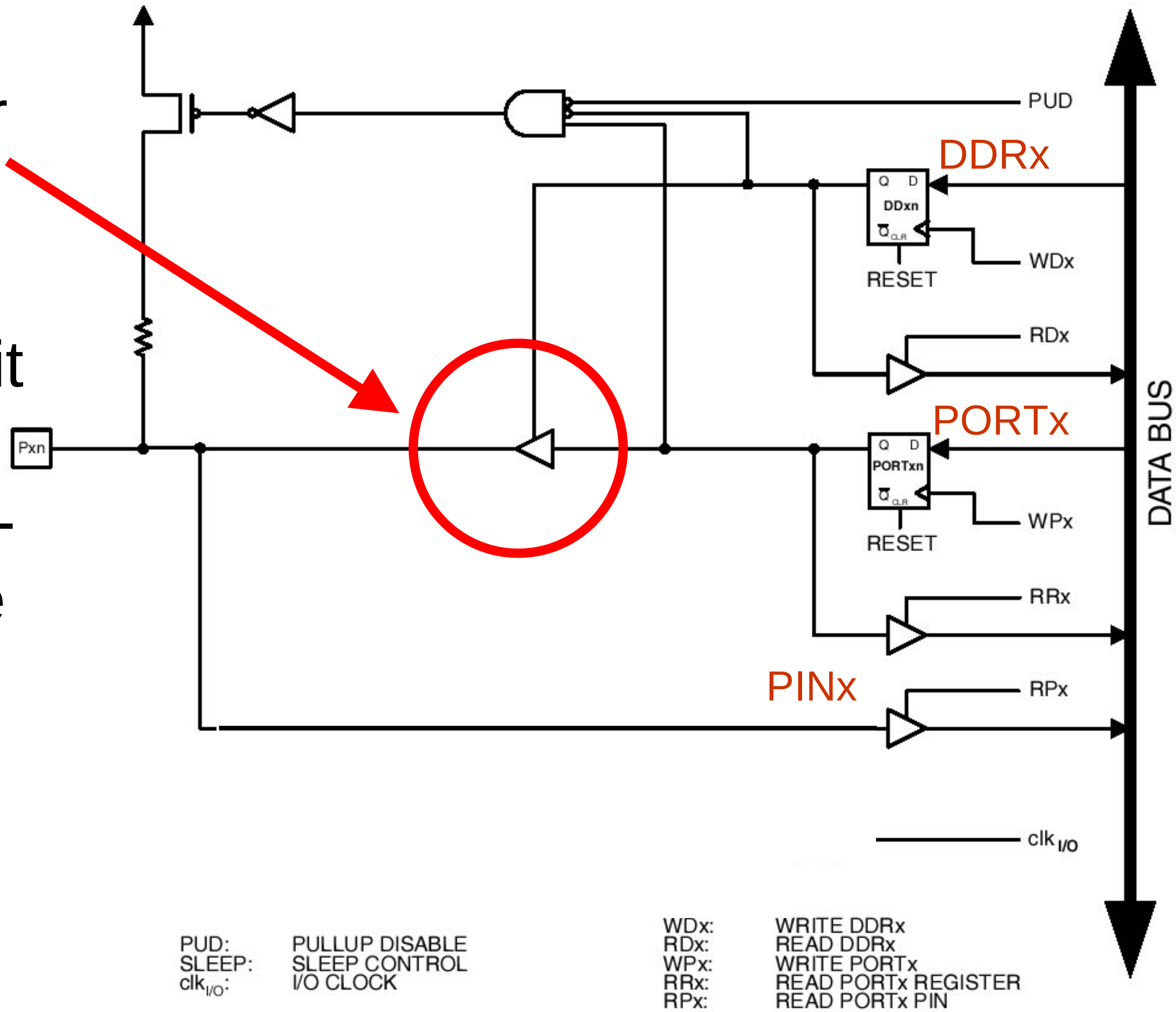
- Defines the value that is written out to the pin (if it is an output)



I/O Pin Implementation

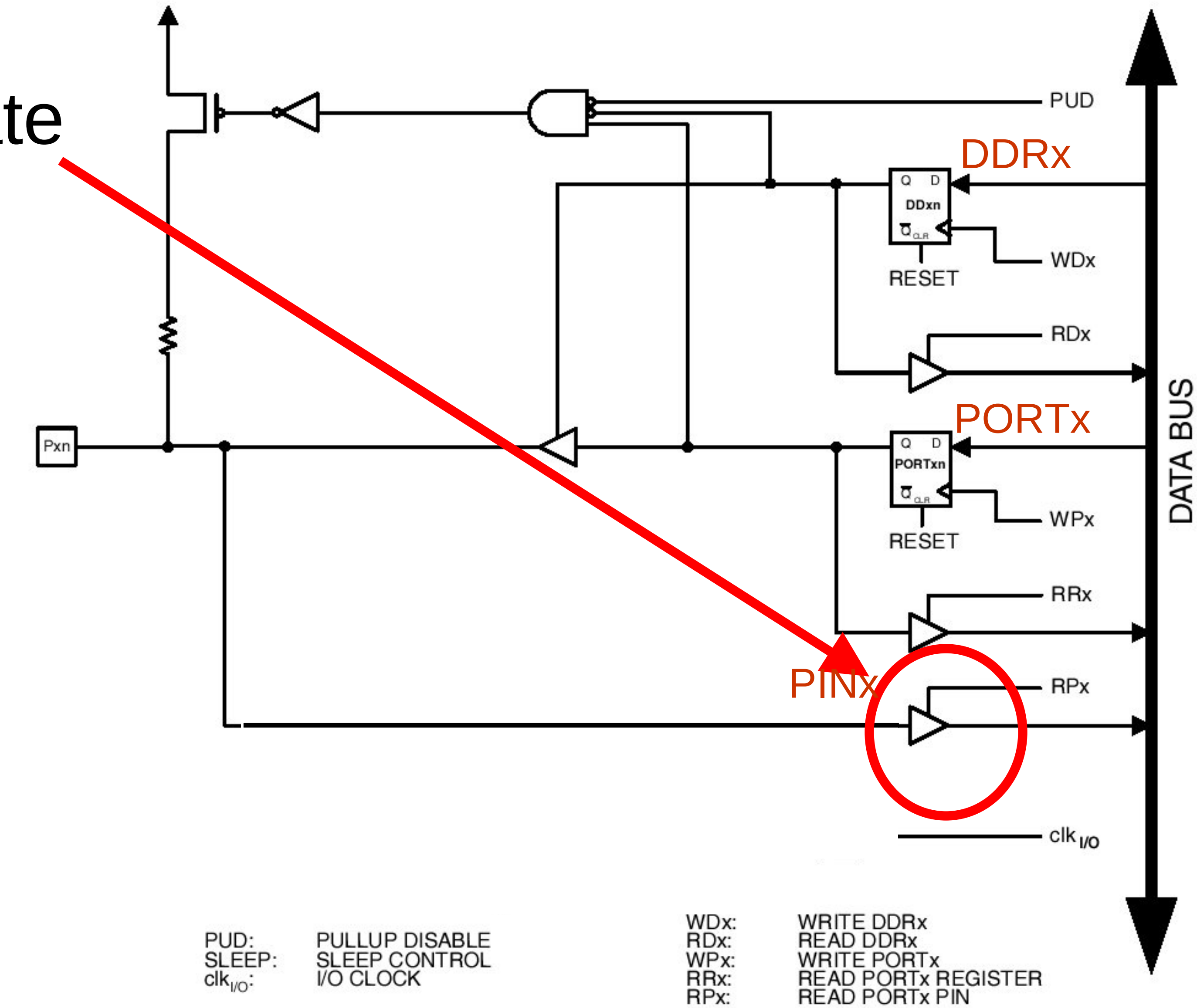
Tristate buffer

- When this pin is an output pin, it allows the PORTB flip-flop to drive the pin

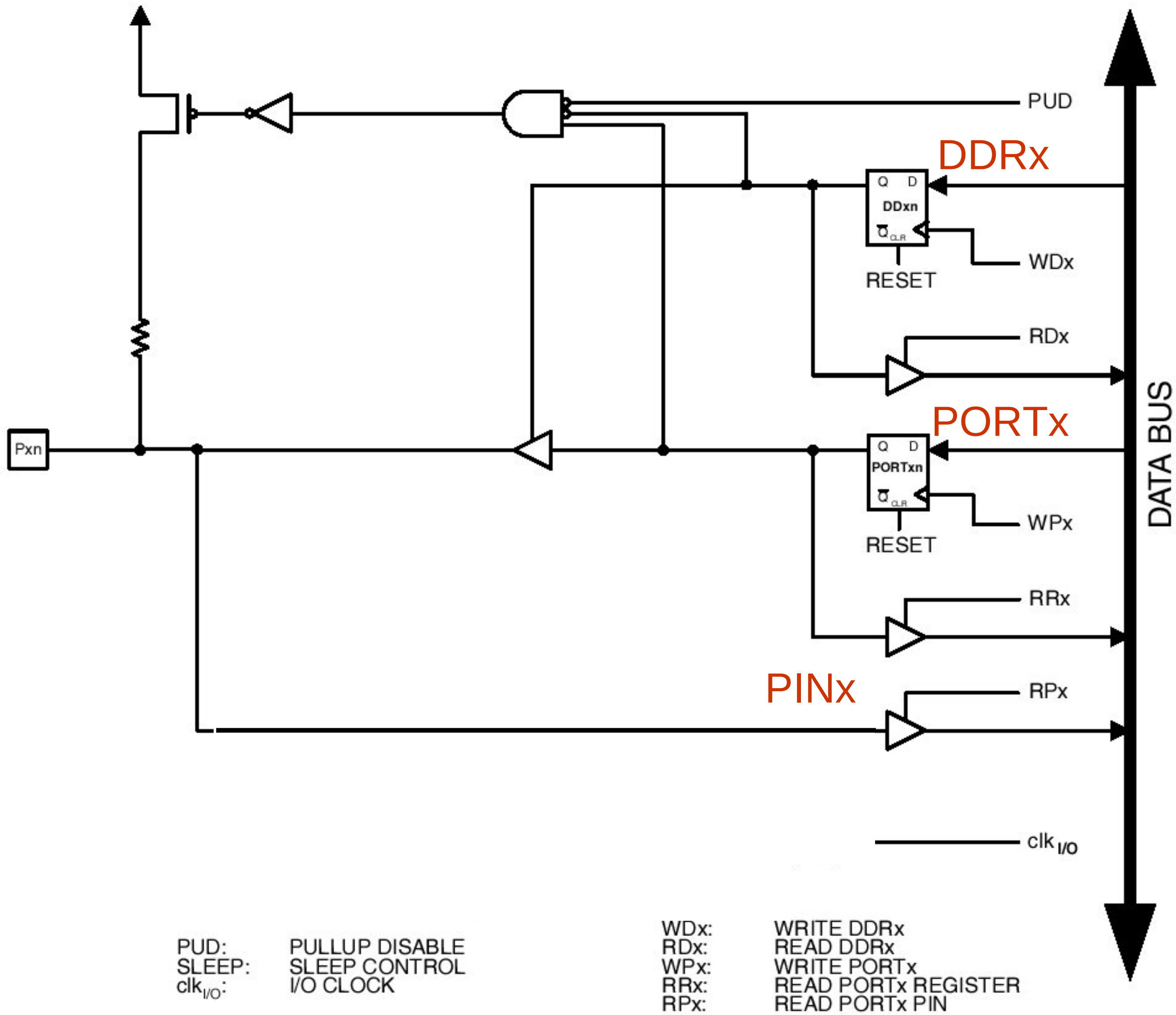


I/O Pin Implementation

Input tri-state buffer

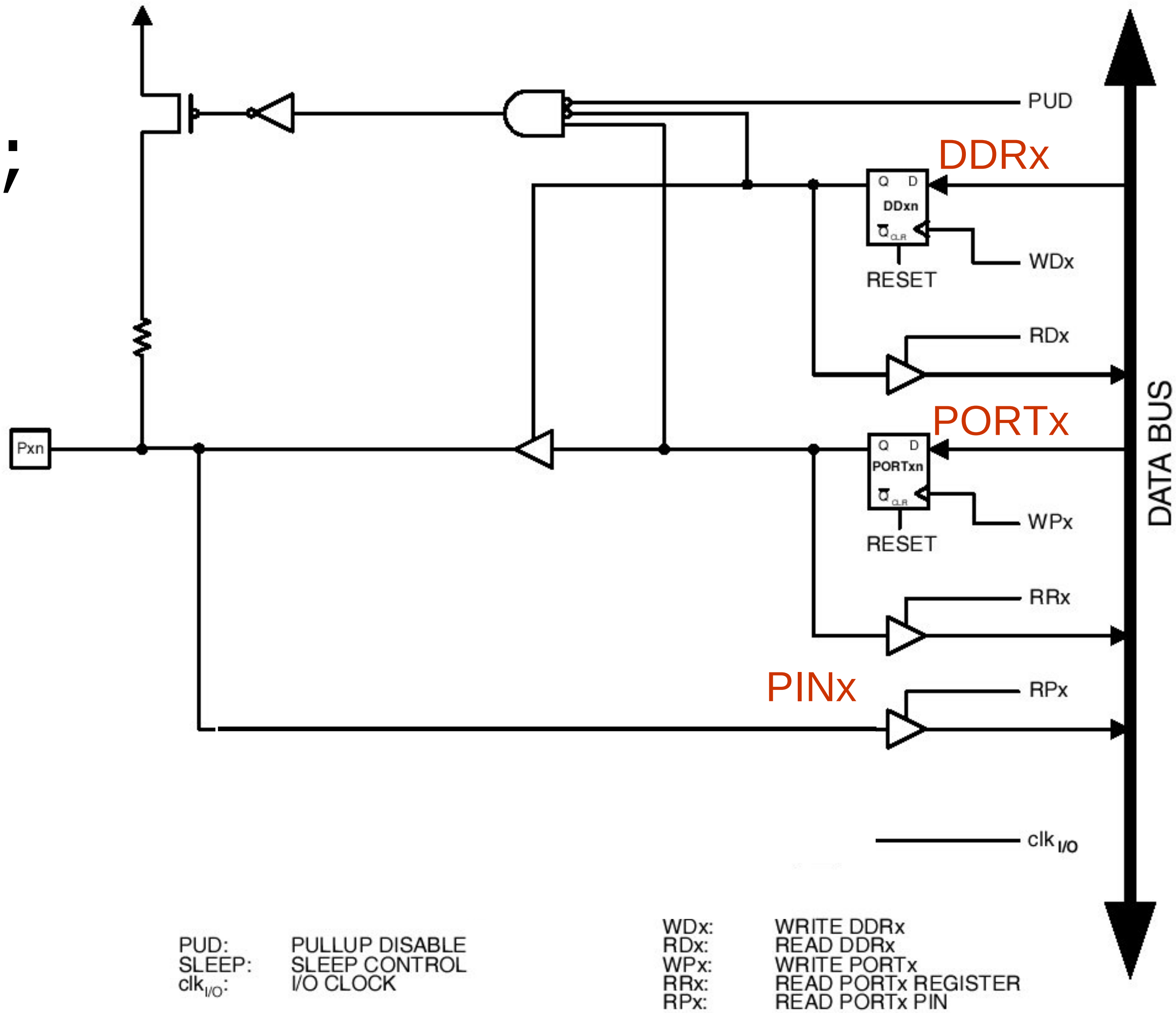


I/O Pin Implementation



I/O Pin Implementation

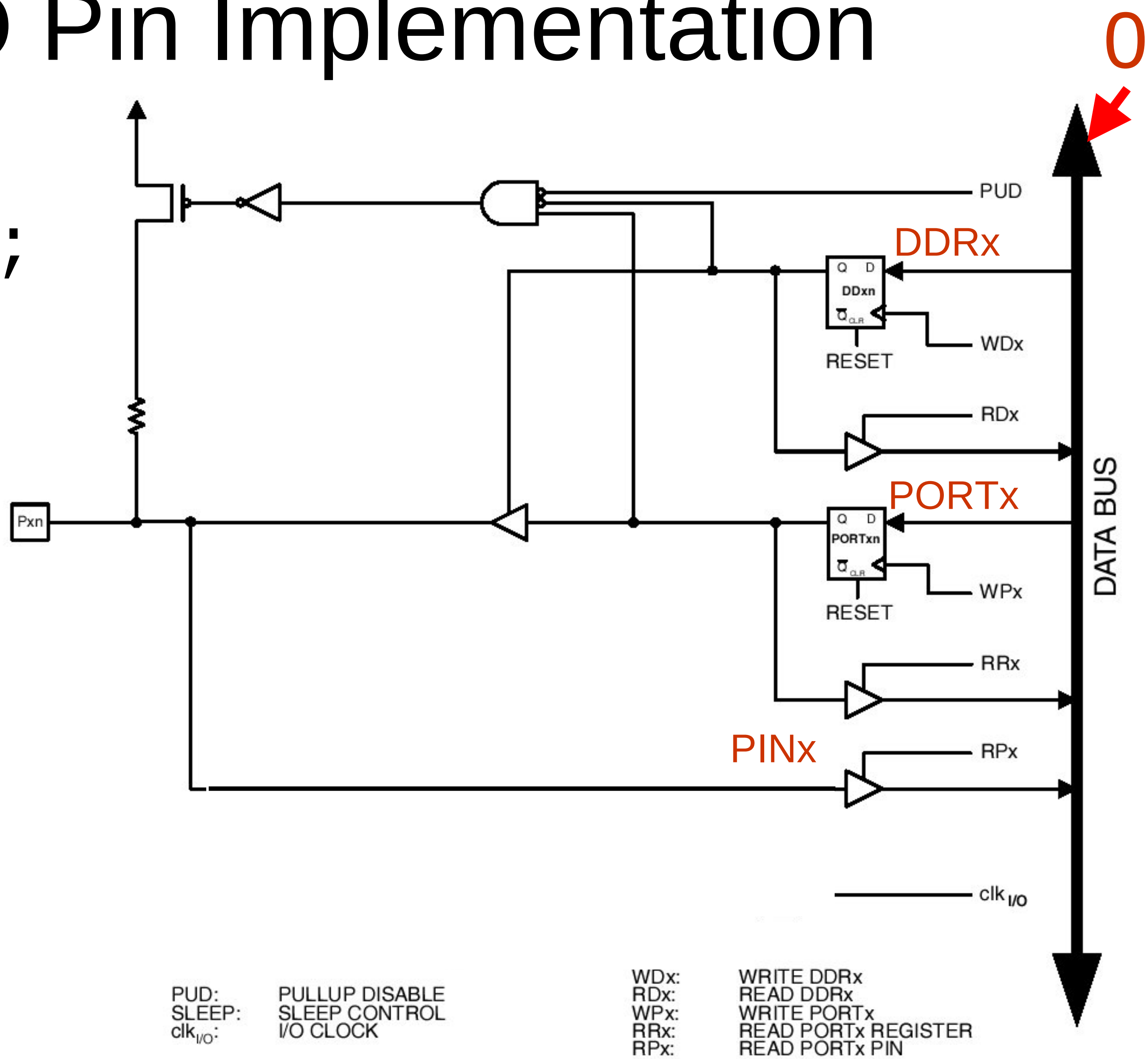
```
DDRB = 0;
```



I/O Pin Implementation

```
DDRB = 0;
```

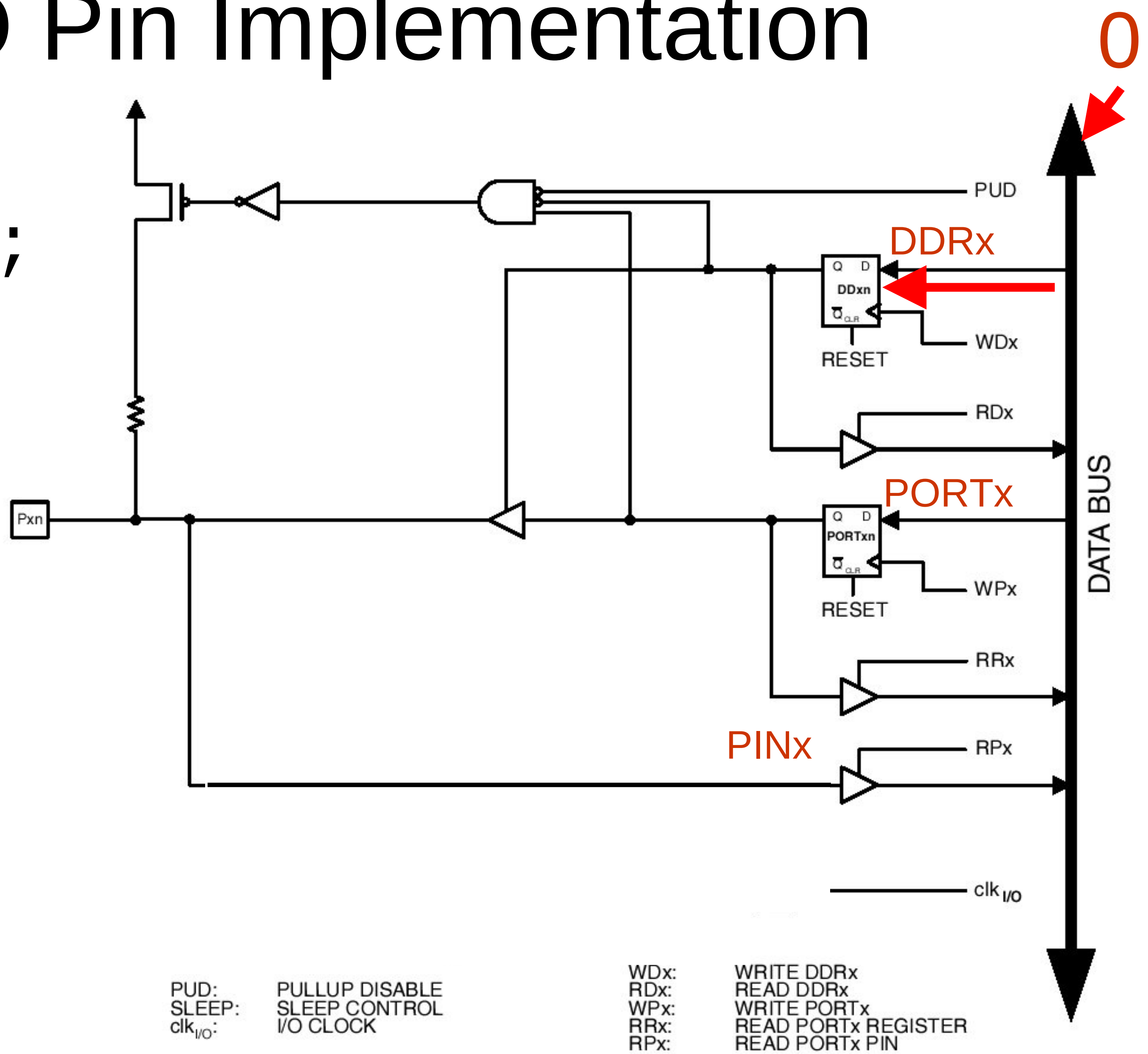
• “0” is written to the data bus



I/O Pin Implementation

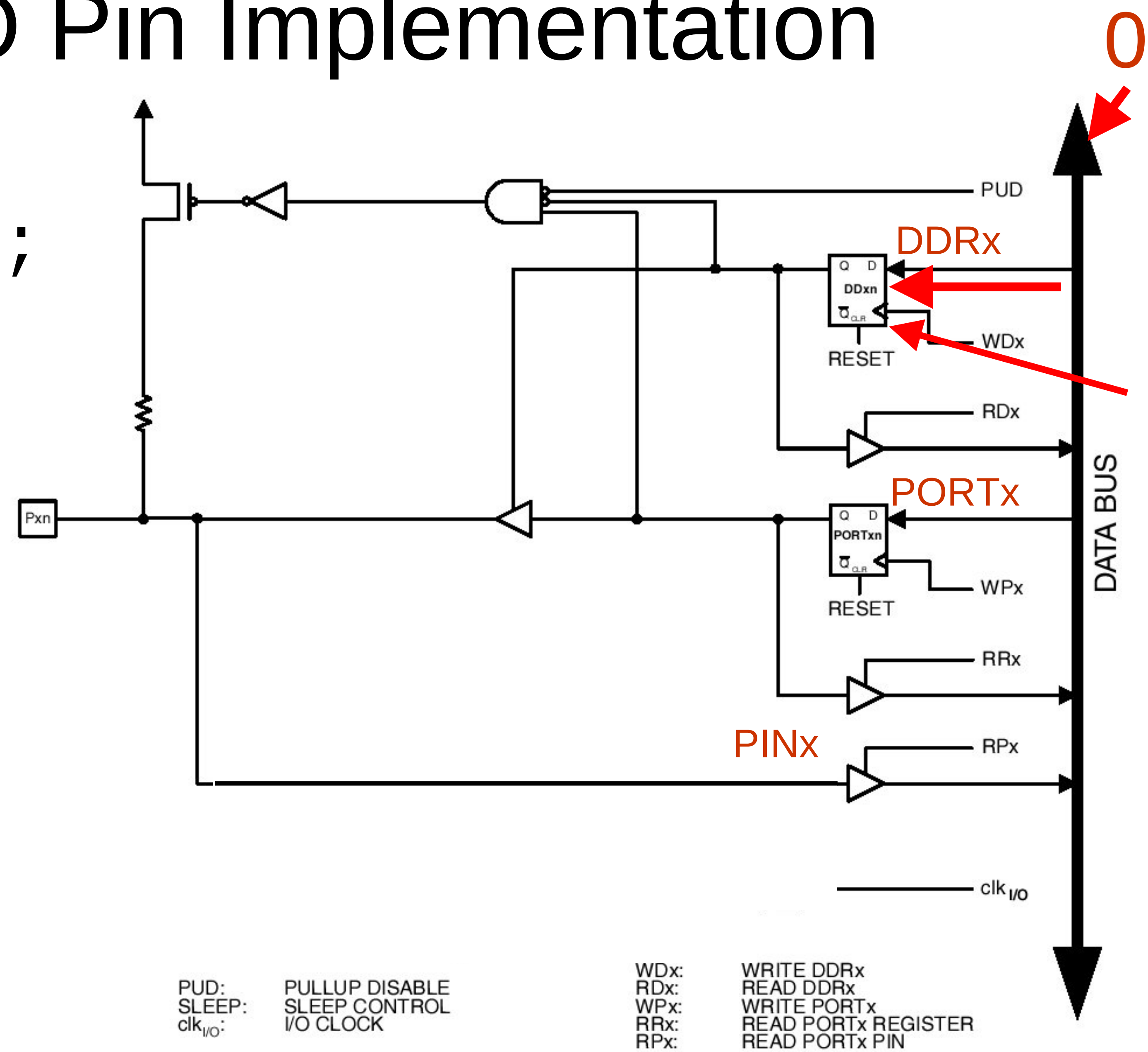
```
DDRB = 0;
```

- “0” is written to the data bus
- This is input to the DDRB register



I/O Pin Implementation

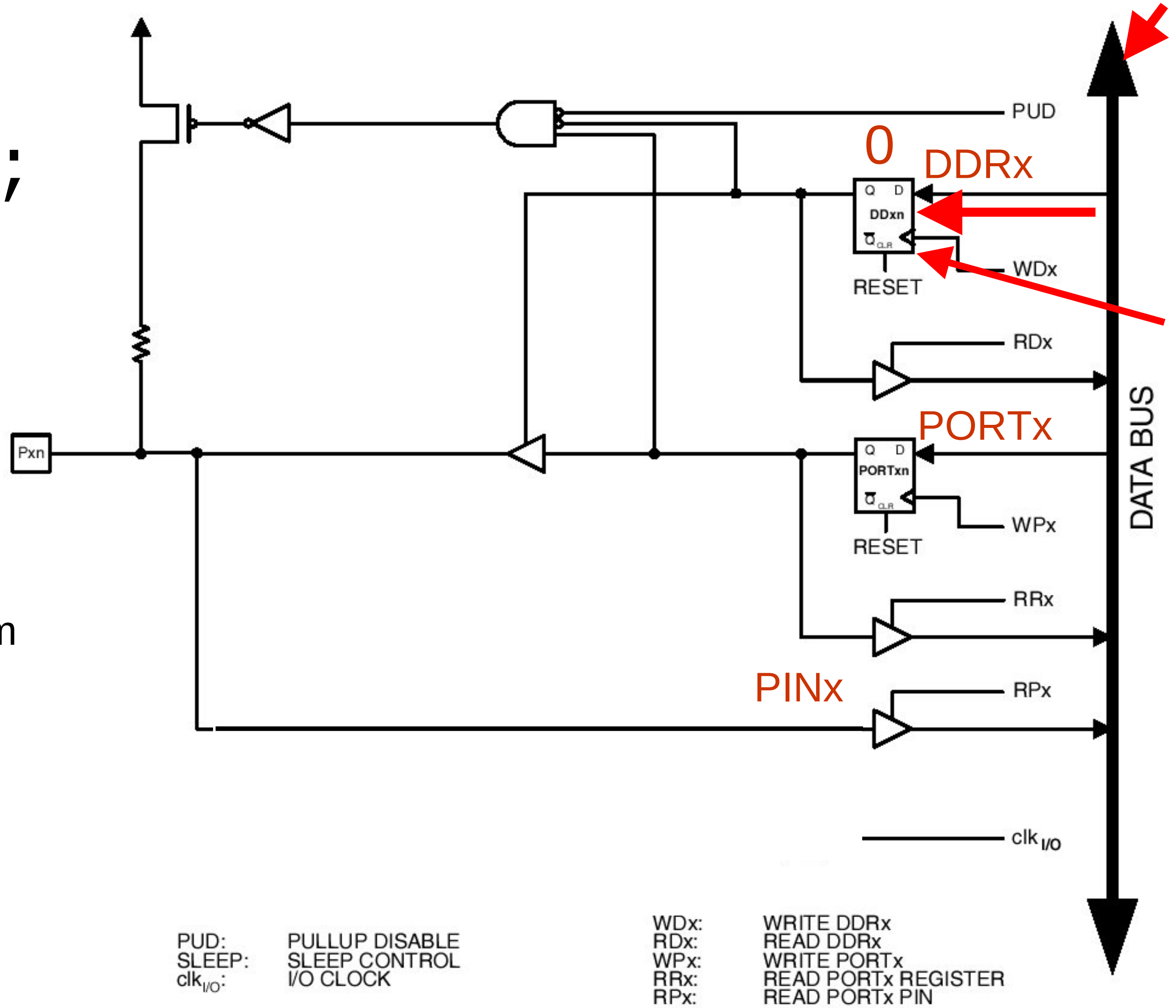
```
DDRB = 0;
```



- “0” is written to the data bus
- This is input to the DDRB register
- WDB is clocked from high to low

I/O Pin Implementation

```
DDRB = 0;
```



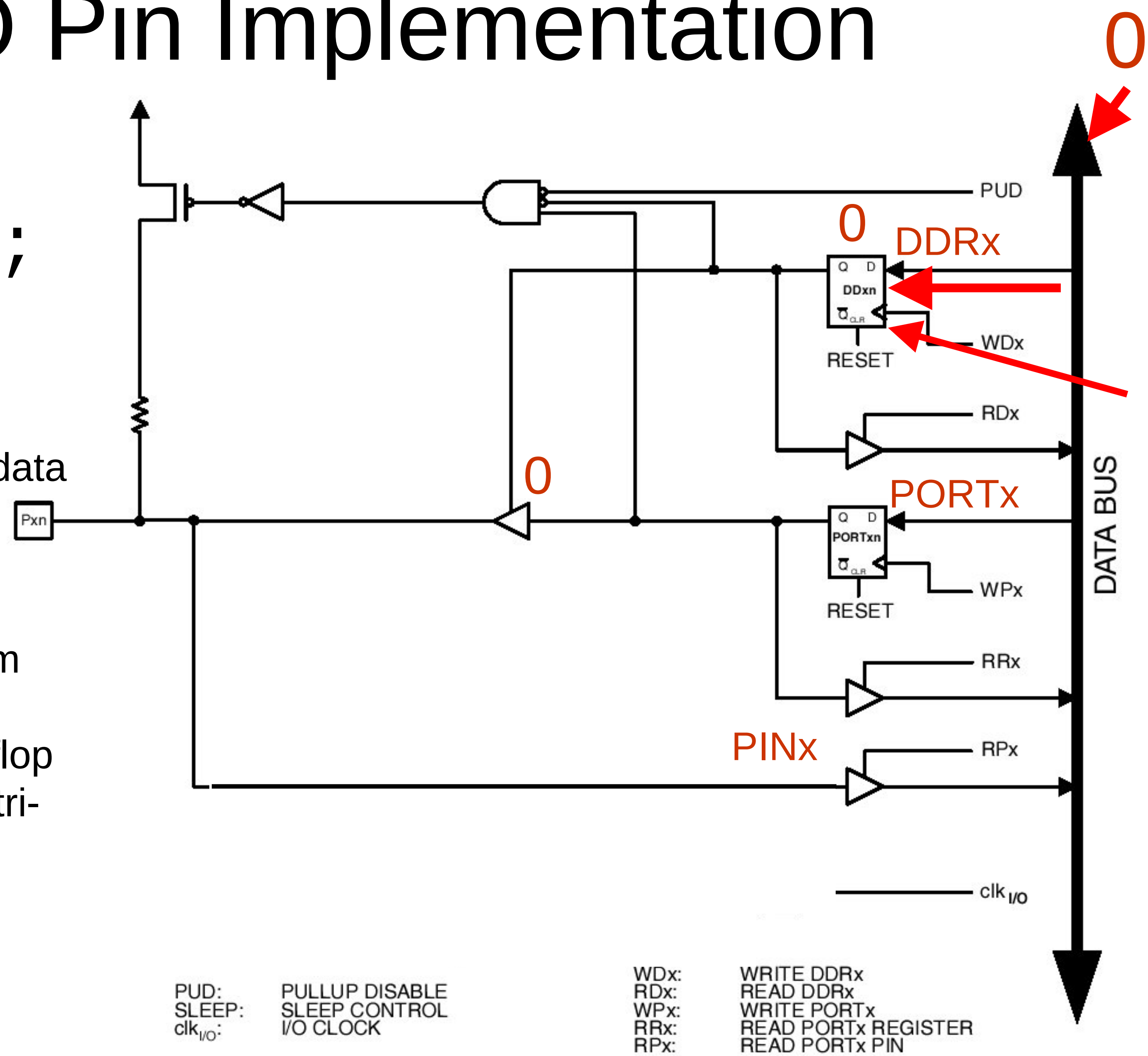
- “0” is written to the data bus
- This is input to the DDRB register
- WDB is clocked from high to low
- “0” is stored by the flip-flop

I/O Pin Implementation

```
DDRB = 0;
```

• “0” is written to the data bus
• This is input to the DDRB register
• WDB is clocked from high to low
• “0” is stored by flip-flop
• Which turns off the tri-state buffer

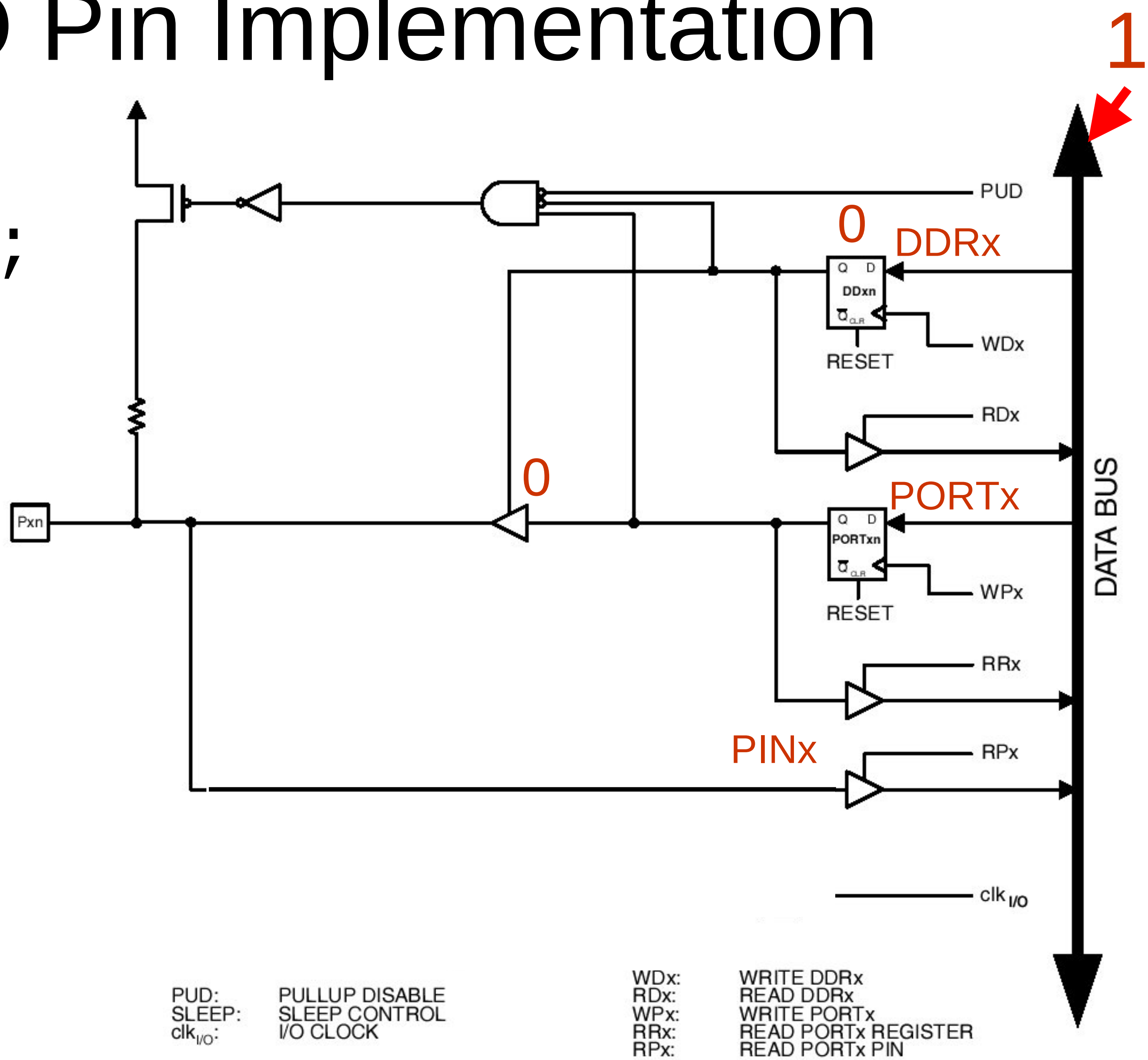
-> this is an input pin



I/O Pin Implementation

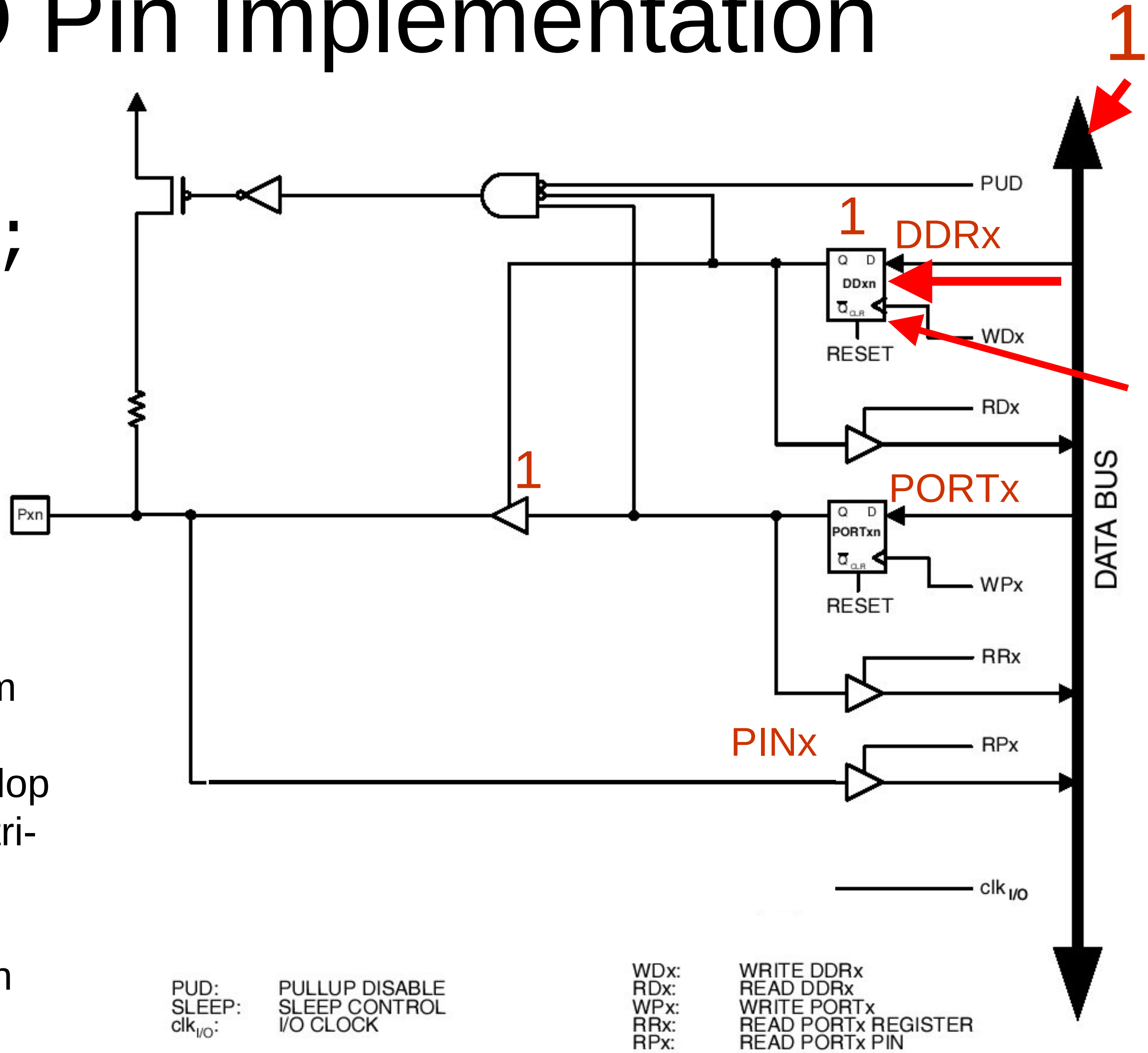
```
DDRB = 1;
```

- “1” is written to the data bus



I/O Pin Implementation

```
DDRB = 1;
```



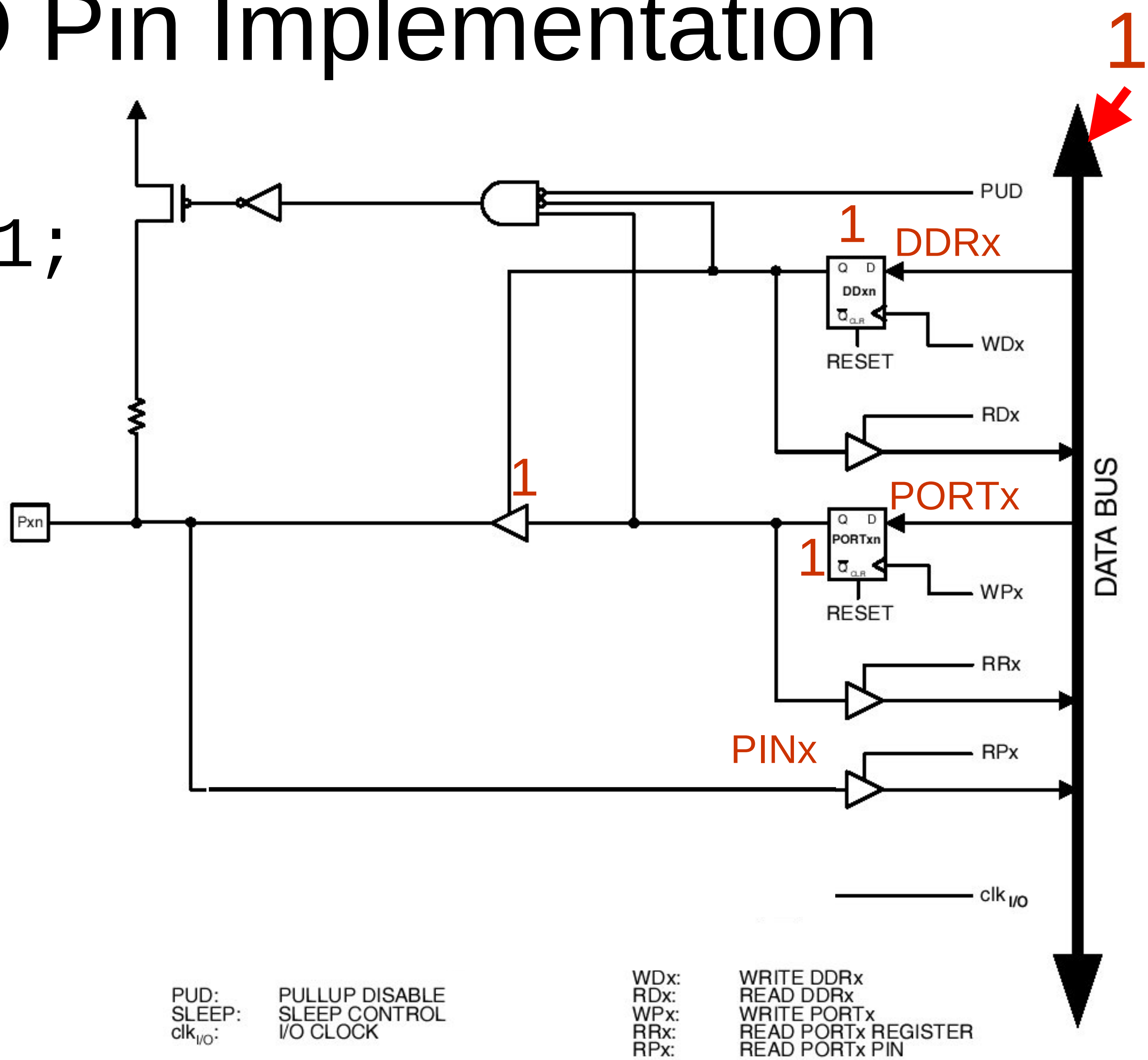
- “1” is written to the data bus
- This is input to the DDRB register
- WDB is clocked from high to low
- “1” is stored by flip-flop
- Which turns on the tri-state buffer

-> this is an output pin

I/O Pin Implementation

```
PORTB = 1;
```

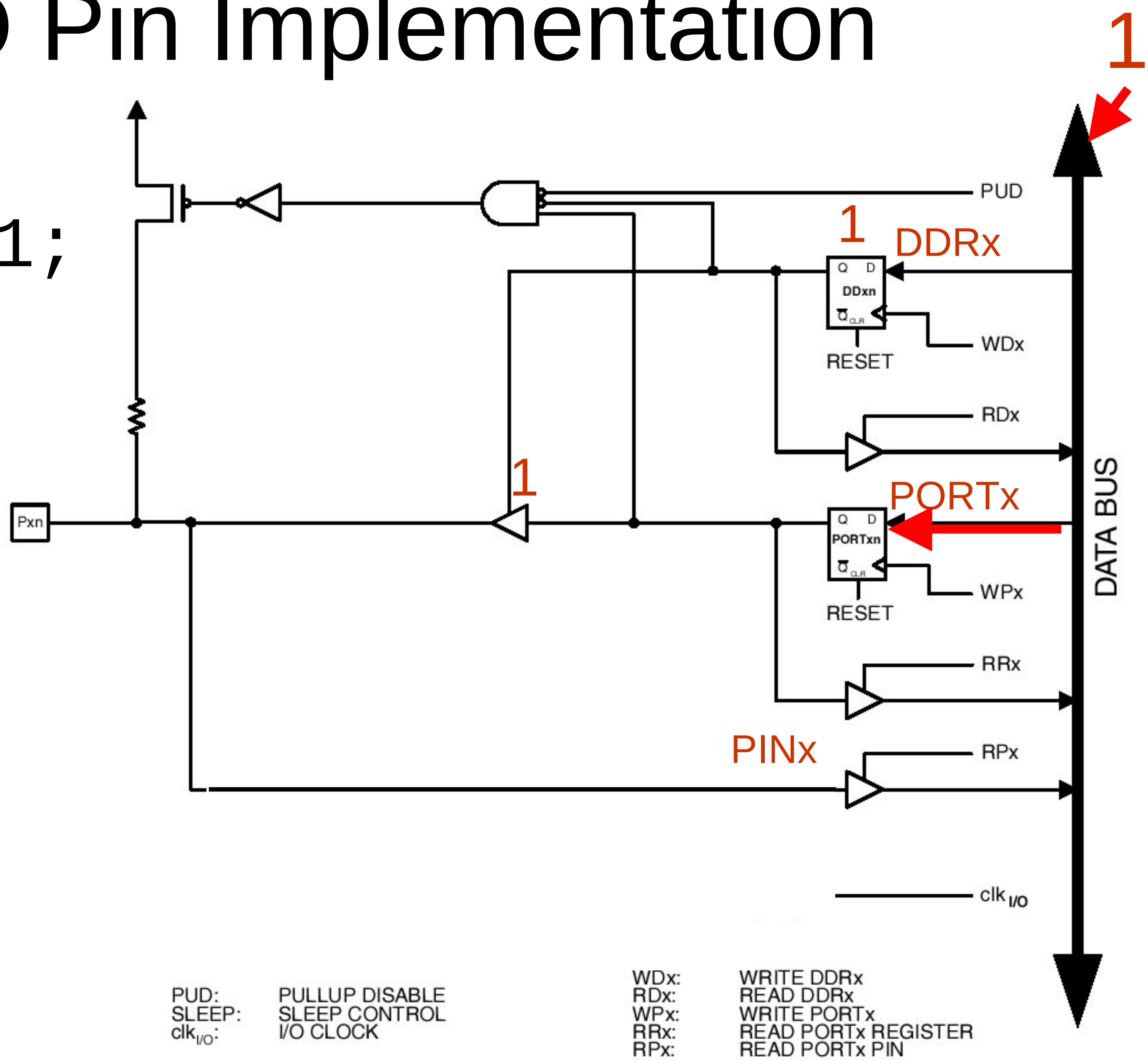
•



I/O Pin Implementation

```
PORTB = 1;
```

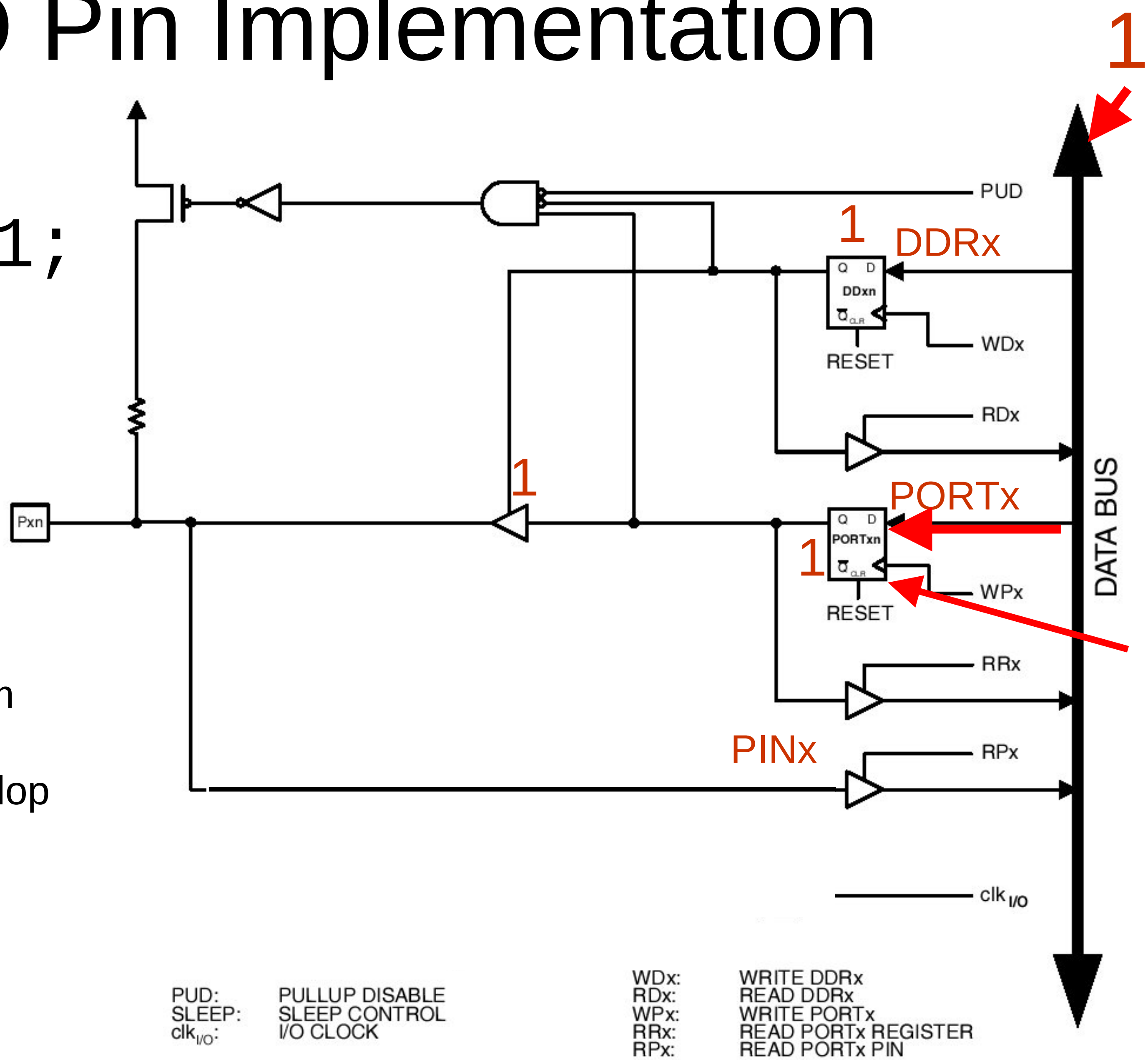
• "1" is written to the data bus
• This is input to the PORTB register



I/O Pin Implementation

```
PORTB = 1;
```

- “1” is written to the data bus
- This is input to the PORTB register
- WPB is clocked from high to low
- “1” is stored by flip-flop

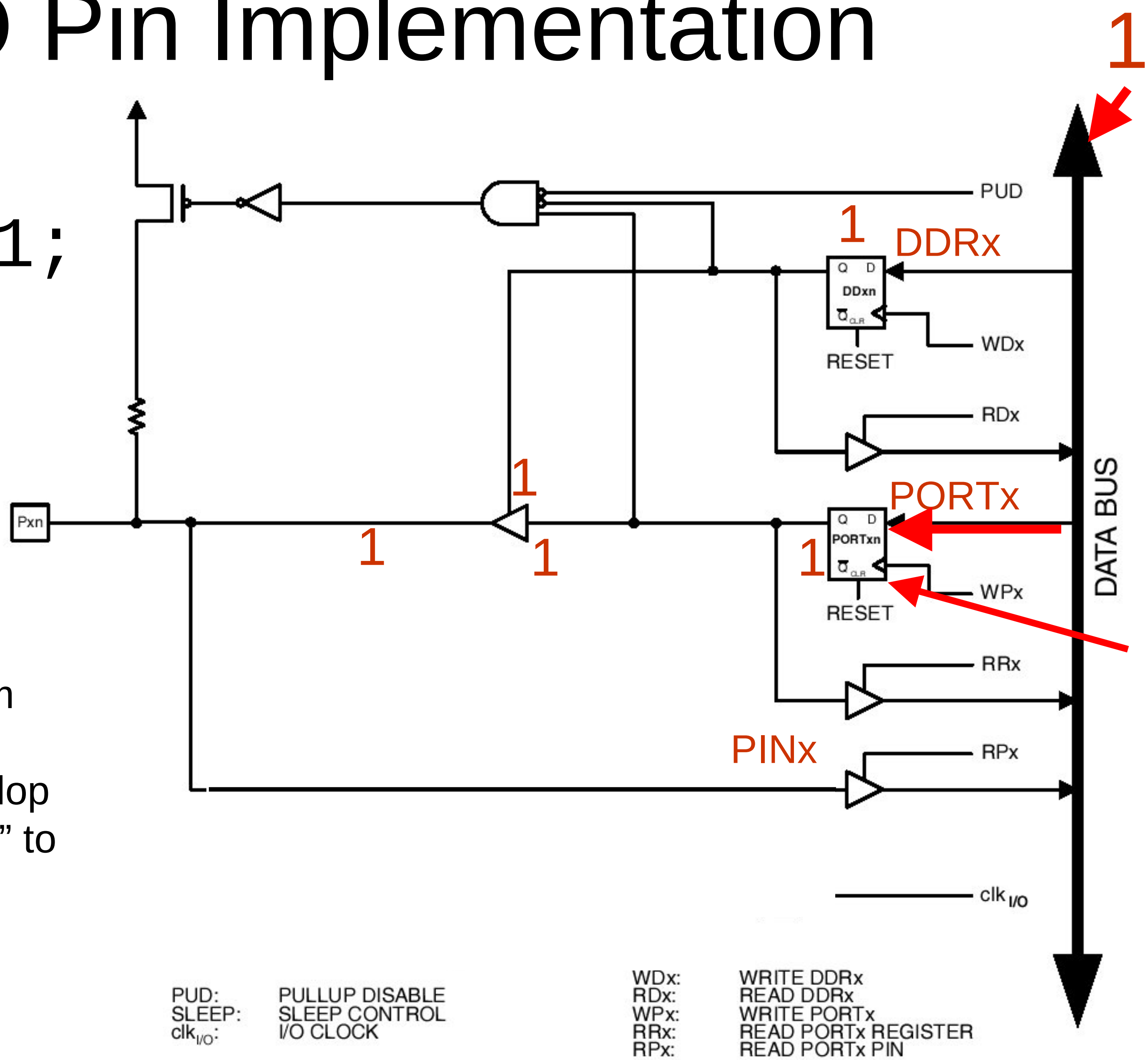


I/O Pin Implementation

```
PORTB = 1;
```

• "1" is written to the data bus
• This is input to the PORTB register
• WPB is clocked from high to low
• "1" is stored by flip-flop
• Which provides a "1" to the tri-state buffer

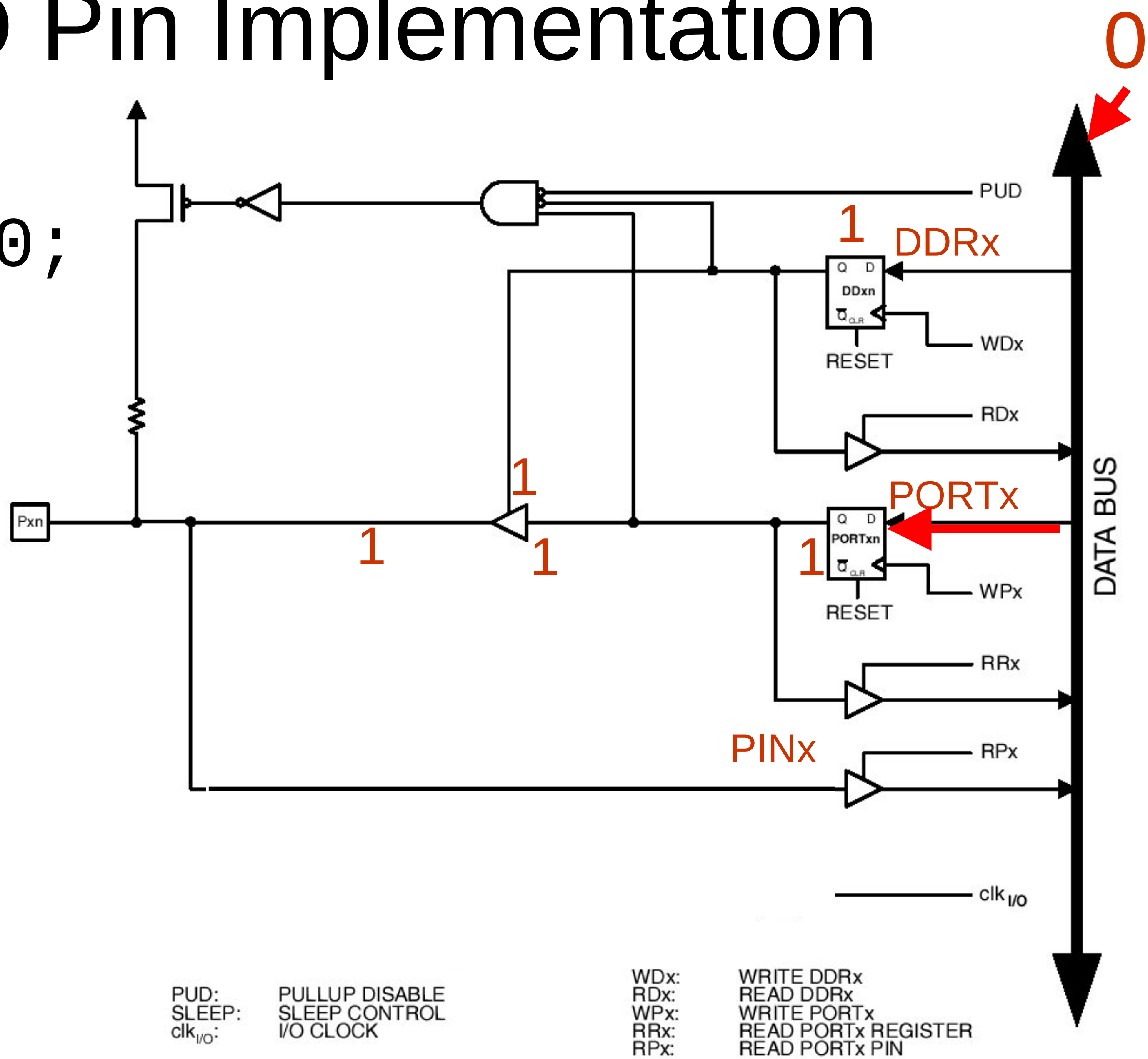
-> output a "1"



I/O Pin Implementation

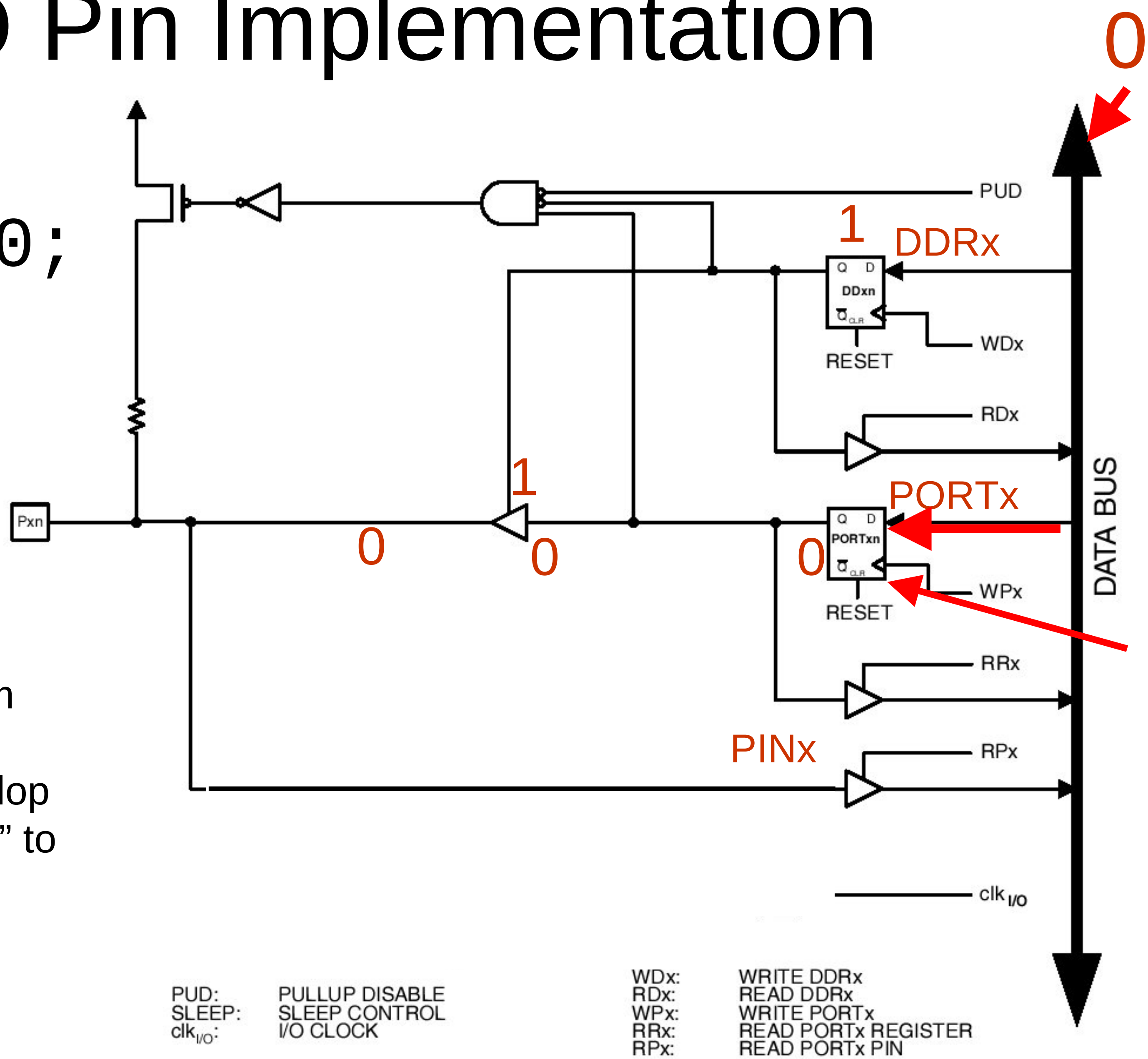
```
PORTB = 0;
```

- “0” is written to the data bus



I/O Pin Implementation

```
PORTB = 0;
```

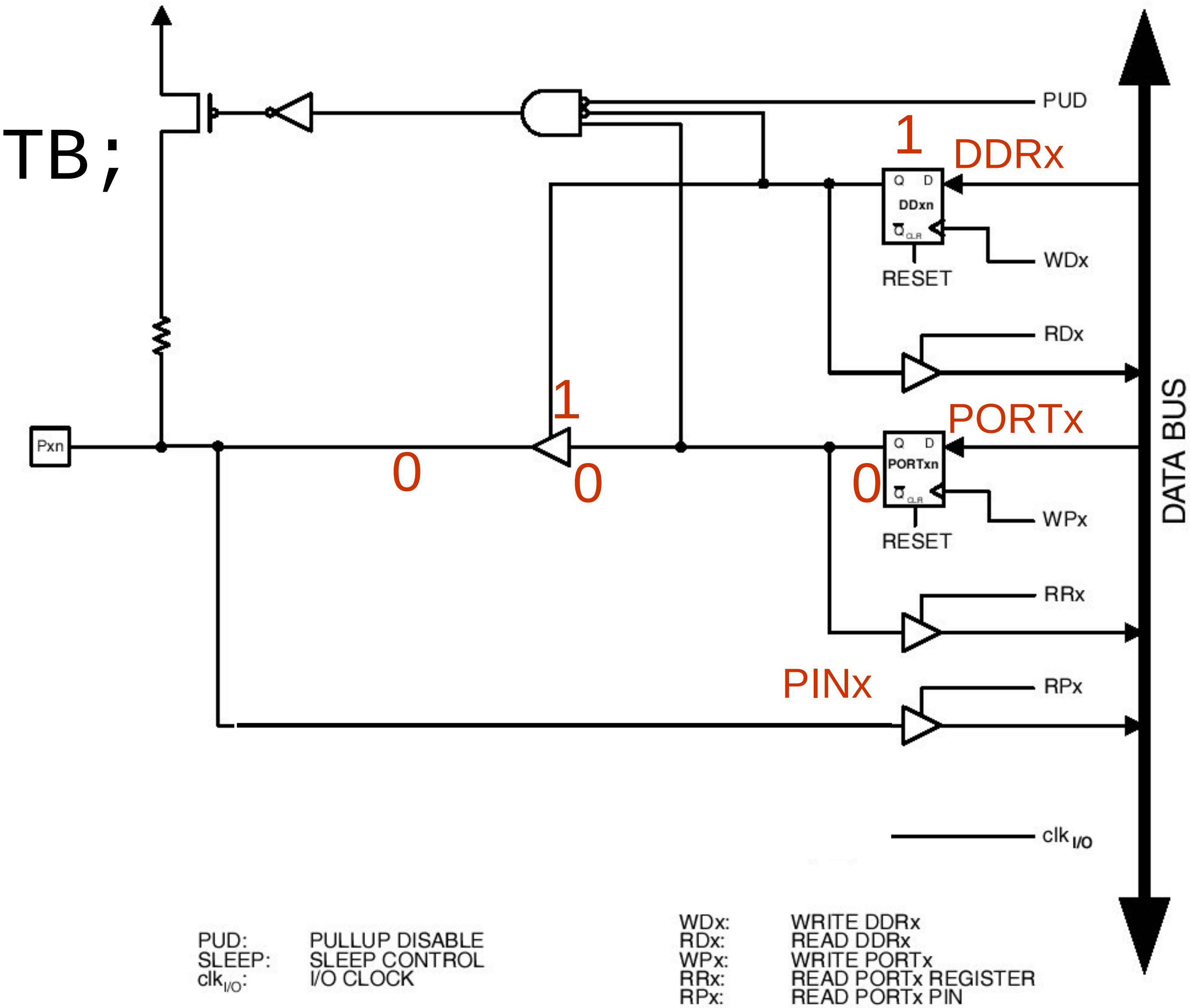


- “0” is written to the data bus
- This is input to the PORTB register
- WPB is clocked from high to low
- “0” is stored by flip-flop
- Which provides a “0” to the tri-state buffer

-> output a “0”

I/O Pin Implementation

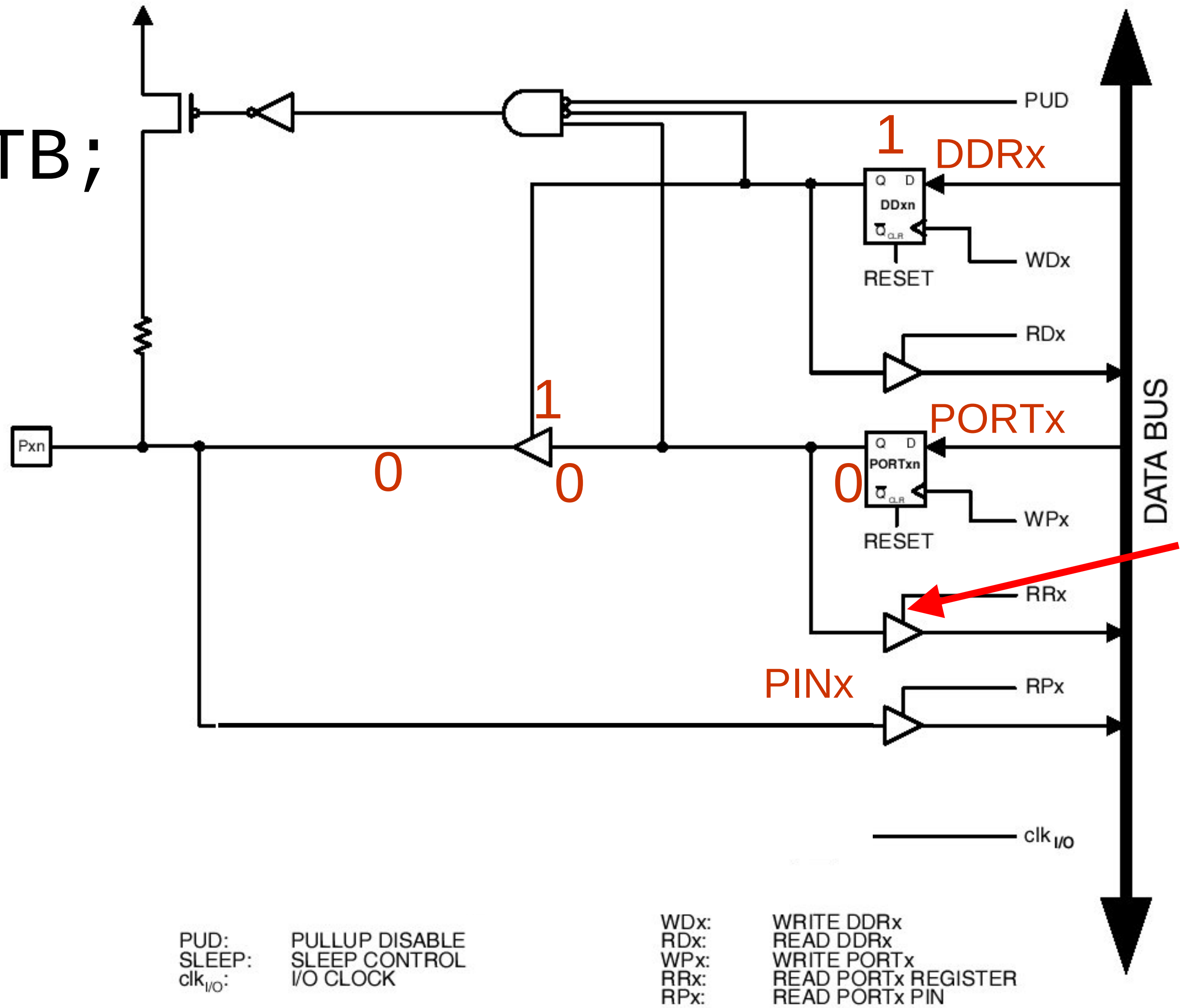
```
foo = PORTB;
```



I/O Pin Implementation

```
foo = PORTB;
```

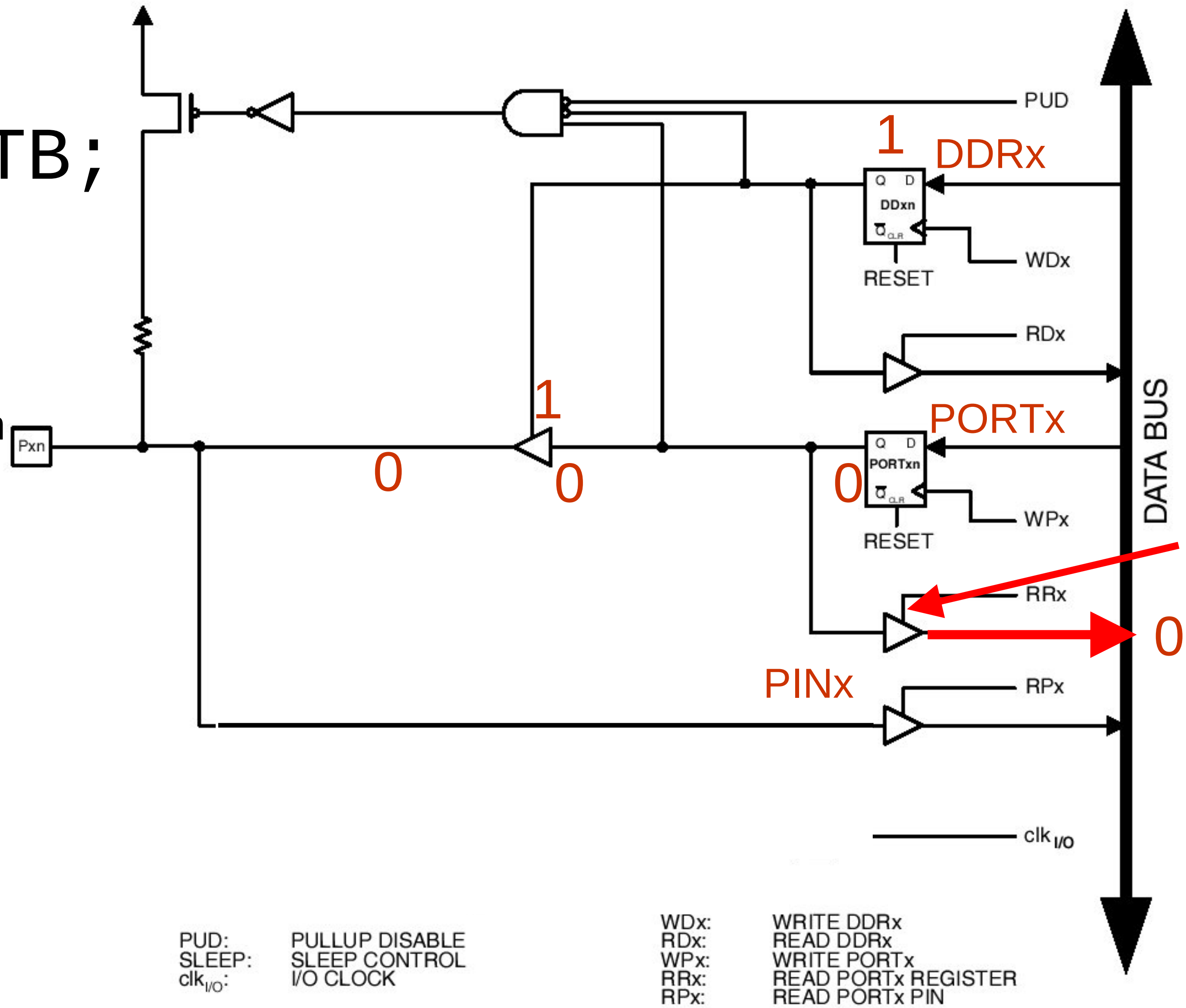
- RPB is set high



I/O Pin Implementation

```
foo = PORTB;
```

- RPB is clocked from high to low
- “0” is written to the data bus

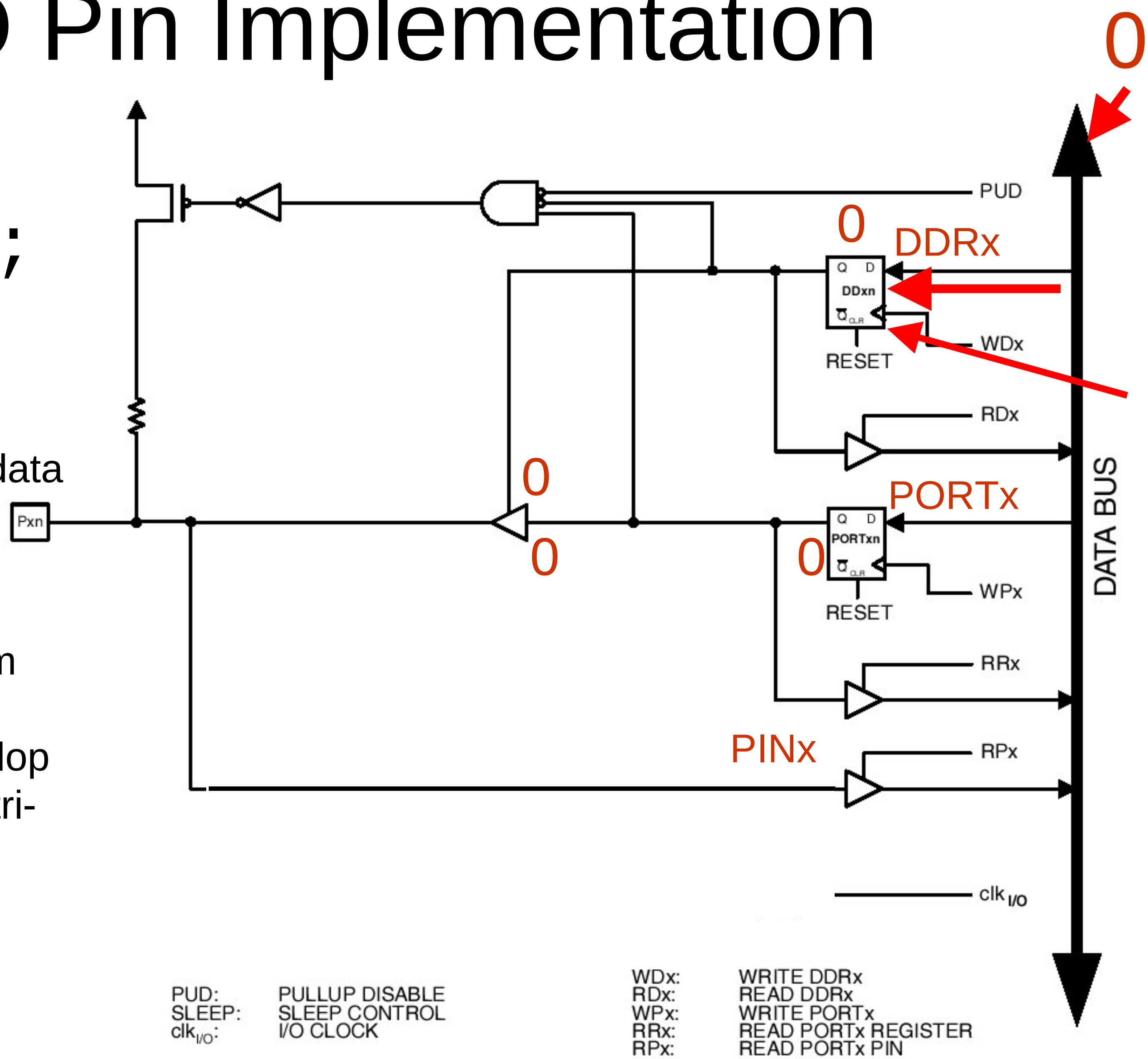


I/O Pin Implementation

```
DDRB = 0;
```

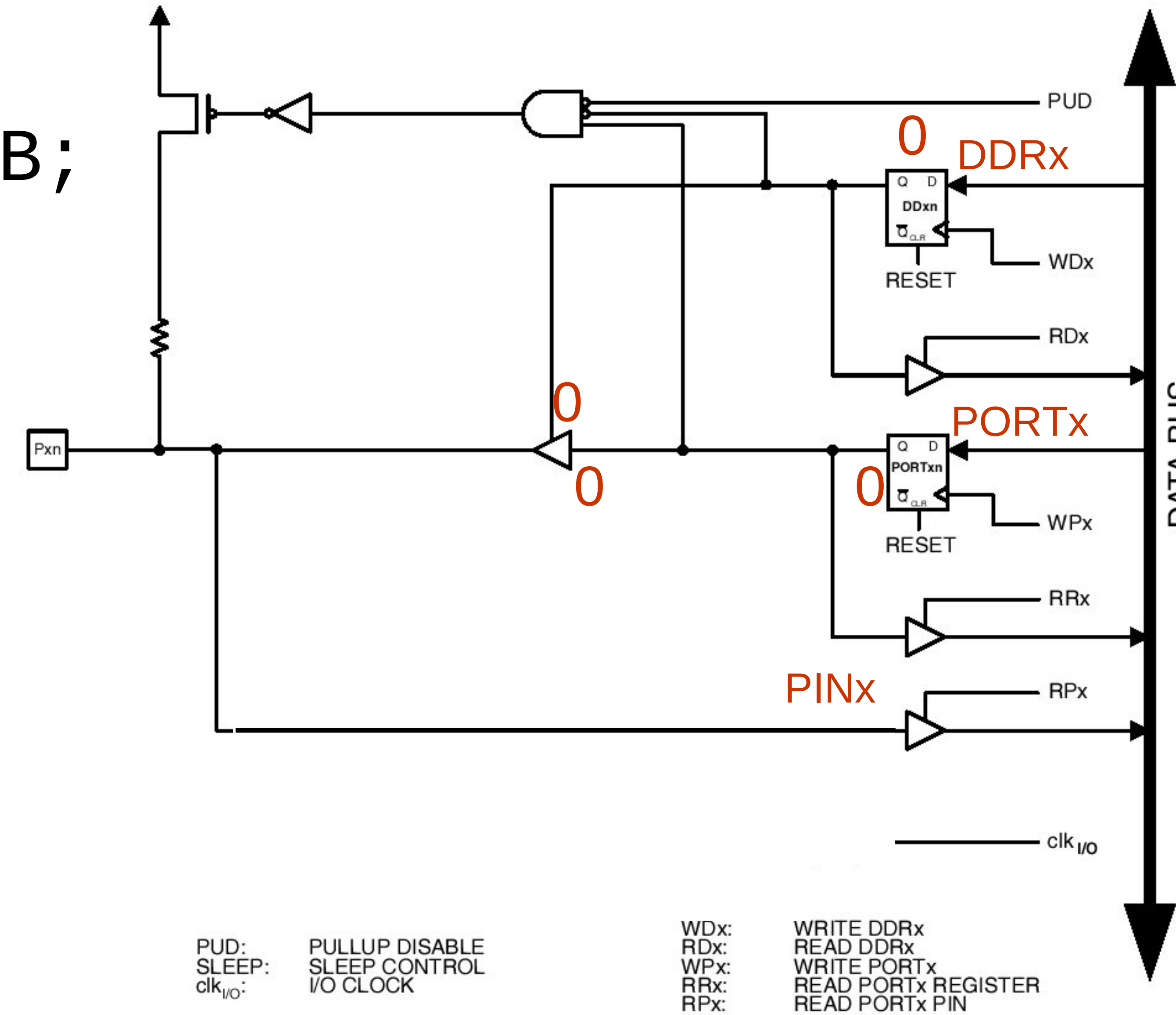
- "0" is written to the data bus
- This is input to the DDRB register
- WDB is clocked from high to low
- "0" is stored by flip-flop
- Which turns off the tri-state buffer

-> this is an input pin



I/O Pin Implementation

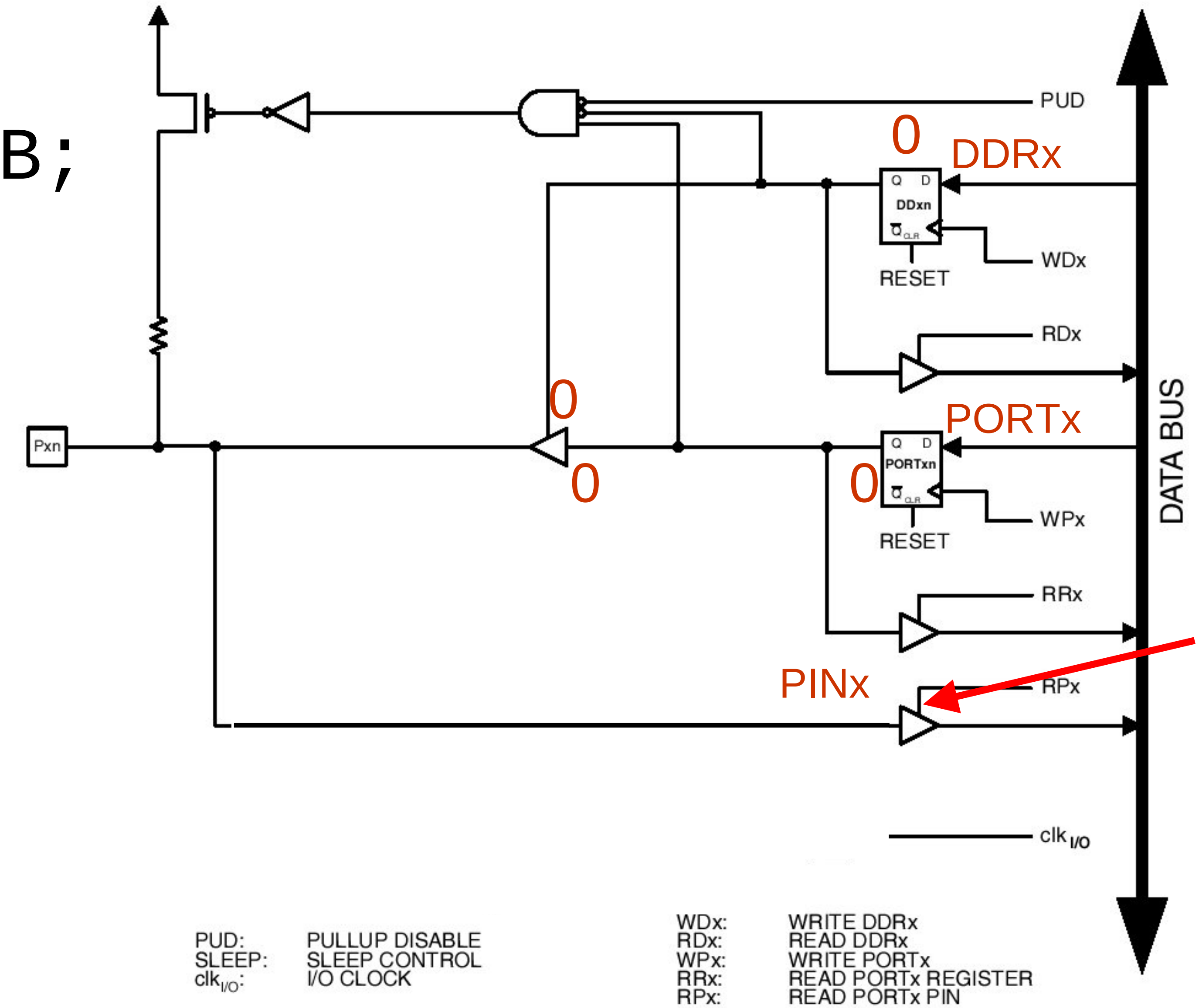
```
foo = PINB;
```



I/O Pin Implementation

`foo = PINB;`

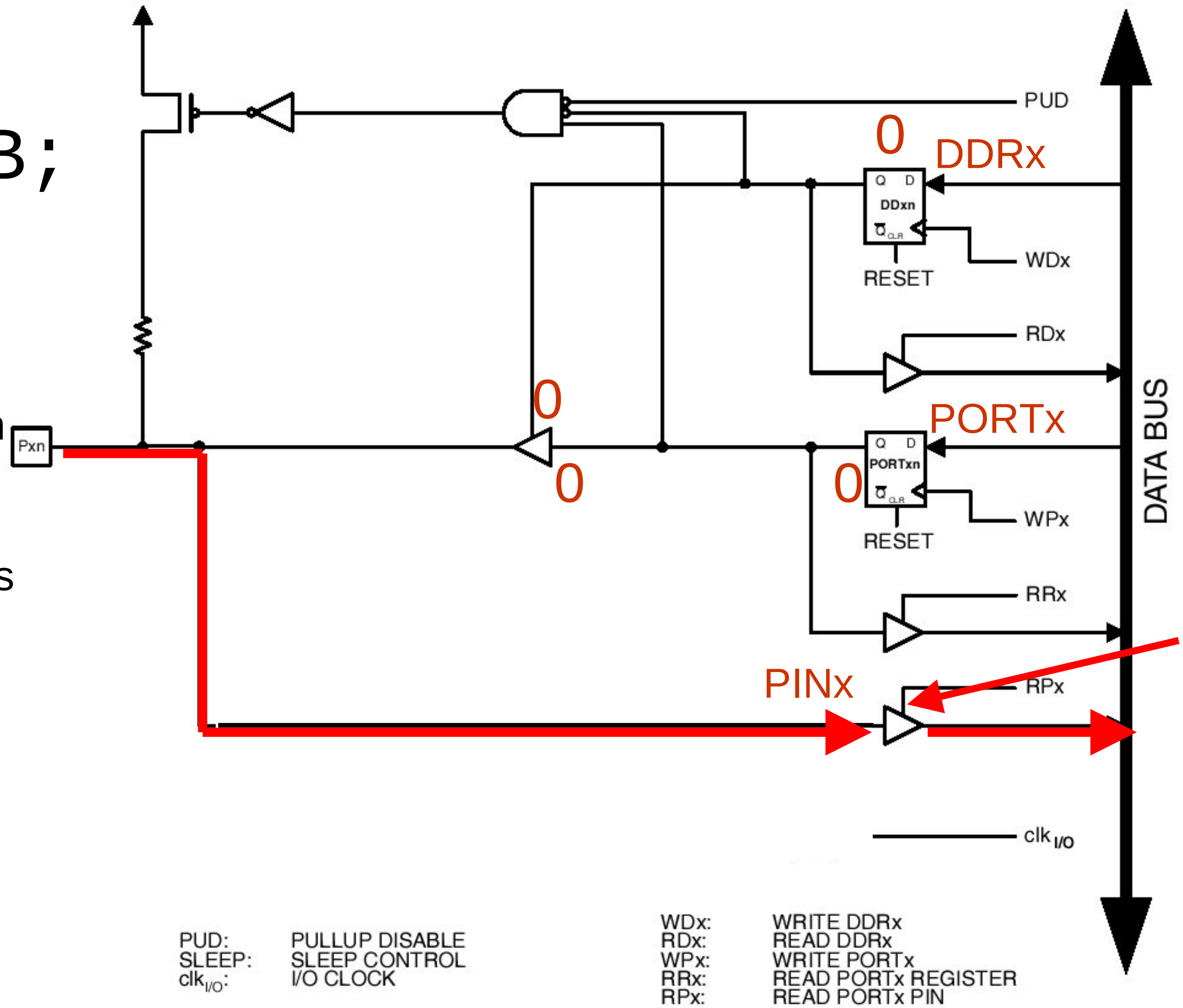
- RPB is set high



I/O Pin Implementation

```
foo = PINB;
```

- RPB is clocked from high to low
- The pin state is copied to the data bus



Bit Manipulation

PORTB is a register

- Controls the value that is output by the set of port B pins
- But – all of the pins are controlled by this single register (which is 8 bits wide)

- In code, we need to be able to manipulate the pins individually

Bit-Wise Operators

If A and B are bytes, what does this code mean?

```
C = A & B;
```

Bit-Wise Operators

If A and B are bytes, what does this code mean?

```
C = A & B;
```

The corresponding bits of A and B are ANDed together

Bit-Wise Operators

0 1 0 1 1 1 1 0	A
1 0 0 1 1 0 1 1	B
?	C = A & B

Bit-Wise Operators

0 1 0 1 1 1 1 0	A
1 0 0 1 1 0 1 1	B

C = A & B

Bit-Wise Operators

0 1 0 1 1 1 1 0	A
1 0 0 1 1 0 1 1	B
0	C = A & B

Bit-Wise Operators

0 1 0 1 1 1 1 0	A
1 0 0 1 1 0 1 1	B
1 0	C = A & B

Bit-Wise Operators

0 1 0 1 1 1 1 0	A
1 0 0 1 1 0 1 1	B
0 0 0 1 1 0 1 0	C = A & B

Bit-Wise Operators

Other Operators:

- OR: |
- XOR: ^
- NOT: ~

Bit Manipulation

Given a byte A, how do we set bit 2 (counting from 0) of A to 1?

Bit Manipulation

Given a byte A, how do we set bit 2 (counting from 0) of A to 1?

```
A = A | 4;
```

Bit Manipulation

Given a byte A, how do we set bit 2 (counting from 0) of A to 0?

Bit Manipulation

Given a byte A, how do we set bit 2 (counting from 0) of A to 0?

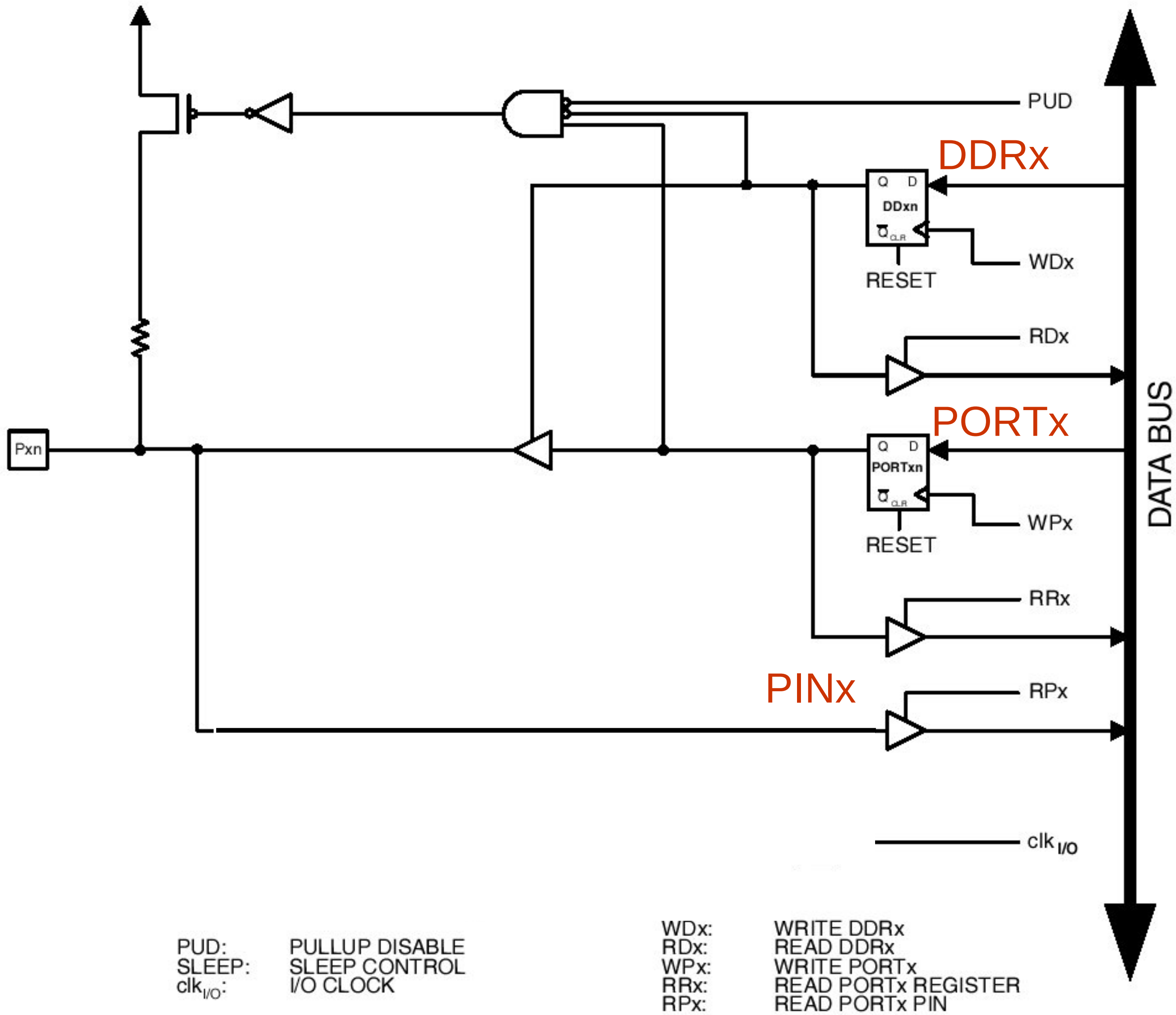
```
A = A & 0xFB;
```

or

```
A = A & ~4;
```

I/O Pin Implementation

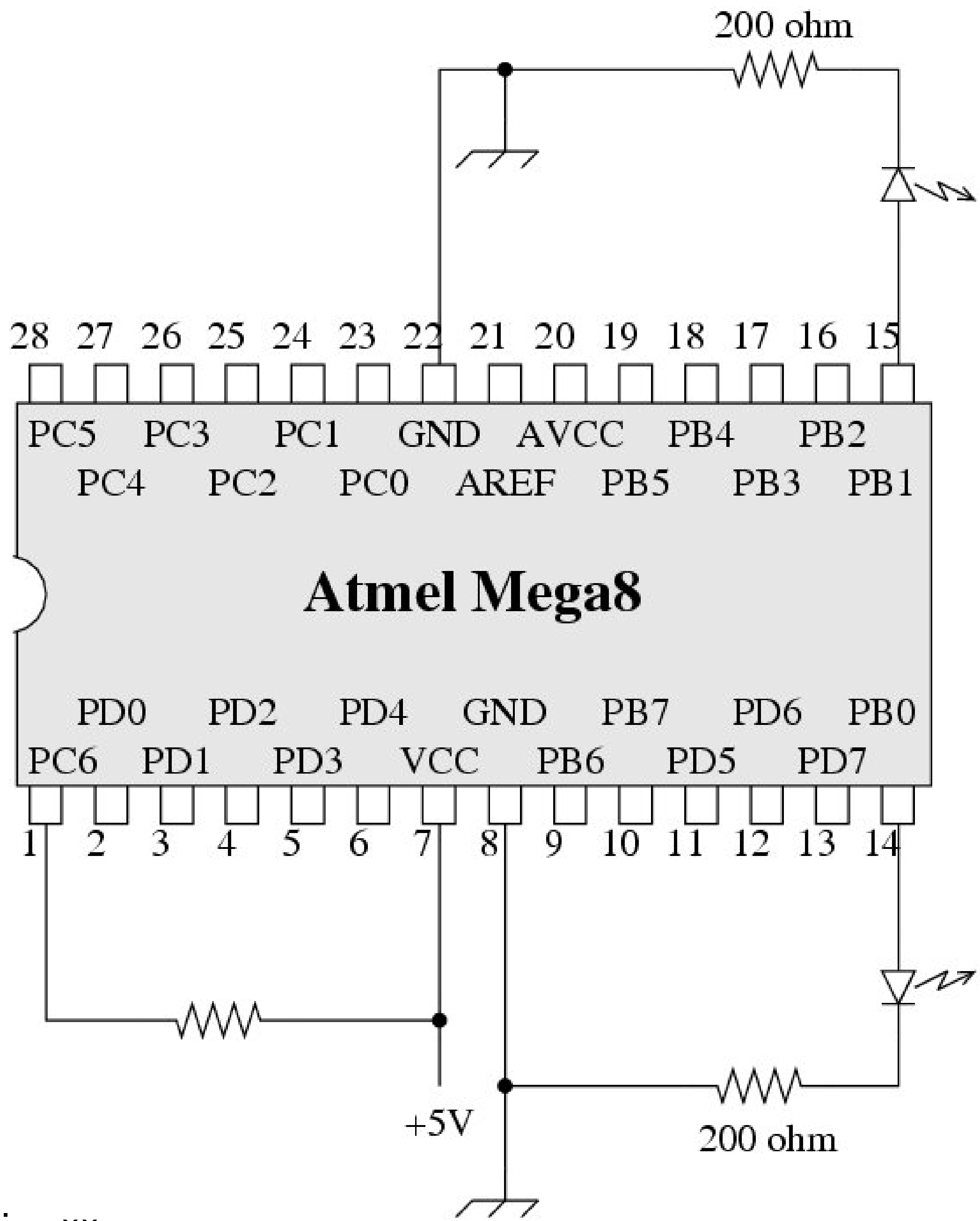
Single bit of PORT B



A First Program

Flash the LEDs at a regular interval

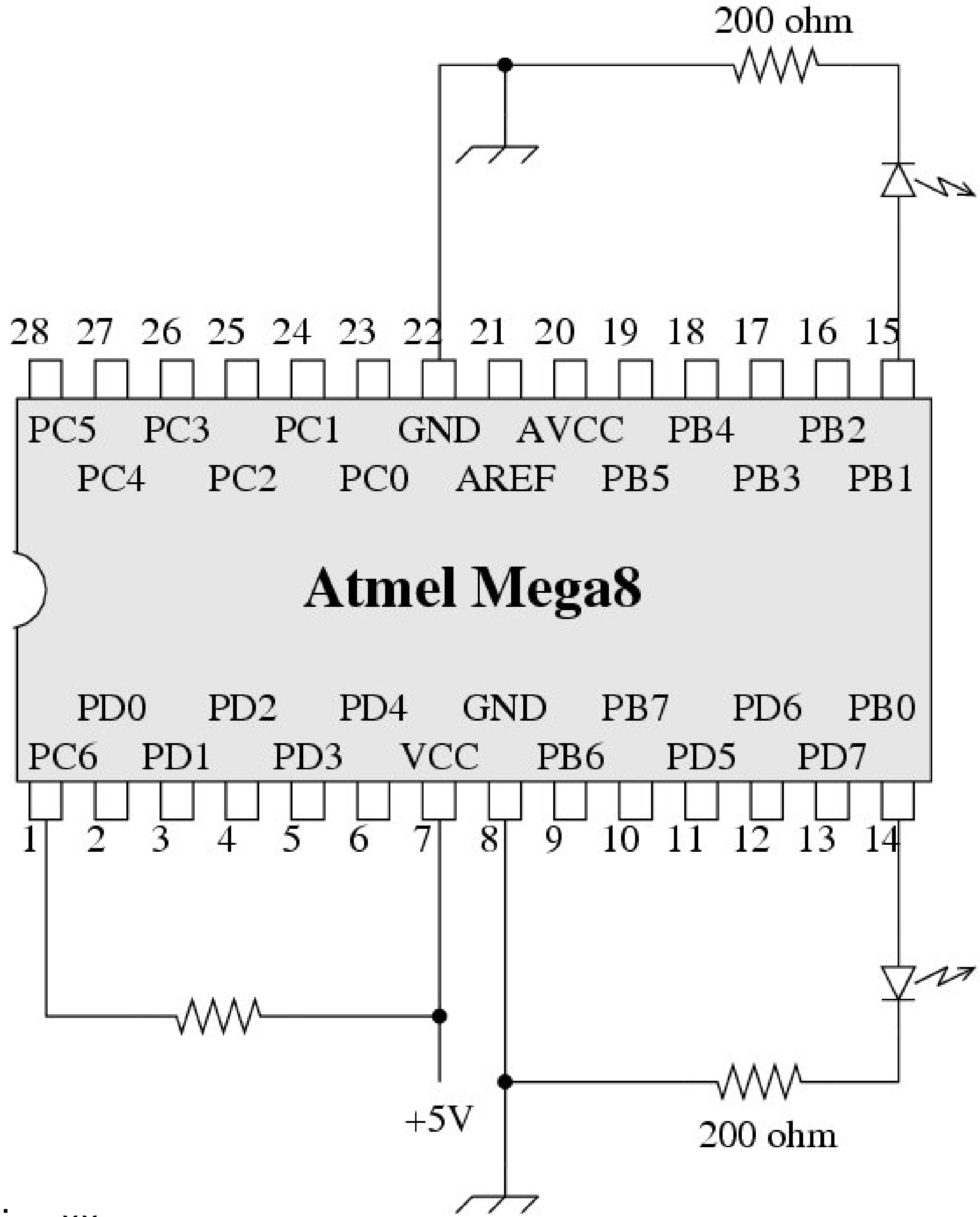
- How do we do this?



A First Program

How do we flash the LED at a regular interval?

- We toggle the state of PB0



A First Program

```
main() {
   DDRB = 1;   // Set port B pin 0 as an output

   while(1) {
        PORTB = PORTB ^ 0x1;   // XOR bit 0 with 1
        delay_ms(500);         // Pause for 500 msec
        }
}
```

A Second Program

```
main() {
   DDRB = 3;   // Set port B pins 0, and 1 as outputs

   while(1) {
        PORTB = PORTB ^ 0x1;   // XOR bit 0 with 1
        delay_ms(500);         // Pause for 500 msec
        PORTB = PORTB ^ 0x2;   // XOR bit 1 with 1
        delay_ms(250);
        PORTB = PORTB ^ 0x2;   // XOR bit 1 with 1
        delay_ms(250);
   }
}
```

What does this program do?

A Second Program

```
main() {
   DDRB = 3;   // Set port B pins 0, and 1 as outputs

   while(1) {
        PORTB = PORTB ^ 0x1;   // XOR bit 0 with 1
        delay_ms(500);         // Pause for 500 msec
        PORTB = PORTB ^ 0x2;   // XOR bit 1 with 1
        delay_ms(250);
        PORTB = PORTB ^ 0x2;   // XOR bit 1 with 1
        delay_ms(250);
   }
}
```

Flashes LED on PB1 at 1 Hz
on PB0: 0.5 Hz

Port-Related Registers

The set of C-accessible register for controlling digital I/O:

	Directional control	Writing	Reading
Port B	DDRB	PORTB	PINB
Port C	DDRC	PORTC	PINC
Port D	DDRD	PORTD	PIND

More Bit Masking

- Suppose we have a 3-bit number (so values 0 … 7)
- Suppose we want to set the state of B3, B4, and B5 with this number (B3 is the least significant bit)
- How do we express this in code?

Bit Masking

```
main() {
   DDRB = 0xF8;   // Set pins B3, B4, B5, B6, B7 as outputs

        :
        :

  unsigned short val;  // A short is 8-bits wide

   val = command_to_robot;   // A value between 0 and 7

   PORTB = (PORTB & 0xC7)        // Set the current B3-B5 to 0s
        | ((val & 0x7)<<3);      // OR with new values (shifted
                                  //  to fit within B3-B5
}
```

Bit Masking

```
main() {
  DDRB = 0xF8;    // Set pins B3, B4, B5, B6, B7 as outputs

       :
       :

  unsigned short val;  // A short is 8-bits wide

   val = command_to_robot; // A value between 0 and 7

   PORTB = (PORTB & 0xC7)         // Set the current B3-B5 to 0s
       | ((val & 0x7))<<3);       // OR with new values (shifted
                                  //  to fit within B3-B5)
}
```

B3-B7 are outputs; all others are still inputs (could be different depending on how other pins are used)

Bit Masking

```
main() {
   DDRB = 0xF8;   // Set pins B3, B4, B5, B6, B7 as outputs

       :
       :

  unsigned short val;  // A short is 8-bits wide

   val = command_to_robot; // A value between 0 and 7

   PORTB = (PORTB & 0xC7)        // Set the current B3-B5 to 0s
       | ((val & 0x7))<<3);      // OR with new values (shifted
                                 //  to fit within B3-B5
}
```

"Mask out" the current values of pins B3-B5 (leave everything else intact)

Bit Masking

```
main() {
   DDRB = 0xF8;    // Set pins B3, B4, B5, B6, B7 as outputs

        :
        :

  unsigned short val;  // A short is 8-bits wide

   val = command_to_robot; // A value between 0 and 7

   PORTB = (PORTB & 0xC7)          // Set the current B3-B5 to 0s
        | ((val & 0x7))<<3);       // OR with new values (shifted
                                   //  to fit within B3-B5
}
```

Substitute an arbitrary value into these bits

Bit Masking

```
main() {
   DDRB = 0xF8;   // Set pins B3, B4, B5, B6, B7 as outputs

      :
      :

  unsigned short val;  // A short is 8-bits wide

   val = command_to_robot; // A value between 0 and 7

   PORTB = (PORTB & 0xC7)          // Set the current B3-B5 to 0s
        | ((val & 0x7))<<3);       // OR with new values (shifted
                                   //  to fit within B3-B5
}
```

And use the result to change the output state of port B

Reading the Digital State of Pins

Given: we want to read the state of PB6 and PB7 and obtain a value of 0 … 3

- How do we configure the port?
- How do we read the pins?
- How do we translate their values into an integer of 0 .. 3?

Reading the Digital State of Pins

```
main() {
   DDRB = 0x38;    // Set pins B3, B4, B5 as outputs
                   //   All others are inputs (suppose we care
                   //   about bits B6 and B7 only (so a 2-bit
                   //    number)
       :
       :

  unsigned short val, outval;  // A short is 8-bits wide

   val = PINB;

   outval = (val & 0xC0) >> 6;
}
```

Reading the Digital State of Pins

```
main() {
  DDRB = 0x38;    // Set pins B3, B4, B5 as outputs
                  //   All others are inputs (suppose we care
                  //   about bits B6 and B7 only (so a 2-bit
                  //    number)
      :
      :

  unsigned short val, outval;  // A short is 8-bits wide

  val = PINB;

  outval = (val & 0xC0) >> 6;
}
```

B6 and B7 are configured as inputs

Reading the Digital State of Pins

```
main() {
   DDRB = 0x38;    // Set pins B3, B4, B5 as outputs
                   //   All others are inputs (suppose we care
                   //   about bits B6 and B7 only (so a 2-bit
                   //    number)
        :
        :

  unsigned short val, outval;  // A short is 8-bits wide

   val = PINB;

   outval = (val & 0xC0) >> 6;
}
```

Read the value from the port

Reading the Digital State of Pins

```
main() {
   DDRB = 0x38;    // Set pins B3, B4, B5 as outputs
                   //   All others are inputs (suppose we care
                   //   about bits B6 and B7 only (so a 2-bit
                   //    number)
        :
        :

  unsigned short val, outval;  // A short is 8-bits wide

   val = PINB;

   outval = (val & 0xC0) >> 6;
}
```

"Mask out" all bits except B6 and B7

Reading the Digital State of Pins

```
main() {
   DDRB = 0x38;    // Set pins B3, B4, B5 as outputs
                   //   All others are inputs (suppose we care
                   //   about bits B6 and B7 only (so a 2-bit
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        :
        :

  unsigned short val, outval;  // A short is 8-bits wide

   val = PINB;

   outval = (val & 0xC0) >> 6;
}
```

Right shift the result by 6 bits – so the value of B6 and B7 are now in bits 0 and 1 of "outval"

A Note About the C/Atmel Book

The book uses C syntax that looks like this:

```
PORTA.0 = 0;      // Set bit 0 to 0
```

This syntax is not available with our C compiler. Instead, you will need to use:

```
PORTA &= 0xFE;
```

or

```
PORTA &= ~1;
```

or

```
PORTA = PORTA & ~1;
```

Putting It All Together

- Program development:
  - On your own laptop
  - We will use a C “crosscompiler” (avr-gcc and other tools) to generate code on your laptop for the mega8 processor
- Program download:
  - We will use “in circuit programming”: you will be able to program the chip without removing it from your circuit

Compiling and Downloading Code

- We will work through the details on Thursday. Before then:
  – See the Atmel HowTo (pointer from the schedule page)
  – Windoze: Install AVR Studio and WinAVR
  – OS X: Install OSX-AVR
    - We will use ‘make’ for compiling and downloading
  – Linux: Install binutils, avr-gcc, avr-libc, and avrdude
    - Same as OS X