

## Problem 1:

Define each of the following:

1. Processor

A processor is a circuit that performs some task based on the input and produces output.

2. CPU

Acronym for Central Processing Unit; The main processor of a (micro)computer. Contains the finite state machine elements, register file, ALU, and controllers to perform the fetch, decode, execute steps from a memory input and output connected to components such as memories and I/O (depending on architecture).

3. Microprocessor

A microprocessor is a processor on an integrated circuit (IC, “chip”).

4. Microcomputer

A microcomputer is a computer on an IC (“chip”)

5. Microcontroller

A microcontroller is a microprocessor with control interfaces, ADCs, and DACs. Currently synonymous with microprocessor.

## Problem 2:

A 4-bit processor X has:

1. 32 KiB address space.
2. Reset vector at the beginning of the address space, i.e., at address 0.
3. 4-bit data bus.

You are asked to build a basic computer with one  $4 \text{ KiB} \times 4$  RAM and one  $8 \text{ KiB} \times 4$  ROM. Show all calculations and the memory map when using the following strategies:

- a) Full-memory decoding

a) full memory decoding

RAM:  $4 \text{ KiB} \times 4$

$$1 \text{ KiB} = 2^{10} \text{ bytes}$$

ROM:  $8 \text{ KiB} \times 4$

$$2^m \cdot 4 = 2^m \cdot \frac{1}{2} = 4 \text{ KiB} = 2^2 \cdot 2^{10} \text{ bytes}$$

$$2^m \cdot \frac{4}{8} = 2^m \cdot \frac{1}{2} = 8 \text{ KiB} = 2^3 \cdot 2^{10} \text{ bytes}$$

$$2^m = 2^1 \cdot 2^2 \cdot 2^{10} \text{ bytes} = 2^{23} \text{ bytes}$$

$$2^m = 2^2 \cdot 2^3 \cdot 2^{10} \text{ bytes} = 2^{24} \text{ bytes}$$

$$m = \log_2(2^{23}) = 23$$

$$m = \log_2(2^{24}) = 24$$

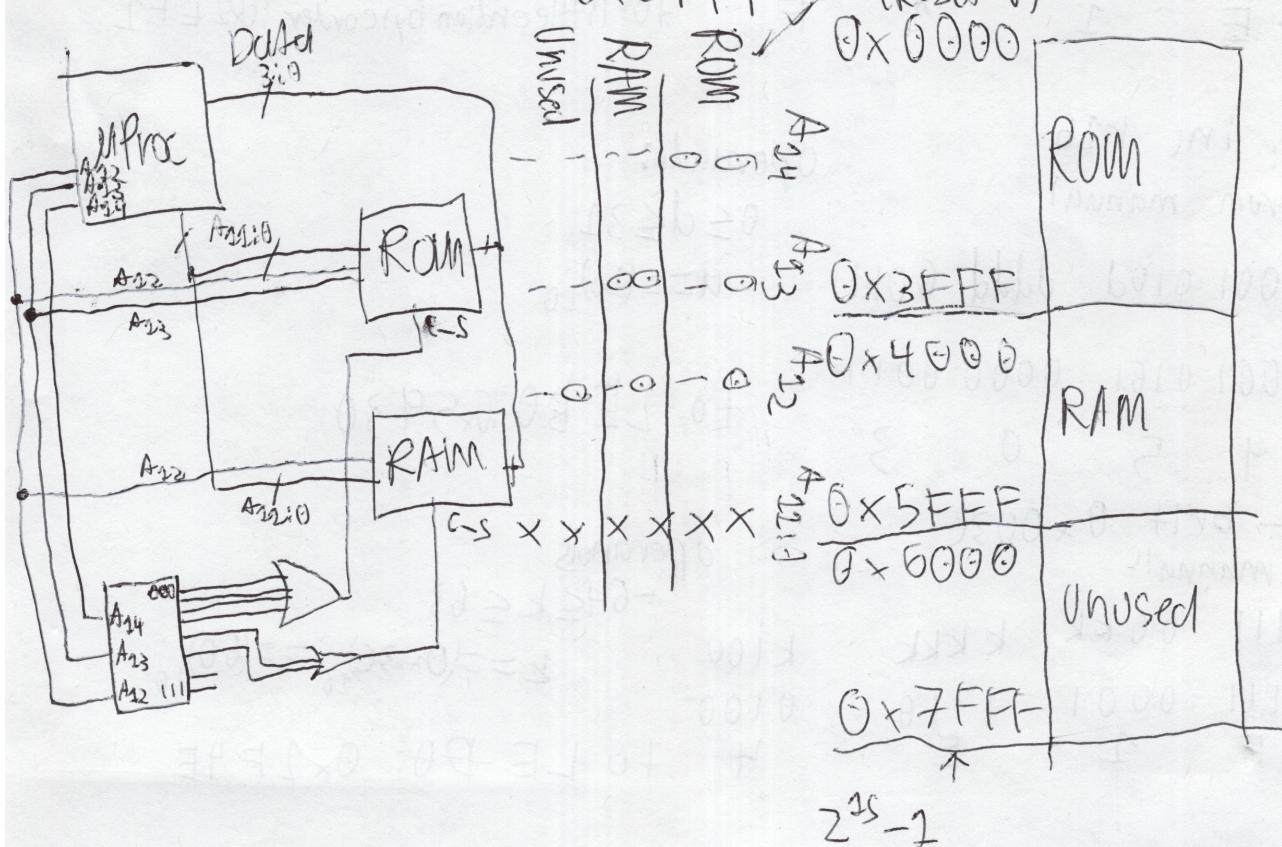
$$2^{23} = 0x2000$$

$$2^{24} = 0x4000 \quad 2^{24}-1 = 0x3FFF$$

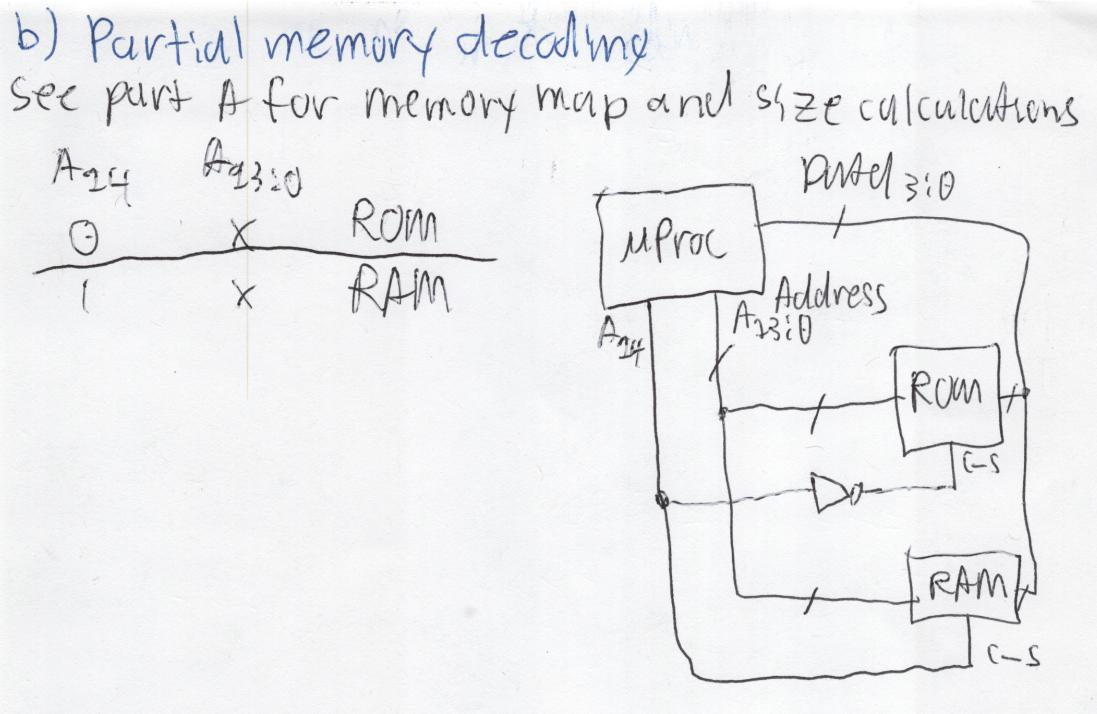
$$2^{23}-1 = 0x2000 - 0x1 = 0x1FFF \quad \text{Memory Map}$$

RAM range  $0x0000 - 0x1FFF$

(Reset V)



## b) Partial-memory decoding

**Problem 3:**

Looking at the machine code of the instruction in the program memory location 0x0014, and it was found to be 0x5406. Answer the following:

1. What is the instruction?

sbc r22, 80 ;subtract (from r22) immediate (decimal 80) with carry set bit in I/O register

2. What are the used addressing modes?

Register direct, single register

3. What are the operands?

Rd==0110<sub>2</sub>, K==0101 0000<sub>2</sub>

**Problem 4:**

By hand, convert each of the following AVR assembly instructions to its equivalent machine code. For each instruction assume that it is located at address 0x0050 in the program memory. Show all the steps.

1. clr r1

from instruction manual:

0010 01dd dddd dddd

operands:

 $0 \leq d \leq 31$  $r1 = d = (1)_{20}$ 

Since AVR little endian byteorder

0010 0100 0000 0001

0x4210 for instruction

0x2 4 0 1

2. ldi r27,31

from instr. manual:

1110 KKKK dddd KKKK  
d=1  
 $\uparrow$   
 $d=1$        $K=(31)_{20}$   
 $17-26=1)_{20}$ 

operands

 $16 \leq d \leq 31, 0 \leq K \leq 255$ 1110 0001 0001 1111  
0xE 1 2 F to little endian byteorder: 0x1EF1

3. inc r16

from manual

1001 010d dddd 0011  
 $d=(16)_{10}$ 

operands:

 $0 \leq d \leq 31$  $d=(16)_{10}$ 1001 0101 0000 0011  
0x9 5 0 3

to LE B0 0x5930

4. brlt 0x0030  
manual:1111 00kk kkkk k100  
1111 0001 1110 0100  
0xF 1 E 4

operands

 $-64 \leq k \leq 63$  $k=(0x30)_{16} = (60)_{20}$ 

to LE -#0: 0x1F4E