Components of a Microprocessor

Components of a Microprocessor

- Memory:
  - Storage of data
  - Storage of a program
- Registers: small, fast memories
  - General purpose: store arbitrary data
  - Special purpose: used to control the processor

Special Purpose Registers

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

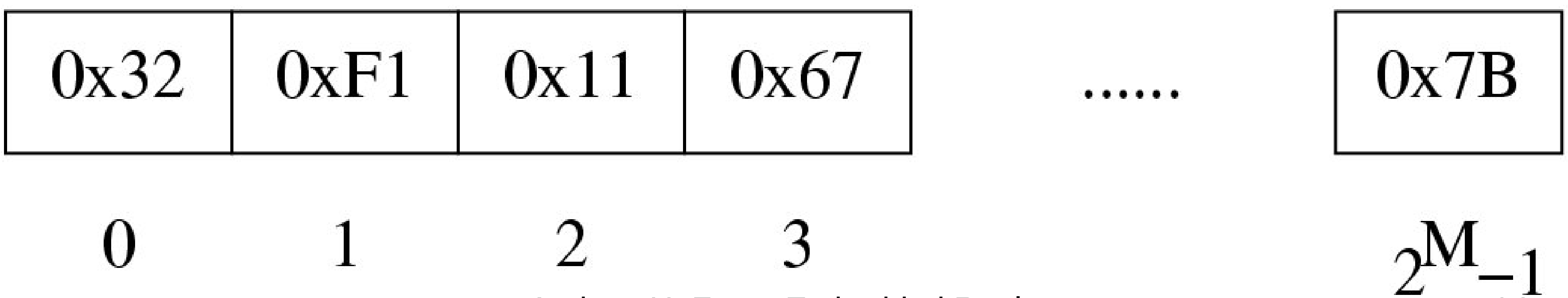
- A data bus typically captures a set of bits simultaneously
- So: one wire for each of these bits
- In the Atmel Mega8: the data bus is 8-bits "wide"
- In your home machines: 32 or 64 bits

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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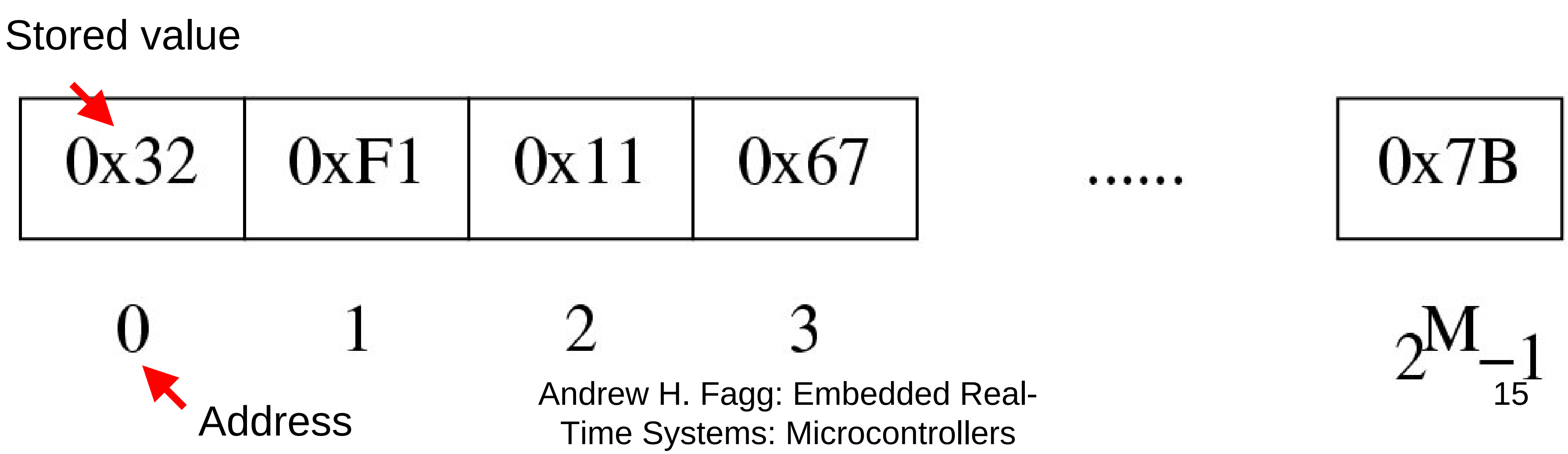


Memory Operations

Read

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

reads the value from the memory location referenced by ‘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

Last Time

- Flip-flops as 1-bit storage devices
- Microprocessor components
  - Random access memory
  - Program memory
  - Instruction decoder
  - Arithmetic logical unit
- Binary and hexadecimal number systems

Today

- Memory behavior
- Atmel mega8 microcontroller
- Assembly language (just a hint)
- Digital I/O with the Atmel mega8

Administrivia

- Homework 2 is out
  - Due on February 14th (one week)

Example: A Read/Write Memory Module

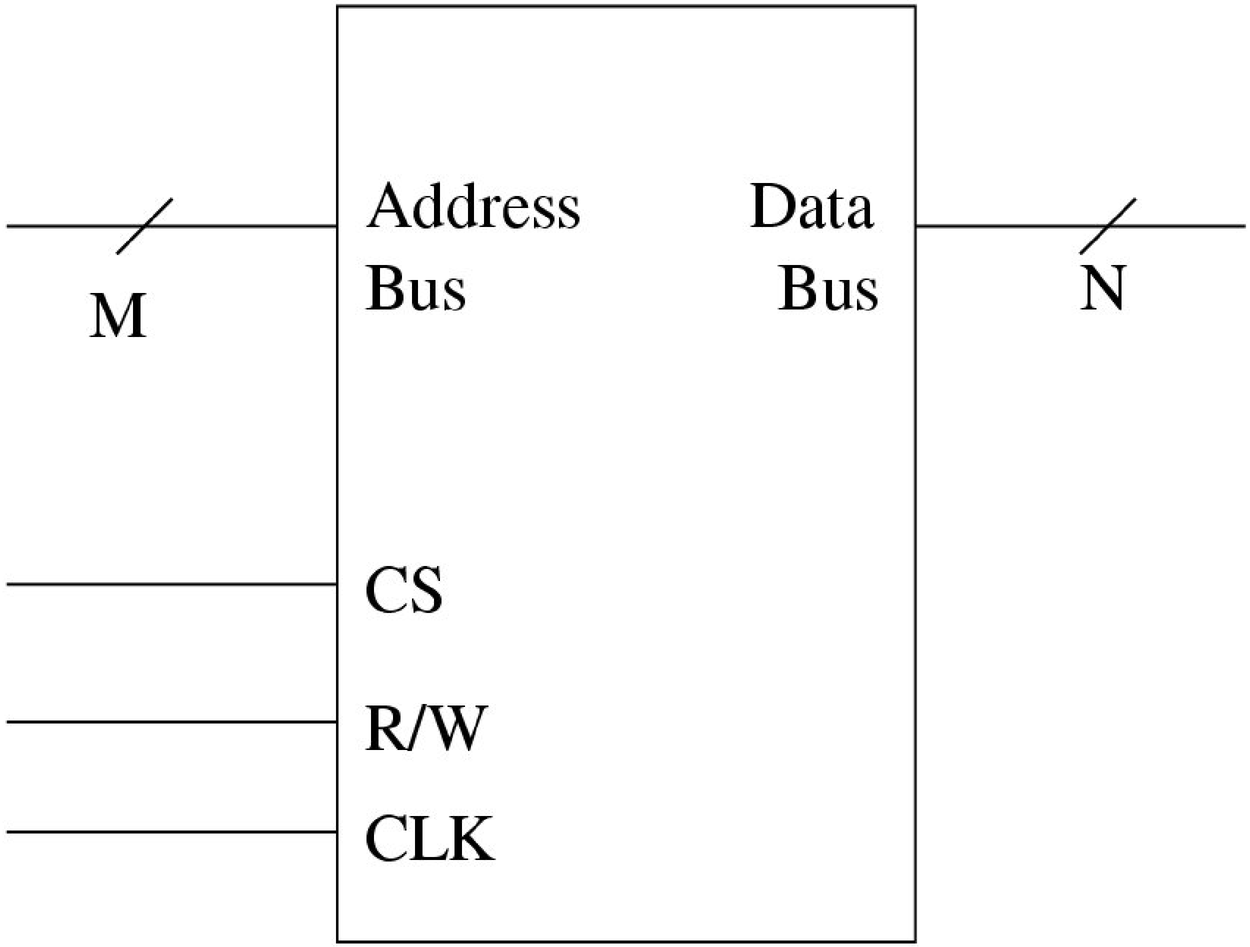
Inputs:

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

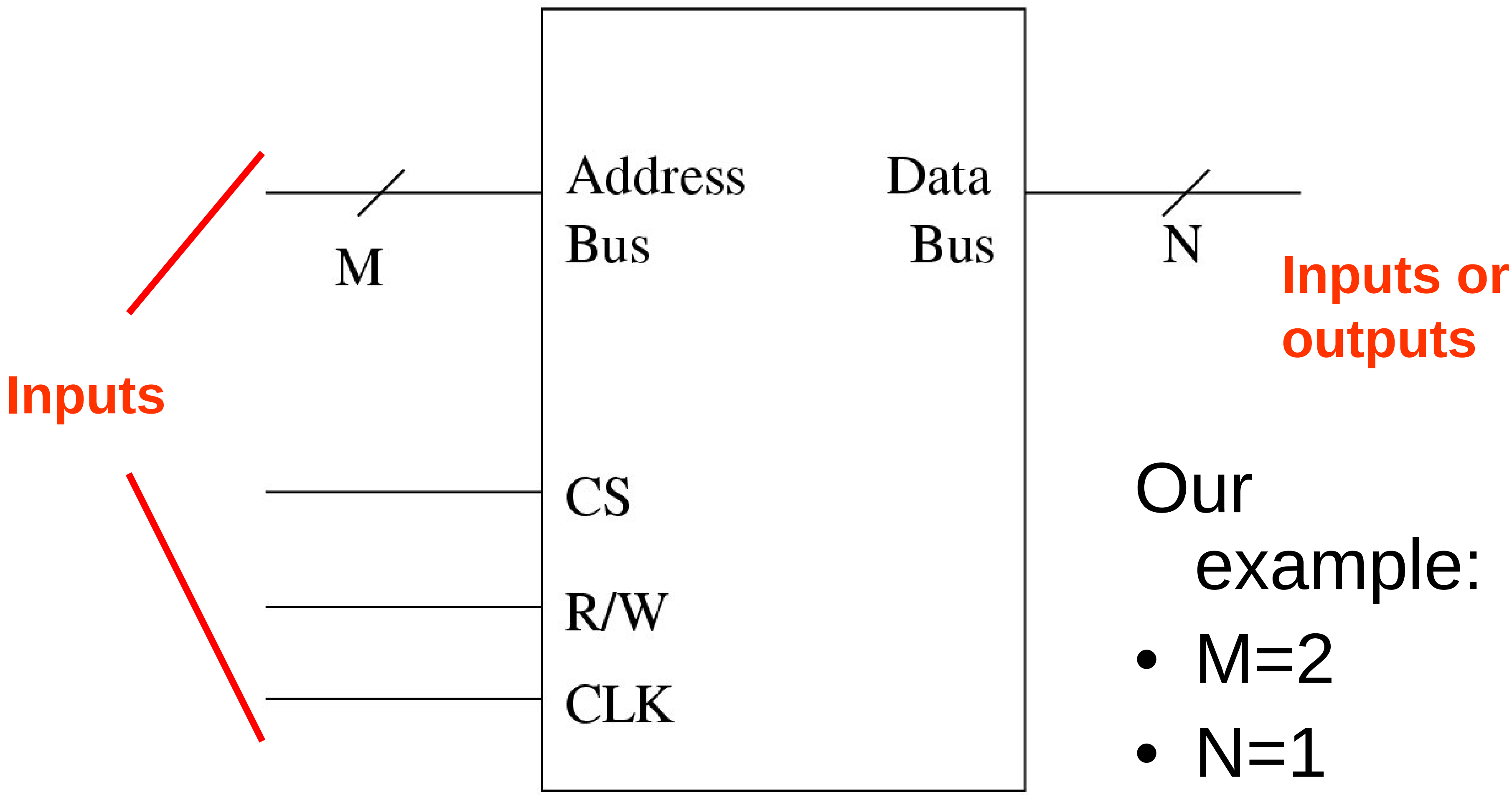
Input or Output:

- 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
  – (more about this later)

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:

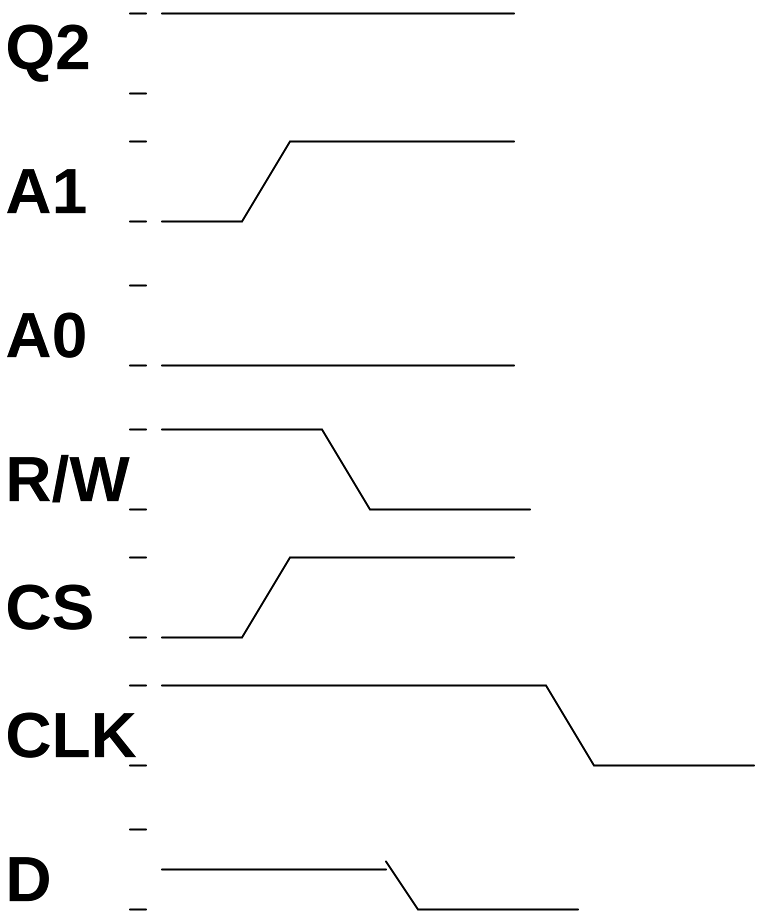
- No memory elements change state
- The memory does not drive the data bus

Memory Module Specification

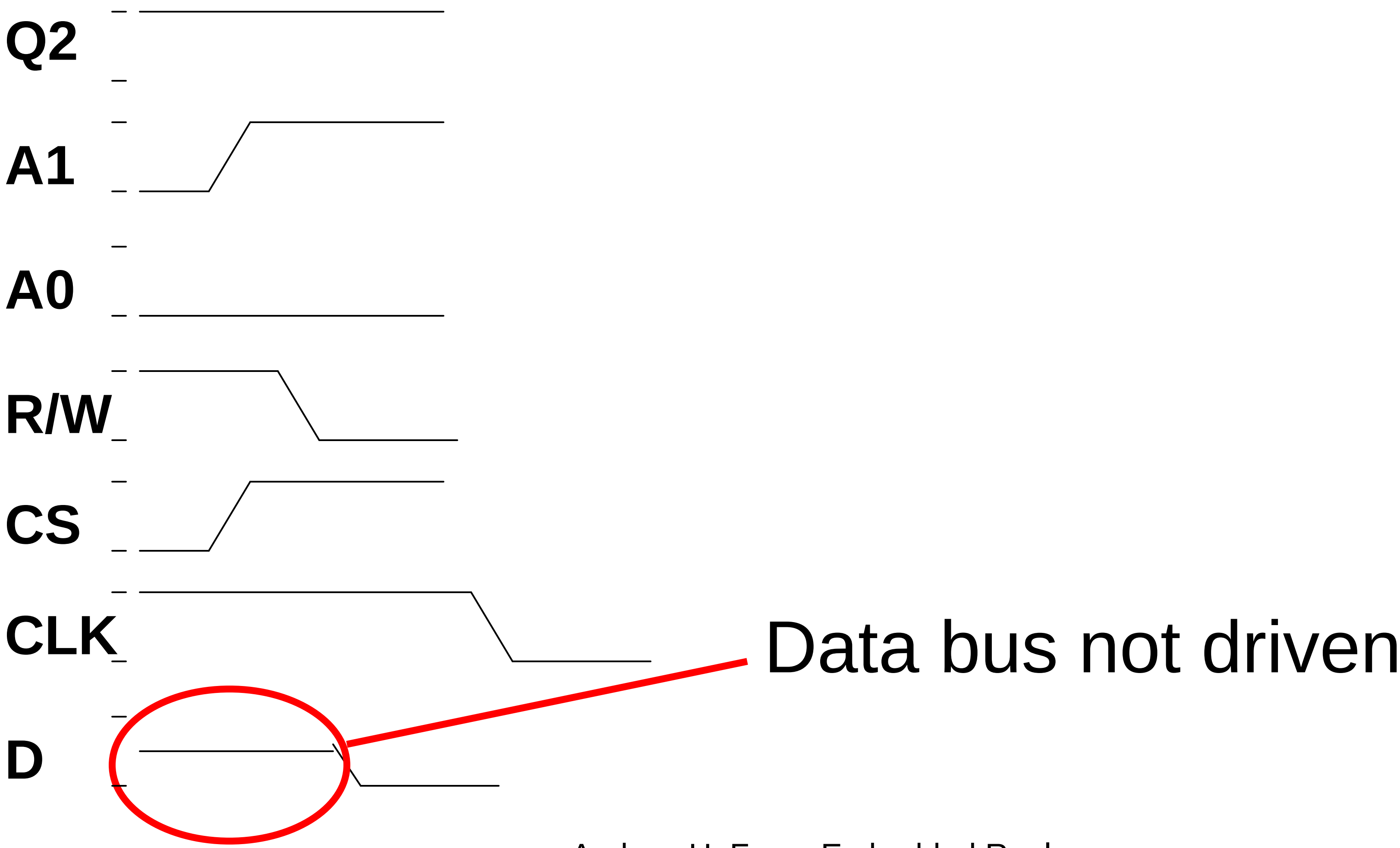
When chip select is high:

- 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

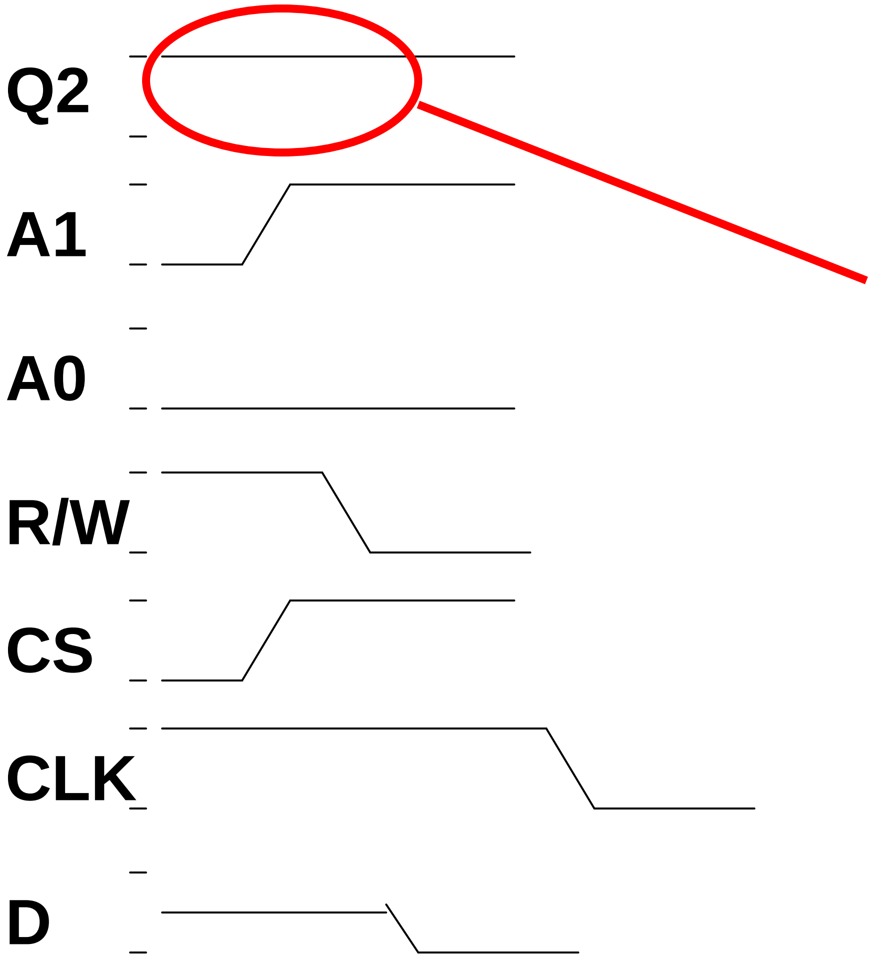
Memory Timing Diagram



Memory Timing Diagram

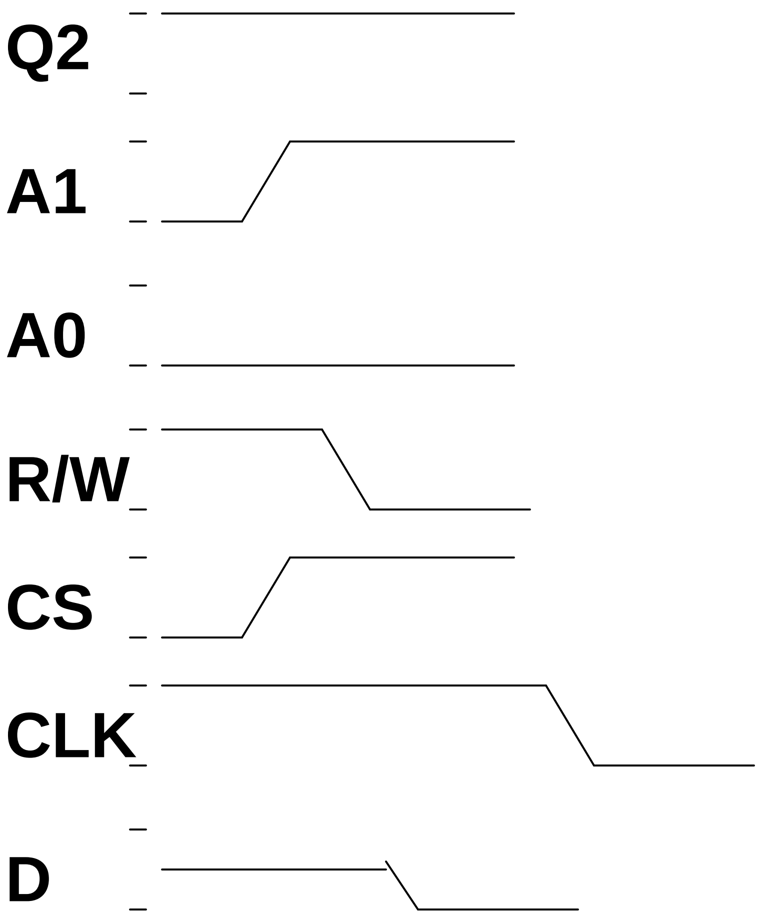


Memory Timing Diagram



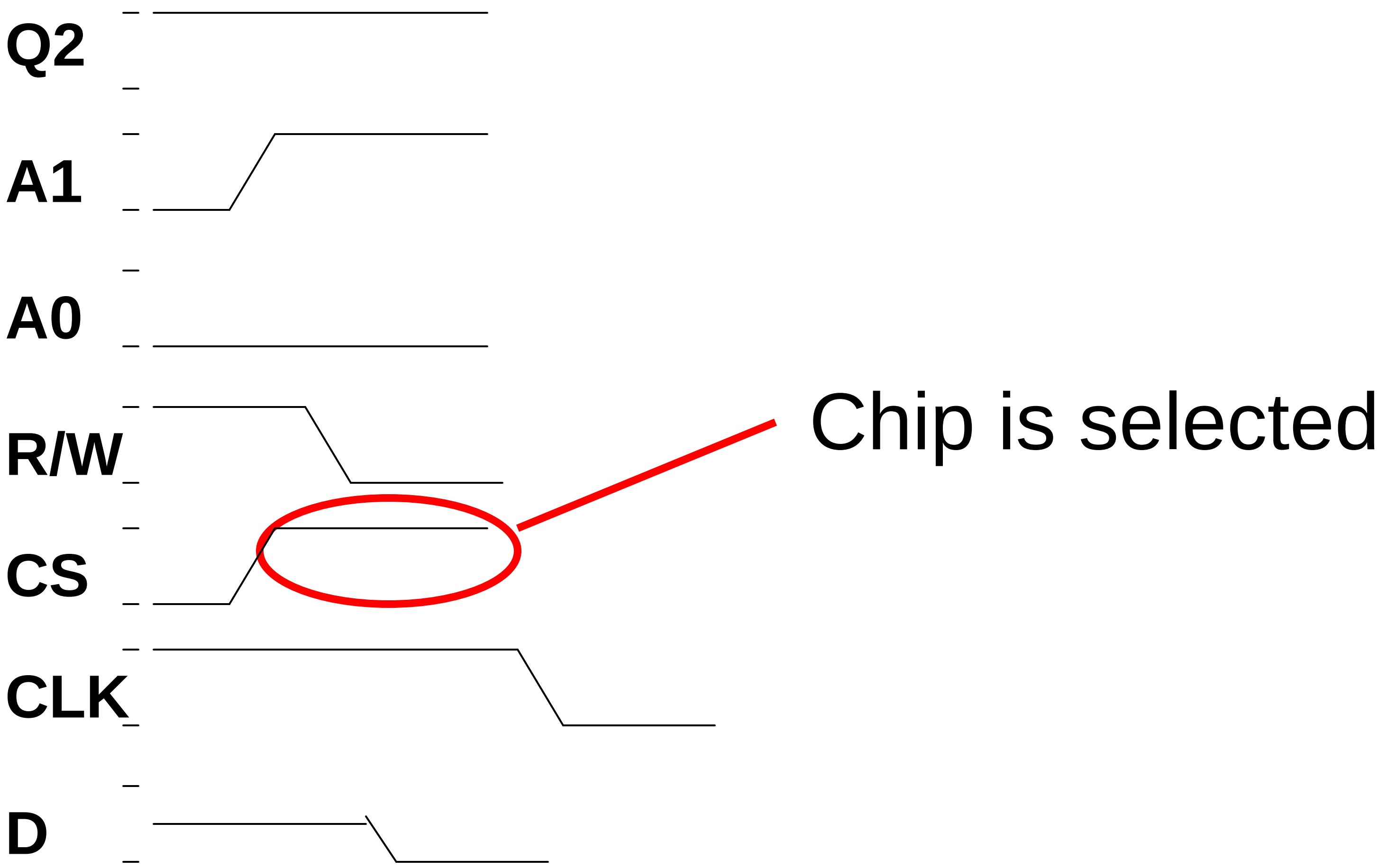
Memory element 2 is initially in a high state

Memory Timing Diagram

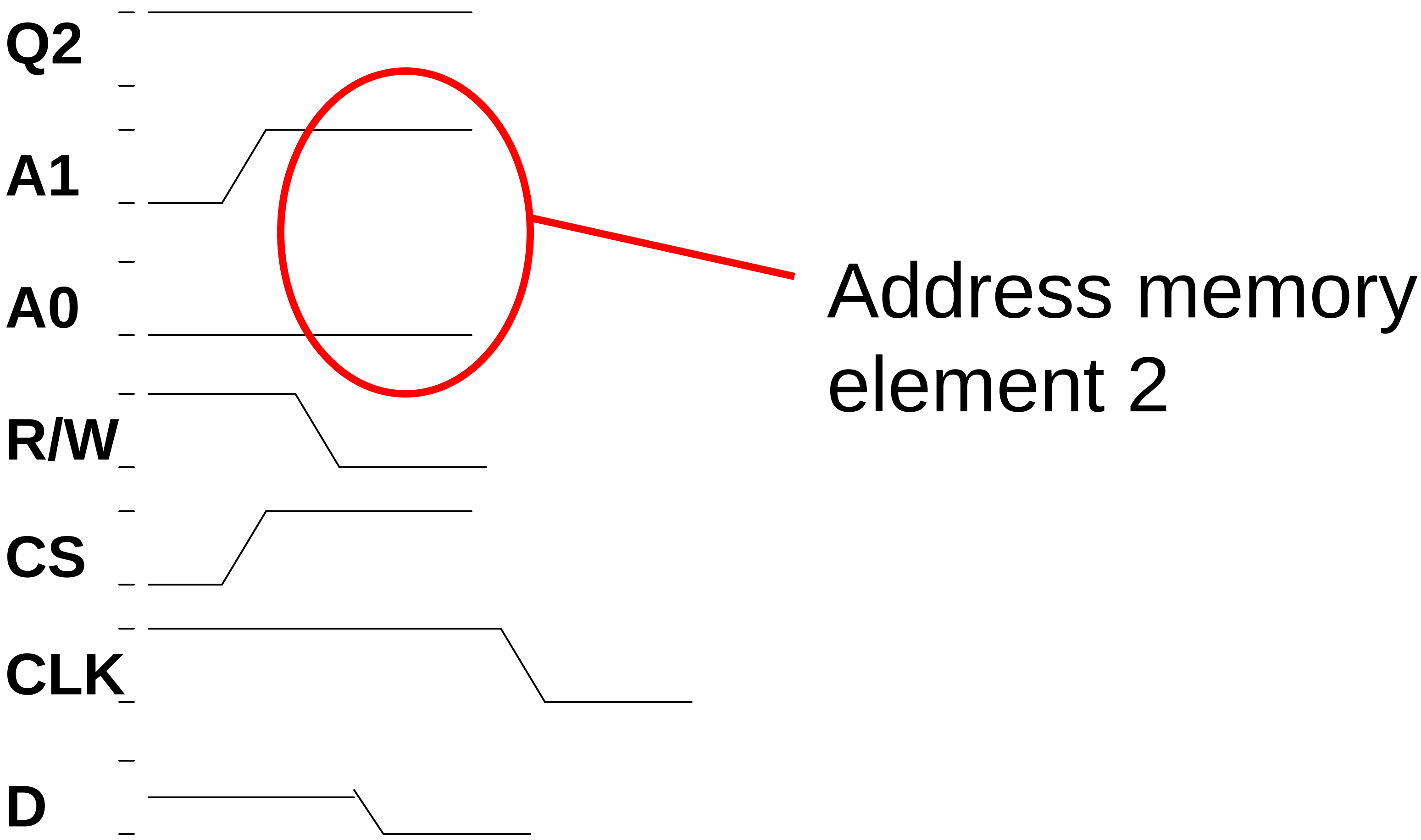


What happens next?

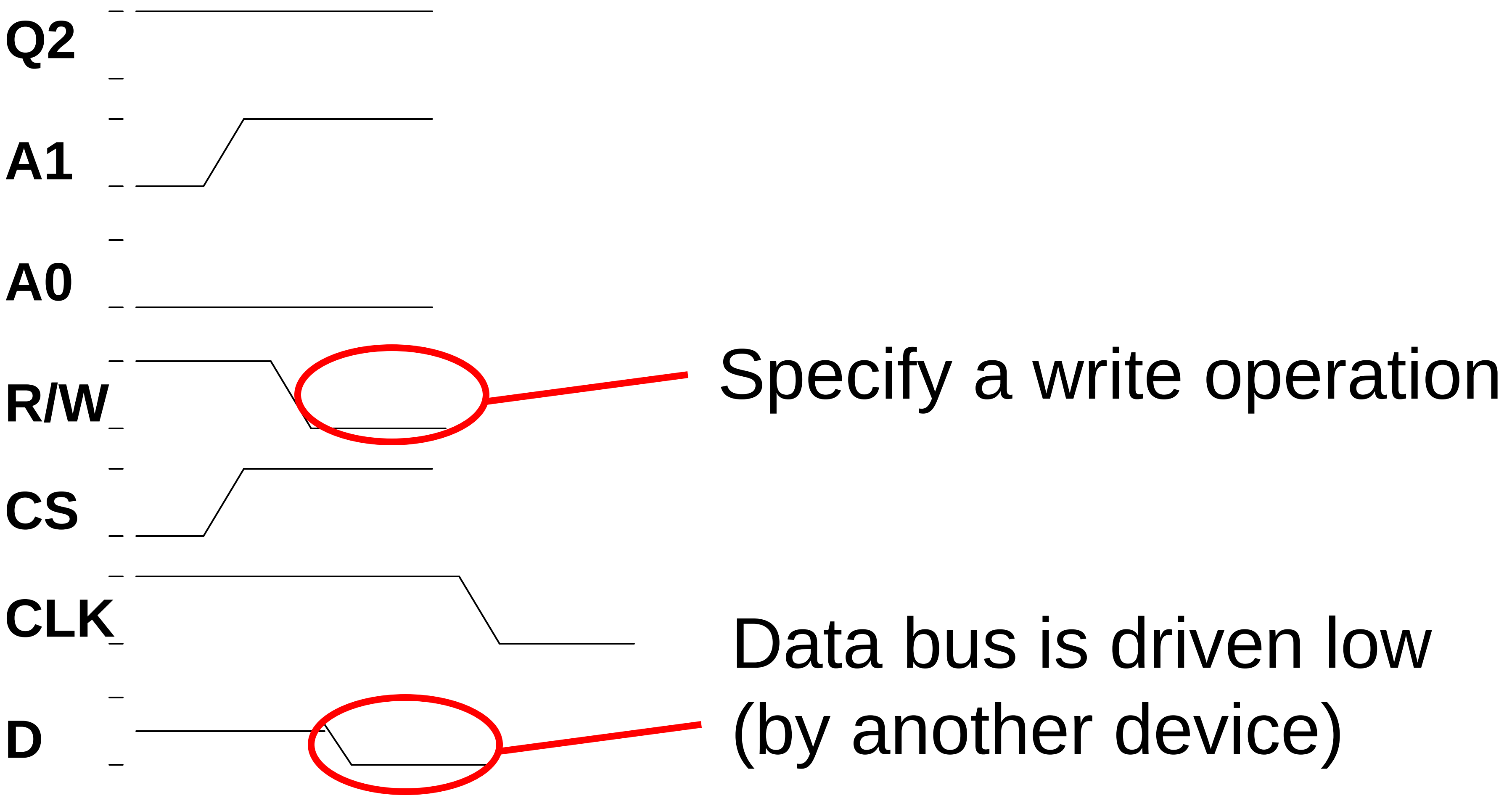
Memory Timing Diagram



Memory Timing Diagram



Memory Timing Diagram



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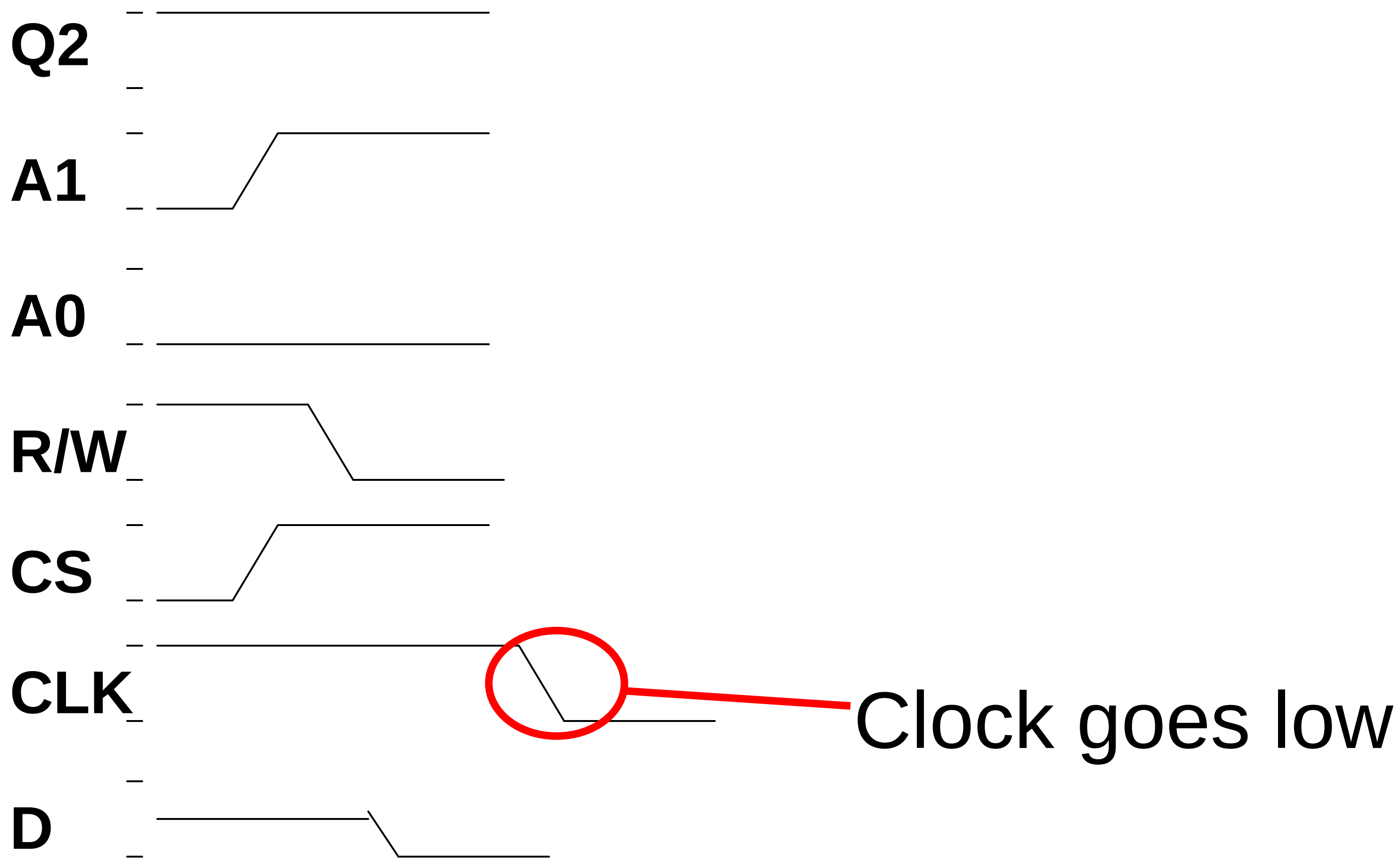
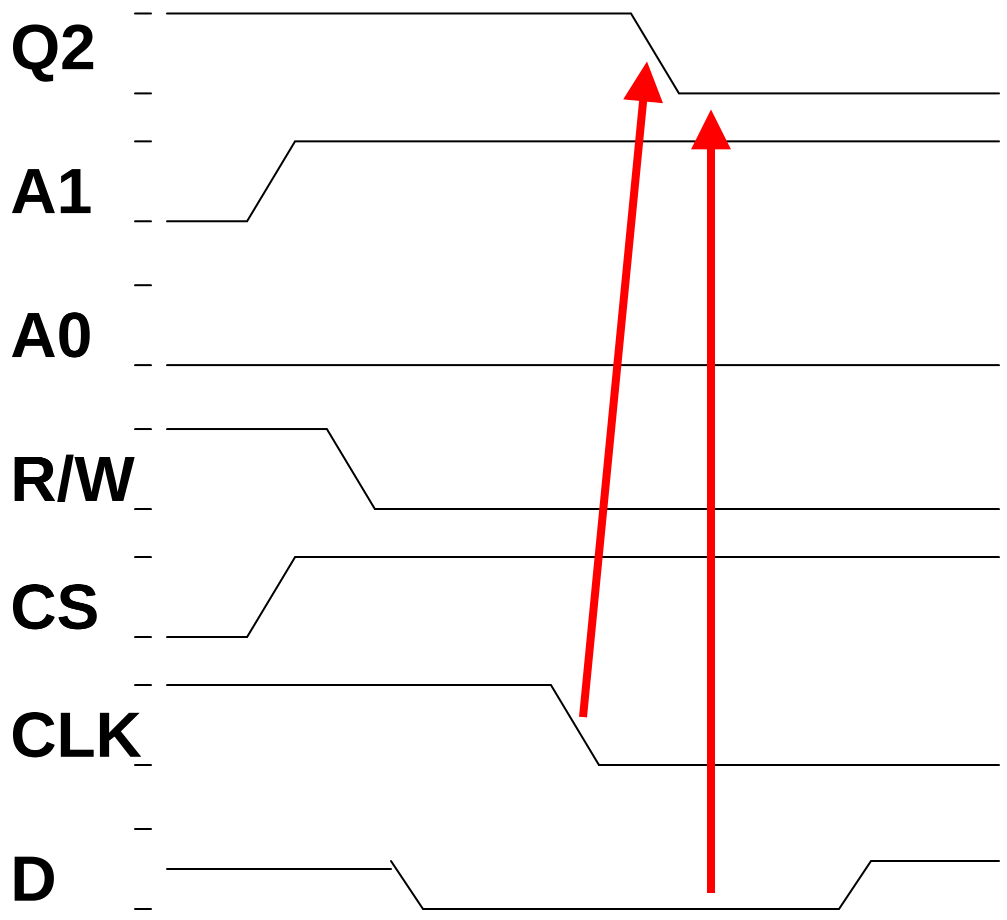
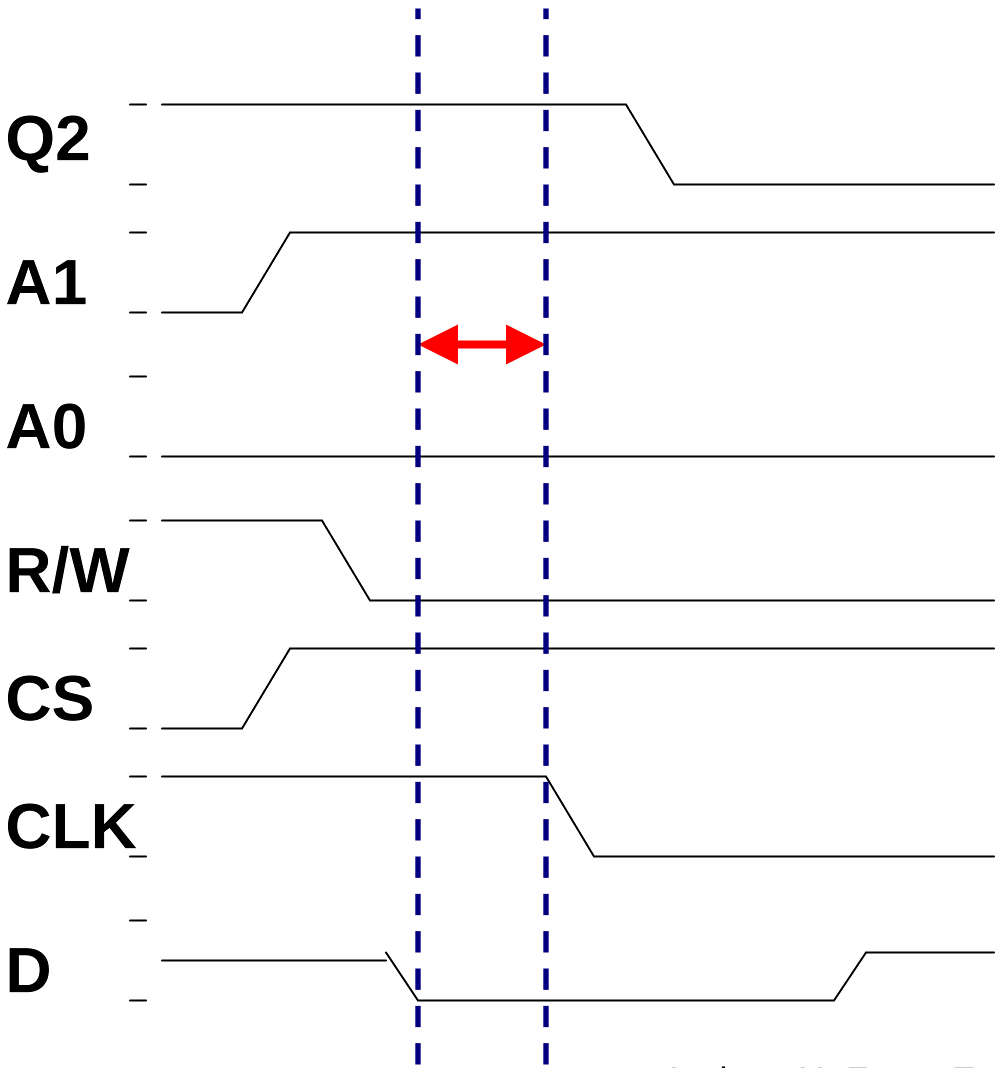


Memory Timing Diagram



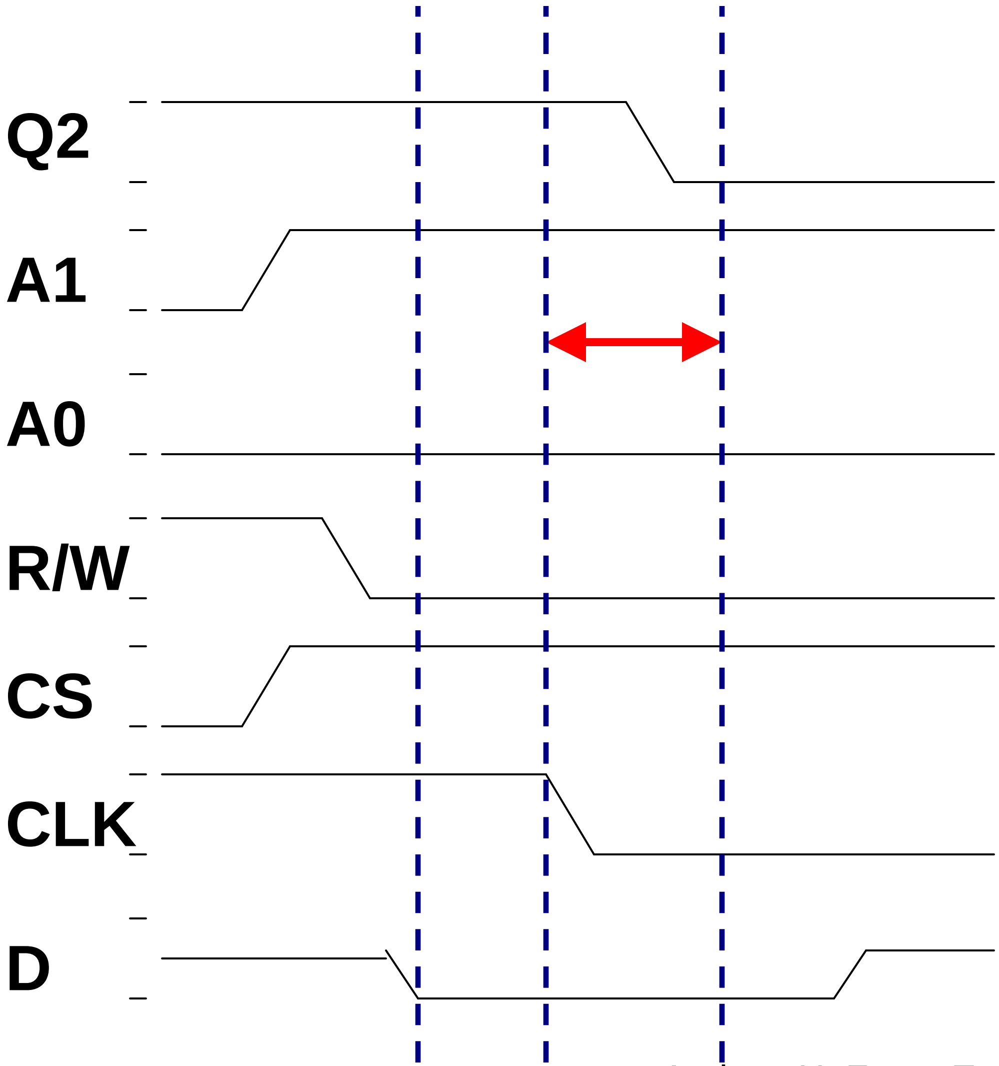
Memory element 2 changes state to low

Memory Timing Diagram



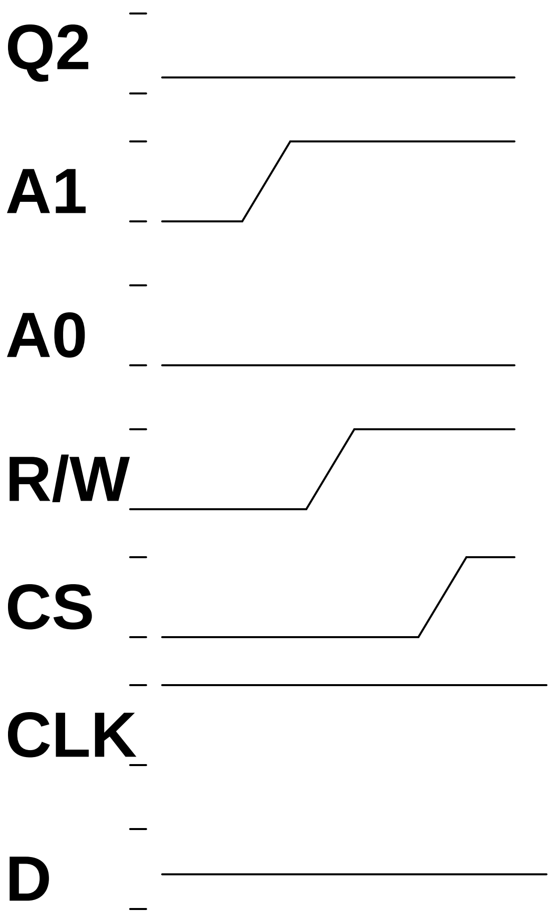
Setup time: all inputs must be valid during this time

Memory Timing Diagram

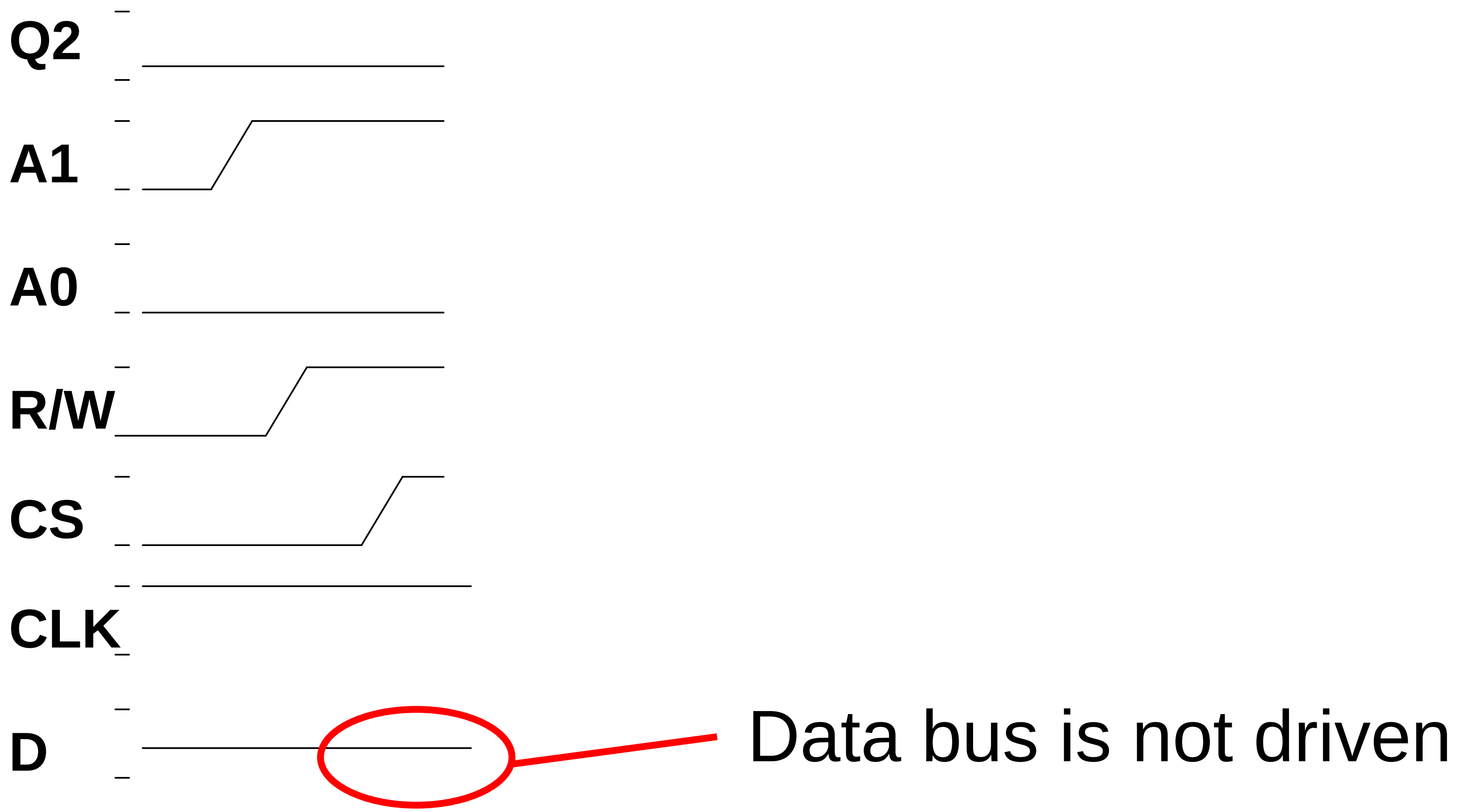


Hold time: all inputs must continue to be valid

Memory Timing Diagram II



Memory Timing Diagram II



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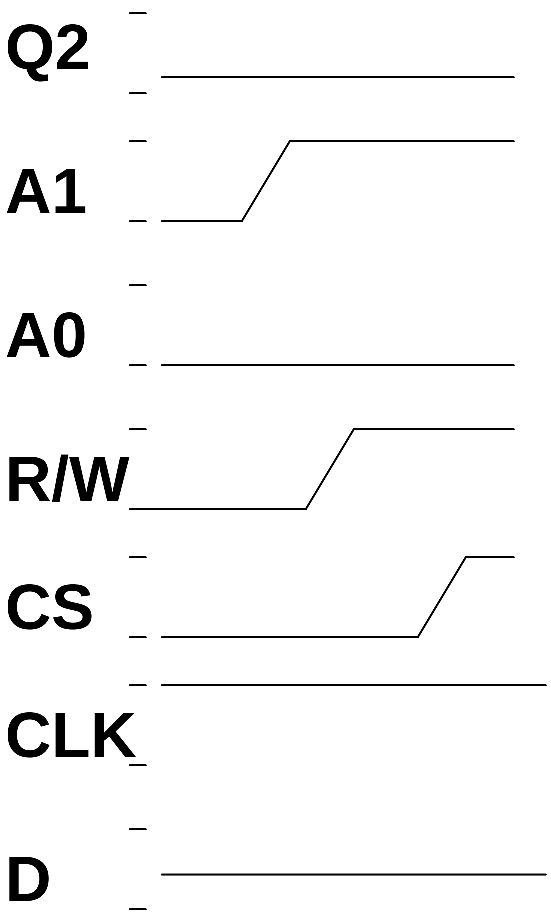
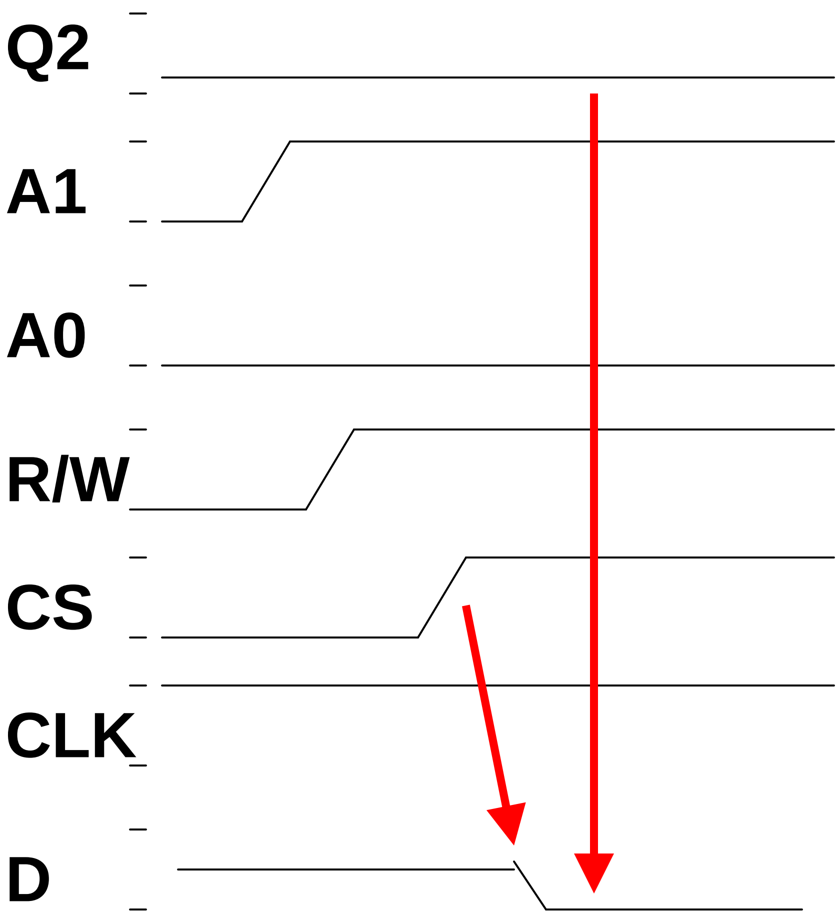


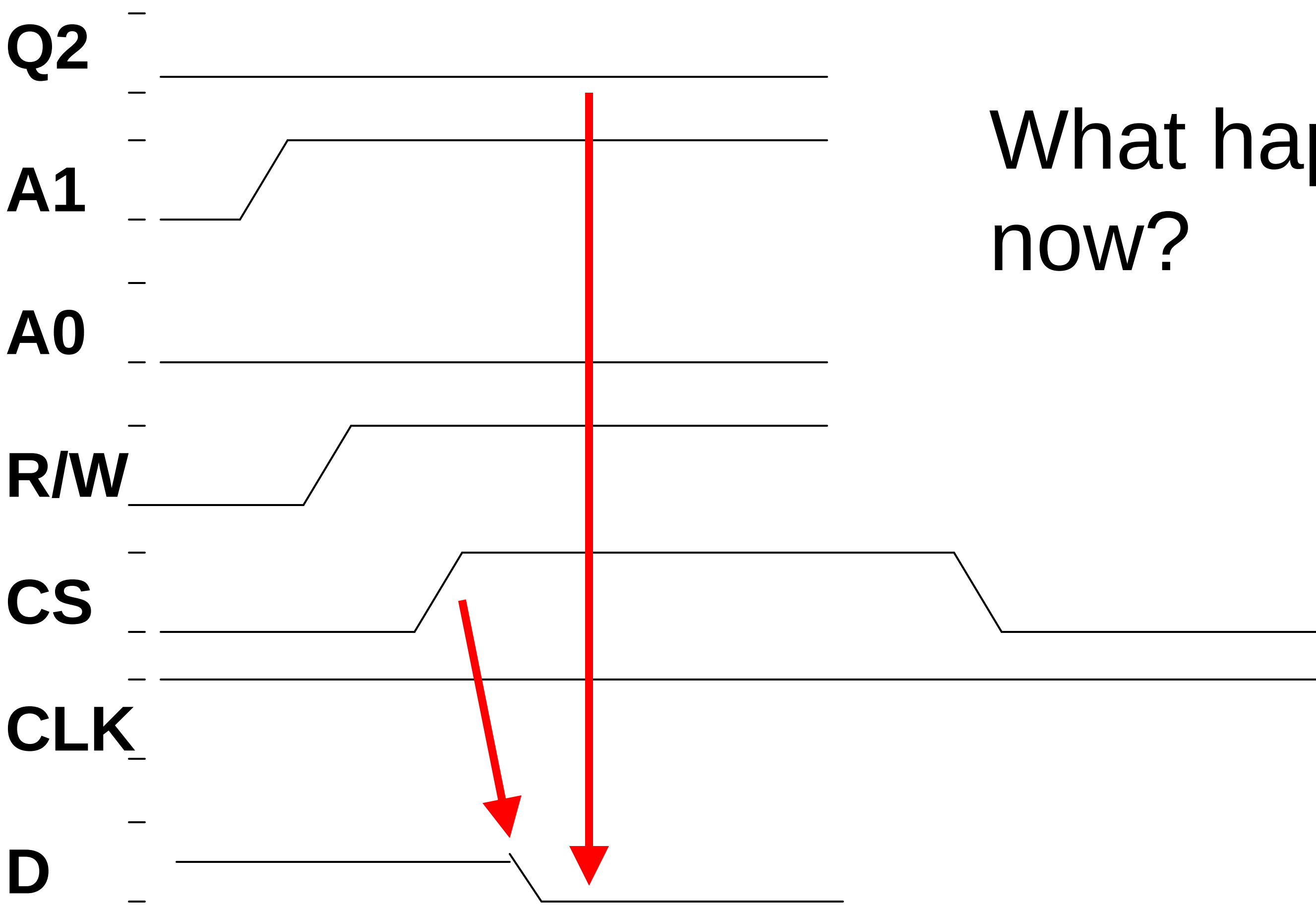
What happens next?

Memory Timing Diagram II



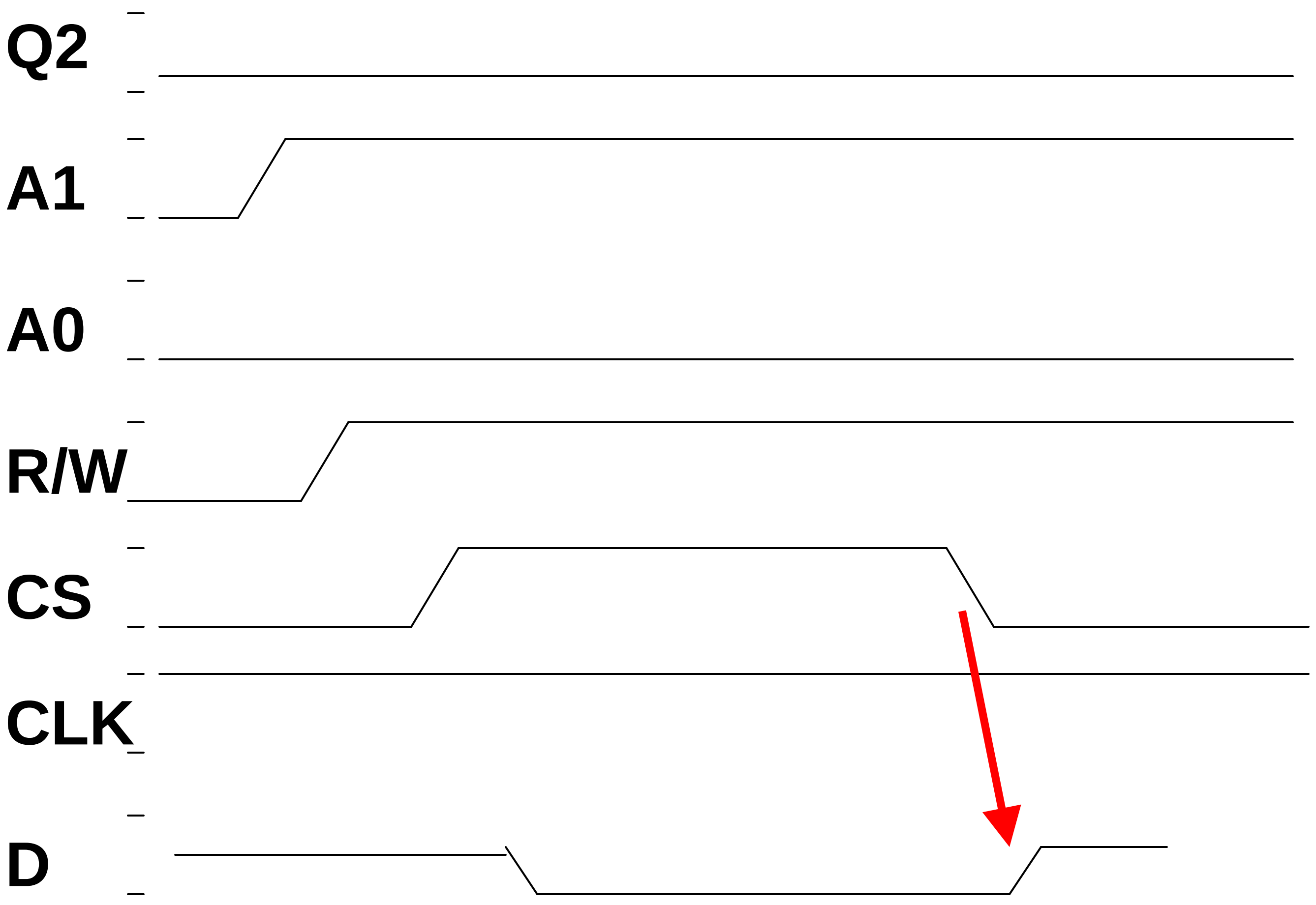
On chip select – drive data bus from Q2

Memory Timing Diagram II



What happens now?

Memory Timing Diagram II

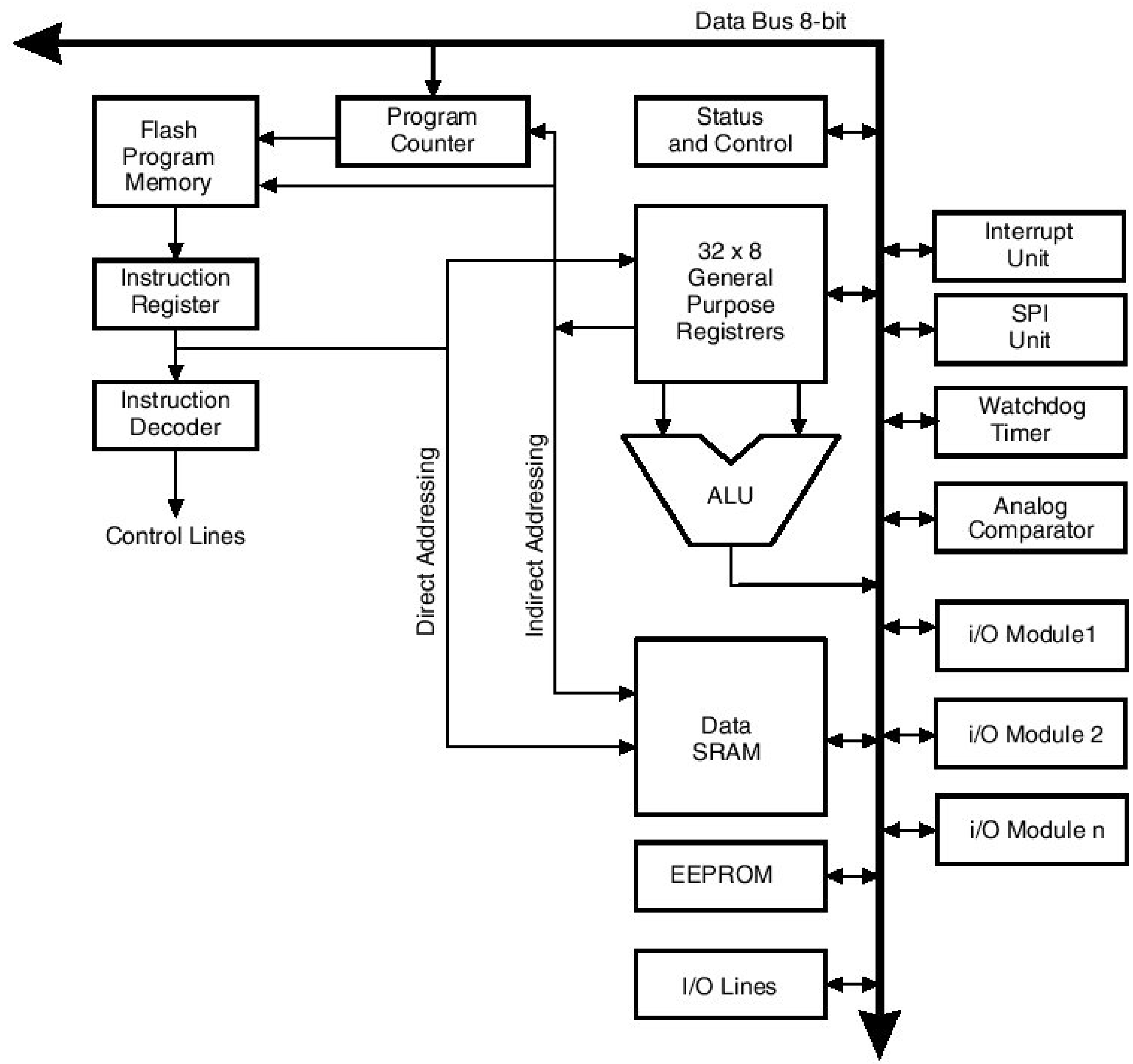


Data bus returns to a non-driven state

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

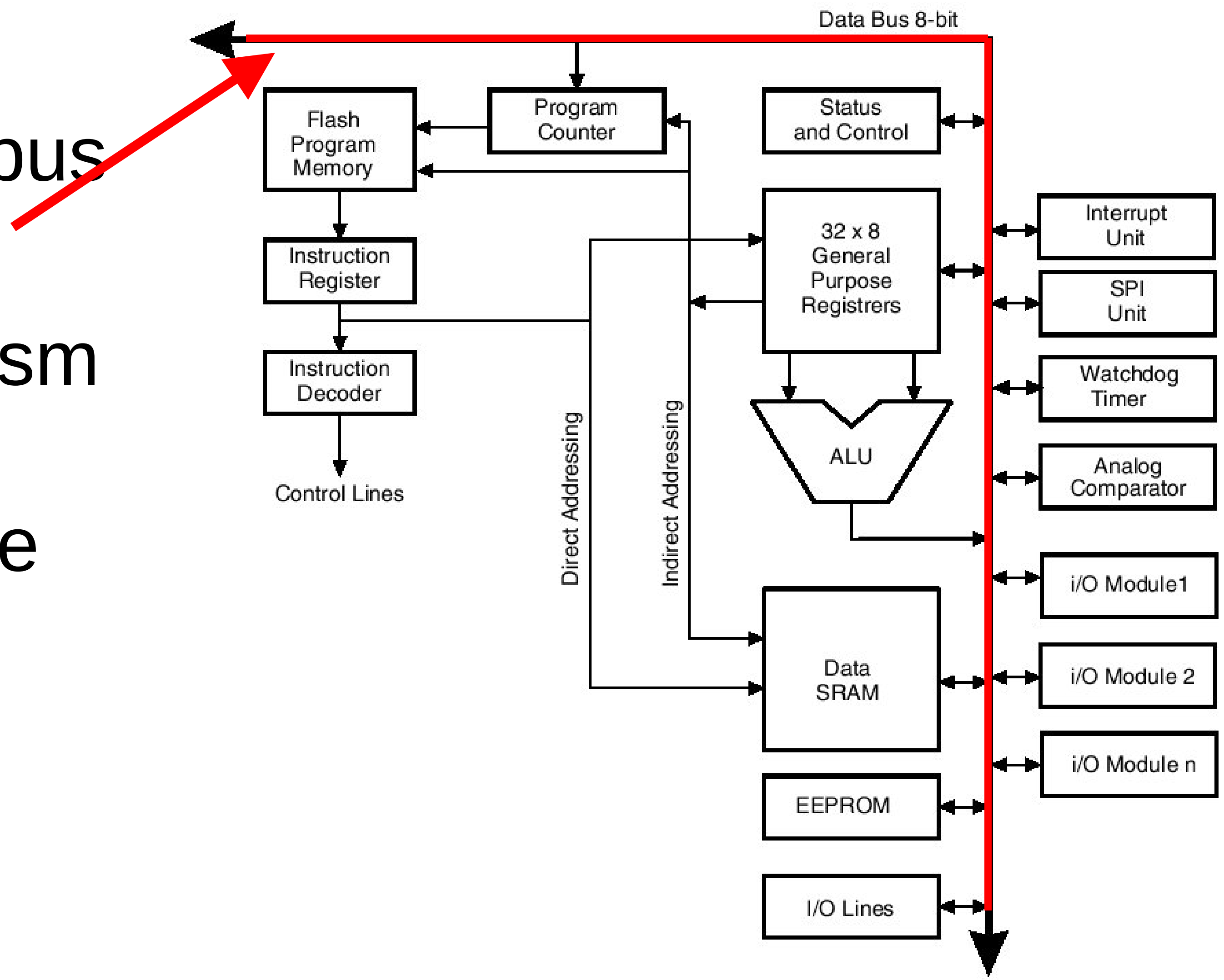
An Example: the Atmel Mega8



Atmel Mega8

8-bit data bus

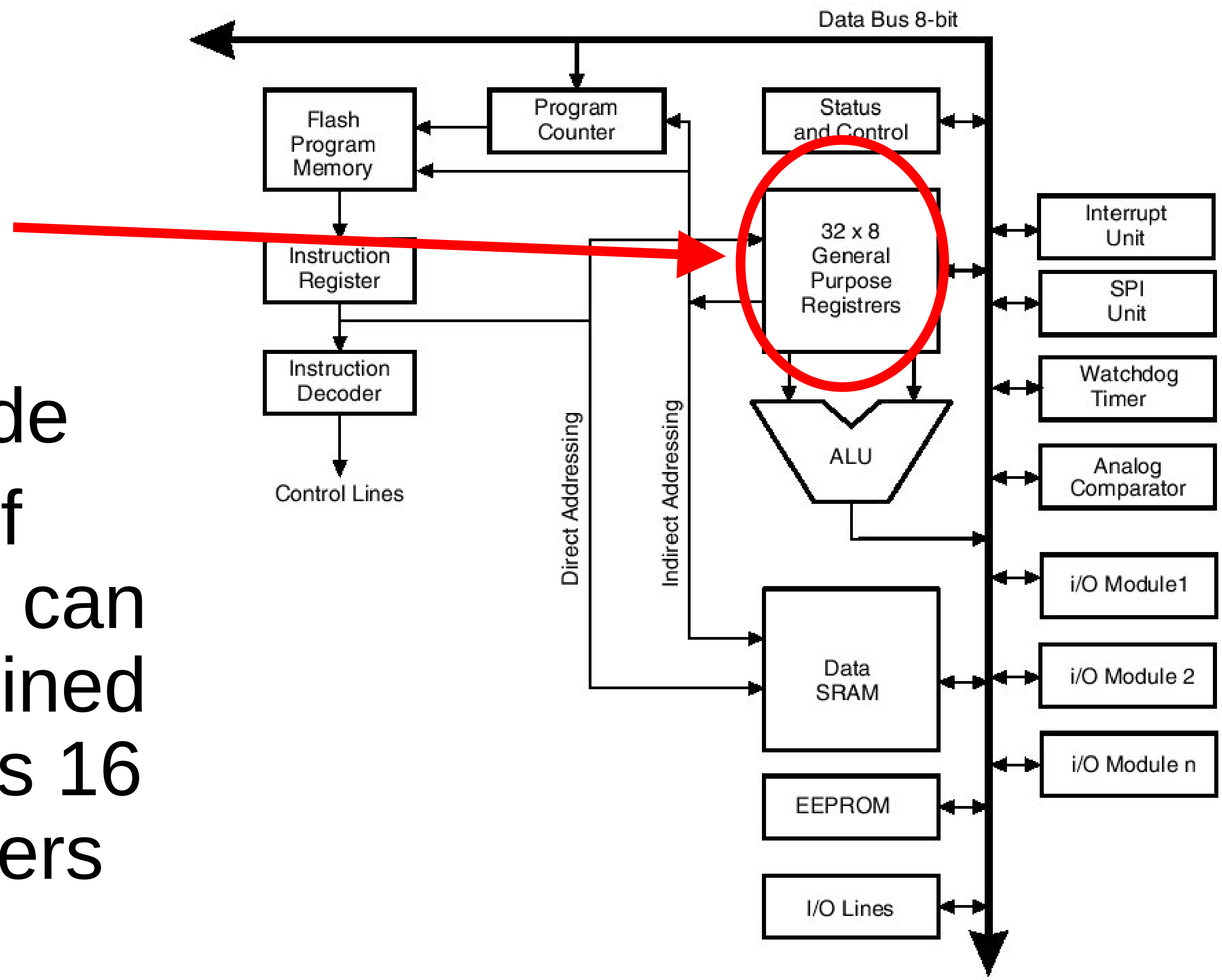
- Primary mechanism for data exchange



Atmel Mega8

32 general purpose registers

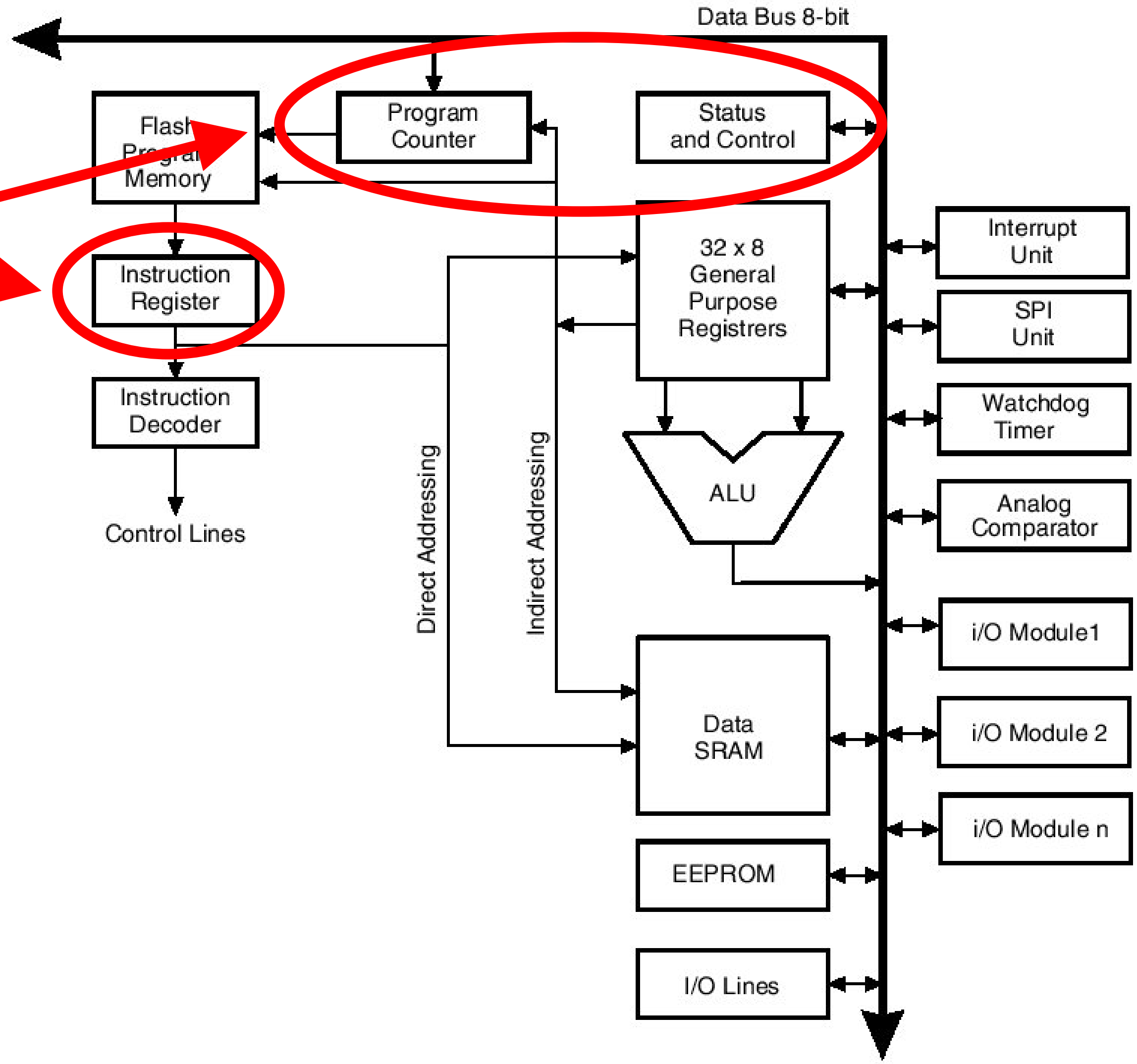
- 8 bits wide
- 3 pairs of registers can be combined to give us 16 bit registers



Atmel Mega8

Special
purpose
registers

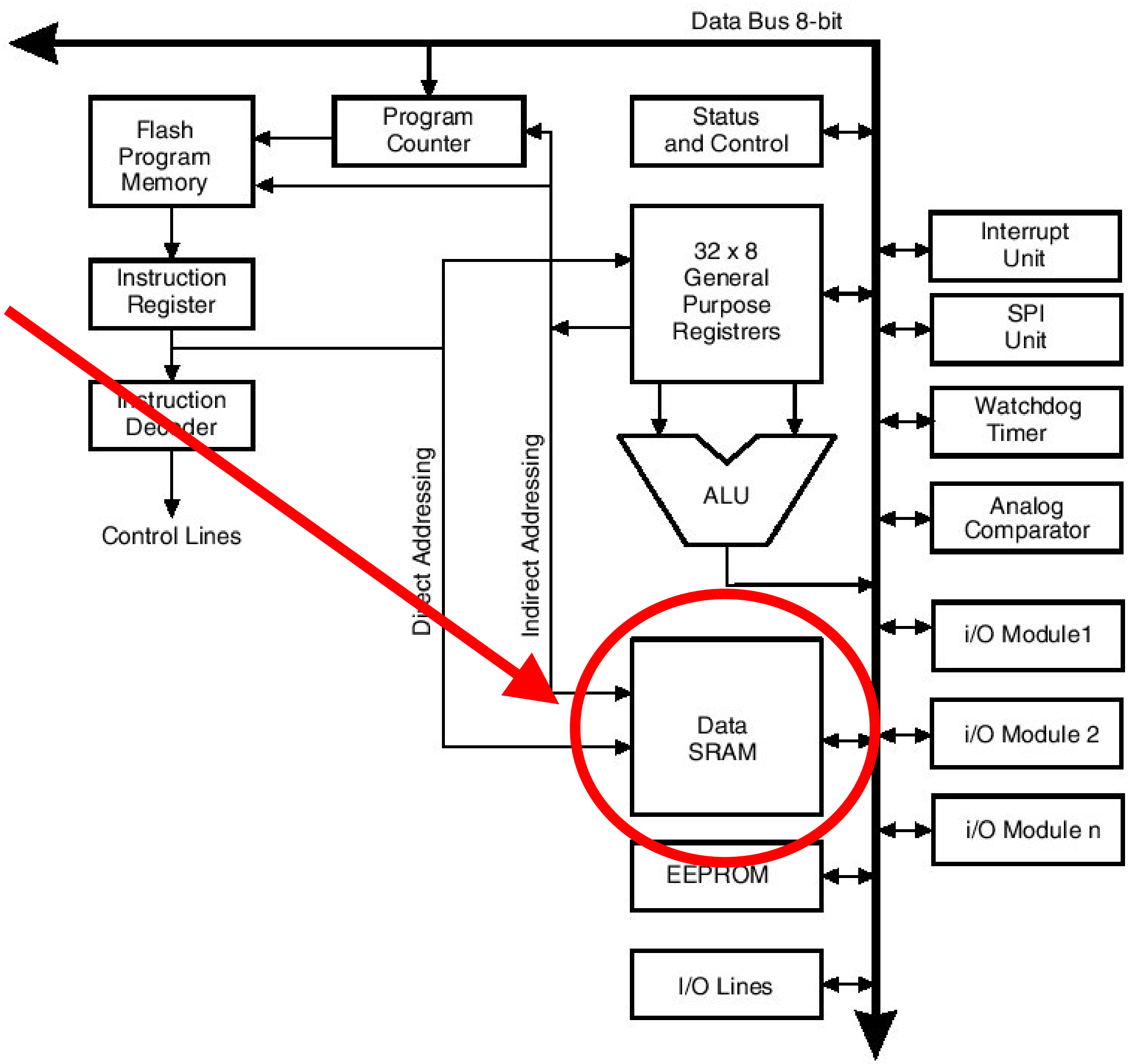
- Control of the internals of the processor



Atmel Mega8

Random Access Memory (RAM)

- 1 KByte in size

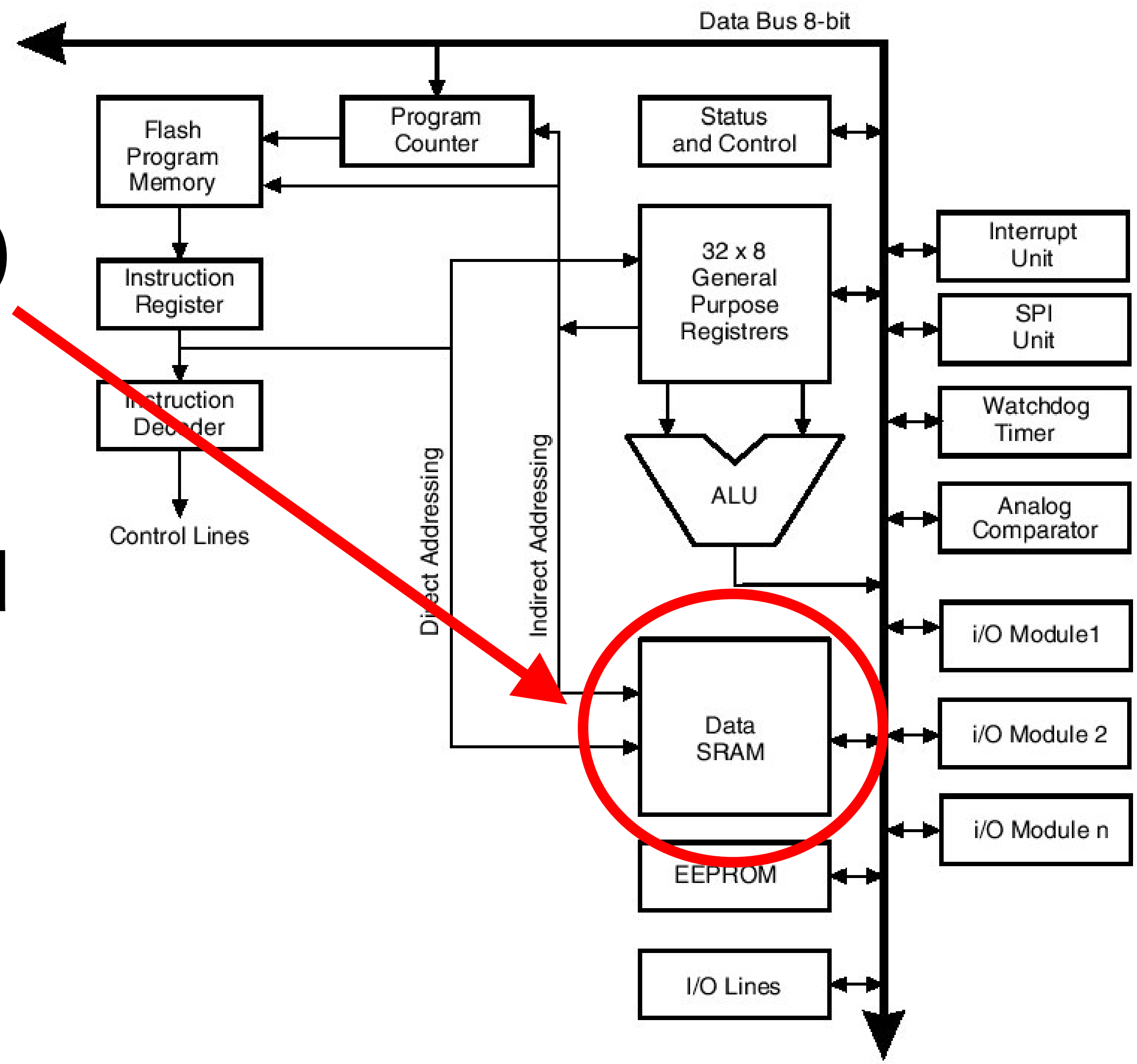


Atmel Mega8

Random Access Memory (RAM)

- 1 KByte in size

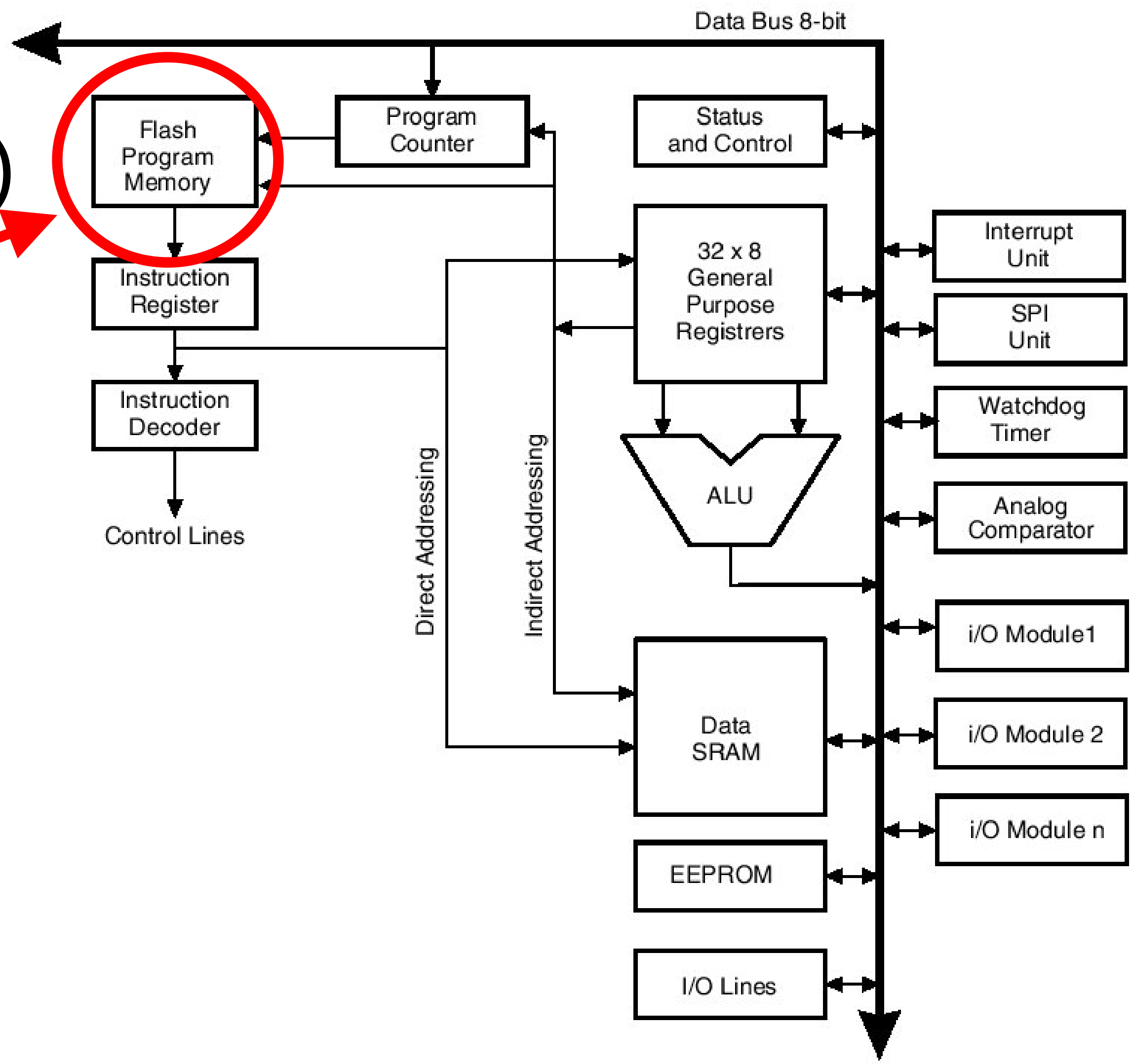
Note: in high-end processors, RAM is a separate component



Atmel Mega8

Flash (EEPROM)

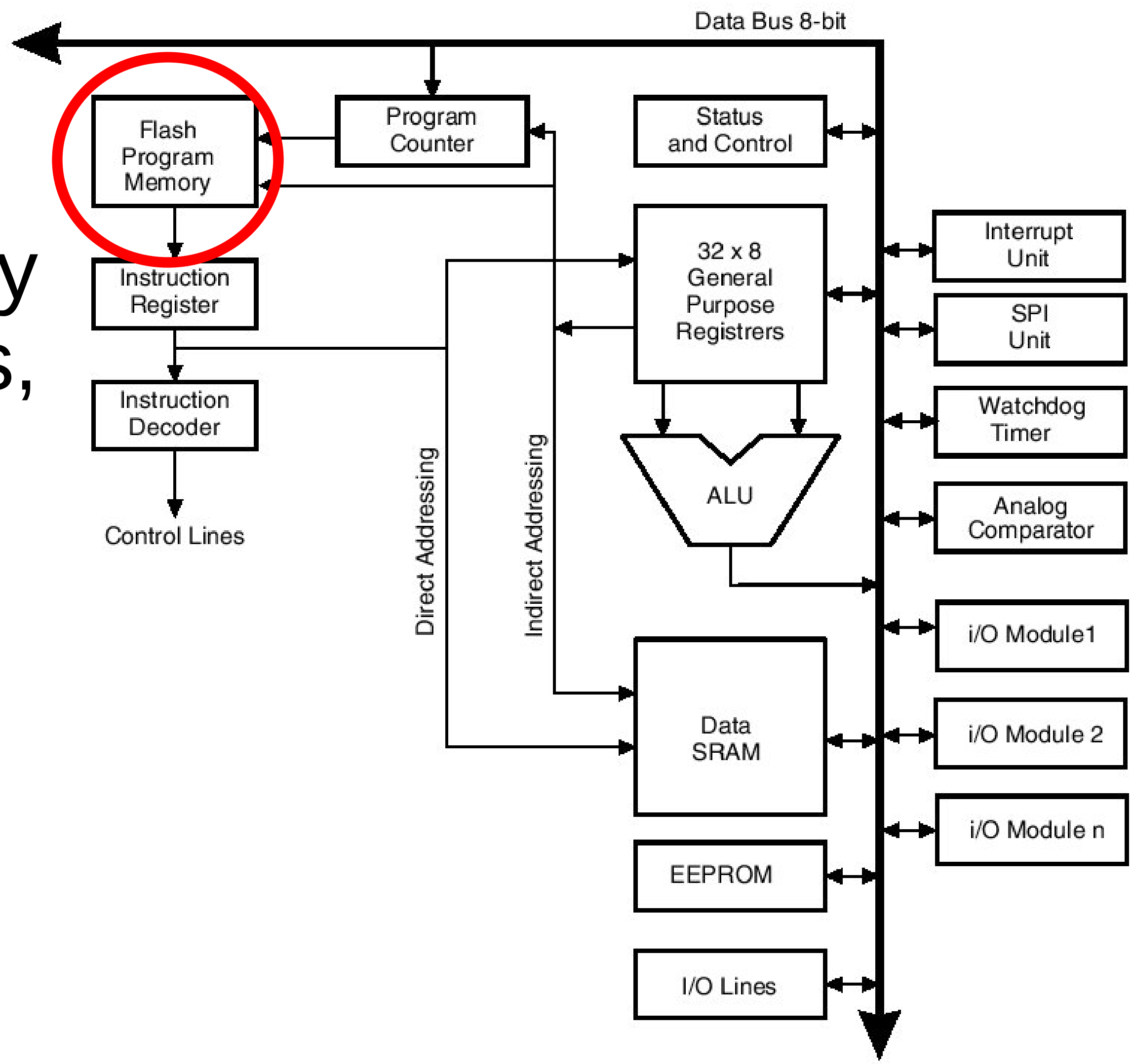
- Program storage
- 8 KByte in size



Atmel Mega8

Flash (EEPROM)

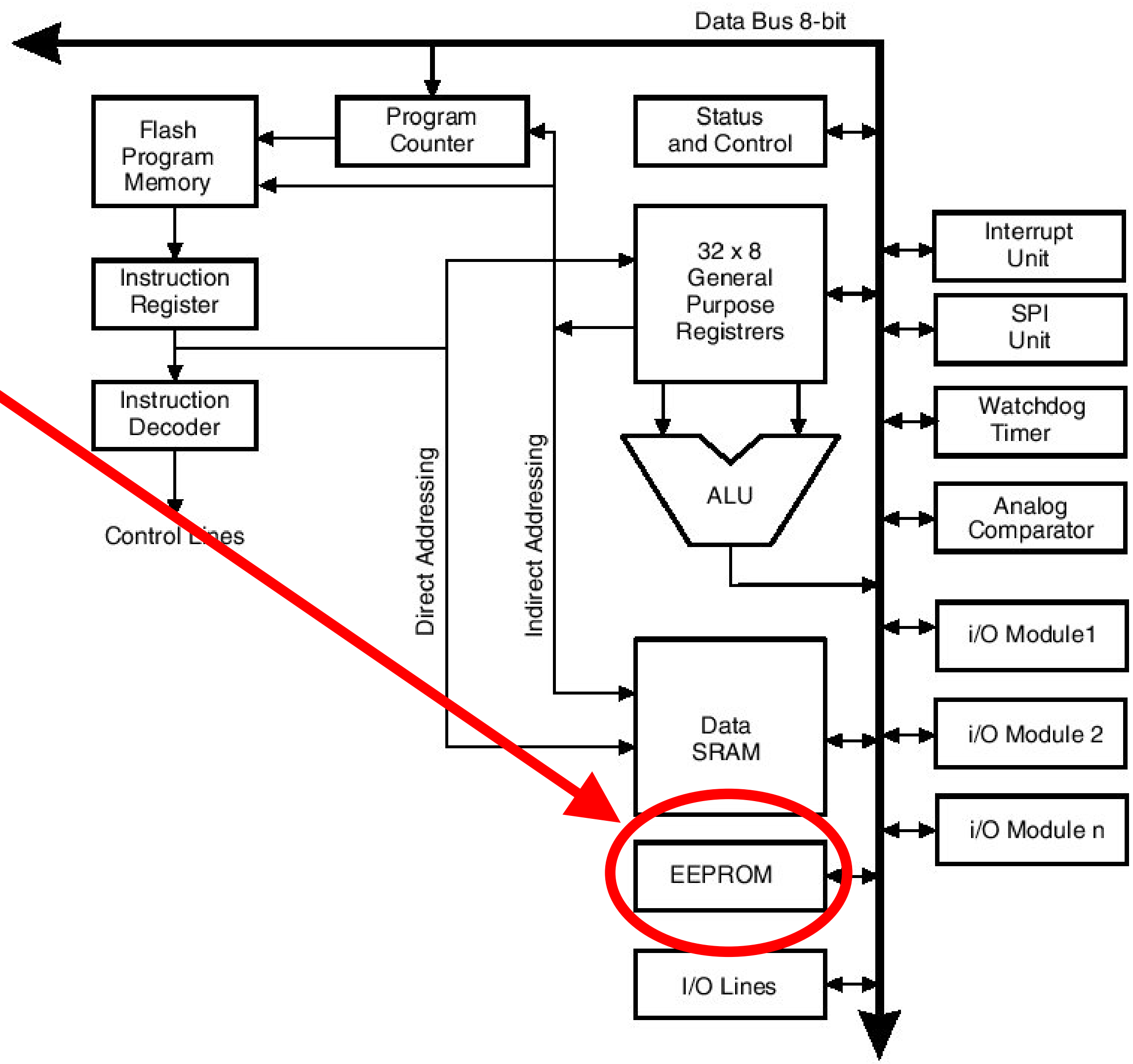
- In this and many microcontrollers, program and data storage is separate
- Not the case in our general purpose computers



Atmel Mega8

EEPROM

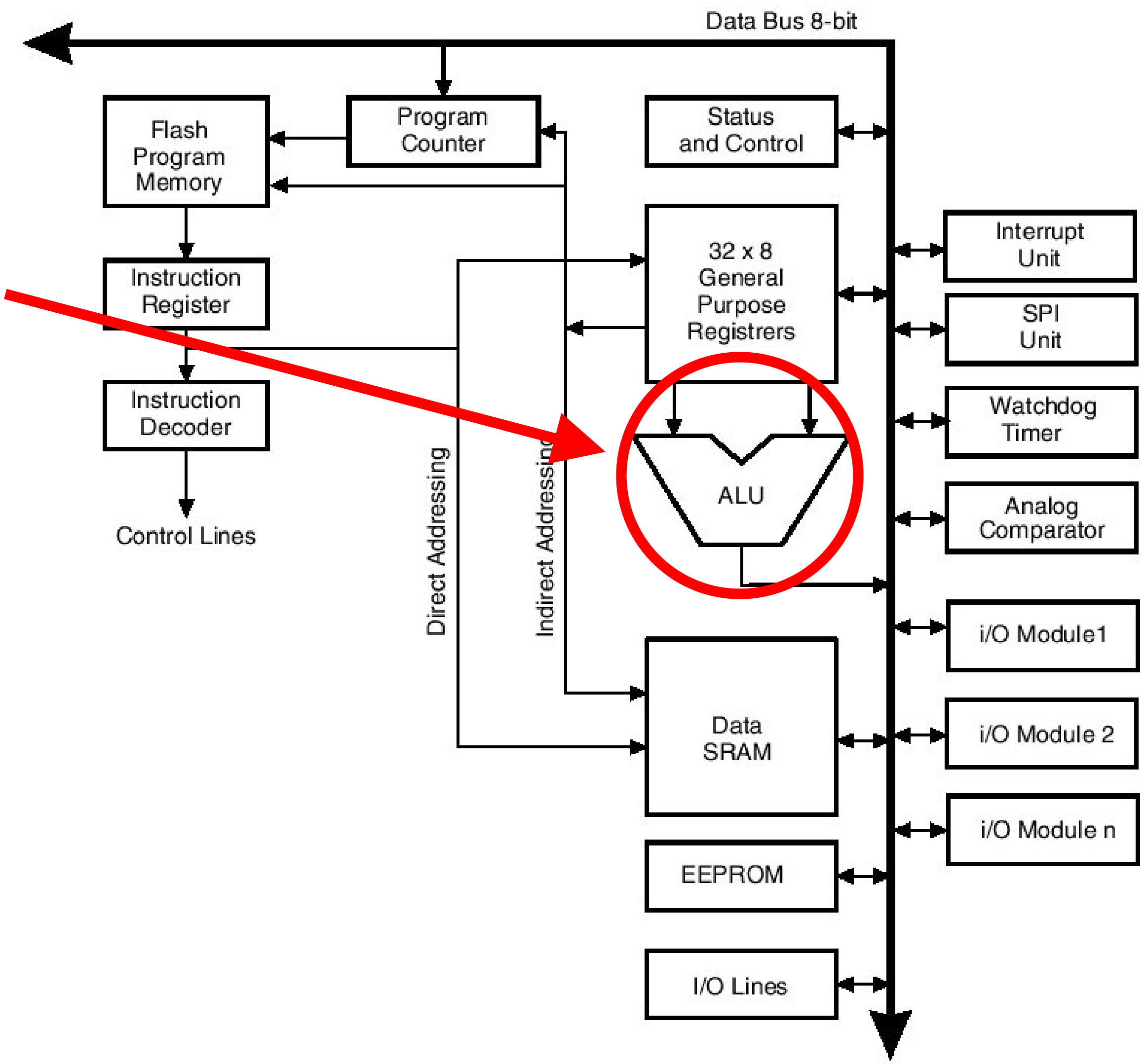
- Permanent data storage



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

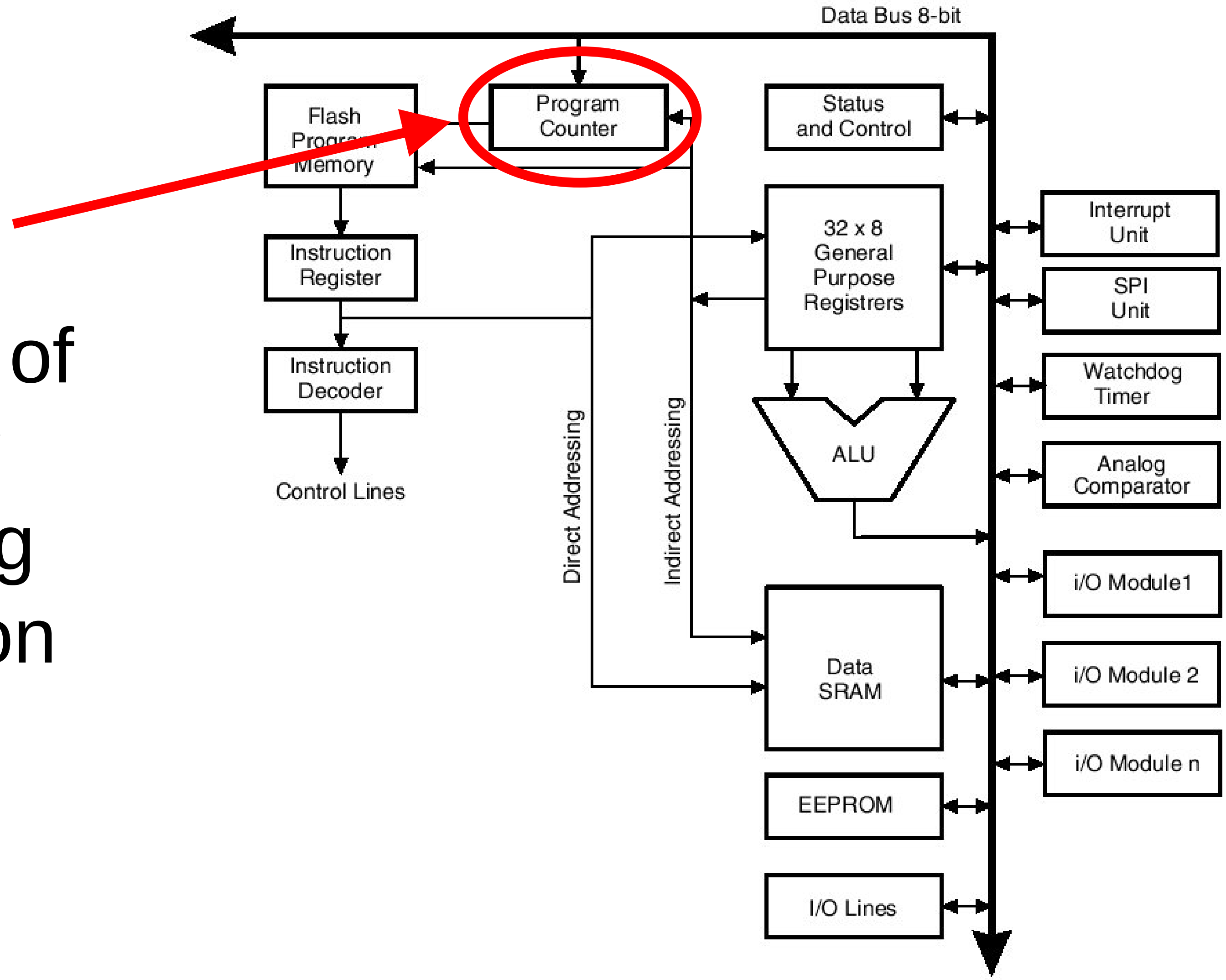
Types of Instructions

- 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

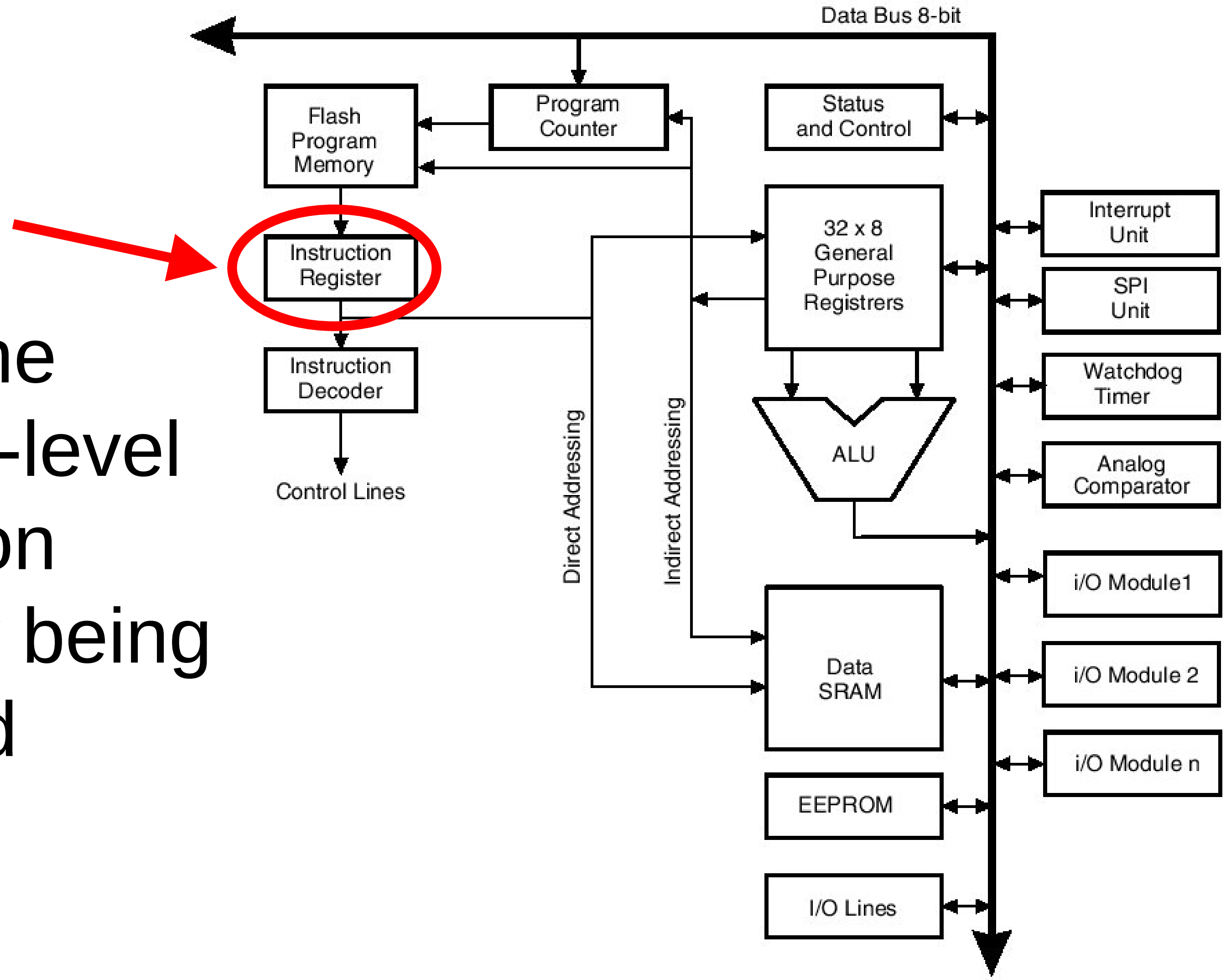
- Address of currently executing instruction



Atmel Mega8: Decoding Instructions

Instruction register

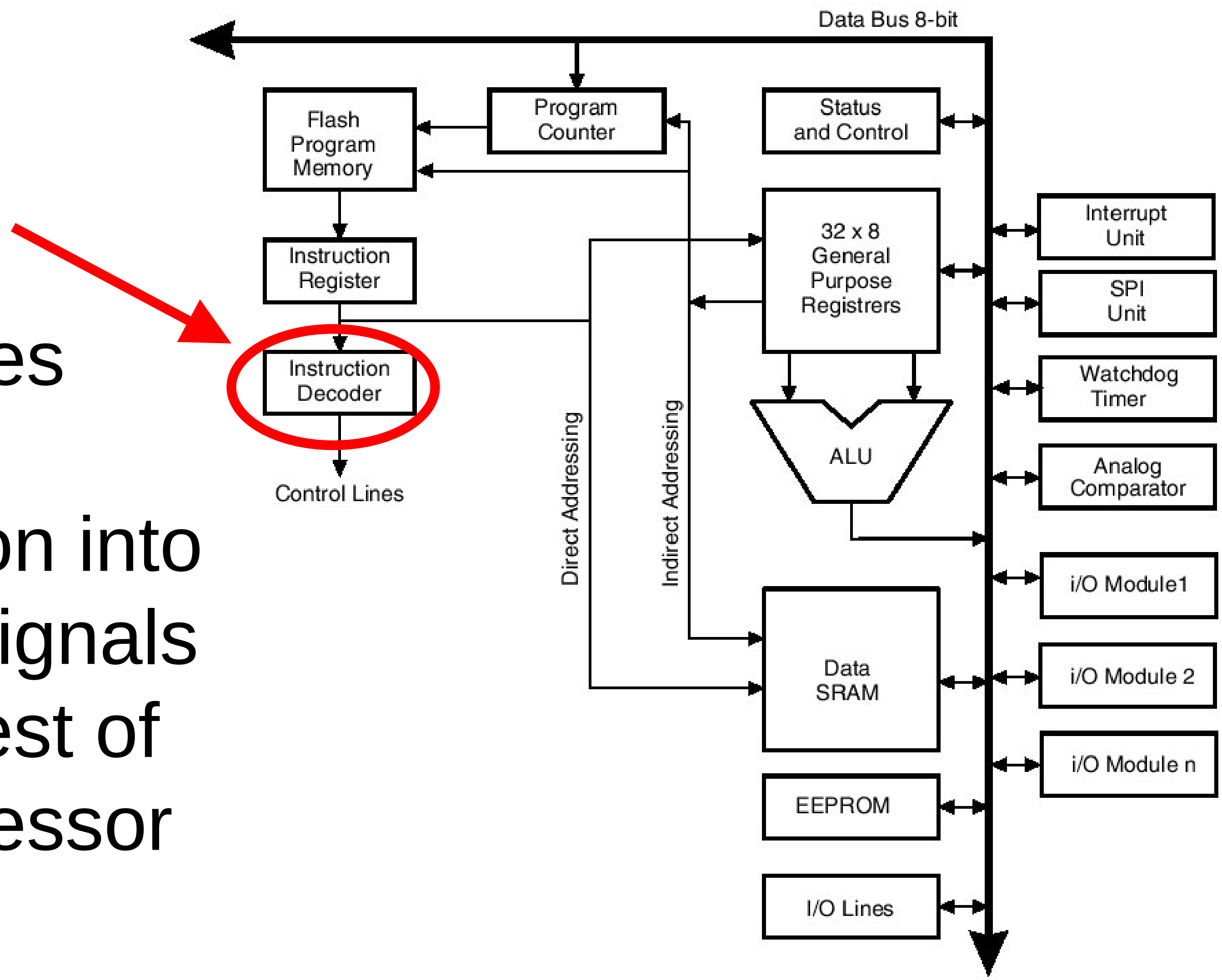
- Stores the machine-level instruction currently being executed



Atmel Mega8

Instruction decoder

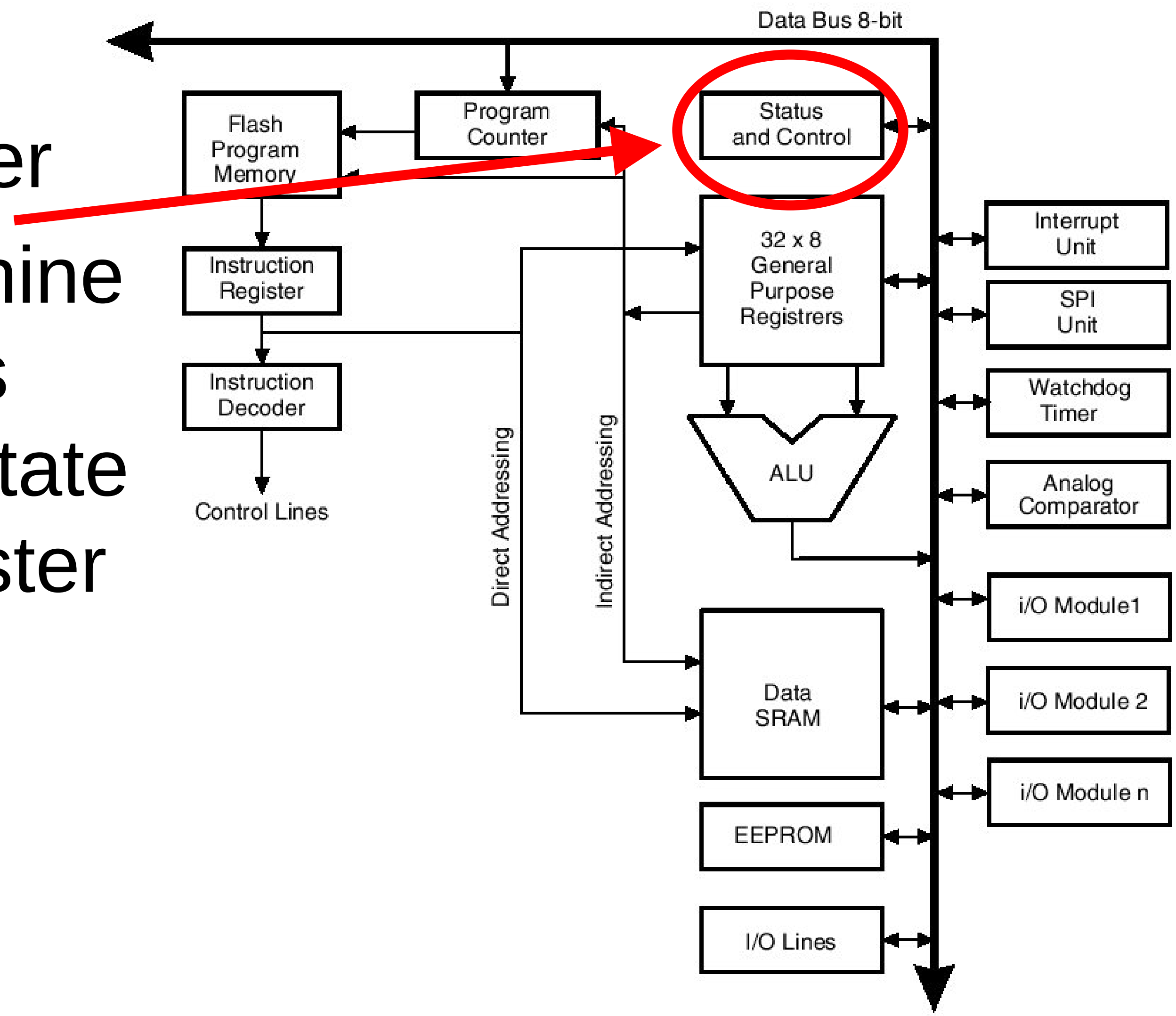
- Translates current instruction into control signals for the rest of the processor



Atmel Mega8

Status register

- Many machine instructions affect the state of this register



Some Mega8 Memory Operations

We refer to this as "Assembly Language"

LDS Rd, k

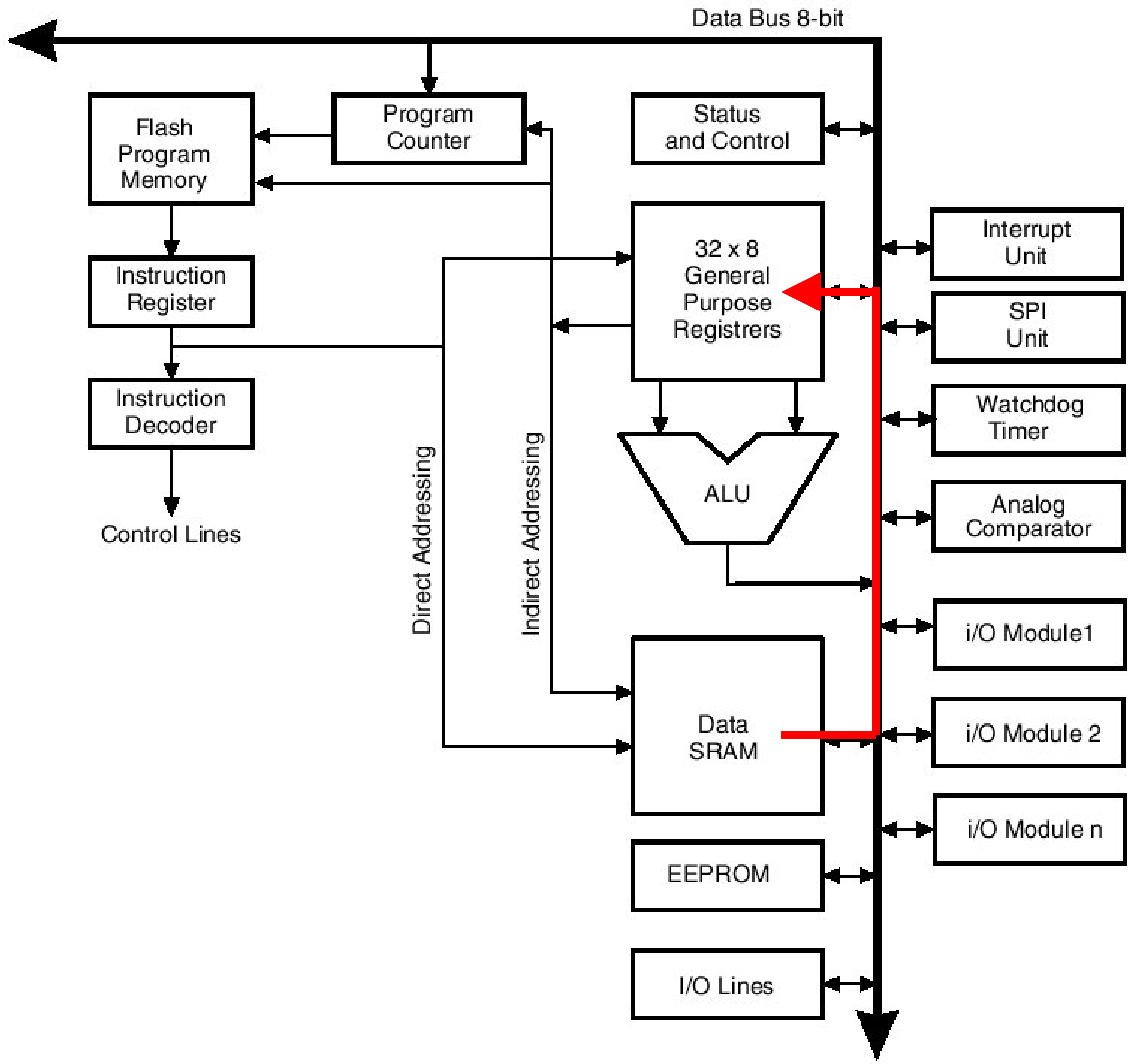
- Load SRAM memory location k into register Rd
- Rd <- (k)

STS Rd, k

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

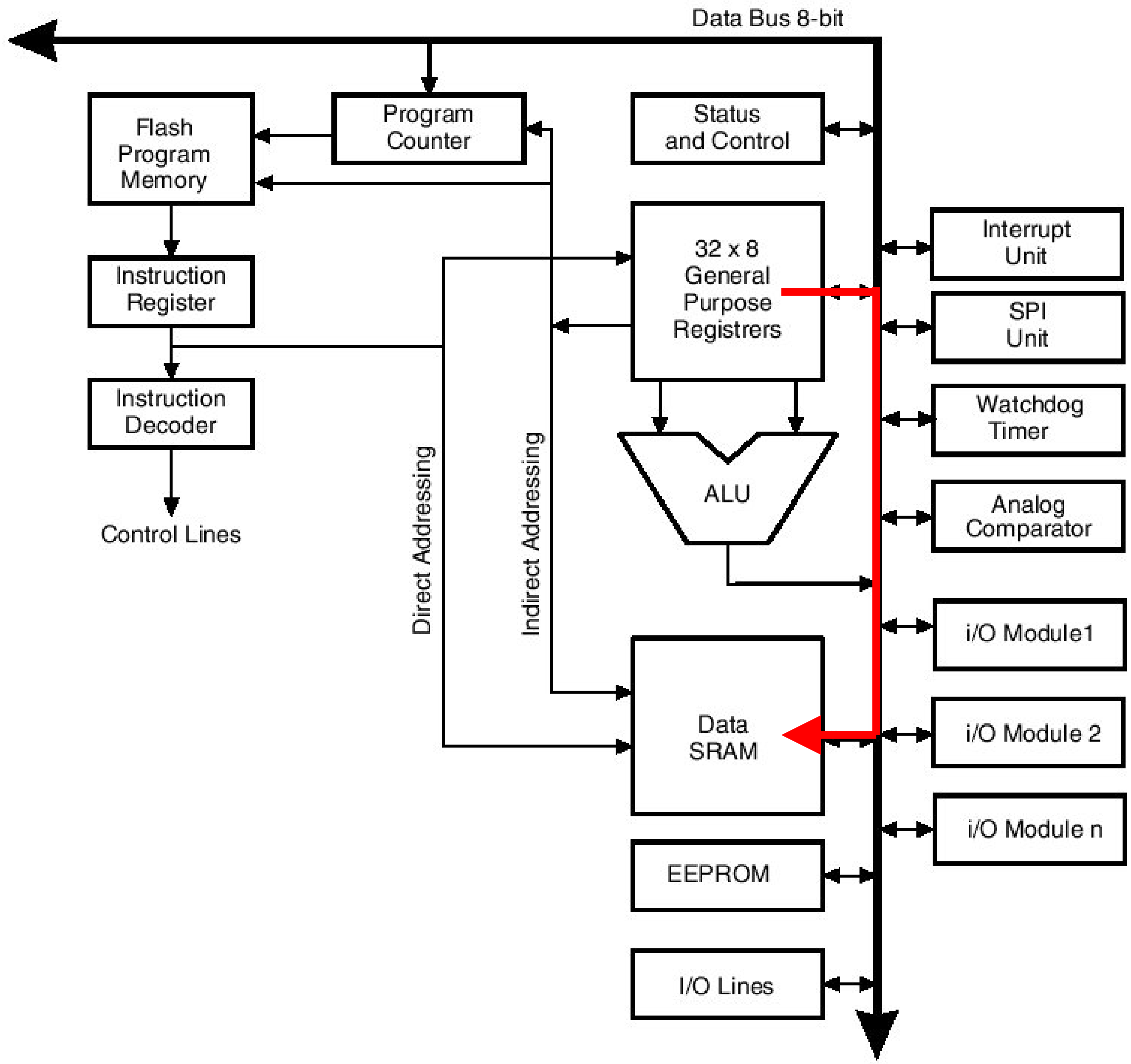
Load SRAM Value to Register

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.)

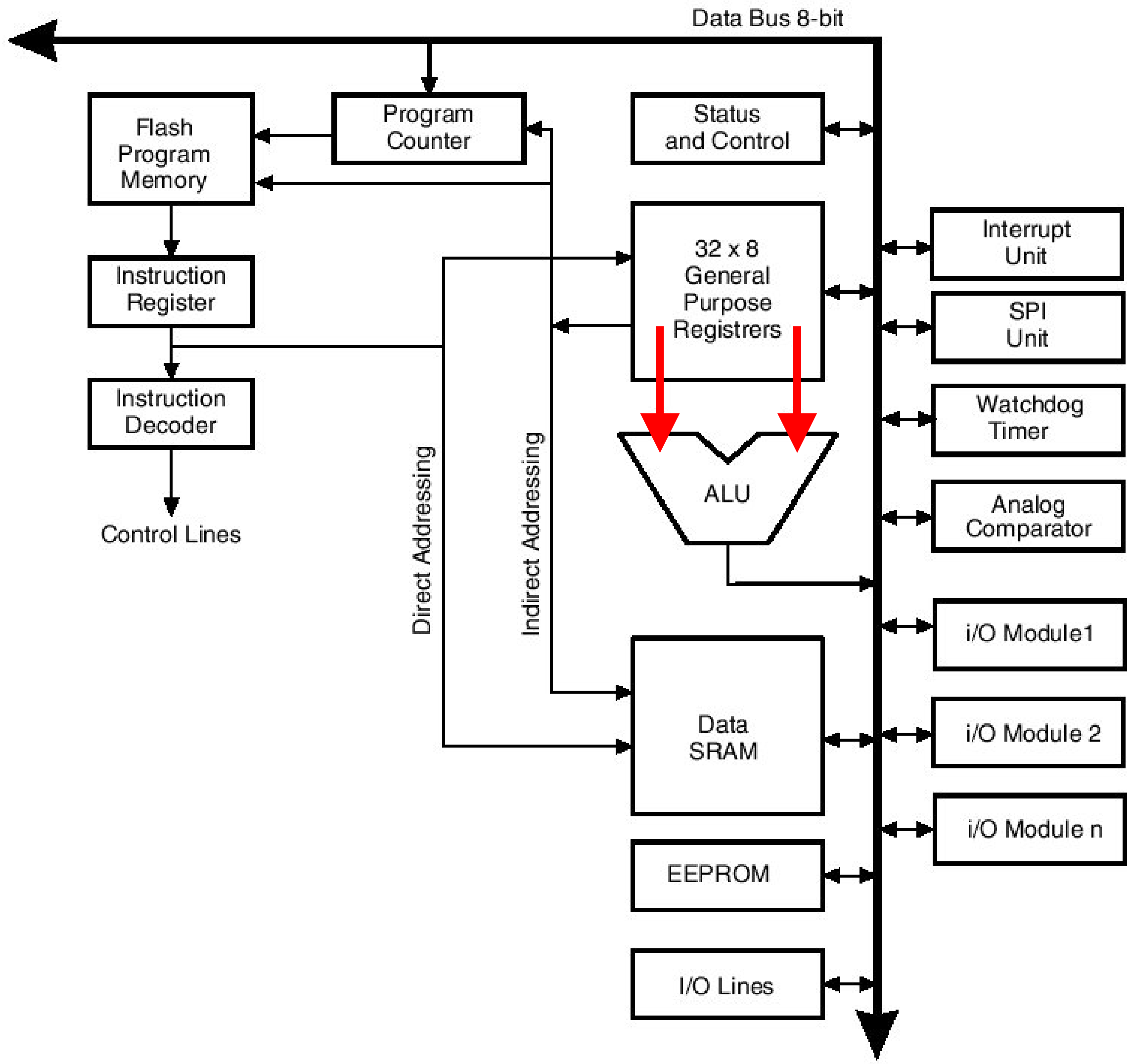
ADC Rd, Rr

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

Add Two Register Values

ADD Rd, Rr

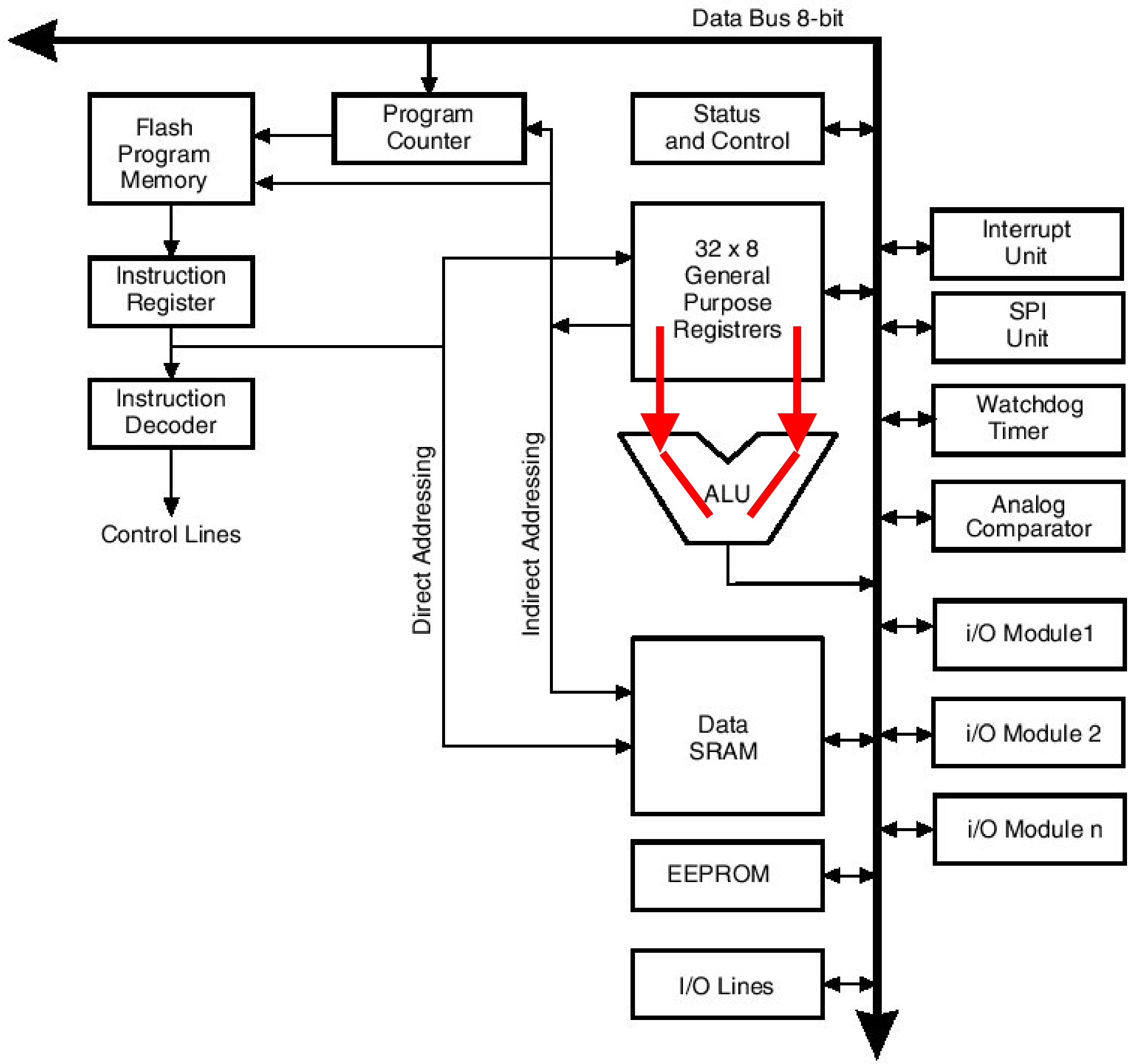
- Fetch register values



Add Two Register Values

ADD Rd, Rr

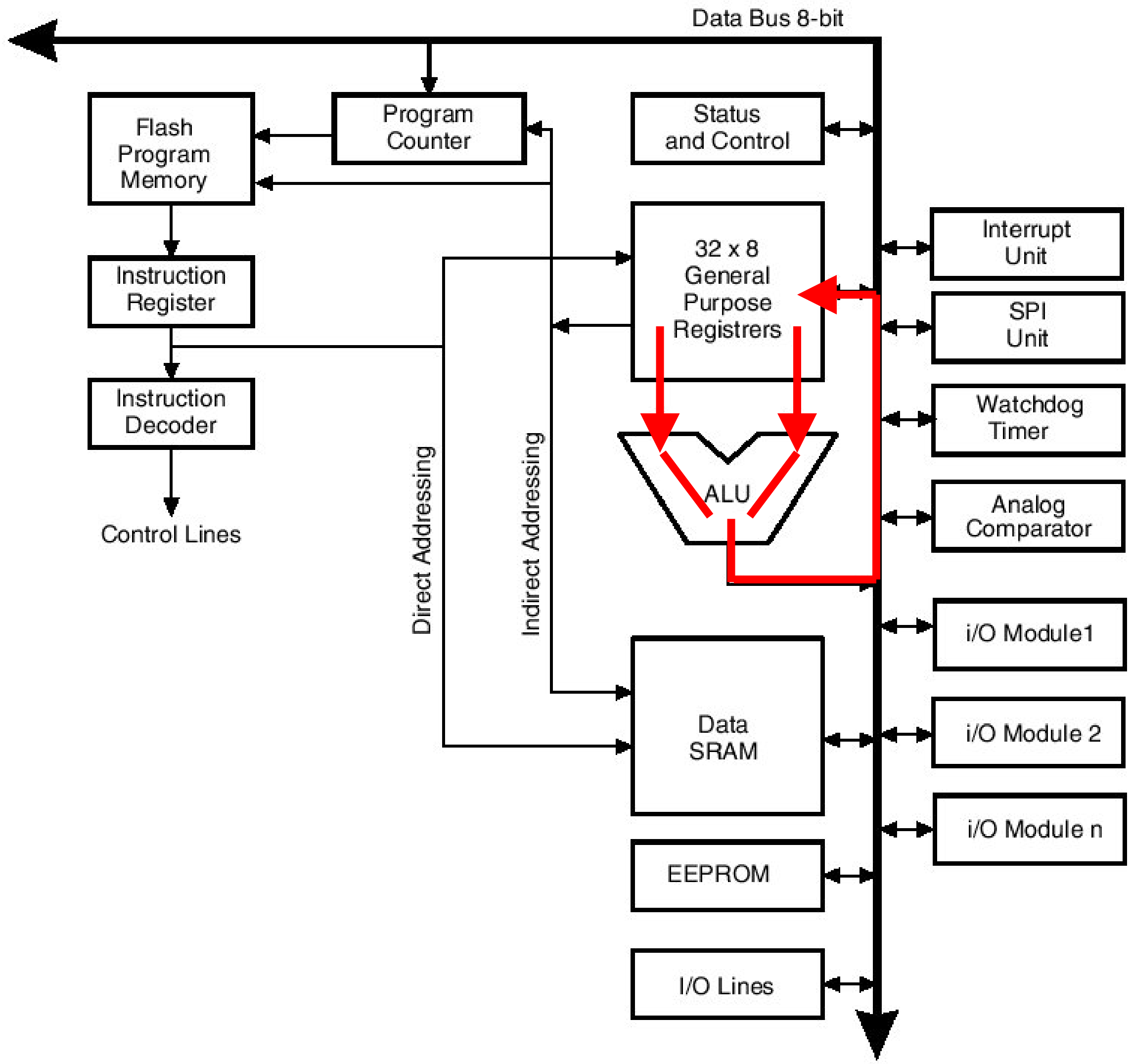
- Fetch register values
- ALU performs ADD



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 Arithmetic and Logical Instructions

NEG Rd: take the two's complement of Rd

AND Rd, Rr: bit-wise AND with a register

ANDI Rd, K: bit-wise AND with a constant

EOR Rd, Rr: bit-wise XOR

INC Rd: increment Rd

MUL Rd, Rr: multiply Rd and Rr (unsigned)

MULS Rd, Rd: multiply (signed)

Some Mega8 Test Instructions

CP Rd, Rr

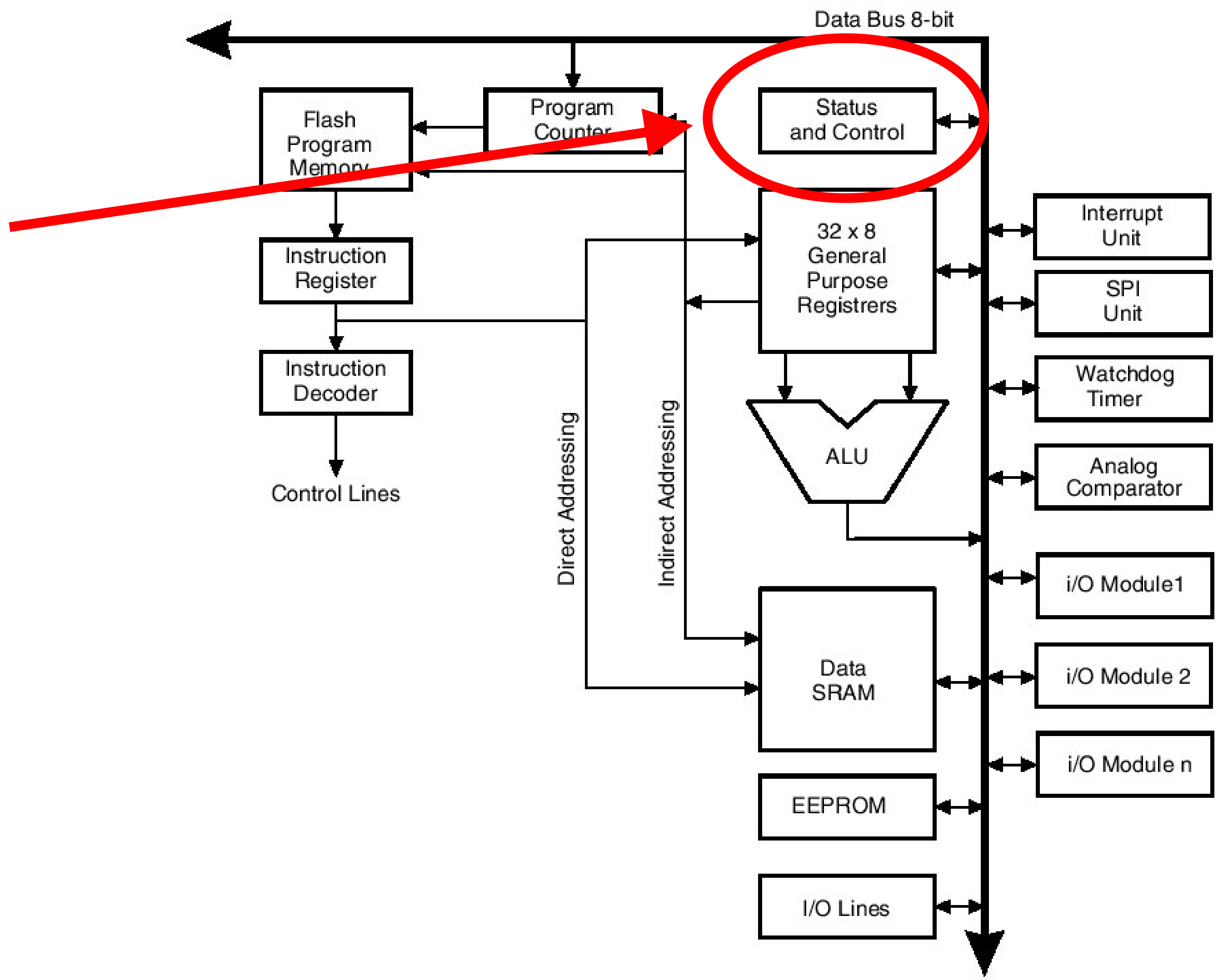
- Compare Rd with Rr
- Alters the status register

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

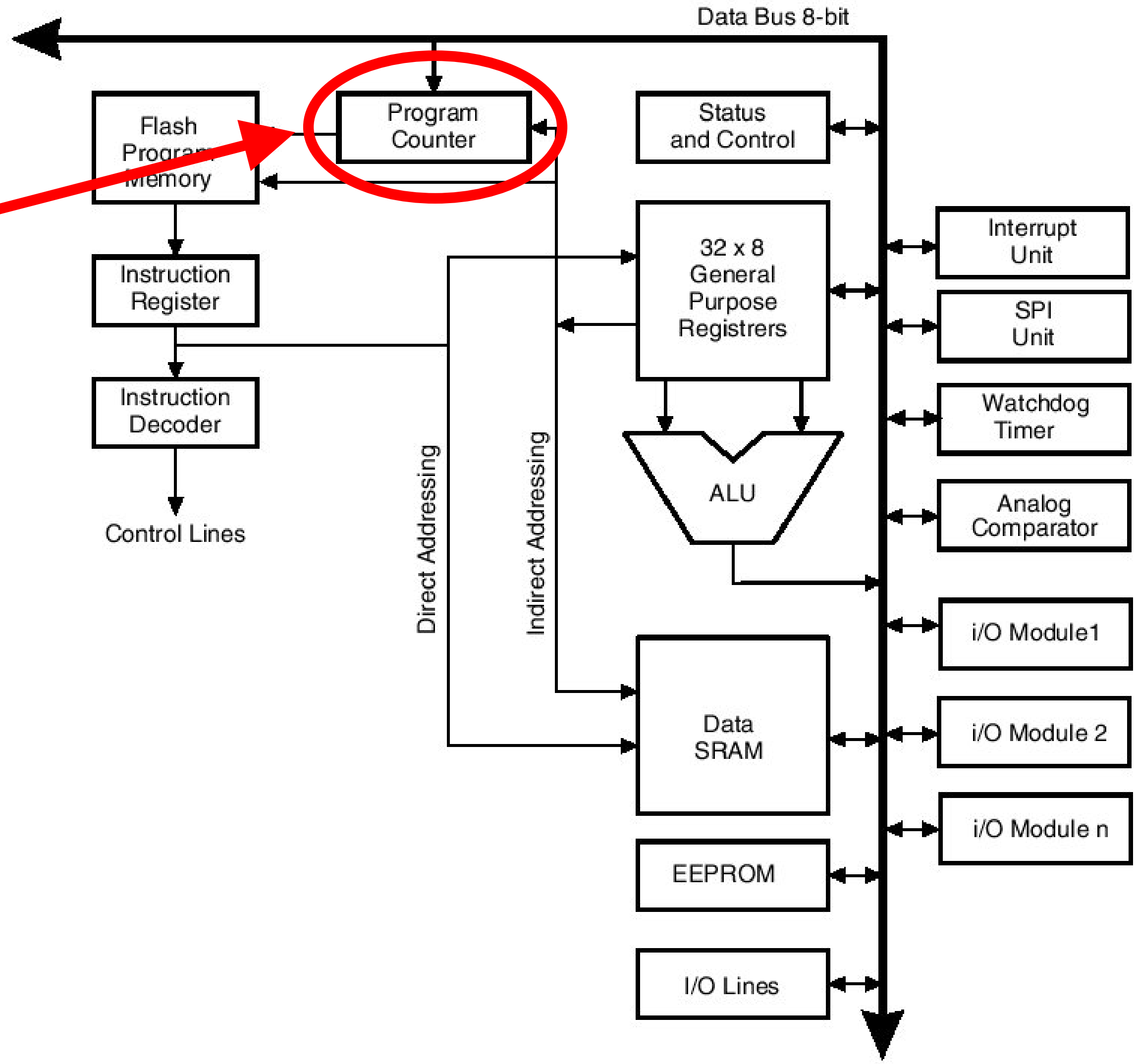
BRCS k

- 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

if not true

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;
}
```

The Assembly :

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

Load the contents of memory location D into register 3

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   <- PC
STS (D), R3
……..
```

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

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

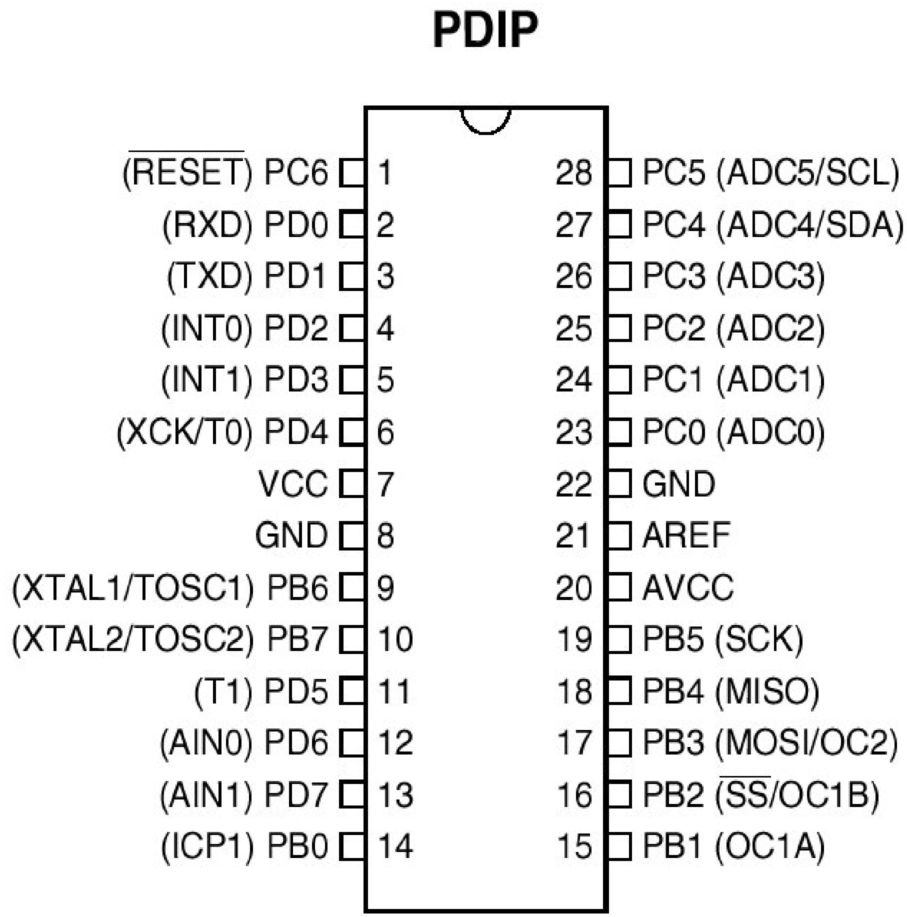
Instructions are the “atomic” actions that are taken by the processor

- 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

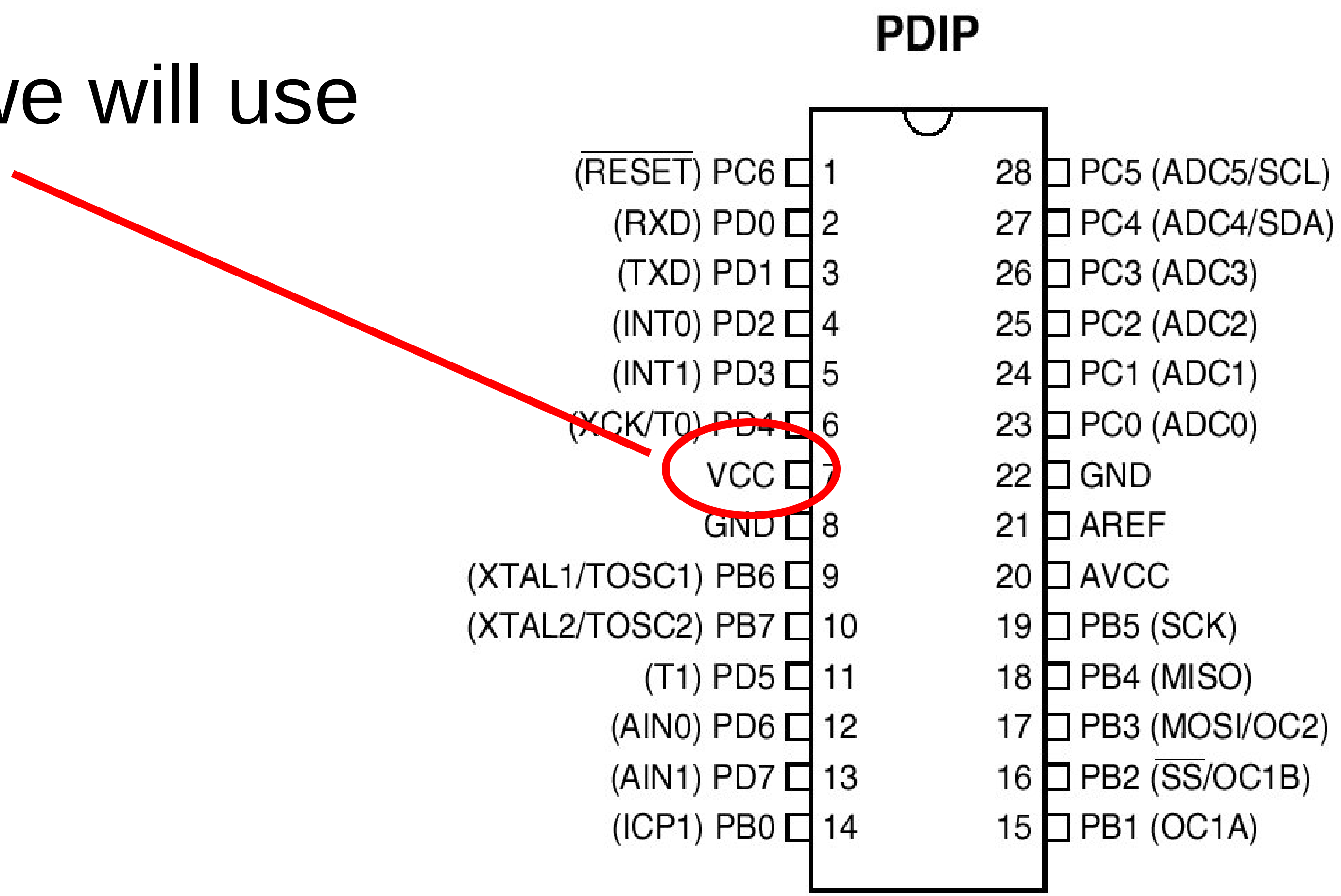
Atmel Mega8 Basics

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



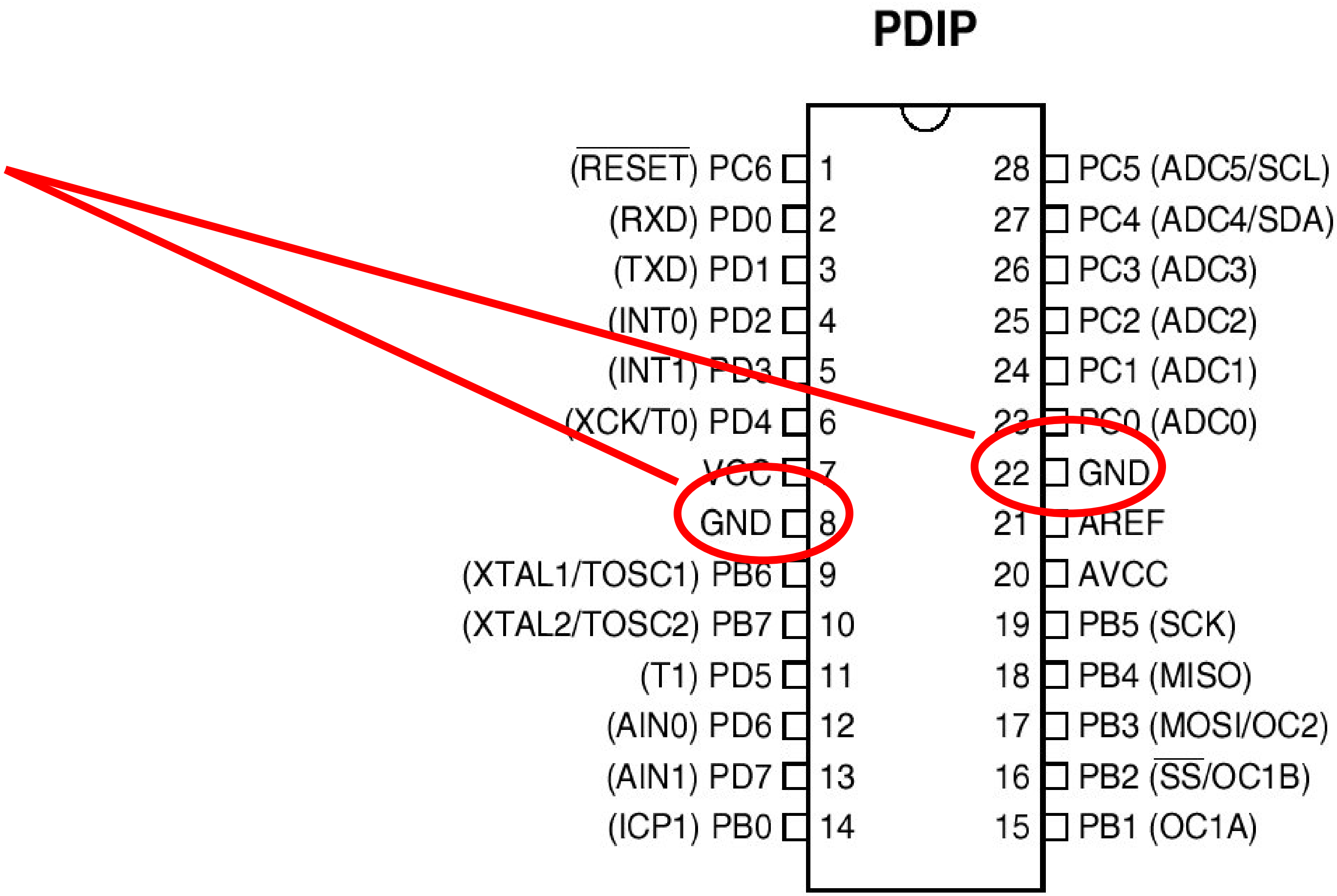
Atmel Mega8 Basics

Power (we will use +5V)



Atmel Mega8 Basics

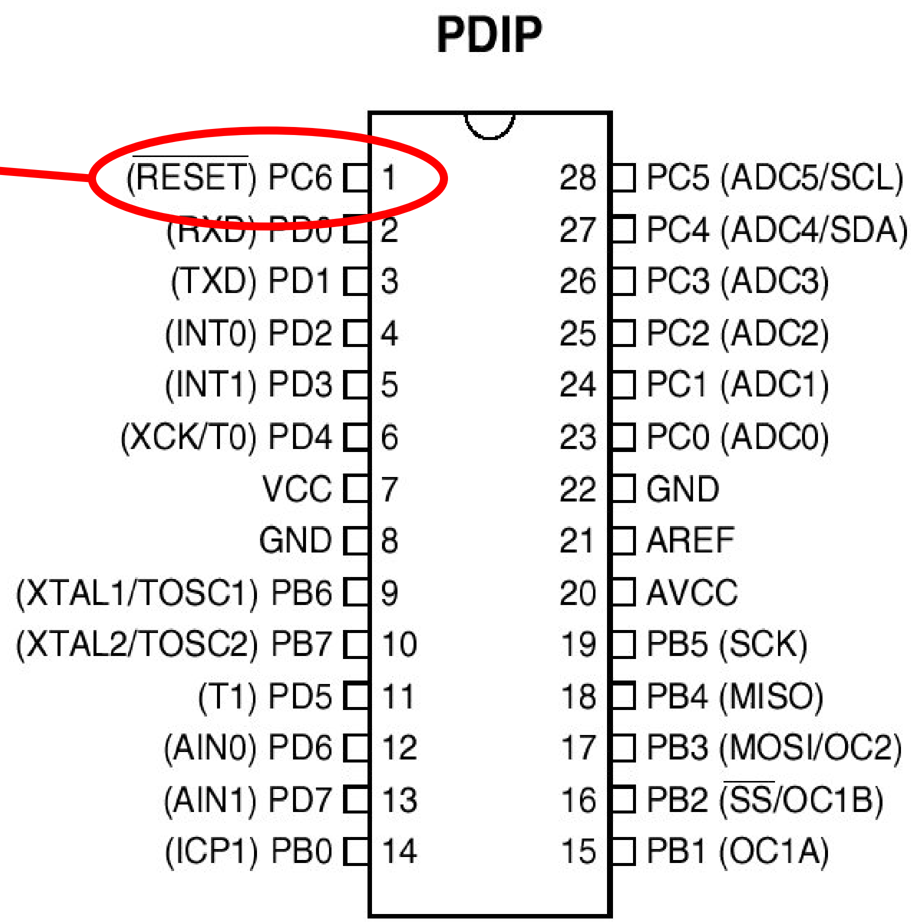
Ground



Atmel Mega8 Basics

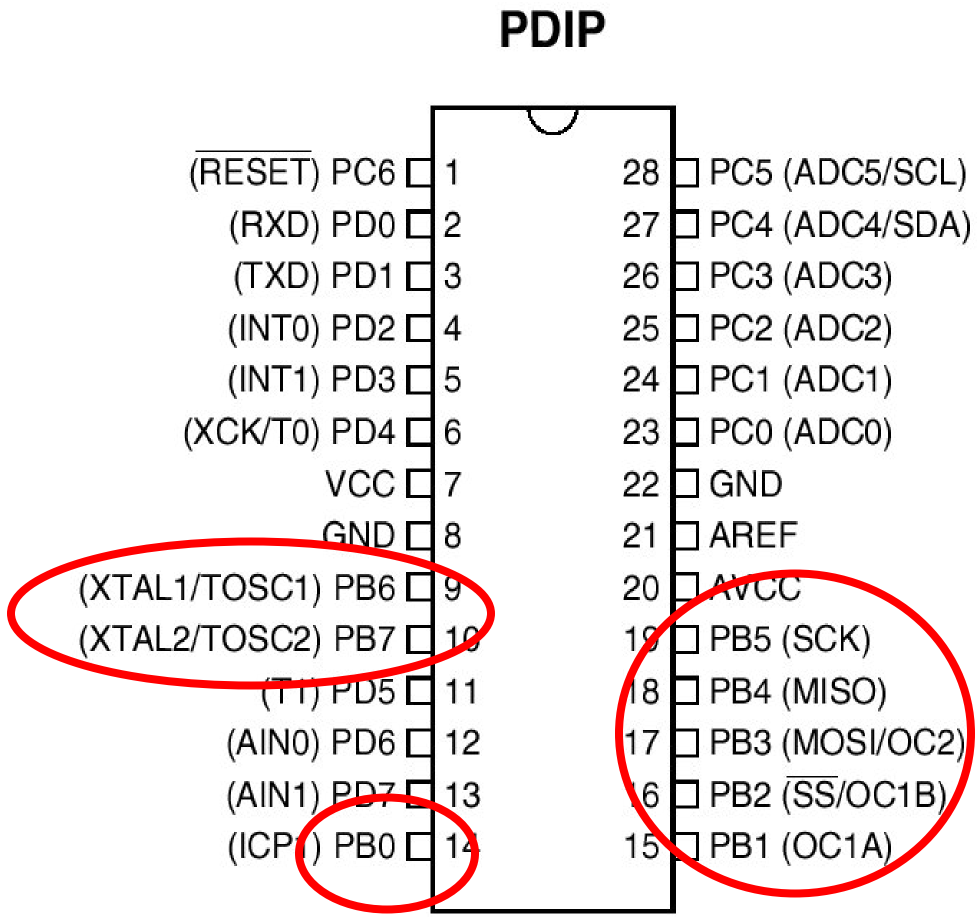
Reset

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



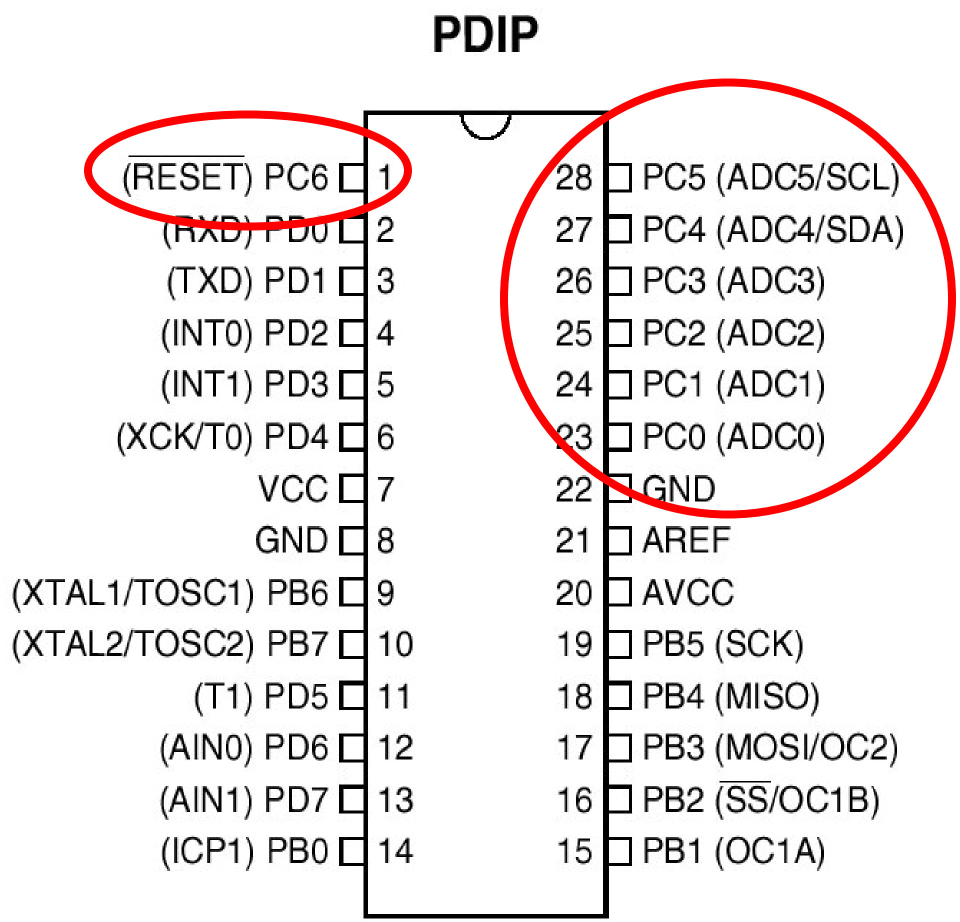
Atmel Mega8 Basics

PORT B



Atmel Mega8 Basics

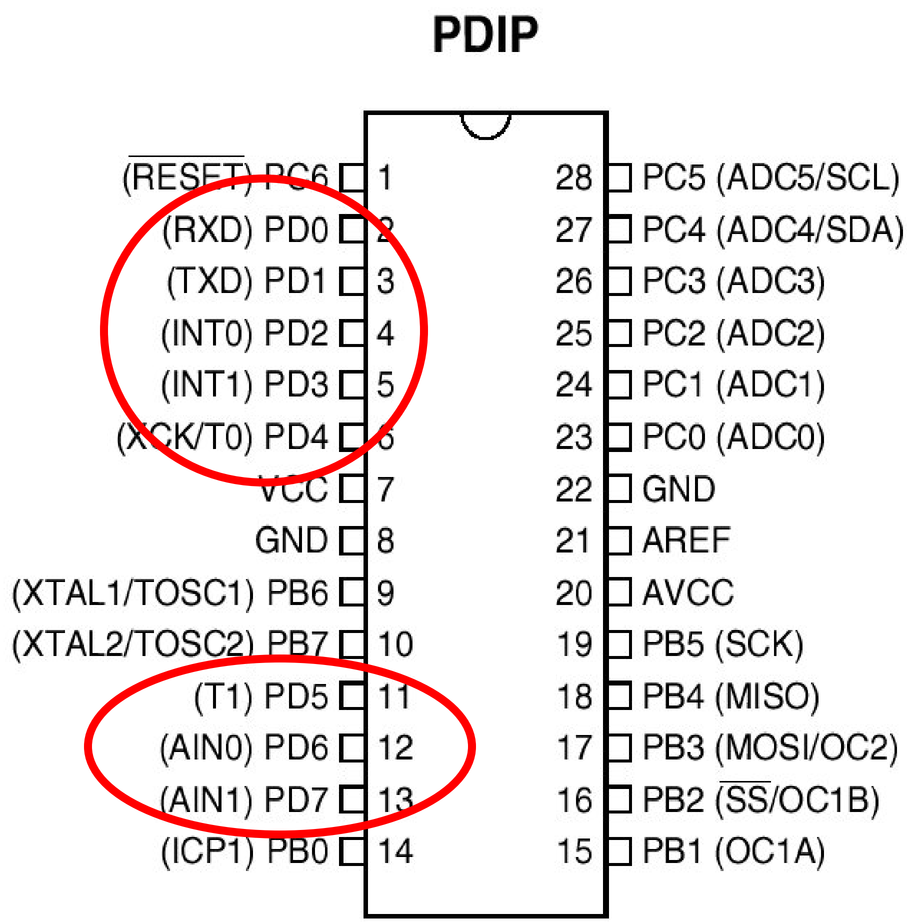
PORT C



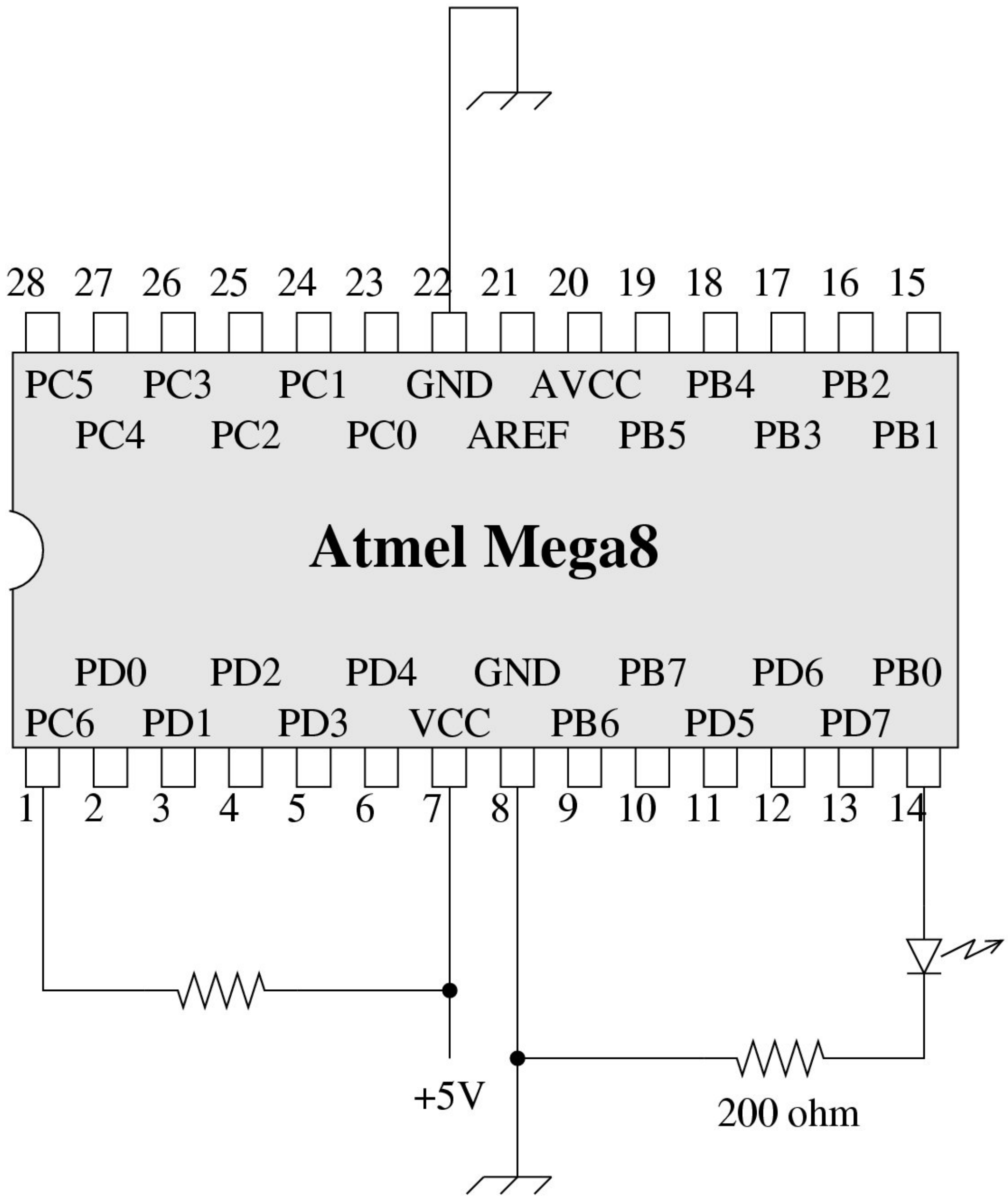
Atmel Mega8 Basics

PORT D

(all 8 bits are available)



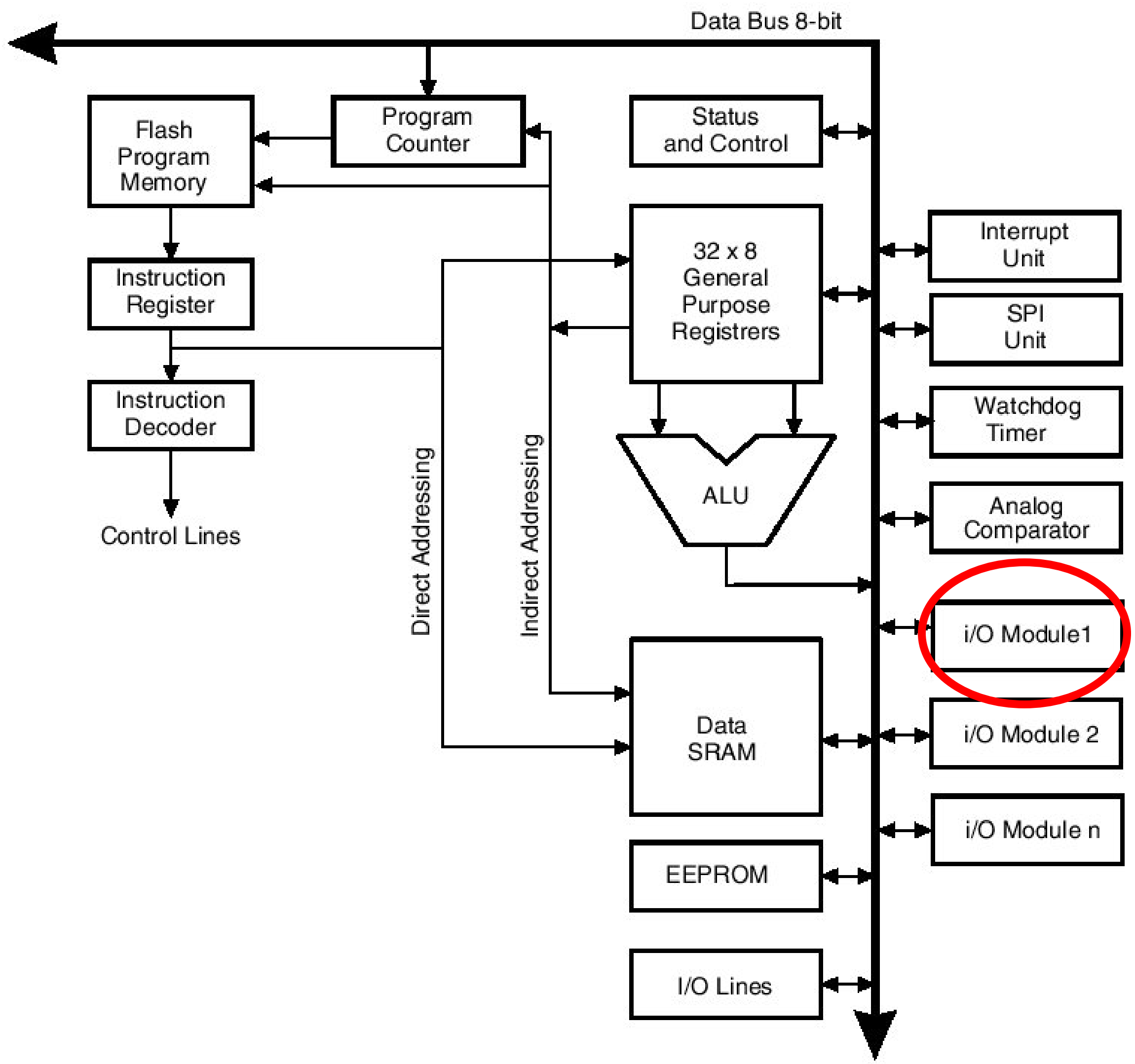
A First Circuit



Atmel Mega8

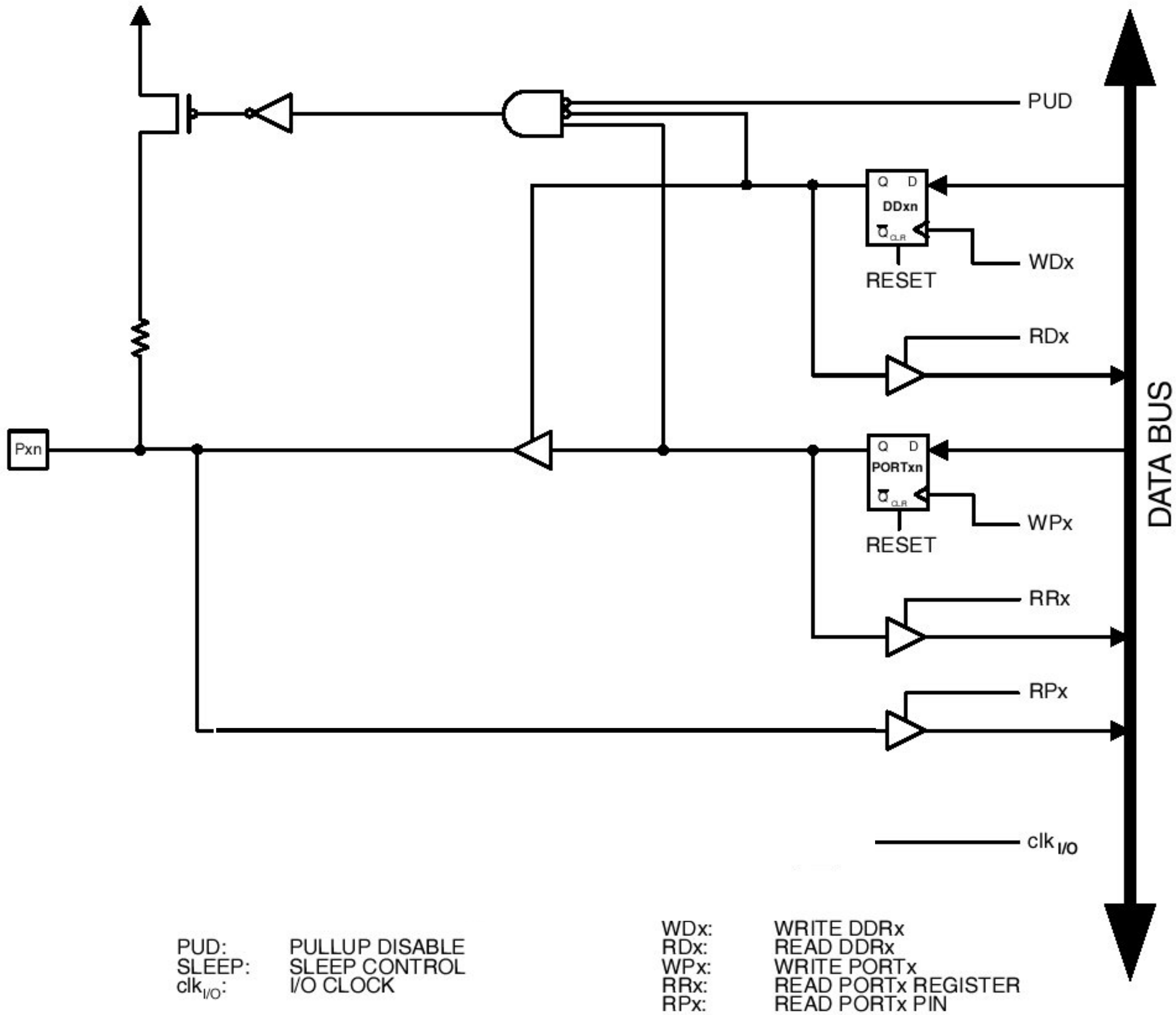
Control the pins through the I/O modules

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

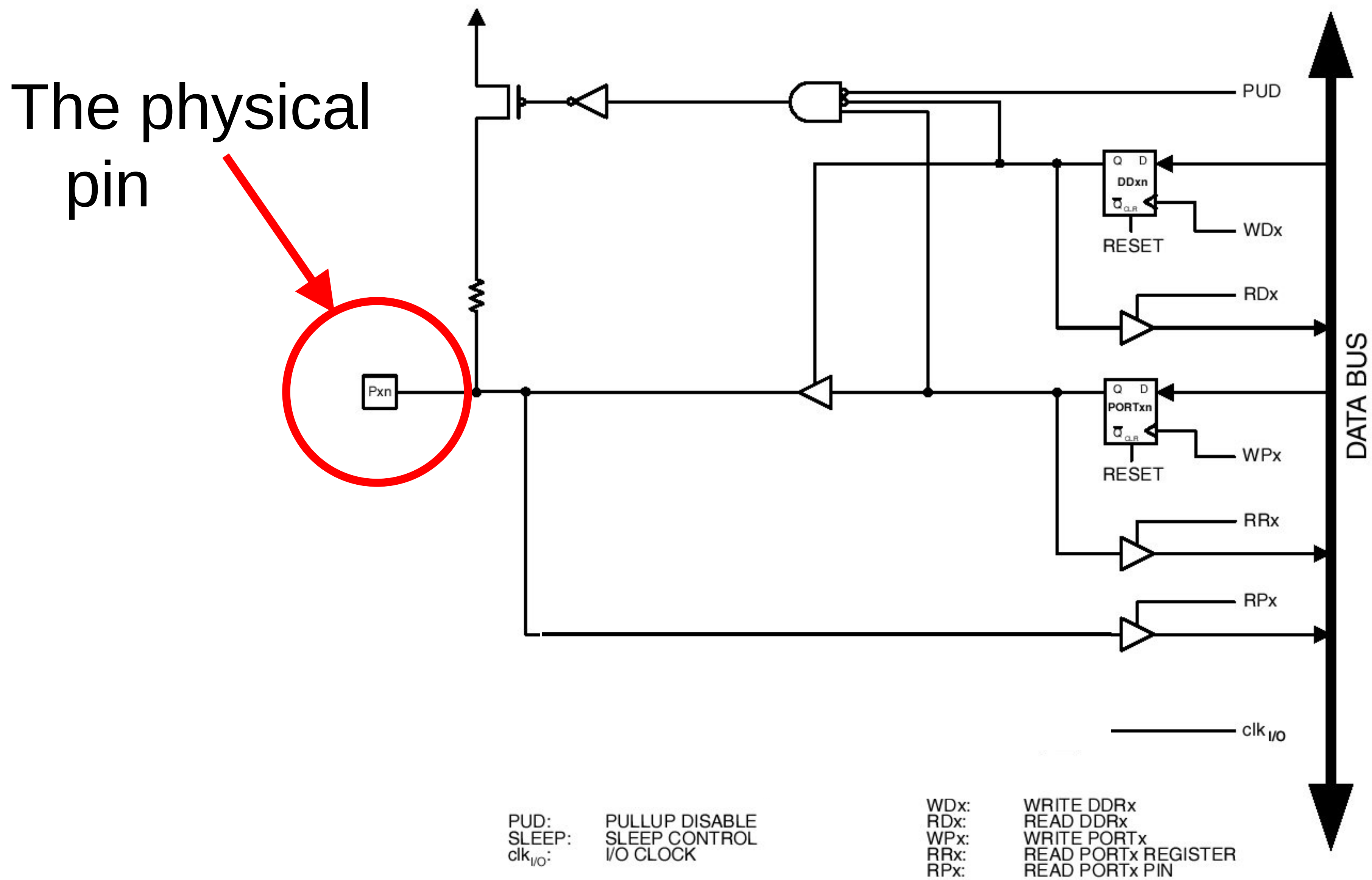


I/O Pin Implementation

Single bit of
PORT B



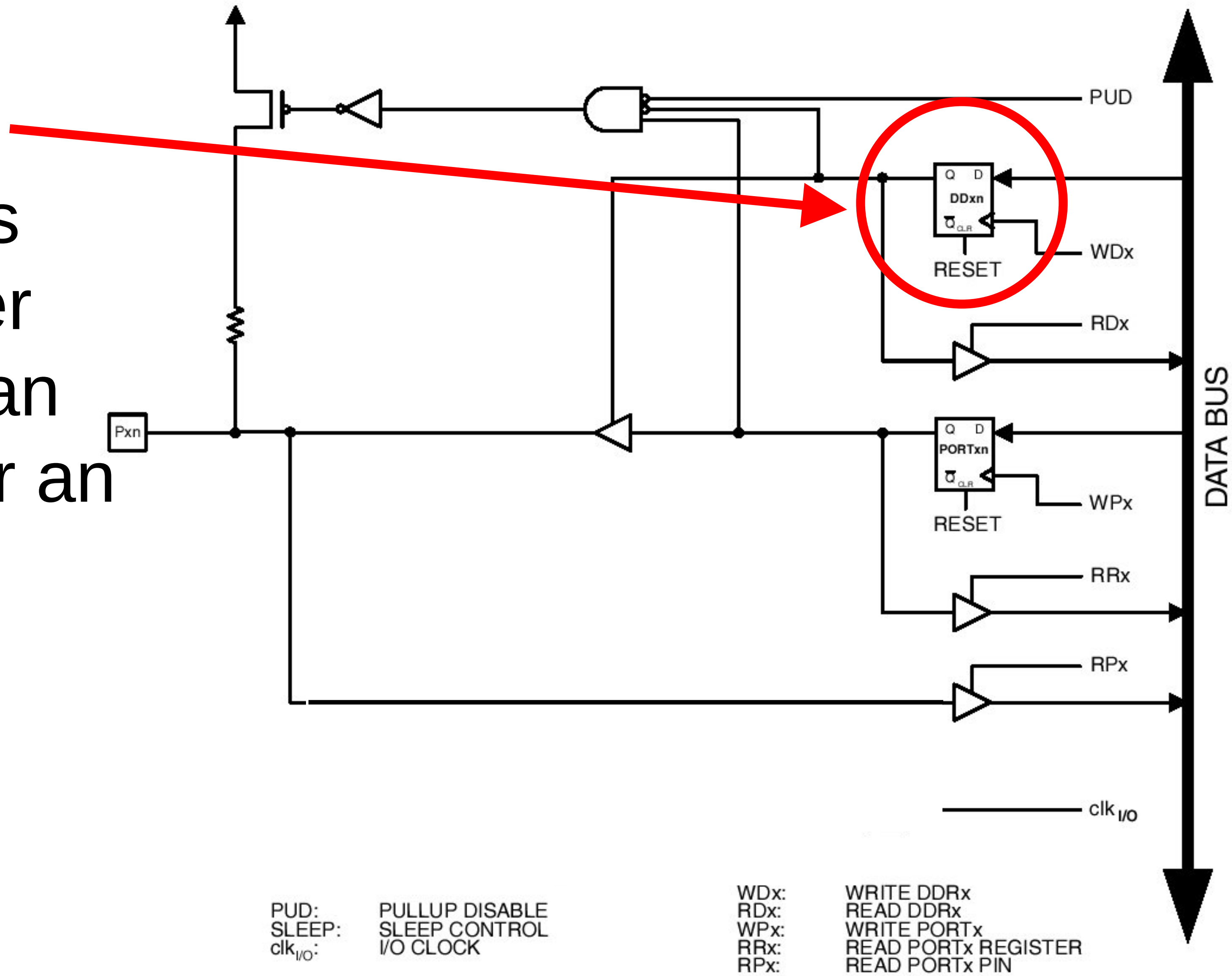
I/O Pin Implementation



I/O Pin Implementation

DDRB

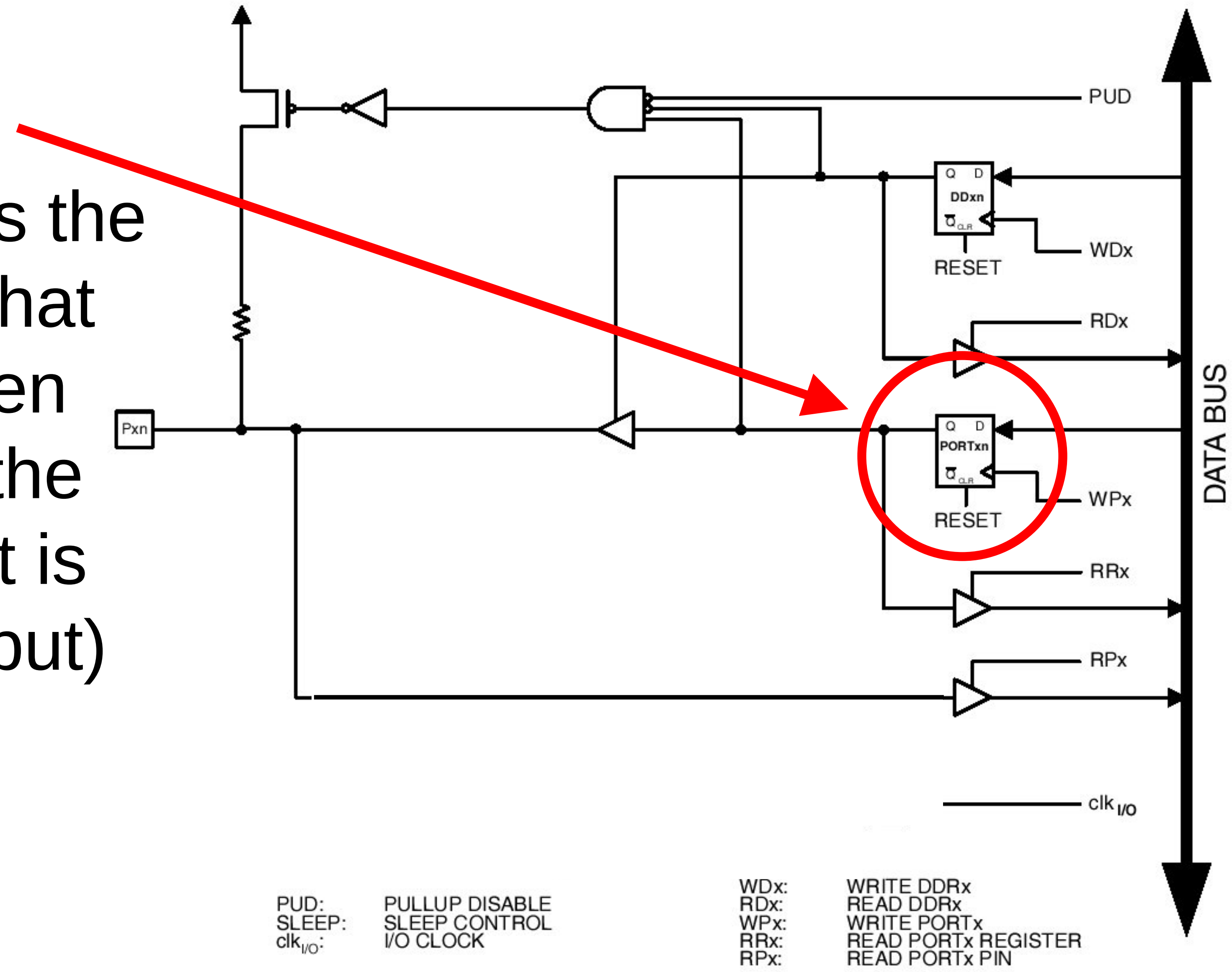
- Defines whether this is an input or an output



I/O Pin Implementation

PORTB

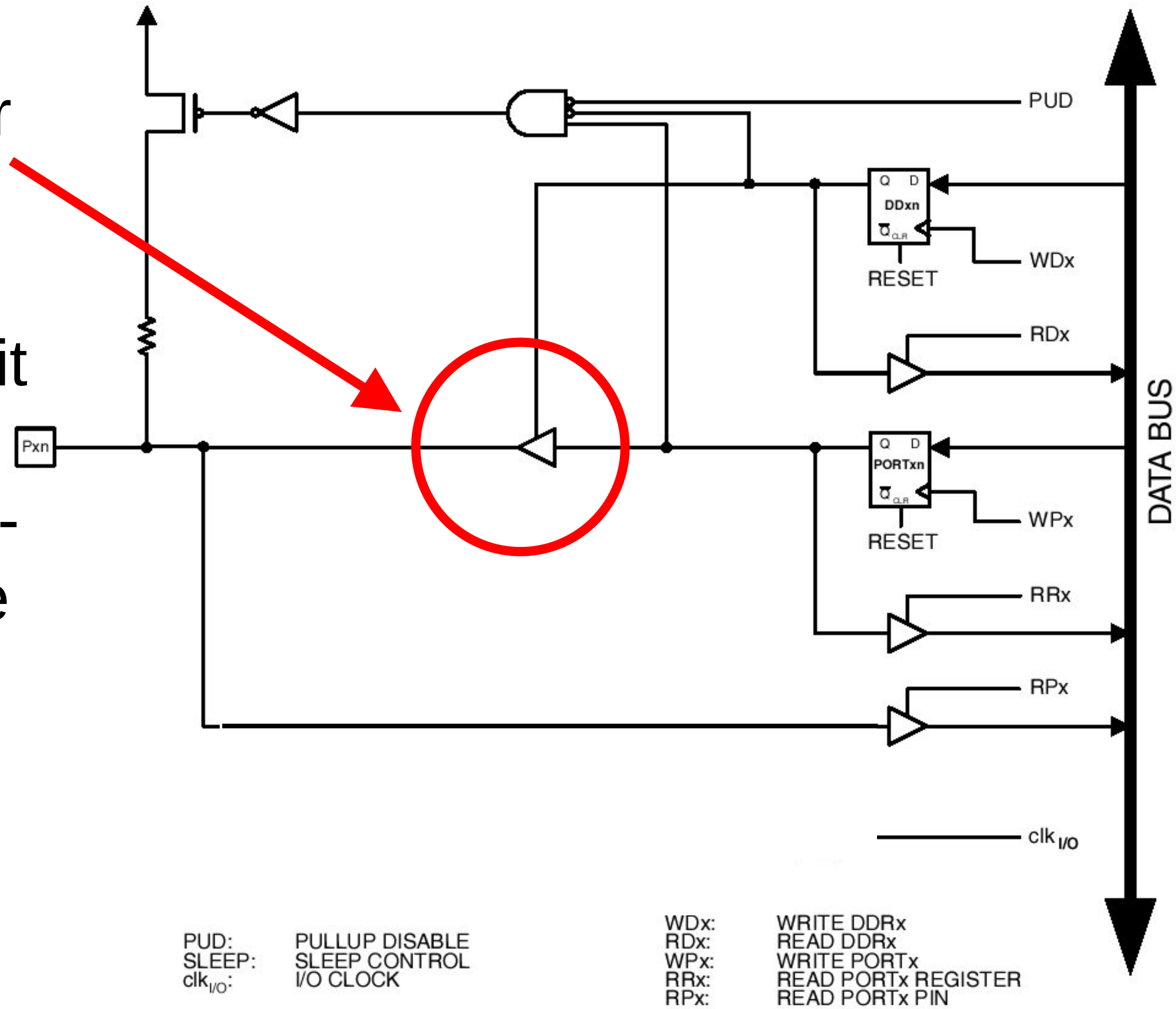
- Defines the value that is written out to the pin (if it is an output)



I/O Pin Implementation

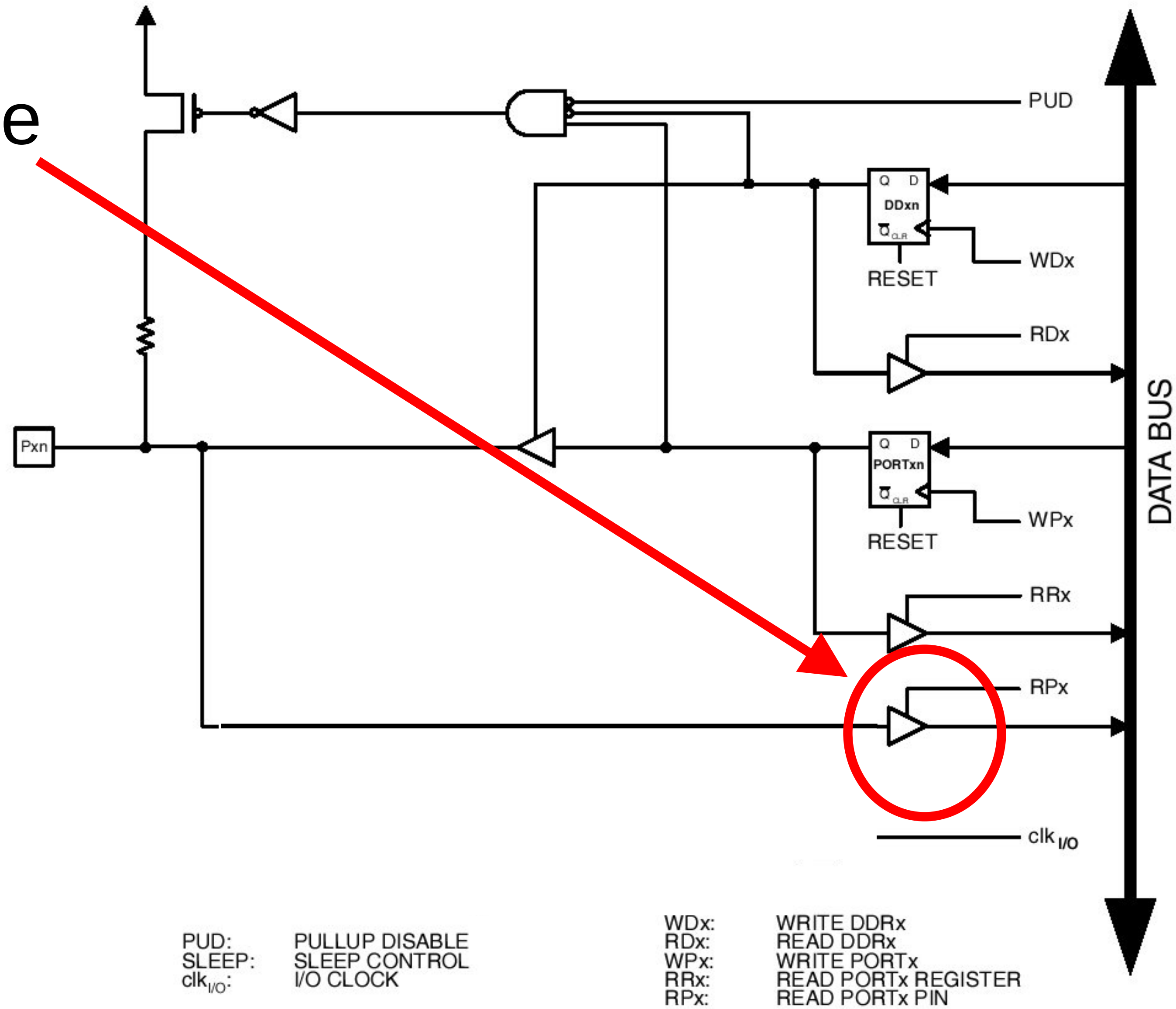
Tristate buffer

- 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



Last Time

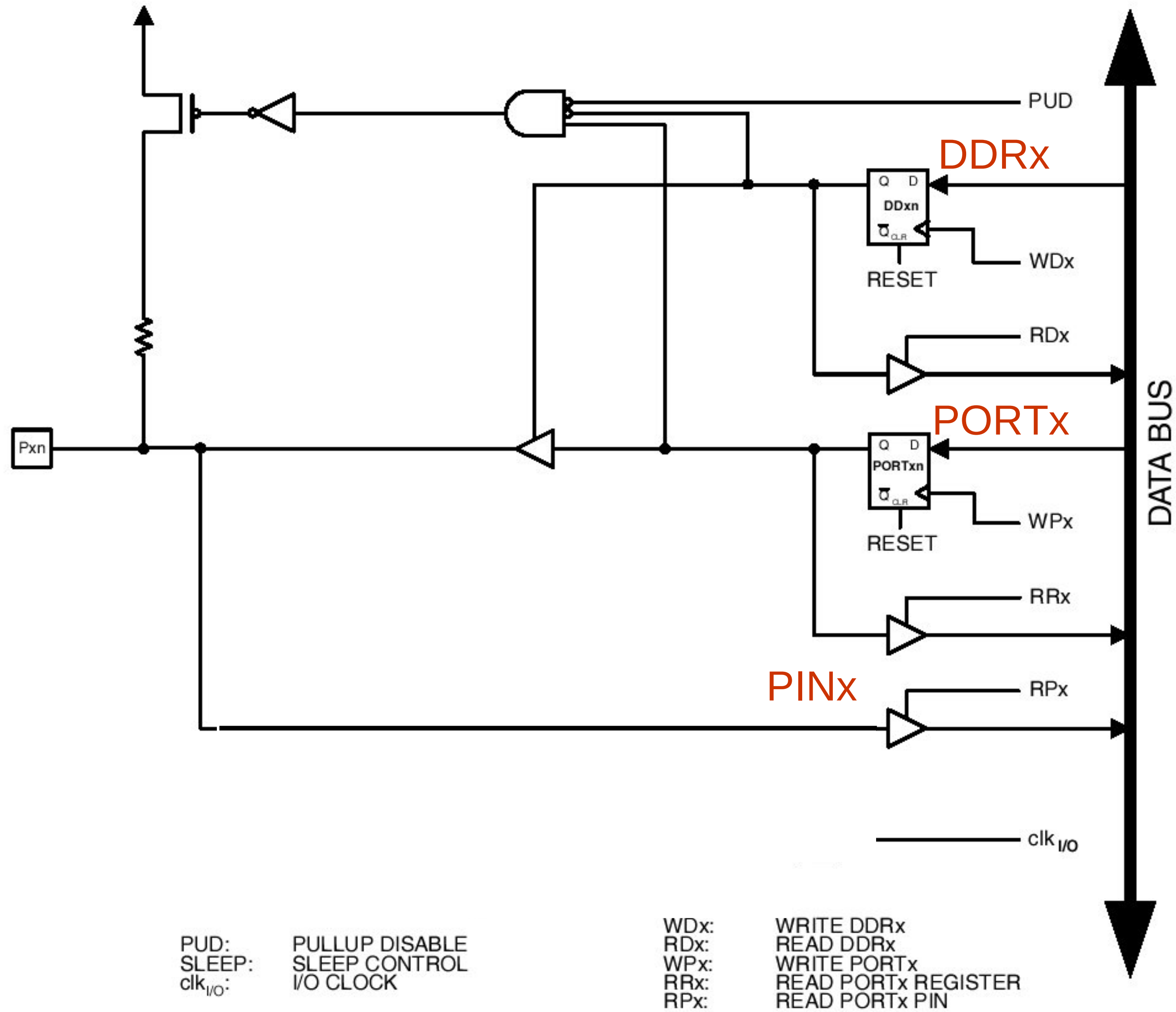
- Memory behavior
- Microprocessor components
- Manipulating the state of pins
  - Registers: DDRx, PORTx, and PINx

Today

- Homework 1 solution set has been posted
- Connecting C code to the I/O pins
- Bit Masking
- Getting into the hardware
  - Compiling and downloading code

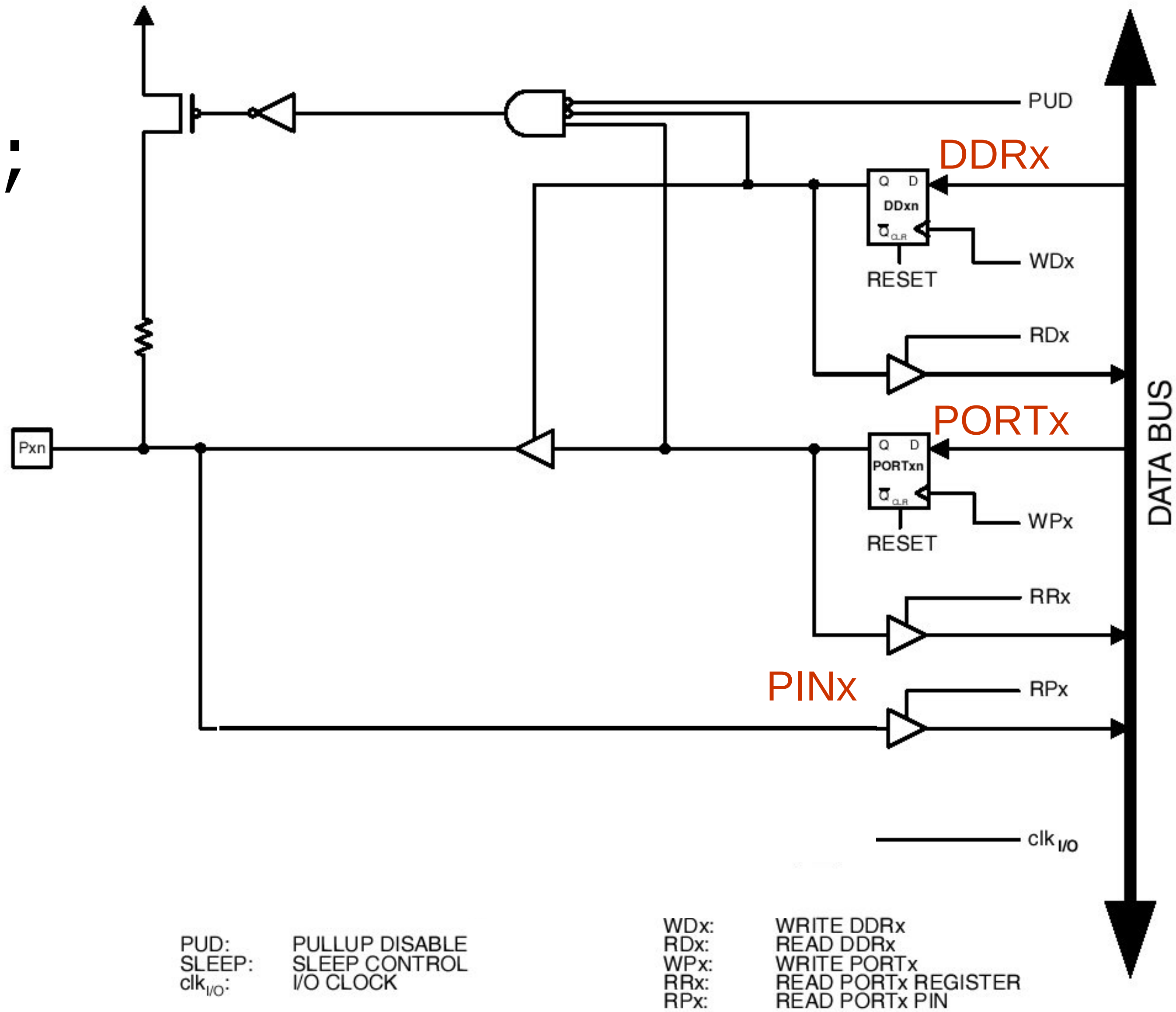
- On Thursday: come ready with winavr and AVRstudio installed on your laptops

I/O Pin Implementation



I/O Pin Implementation

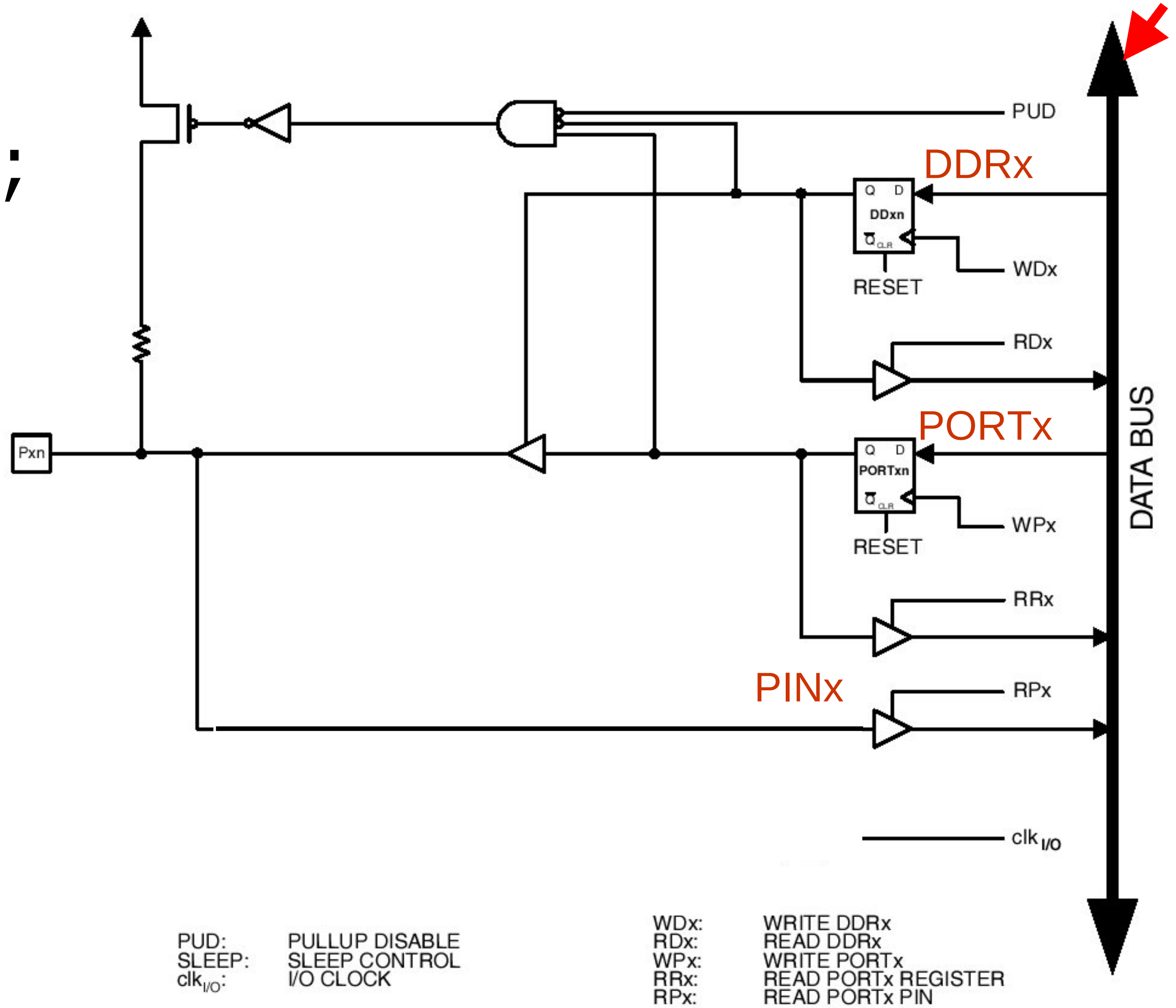
```
DDRB = 0;
```



I/O Pin Implementation

```
DDRB = 0;
```

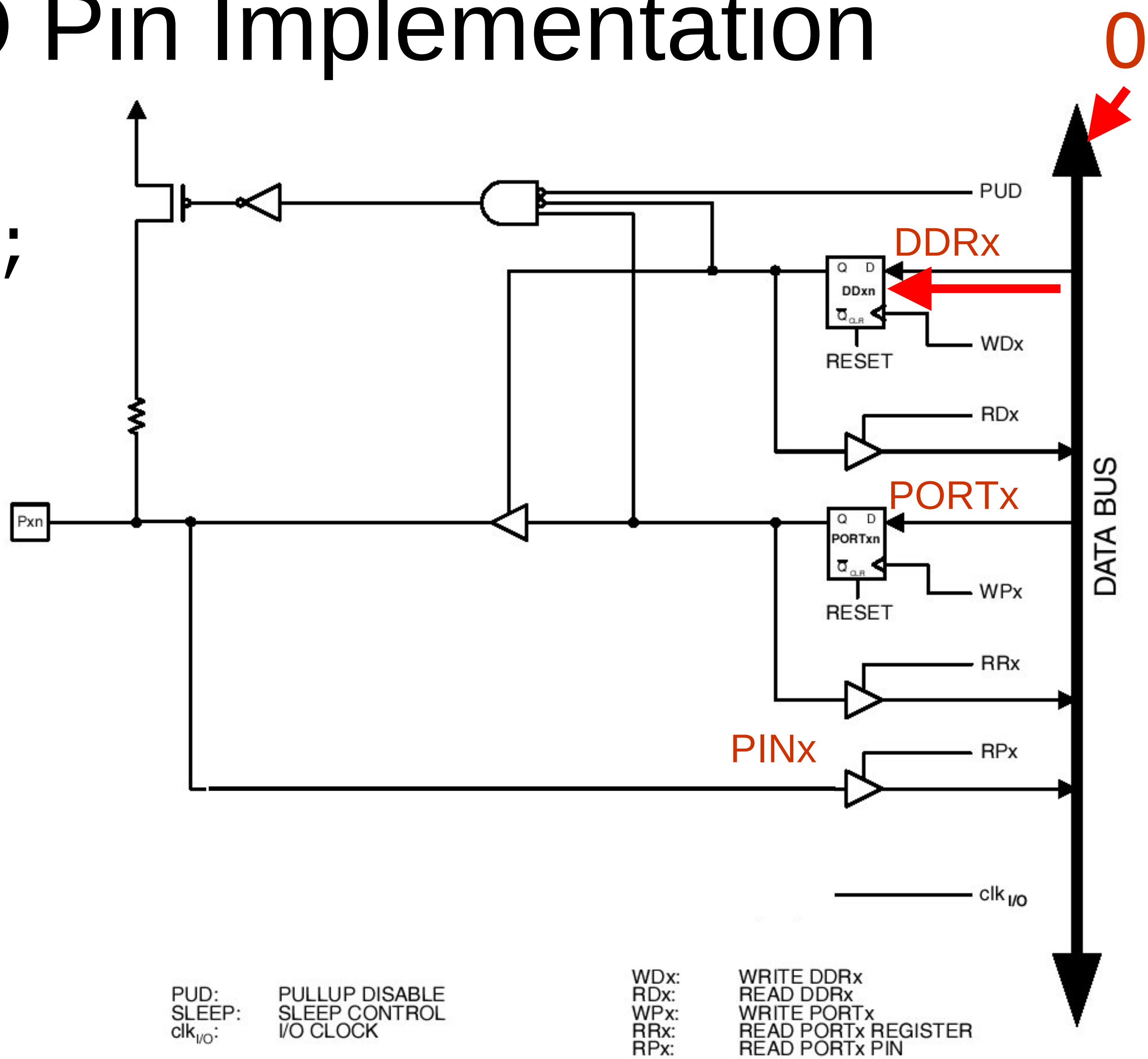
• “0” is written to the data bus



I/O Pin Implementation

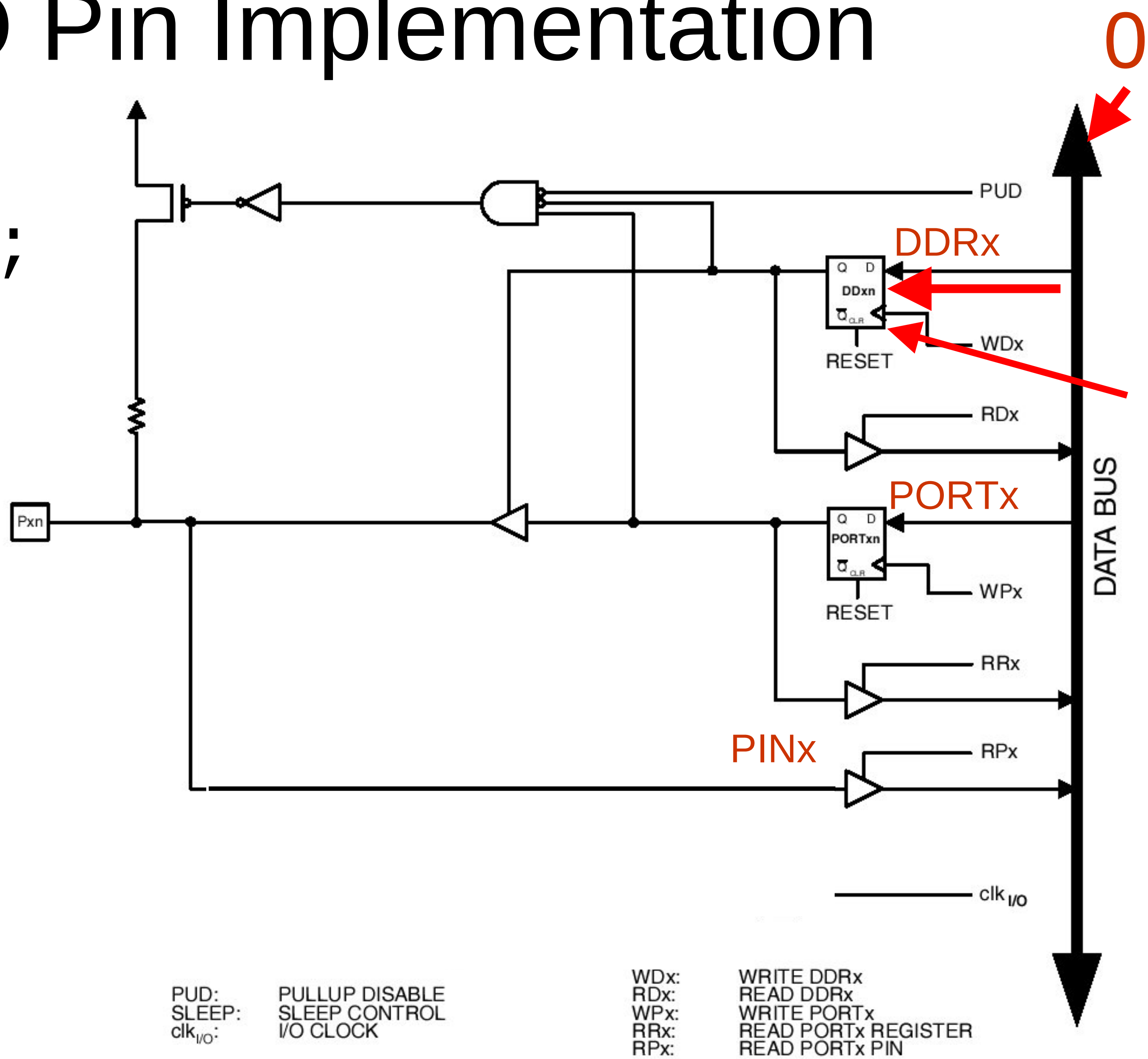
```
DDRB = 0;
```

• "0" is written to the data bus
• This is input to the DDRB register



I/O Pin Implementation

```
DDRB = 0;
```

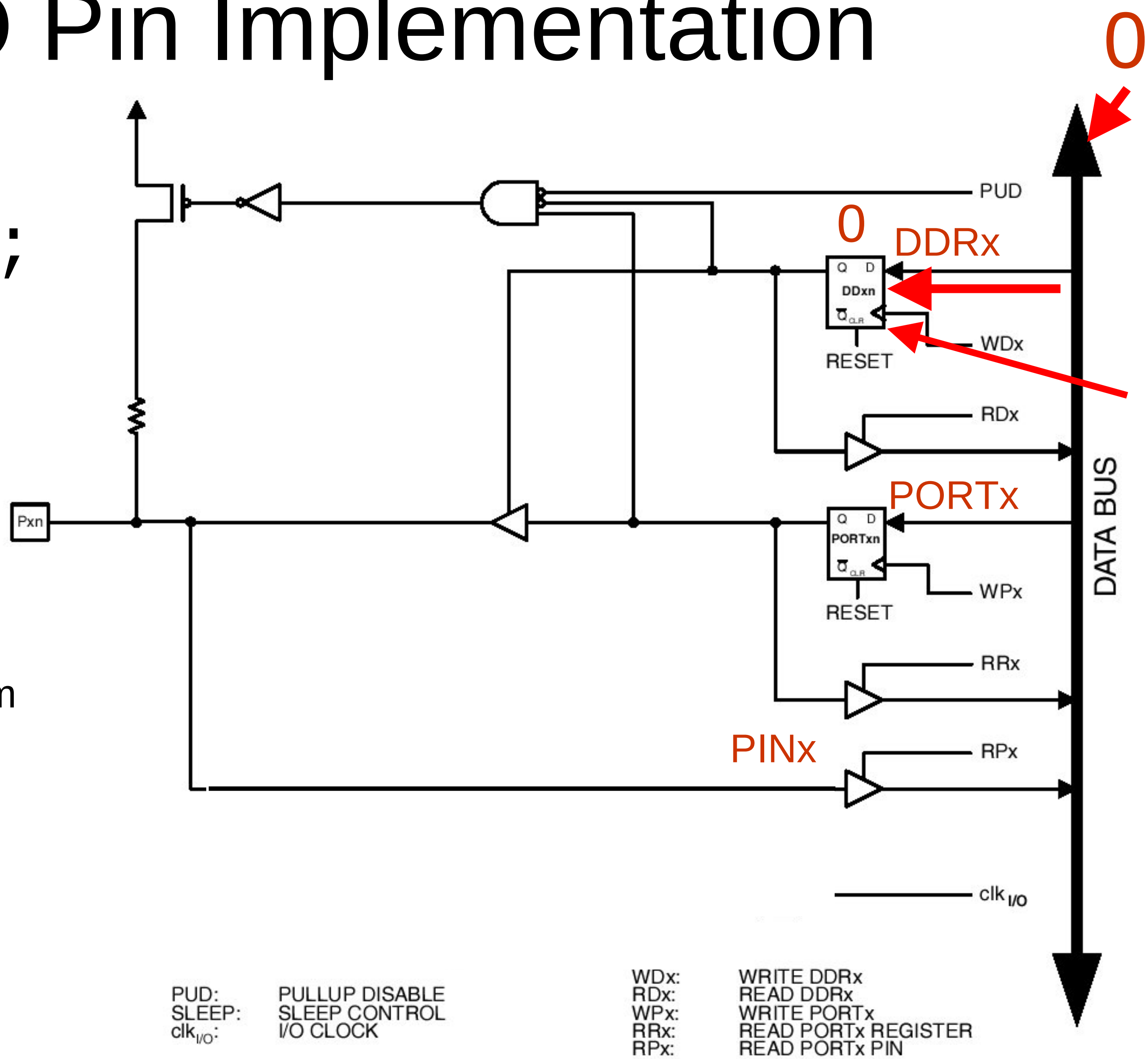


- “0” is written to the data bus
- This is input to the DDRB register
- WDB is clocked from high to low

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

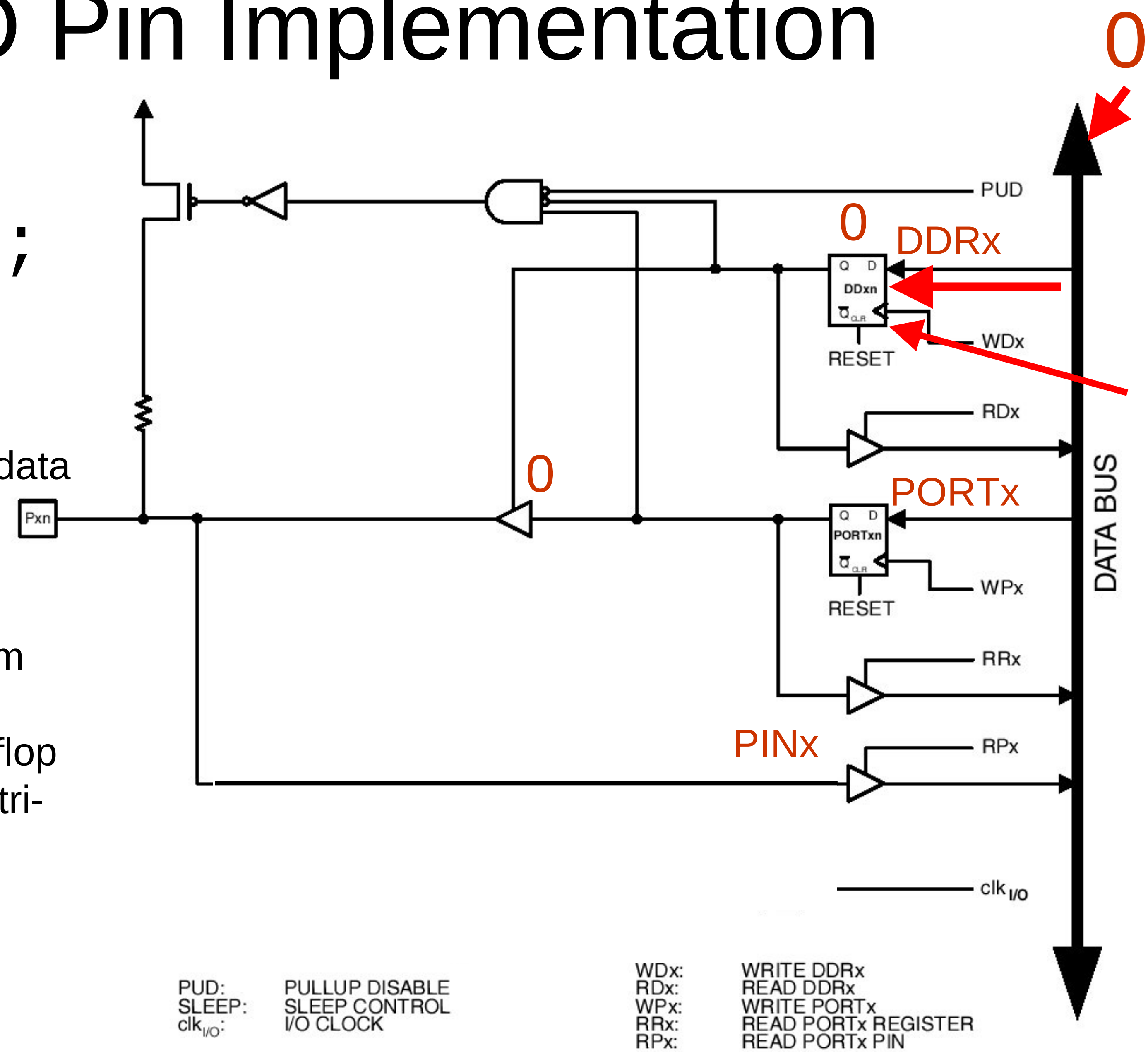


I/O Pin Implementation

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

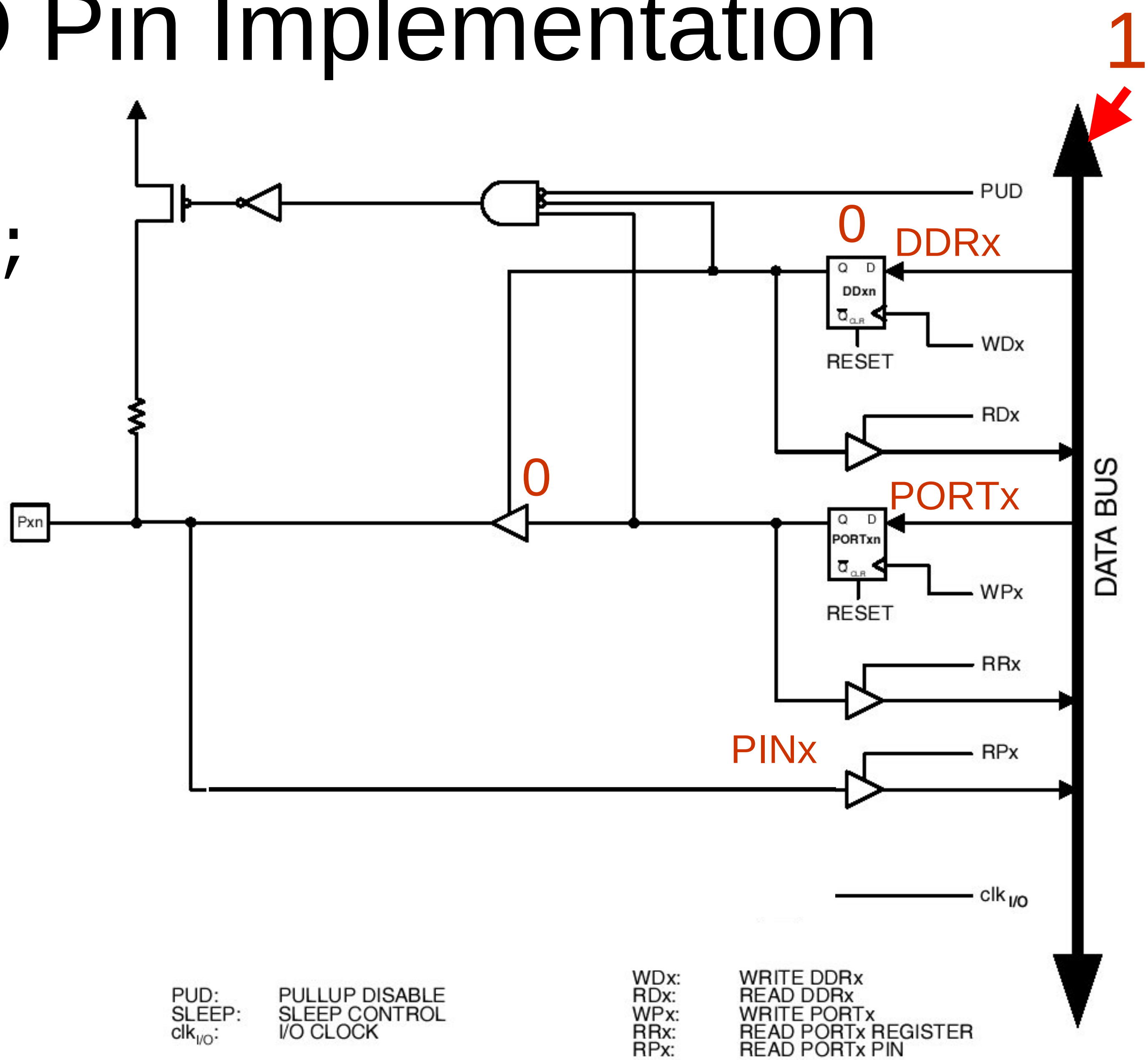
-> this is an input pin



I/O Pin Implementation

```
DDRB = 1;
```

- "1" is written to the data bus

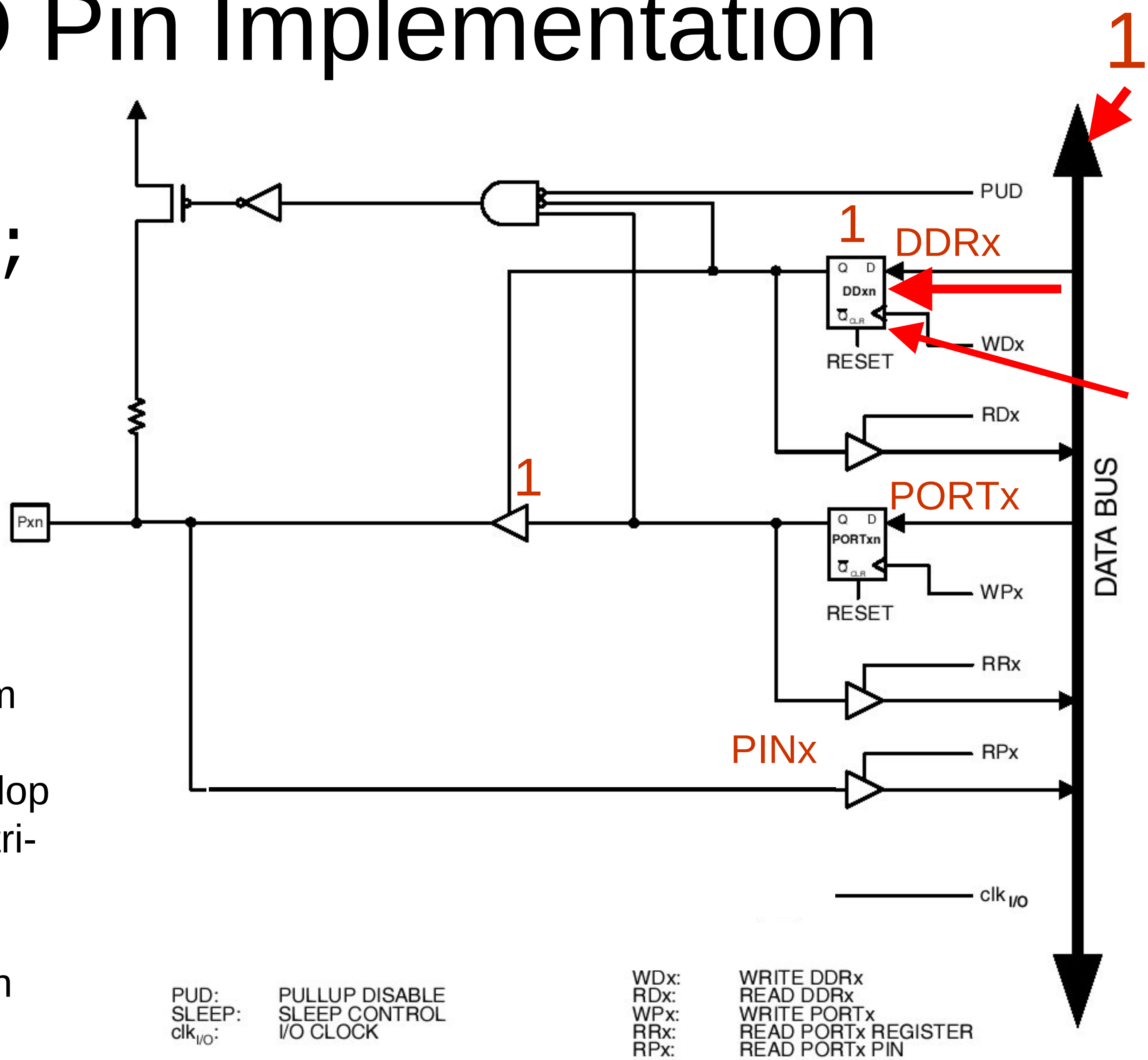


I/O Pin Implementation

```
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

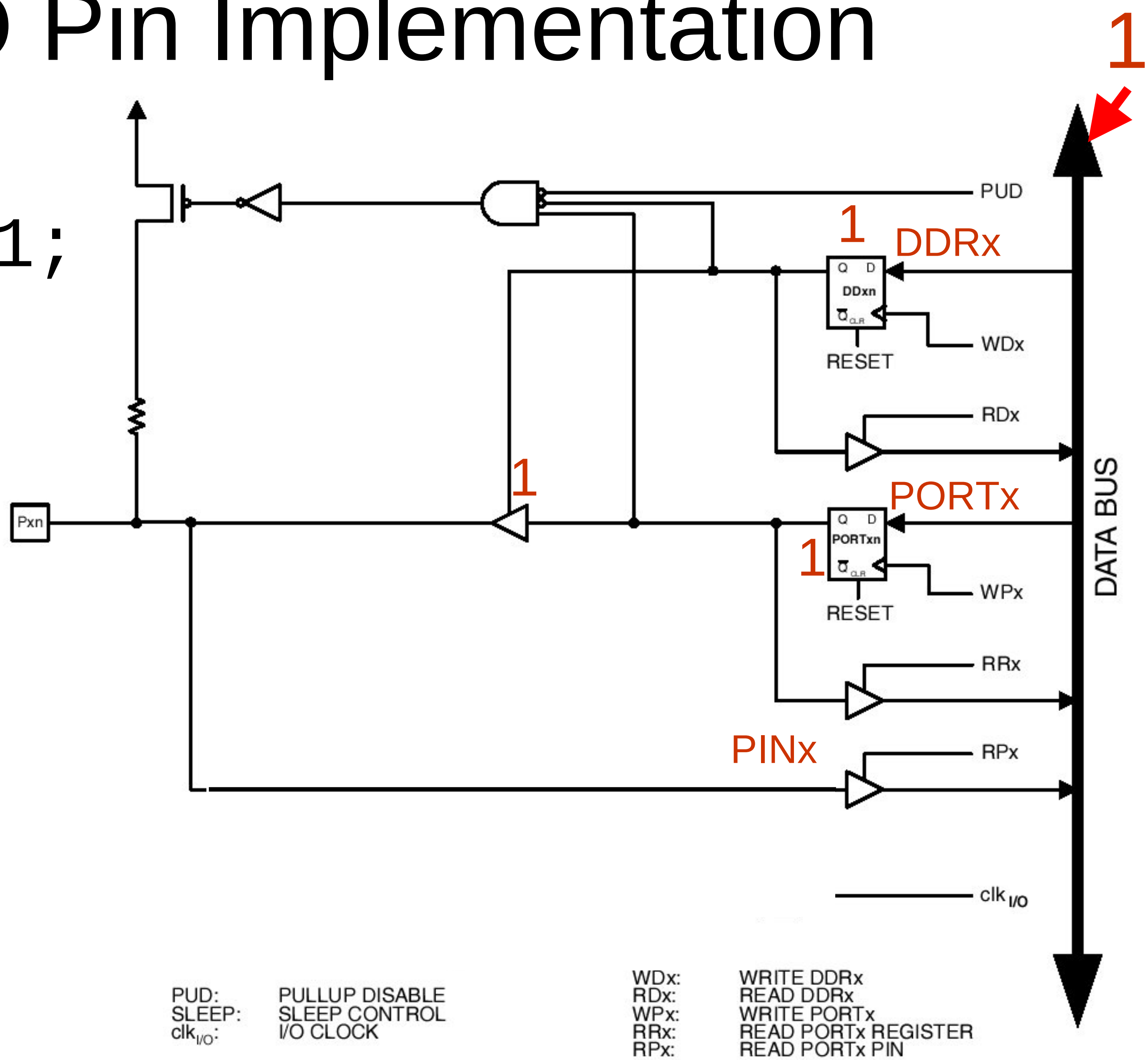
-> this is an output pin



I/O Pin Implementation

```
PORTB = 1;
```

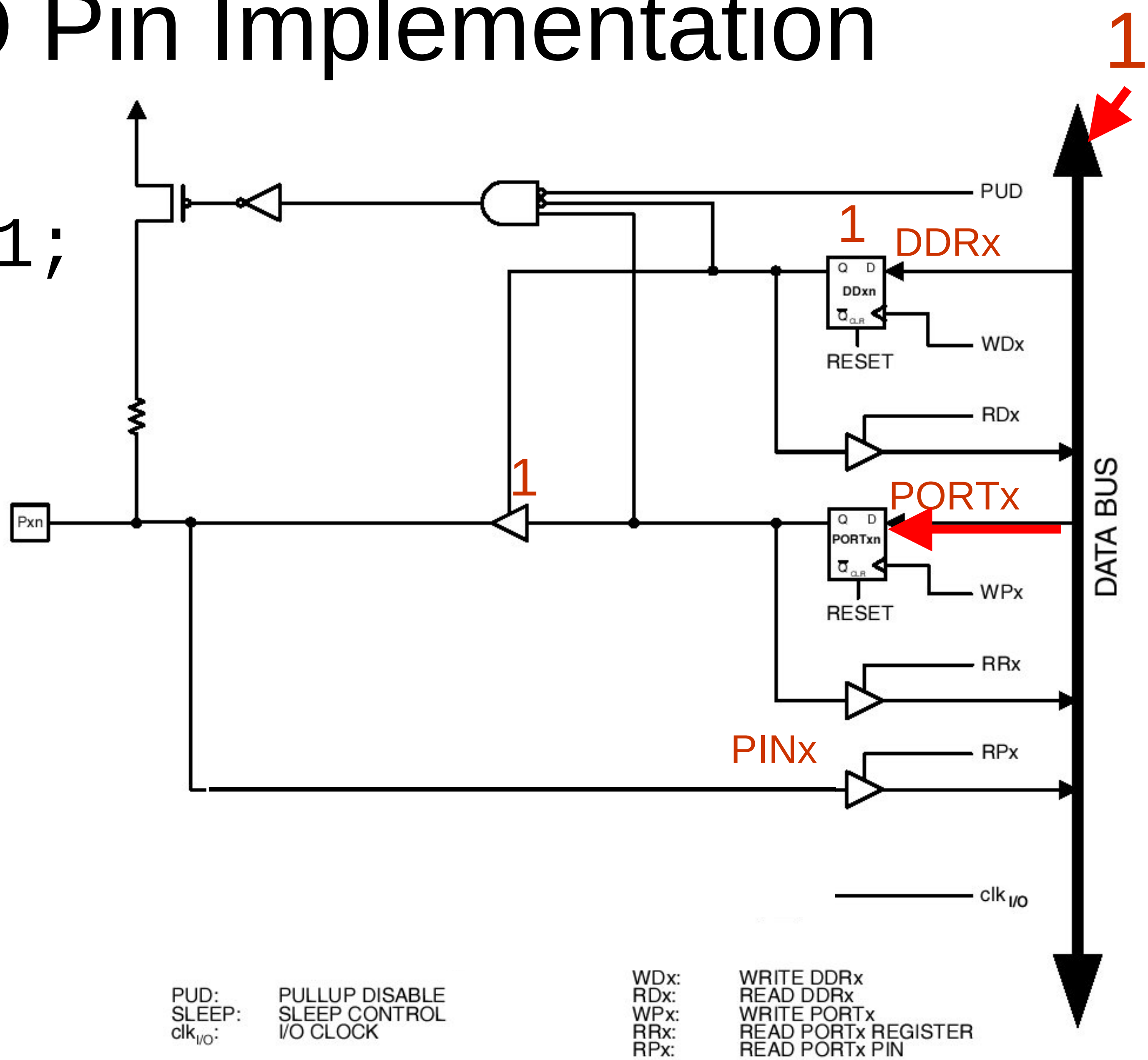
•



I/O Pin Implementation

PORTB = 1;

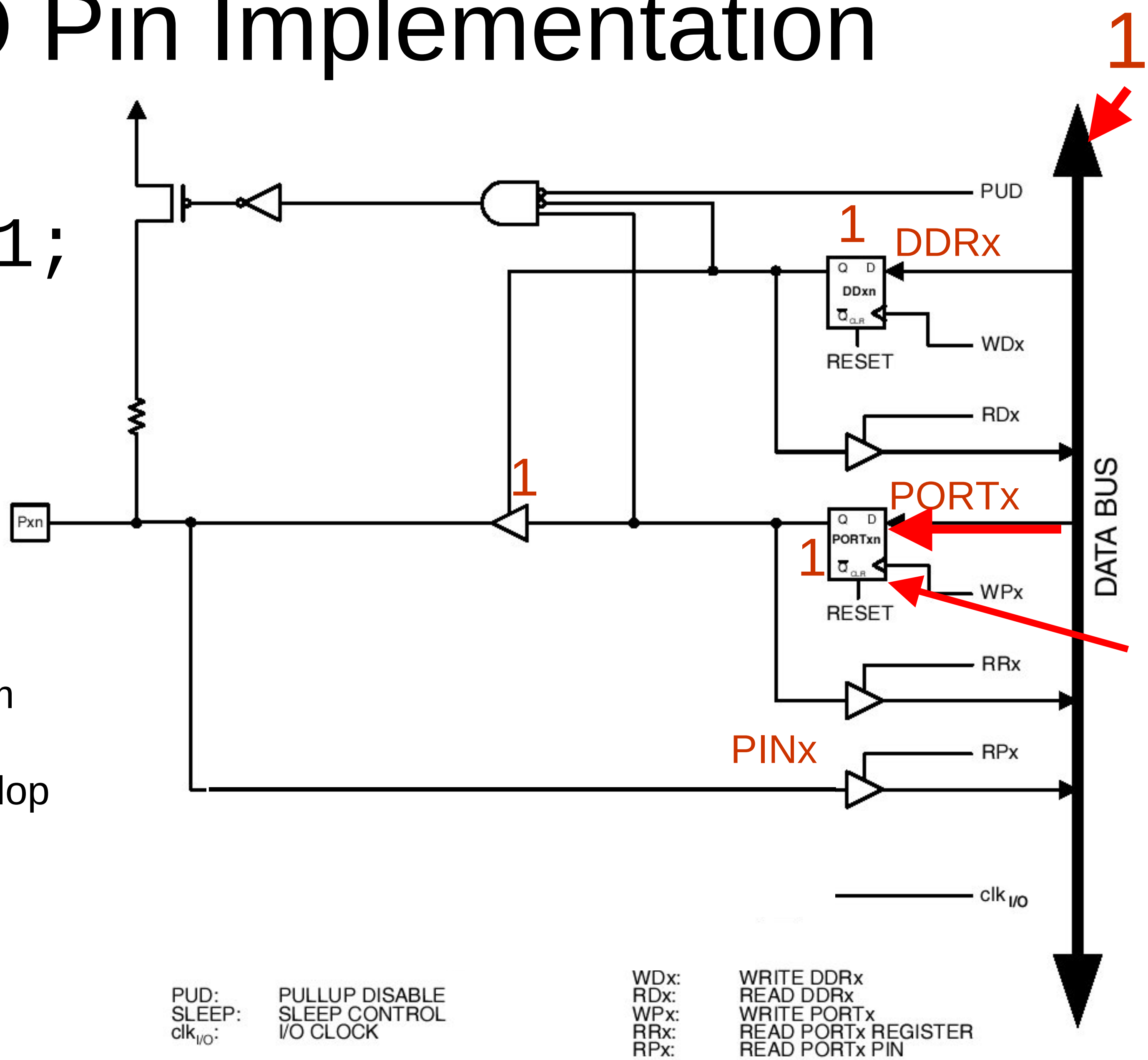
- “1” is written to the data bus
- This is input to the PORTB register



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

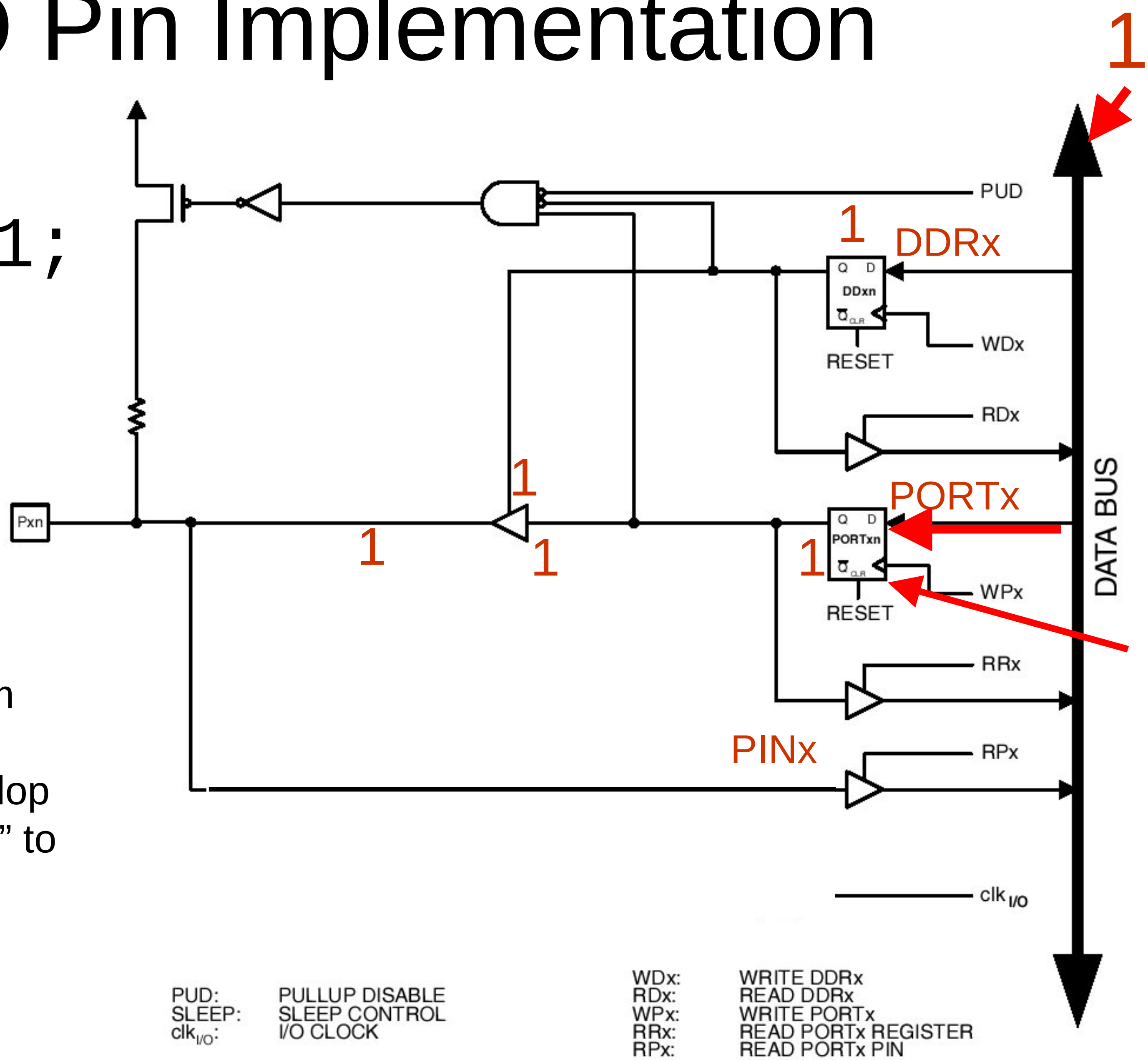


I/O Pin Implementation

```
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

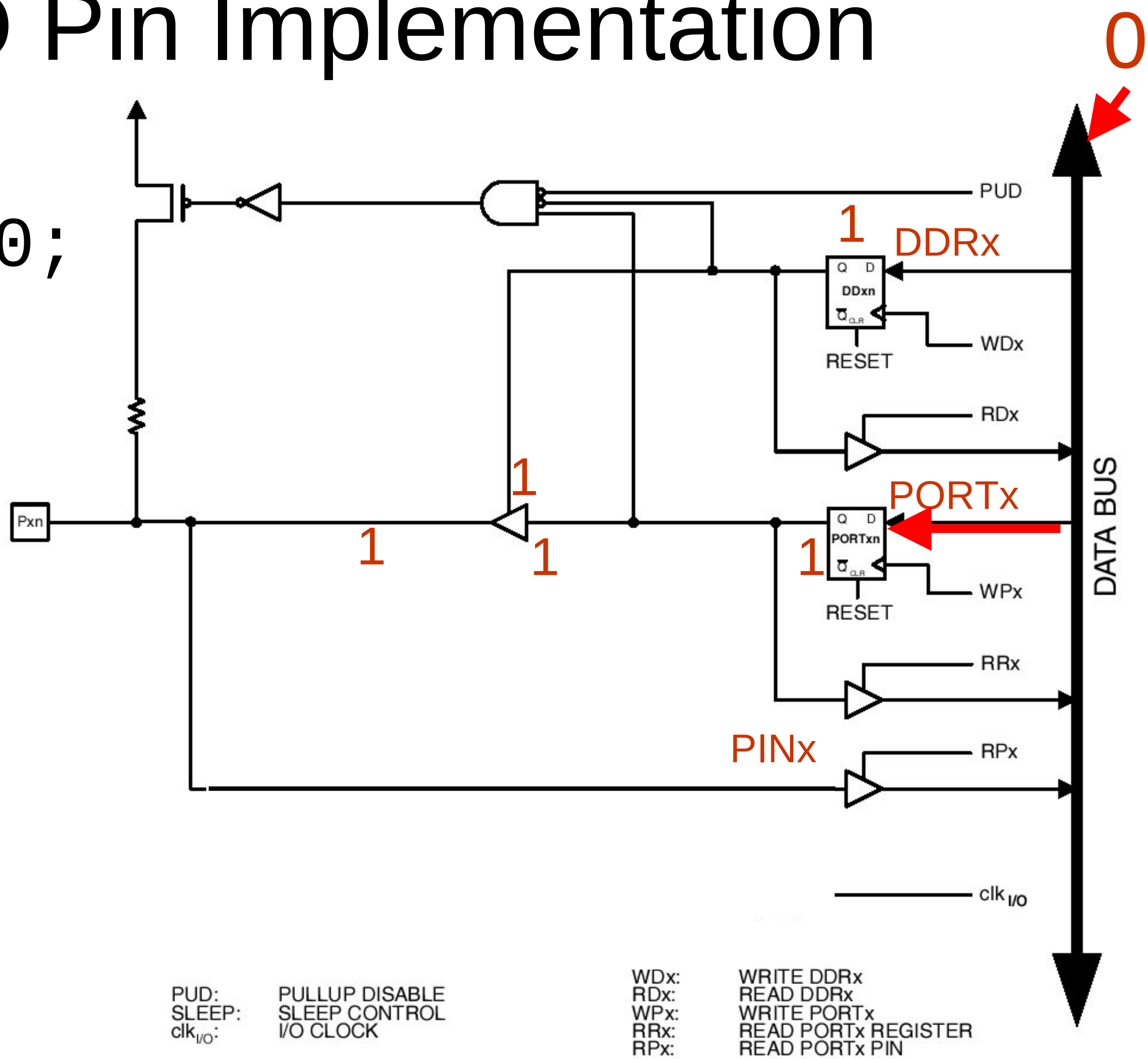
-> output a “1”



I/O Pin Implementation

```
PORTB = 0;
```

- "0" is written to the data bus

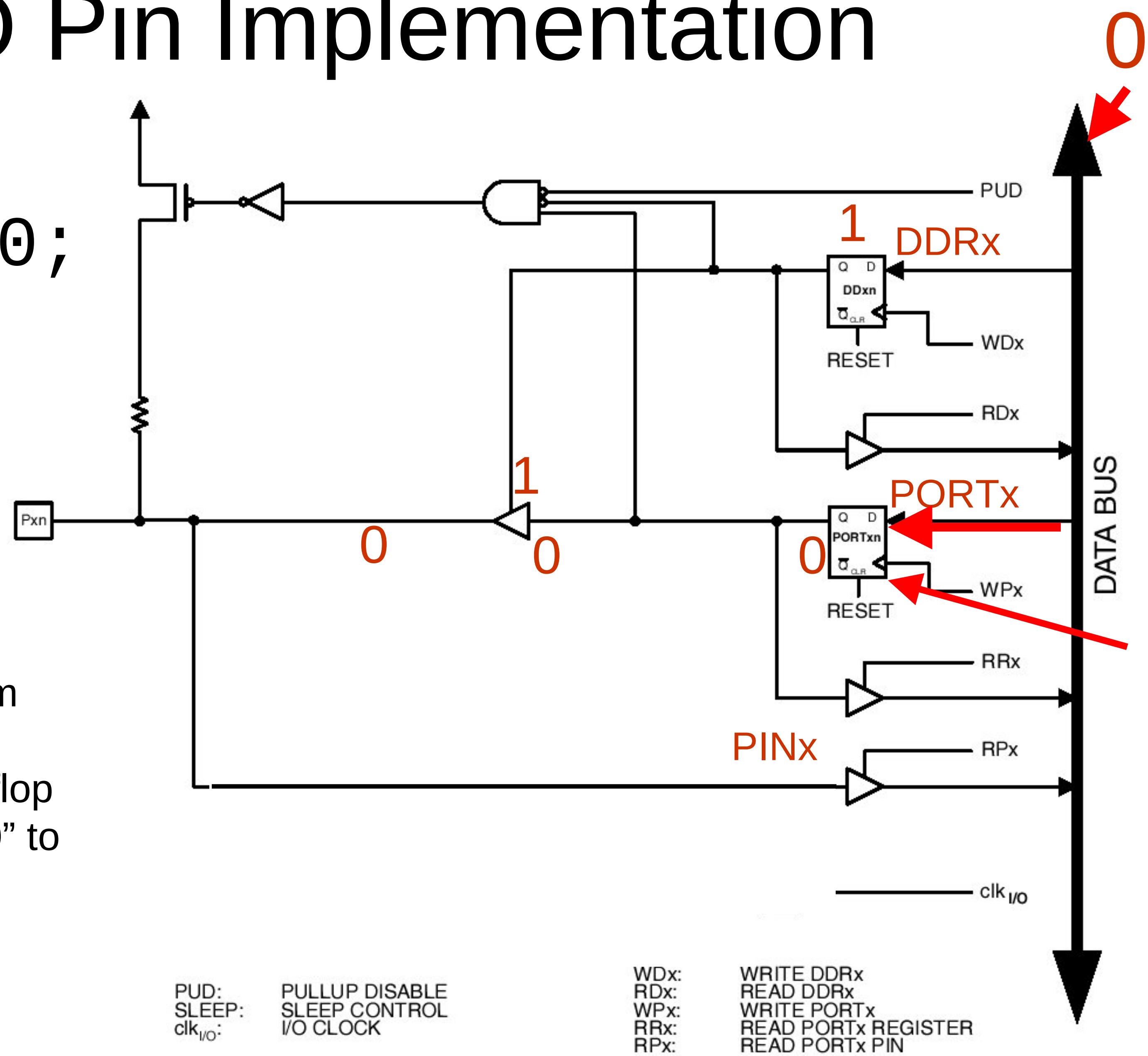


I/O Pin Implementation

```
PORTB = 0;
```

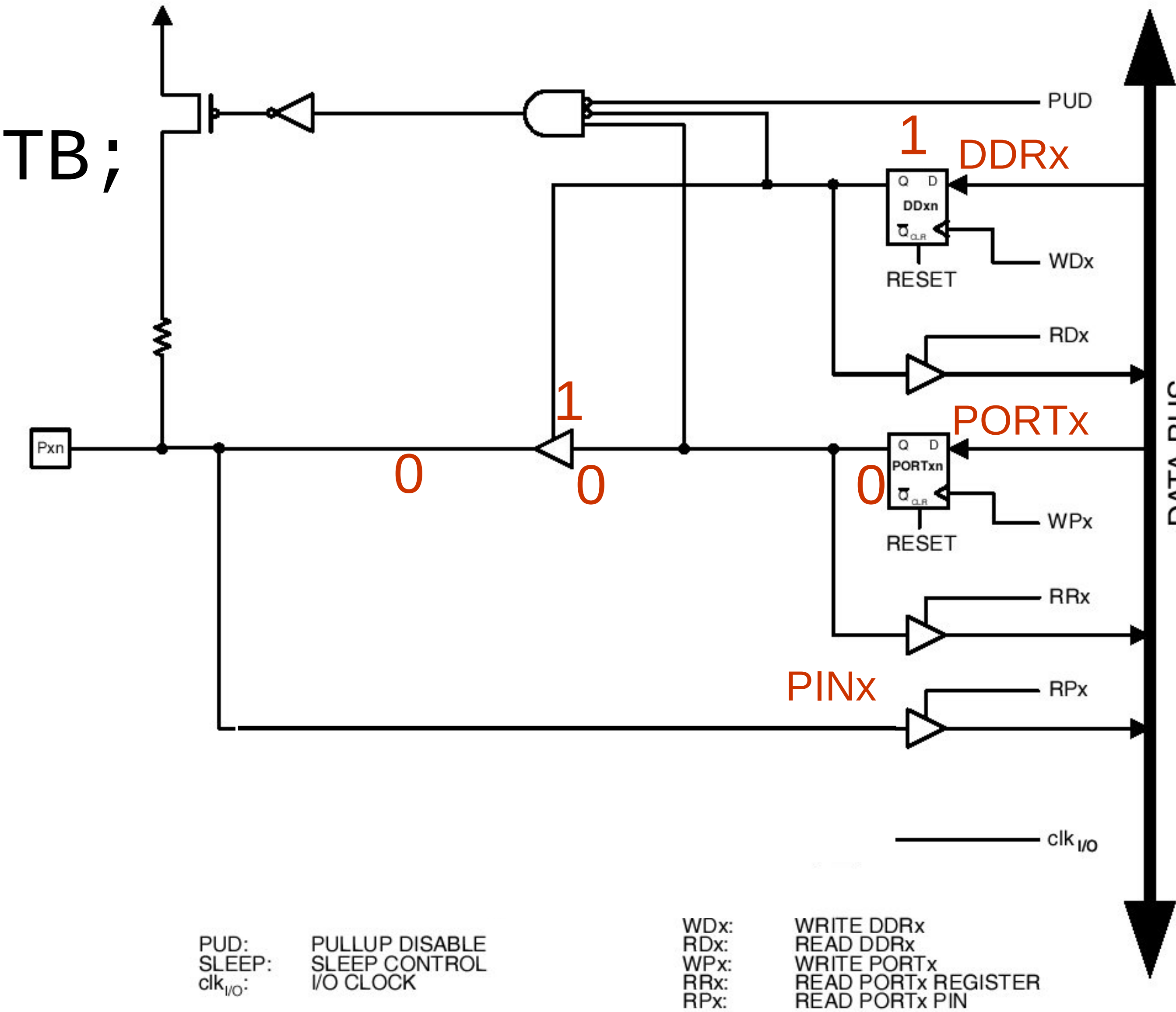
- “0” is written to the data bus
- This is input to the PORTB register
- WPB is clocked from high to low
- “0” is stored by flip-flop
- Which provides a “0” to the tri-state buffer

-> output a “0”



I/O Pin Implementation

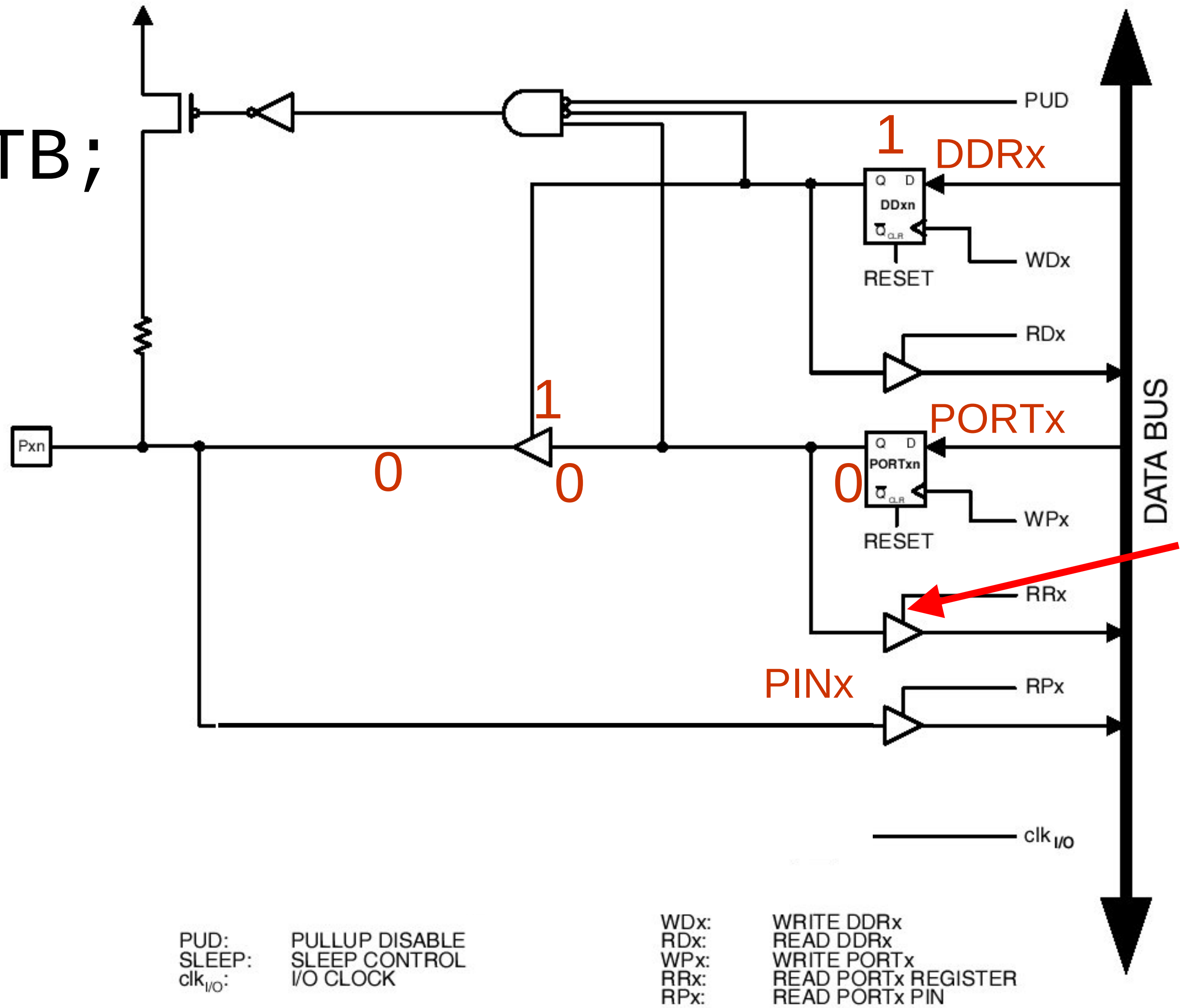
```
foo = PORTB;
```



I/O Pin Implementation

```
foo = PORTB;
```

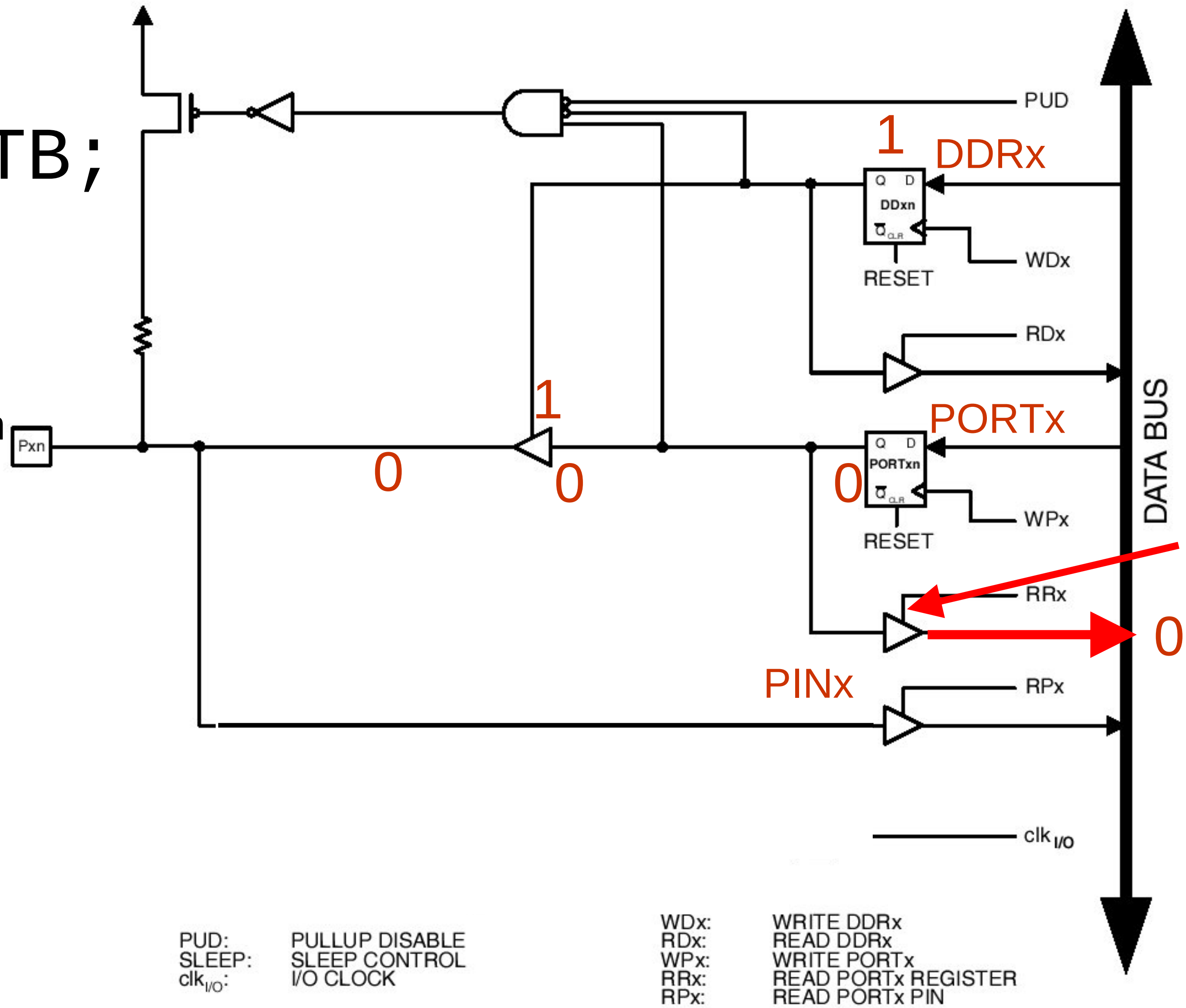
- RPB is set high



I/O Pin Implementation

```
foo = PORTB;
```

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

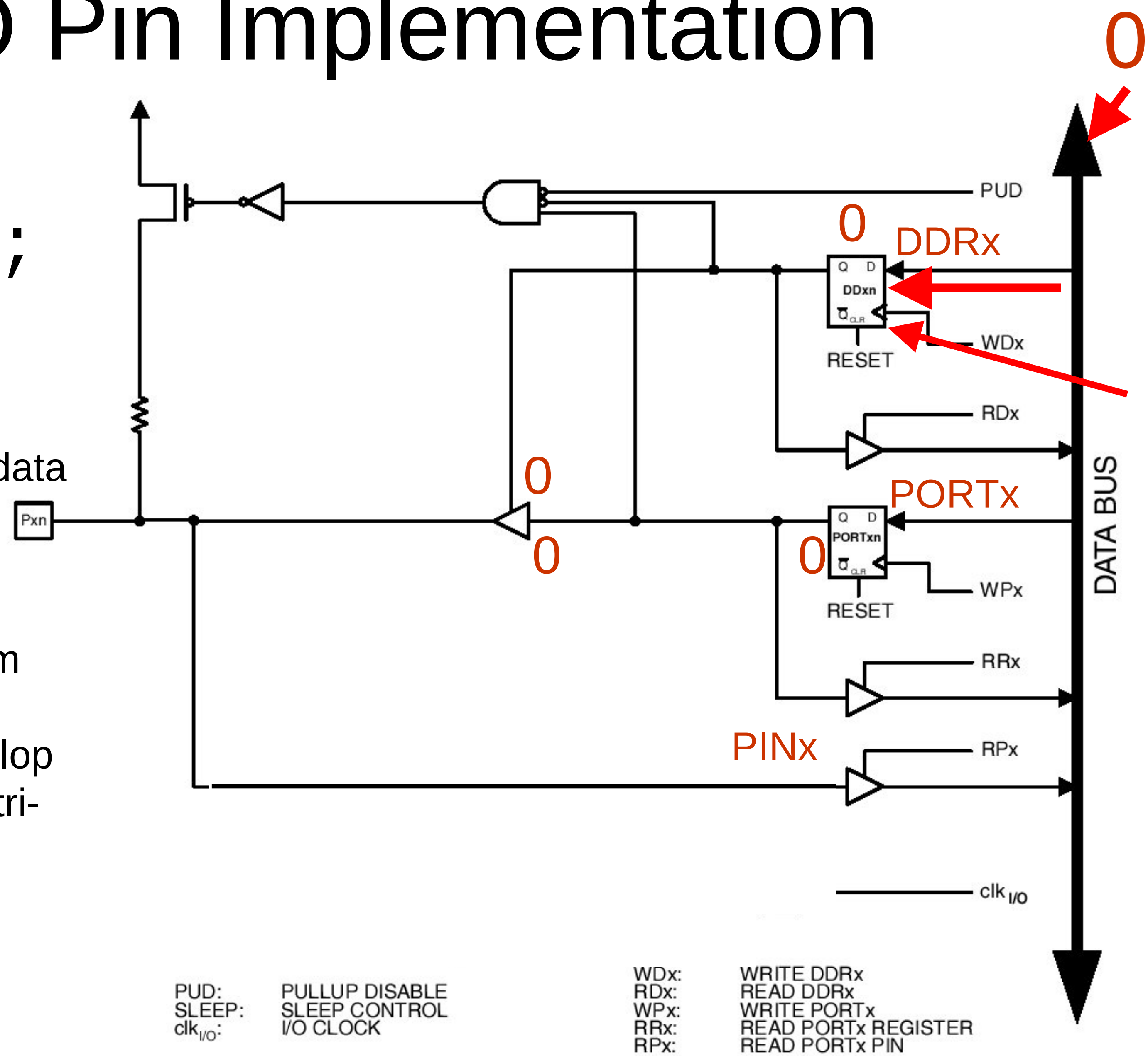


I/O Pin Implementation

```
DDRB = 0;
```

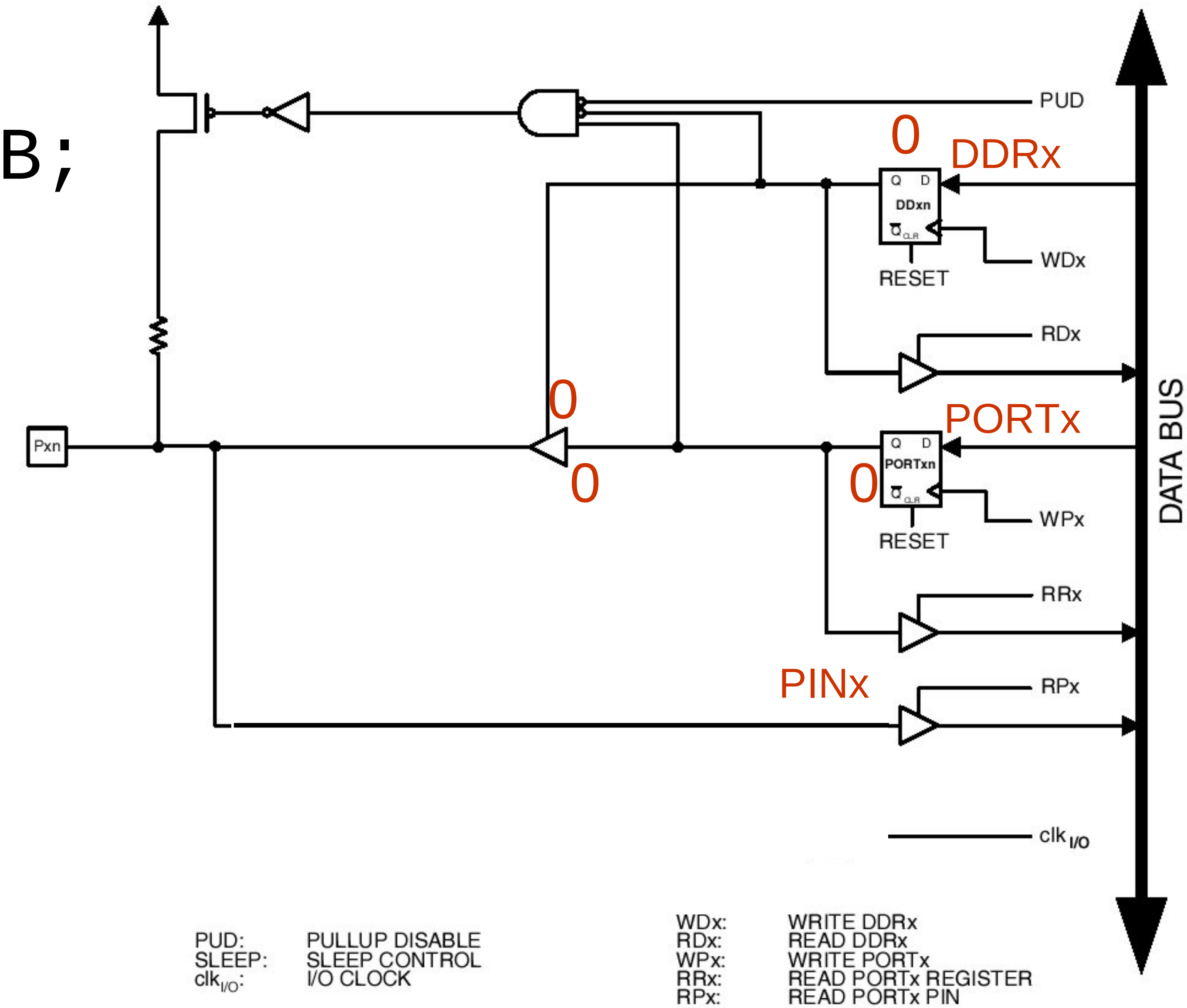
- "0" is written to the data bus
- This is input to the DDRB register
- WDB is clocked from high to low
- "0" is stored by flip-flop
- Which turns off the tri-state buffer

-> this is an input pin



I/O Pin Implementation

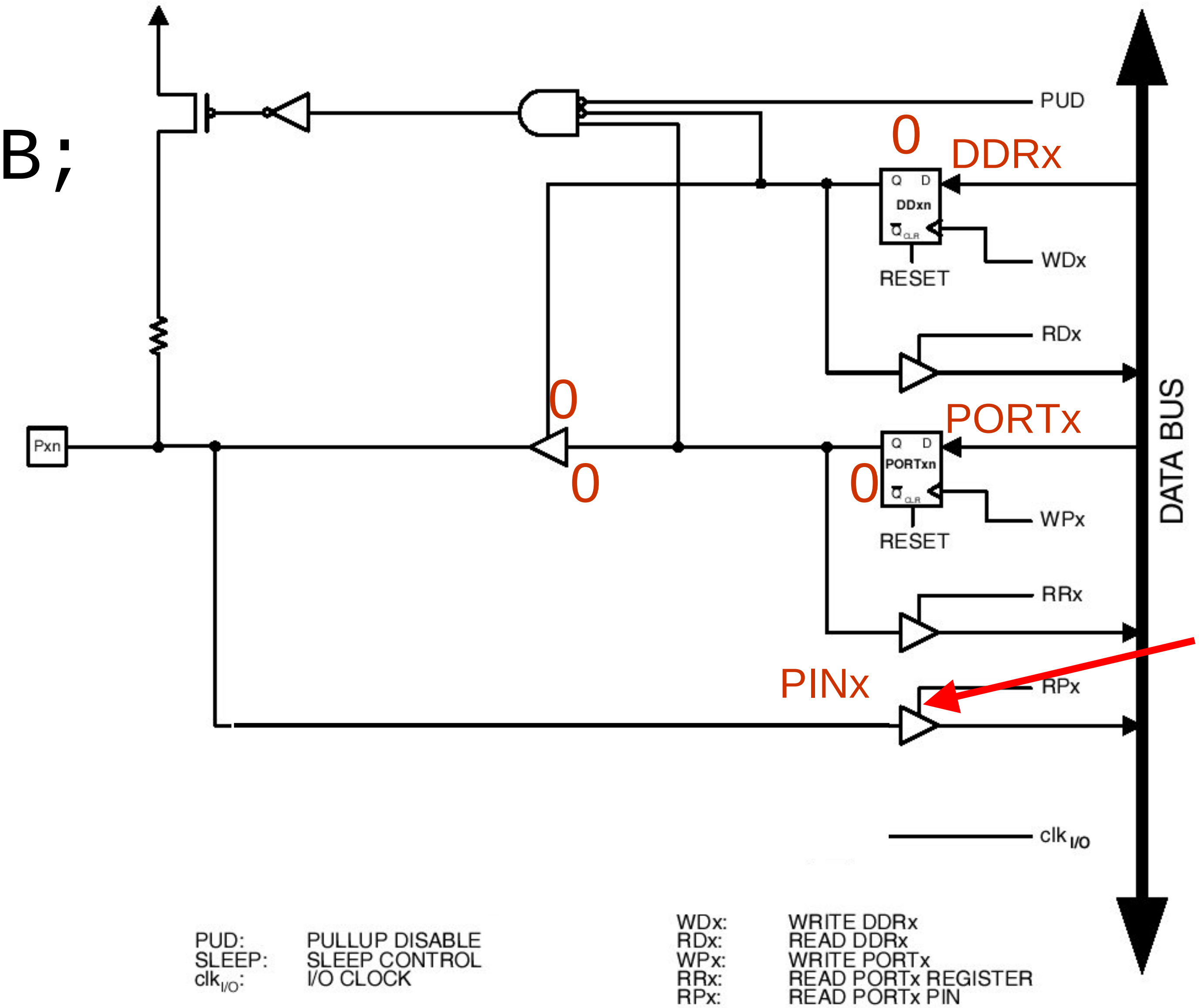
```
foo = PINB;
```



I/O Pin Implementation

```
foo = PINB;
```

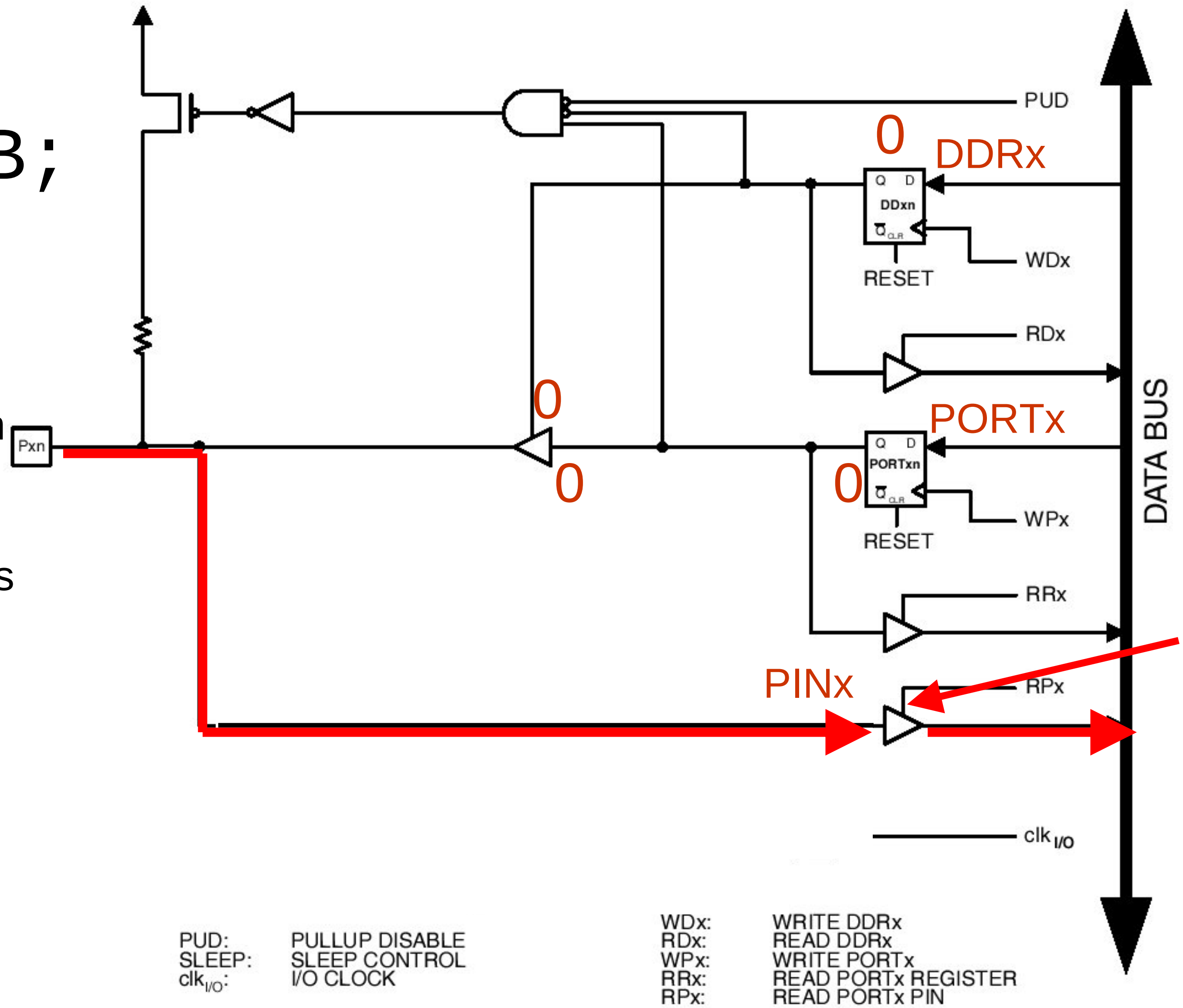
- RPB is set high



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 1?

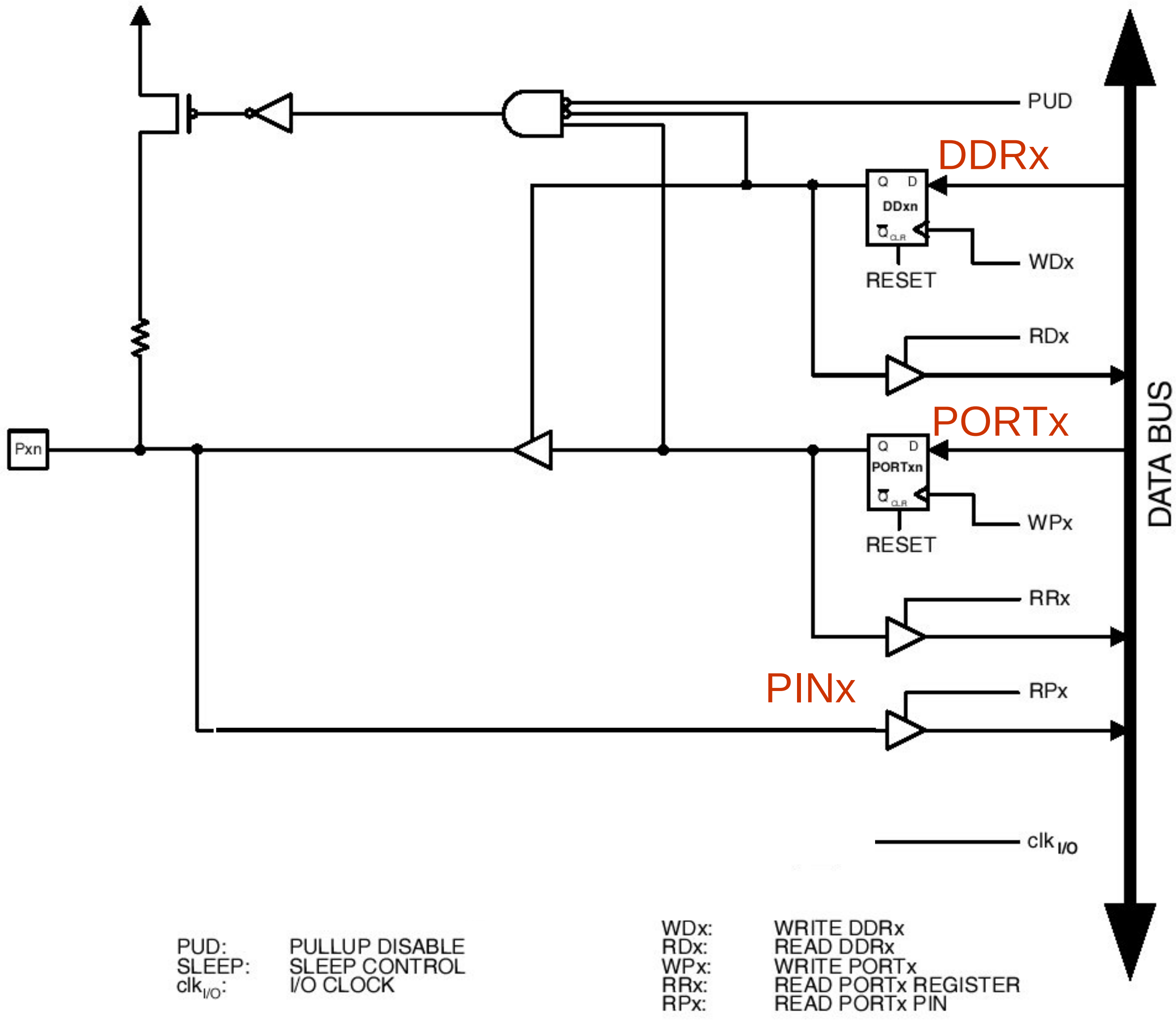
```
A = A & 0xFB;
```

or

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

I/O Pin Implementation

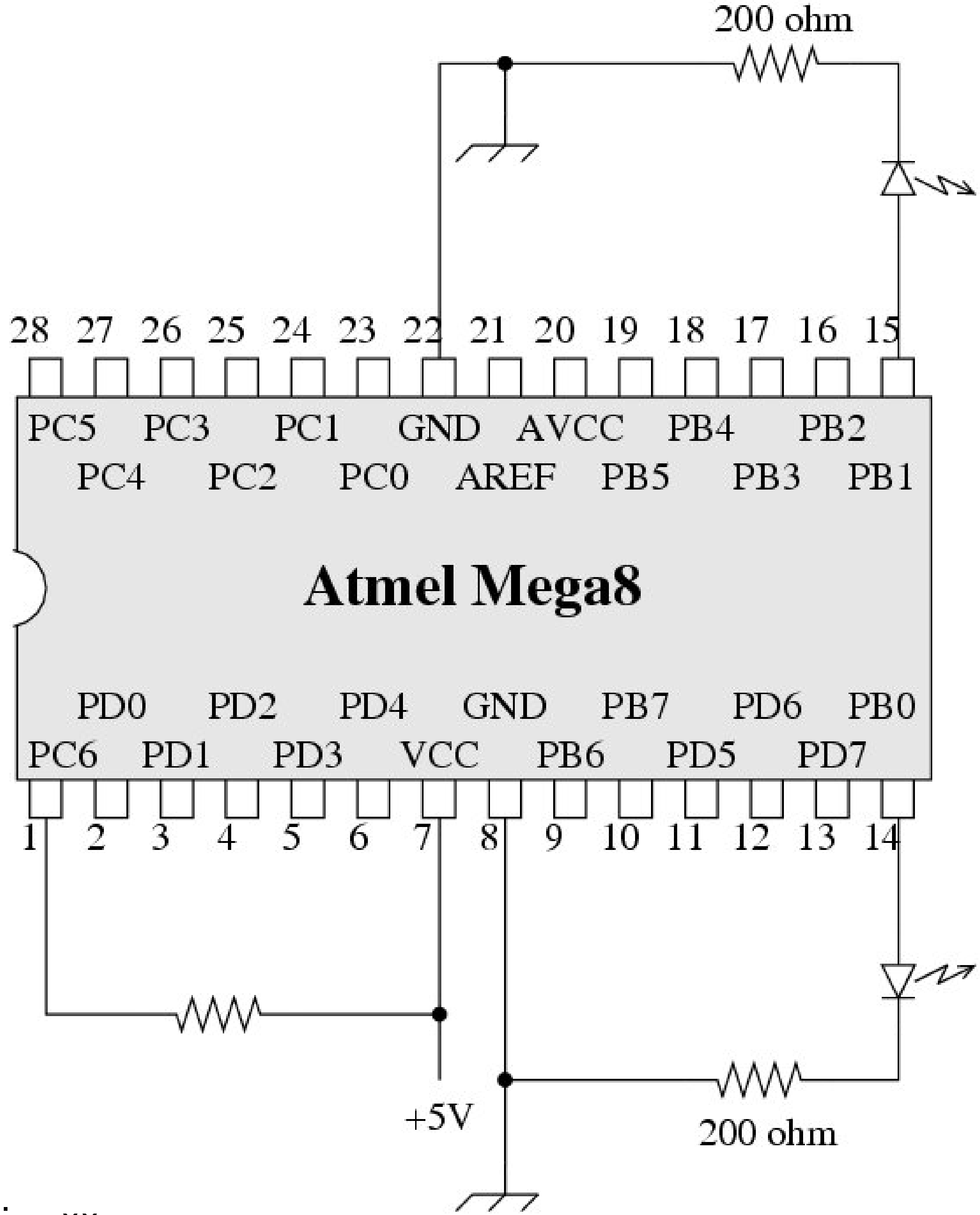
Single bit of
PORT B



A First Program

Flash the LEDs at a regular interval

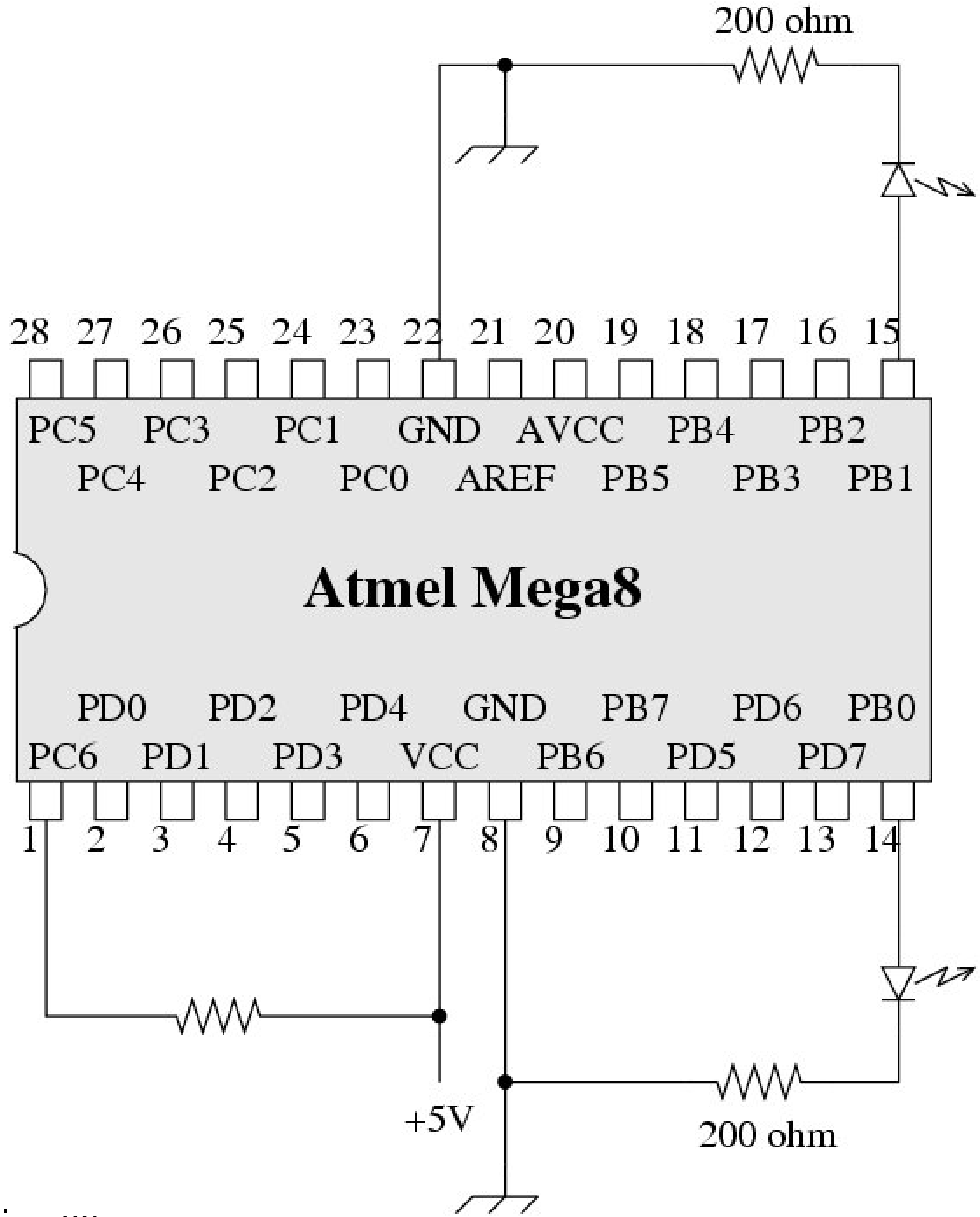
- How do we do this?



A First Program

How do we flash the LED at a regular interval?

- We toggle the state of PB0



A First Program

```
main() {
   DDRB = 7;   // Set port B pins 0, 1, and 2 as outputs

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

A Second Program

```
main() {
   DDRB = 7;   // Set port B pins 0, 1, and 2 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 = 0xFF;   // Set all port B pins 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

Last Time(s)

- Bit manipulation: pin hardware to code
- Bit masking
- Project 1

Today

- A bit more on bit masking
- Homework 1 discussion
- Serial communication

- Project 1 due in one week

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
                   //    number)
        :
        :

  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