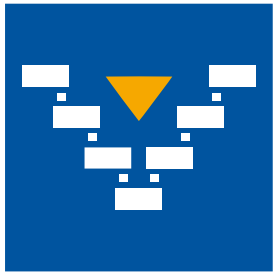

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Introduction to Embedded Systems

Prof. Dr.-Ing. Stefan Kowalewski | Julius Kahle, M. Sc.

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Exercise 1 - Microcontroller

Overview

- General questions
- Digital I/O
- Interrupts and Polling
- Timers and Counters
- Analog Devices

General questions

Task 1: a) – d)

Task 1: a) + b)

a) What is an embedded system? (Definition from the lecture)

- a computer
- integriert in technisches System (eingebettendes System)
- Zweck: gezielte Beeinflussung des —"—
- Bsp.: Motorsteuergerät

b) What is the source of requirements for an embedded systems?

- von den Anforderungen an das einbettende System

Task 1: c)

c) There are 2 categories of embedded systems:

1. What are these categories?
2. What are their characteristics?
3. What kind of hardware is typically used for these categories?
4. Which programming languages are most dominant in these categories?
5. Name at least one example for each category.

1.	Produkt-Automatisierung	Produktions-A.
2.	- hohe Stückzahlen - Ressourcenbeschränkt.	- Einzelanfertigung - wenig Res. beschr.
3.	µC	SPS
4.	C / C++	SPS-Sprachen
5.	Automobil-Elektr.	Fertigungsstraße für Autos

Task 1: d)

d) What is a microcontroller?

A dedicated device for embedded applications.

Digital I/O

Task 2: a) – d)

Task 2: a) + b)

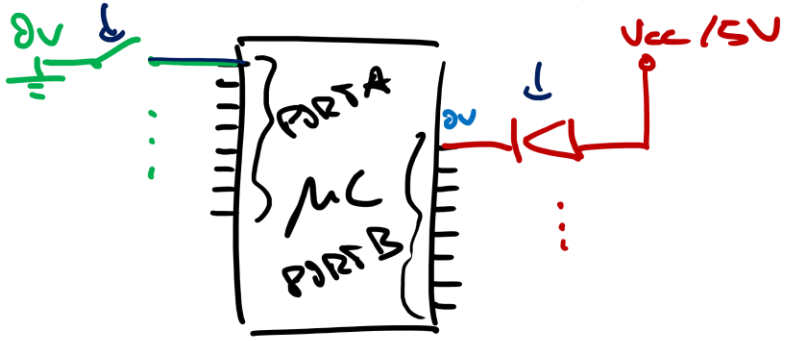
0 1 2 3 4 ... 9 A B C D E F
10 11 12 13 14 15

n-Stellen * Werte = 16^n

$10A1_{16}$
$= 1 \cdot 16^3 + 10 \cdot 16^2 + 1 \cdot 16^0$

In this task, we refer to Atmel ATmega16 microcontroller. Assume 8 buttons are connected to PORTA and GND. Also assume, that 8 LEDs are connected to PORTB and V_{cc}, such that can be lit.

a) What are the registers that control these ports?



Data direction — DDRA, DDRB
Output — PORTB
Input — PINA
Pull-up Widerst. — PORTA
PINB nicht ben.

b) How should these registers be initialized?

$0_{16} = 0000_2 = 0_{10}$

DDRA = $(0000\,0000)_2$ = 0b 0000 0000 = 0x 00 = $(00)_{16}$

DDRB = 0x FF

PORTA = 0x FF

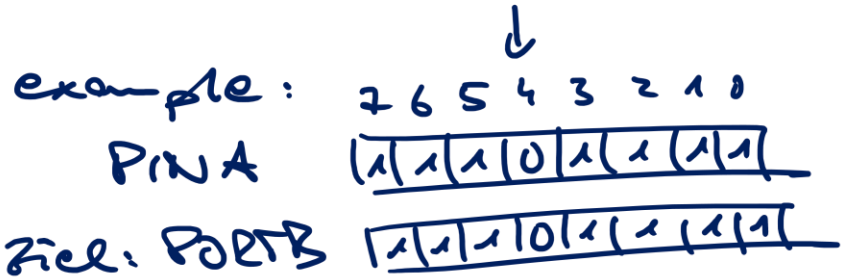
PORTB = 0x FF

PINA? read only

Task 2: c)

c) Write a loop that allows to control the LEDs via the buttons:

1. On a 1-to-1 basis (pushing buttons 4 causes LED 4 to be lit)
2. Priority encoder: show the binary coding for the number of the highest button pushed.

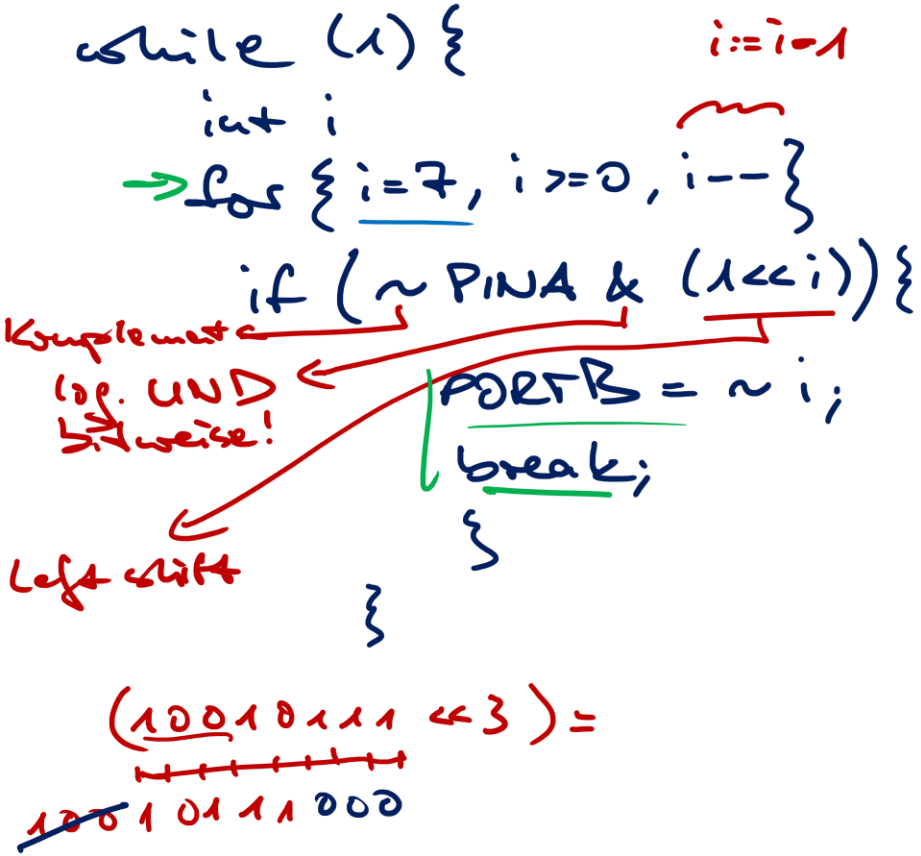


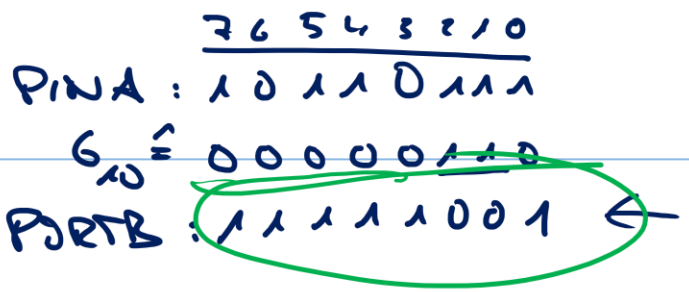
Solution 1.:

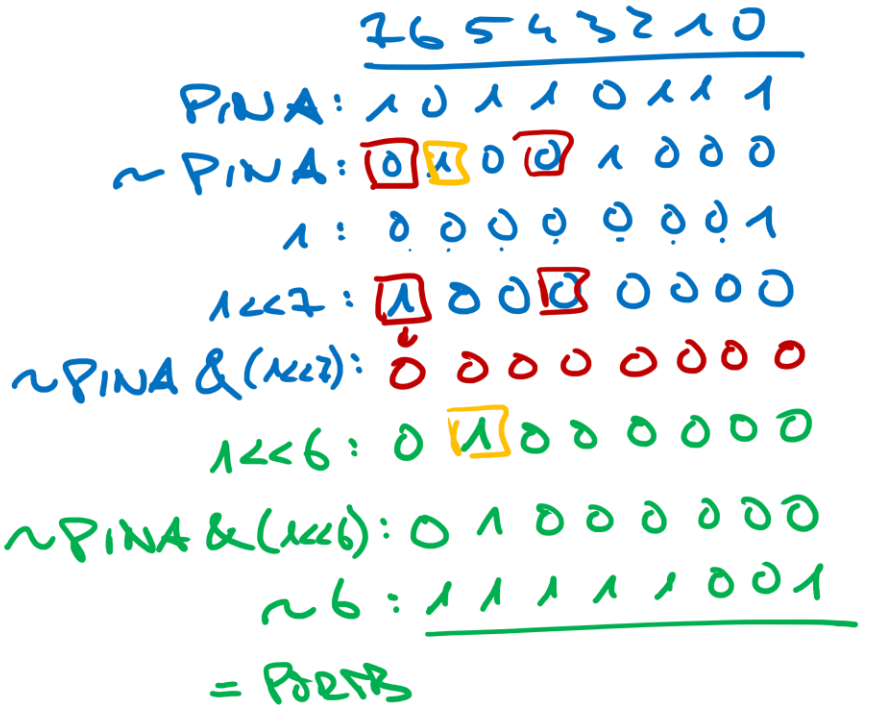
```
while(1) {
  PORTB = PINA;
}
```

Task 2: c)

Solution 2.:







Task 2: d)

Prellen Nennen Sie eine Entprellmethode.

d) What is bouncing? Implement a debouncing method.

Signal-Oszillation bei einer Signaländerung

1. Zählen
2. Tiefpass

Interrupts and Polling

Task 3: a) + b)

Task 3: a)

a) Choose Interrupts or Polling for the following scenarios and explain your choice.

1. The „change input“-button on a monitor.

   Seltenes Ereignis → Interrupt

2. The wireless-receiver of a garage-opener.

   Nicht ständig Zeit → Polling
   Falls Sleep-mode: → Interrupts

3. The keyboard on a standard desktop.

   Häufig → Polling

4. The temperature-sensor of a weather-station.

   Regelmäßig → Polling

Task 3: b)

b) When is an ISR called and how is it done?

Wann: 3 Bits müssen gesetzt sein: Global IE, Indiv. IE, Interr. flag

Wie:
1. PC sichern
2. Global IE := 0
3. PC := Interr. Vector Tabelle, Zeile für betr. IR
4. PC := Start ISR
5. Kontext gesichert
6. ISR wird ausgeführt
7. Kontext zurück geschrieben
8. PC wird auf gesicherten Wert zurückgesetzt
9. Global IE := 1 (möglicherweise verzögert)

Timers and Counters

Task 4: a) – e)

Task 4: a) – c)

a) What is a counter? What is a timer?

Timer zählt clock events.
Counter alle anderen.

b) What components does timer 1 of the ATmega16 have? How are they configured?

Counter register
Control register
Compare register

c) How is the reading and writing of a 16 bit value made atomic?

Task 4: d) + e)

d) What is a watch dog?

- interner Timer
- dient zur Überwachung des µC

e) Why might it be necessary to temporarily disable interrupts when reading 16 bit values? (on a 8-bit platform)

Analog Devices

Task 5: a) – e)

Task 5: a) + b)

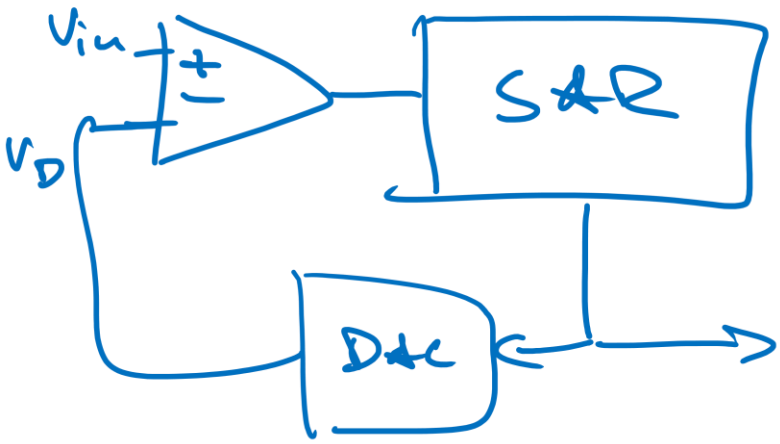
a) What analog devices can be found on an ATmega16?

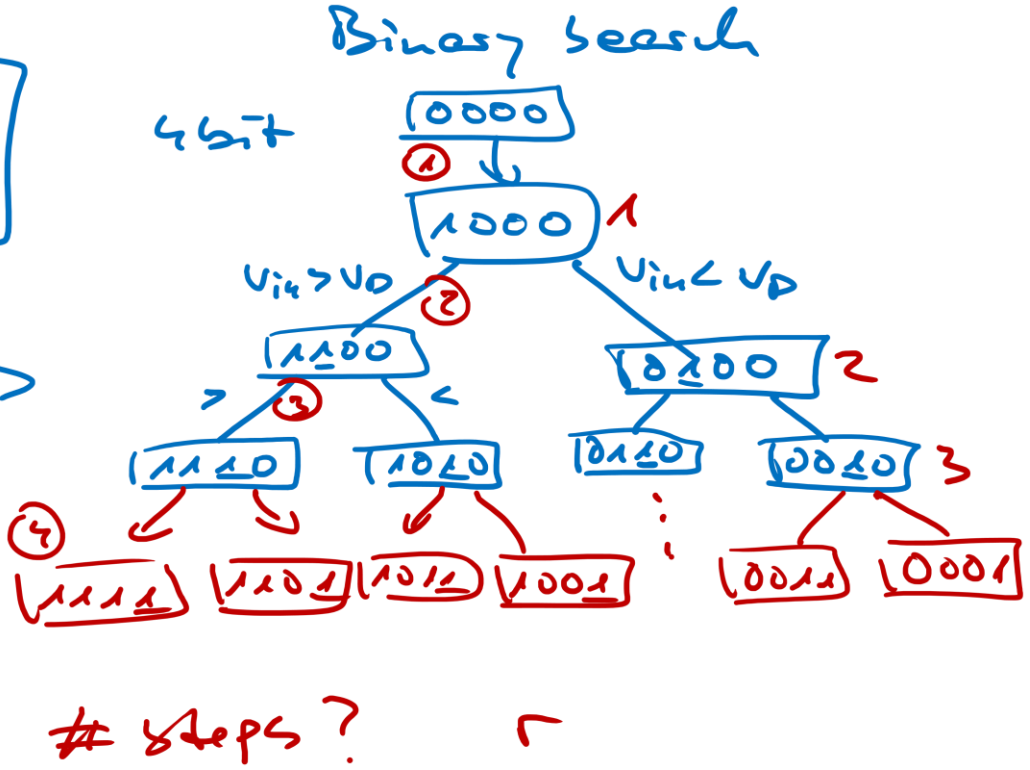
4 PWM, 8 ADC, 1 analog Comparator

b) What is PWM and how does it work?

Task 5: c)

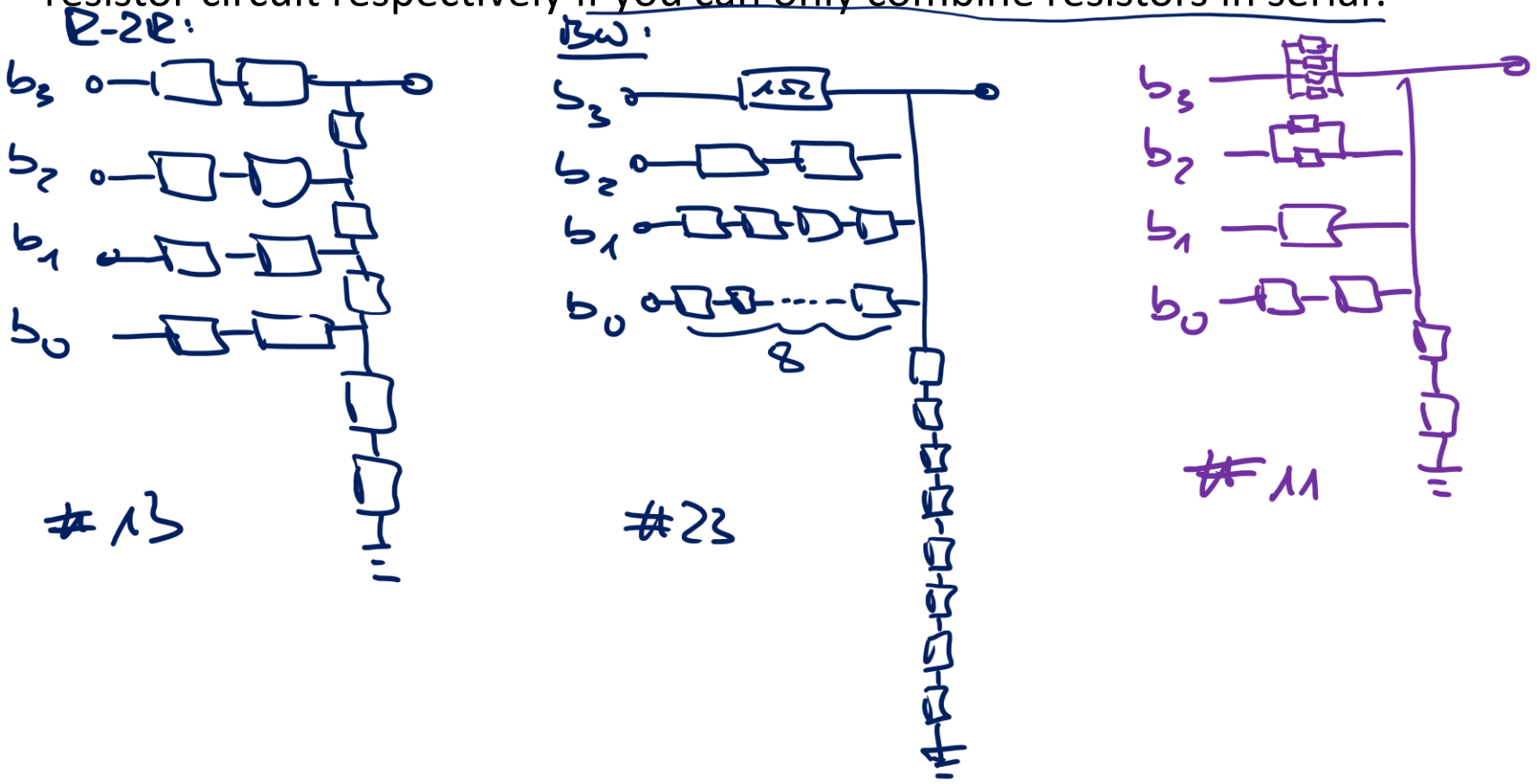
c) Sketch a successive approximation converter and explain how it works.





Task 5: d)

d) Imagine you only have 1 Ohm Resistors available, which cost 10 cents each. What is the minimum achievable cost for a 4Bit R-2R and a 4Bit binary weighted resistor circuit respectively if you can only combine resistors in serial?



Task 5: e)

e) What are the disadvantages of the binary weighted resistor circuit?