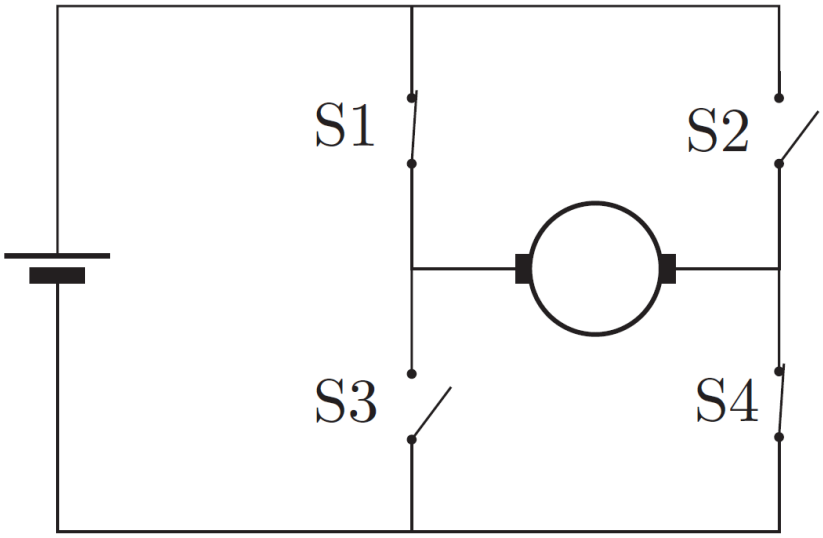
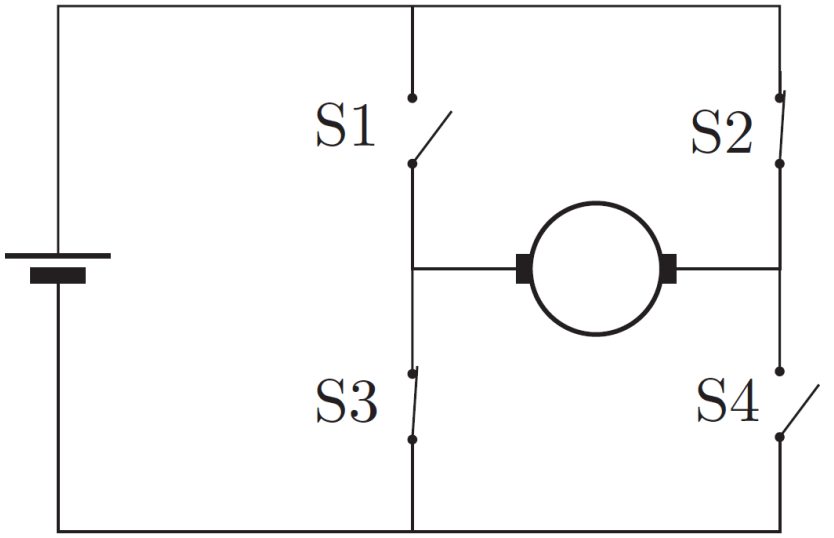
# Mechatronic Actuators

Lecture 4b

# The working principle of the H-bridge

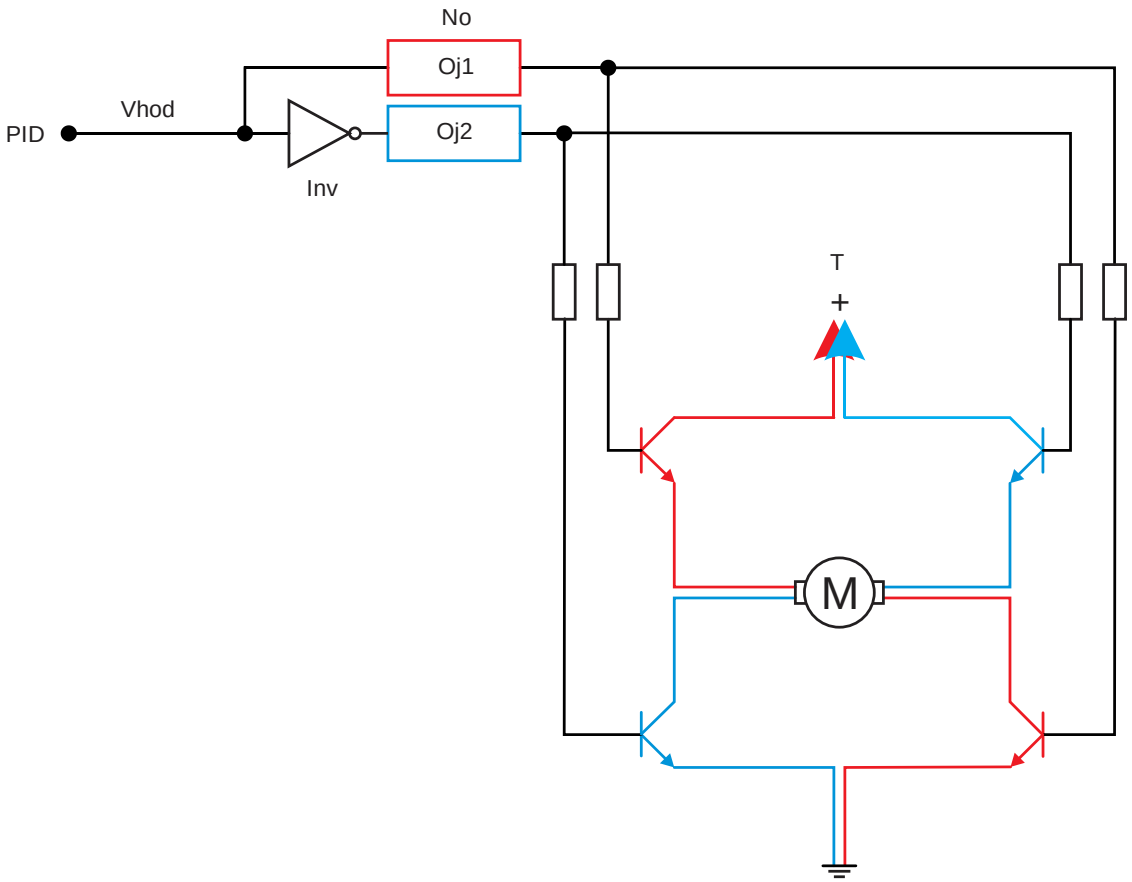


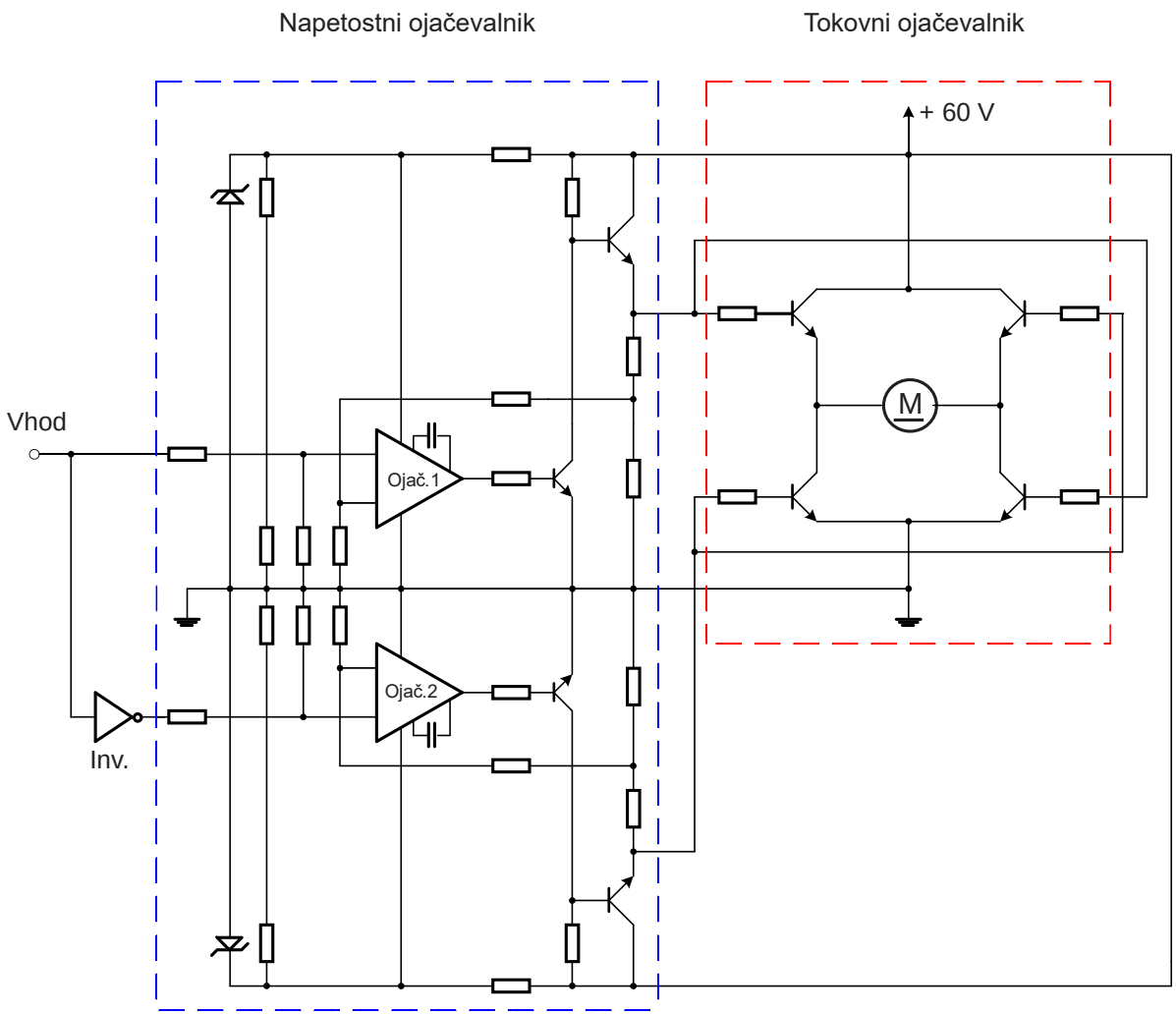
# Possible states and results

| S1 | S2 | S3 | S4 | Rezultat |
|---|---|---|---|---|
| 1 | 0 | 0 | 1 | Vrtenje v eno smer |
| 0 | 1 | 1 | 0 | Vrtenje v drugo smer |
| 0 | 0 | 0 | 0 | Prazen tek |
| 1 | 1 | 0 | 0 | Zaviranje |
| 0 | 0 | 1 | 1 | Zaviranje |
| 1 | 0 | 1 | 0 | Kratek stik |
| 0 | 1 | 0 | 1 | Kratek stik |
| 1 | 1 | 1 | 1 | Kratek stik |

# Implementation (simplified)

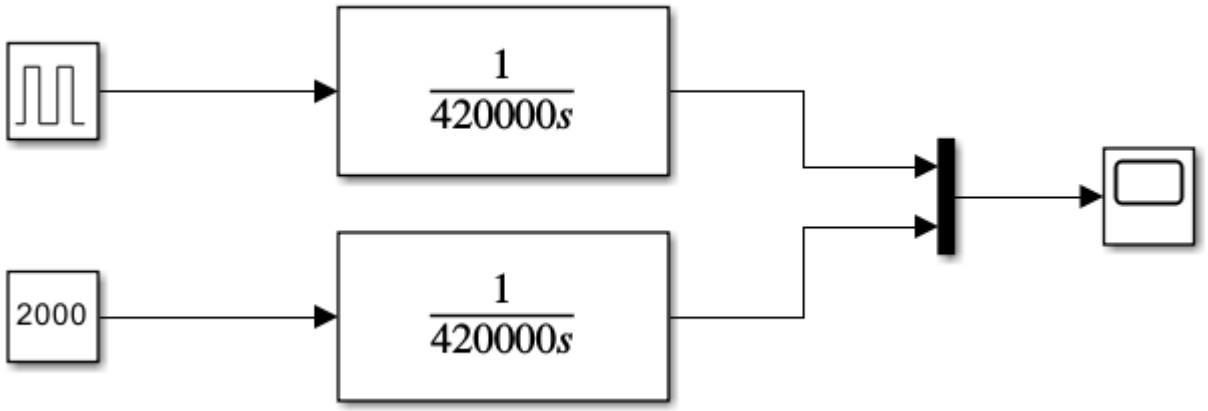


# The actual circuit of the H-bridge

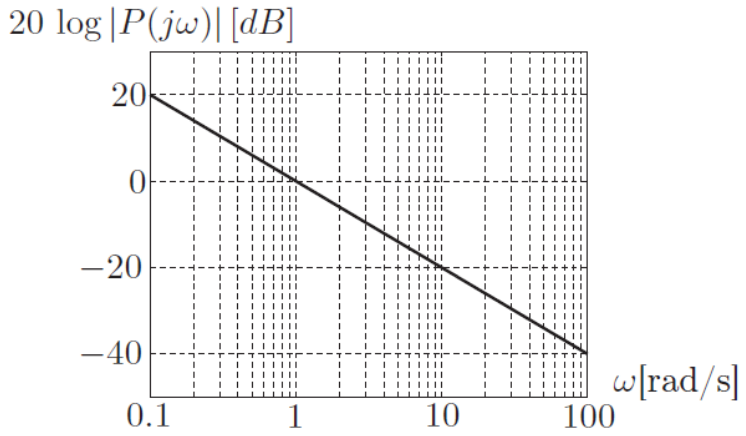


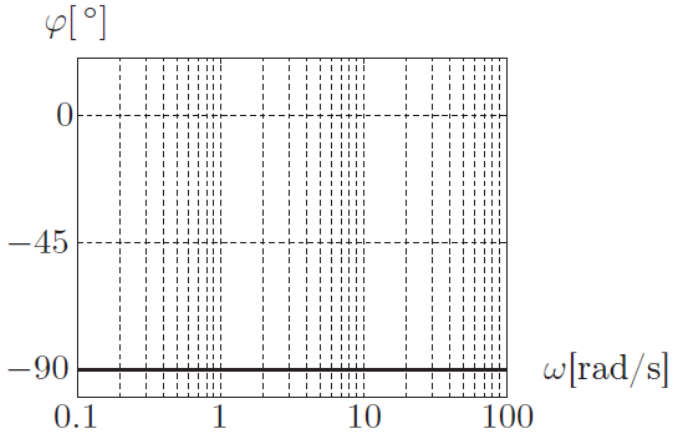
# Water heater

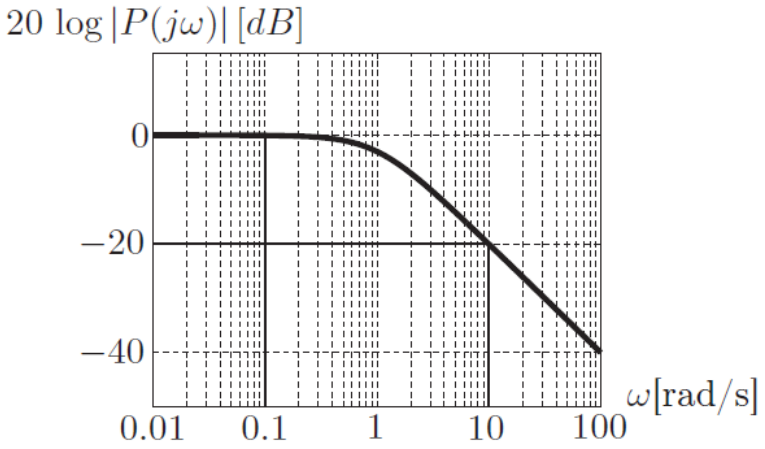
100 l of water, heater power of 2kW

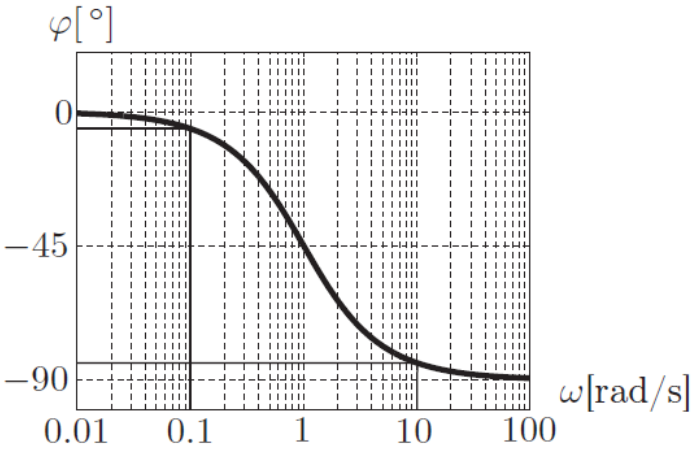


# Frequency characteristics

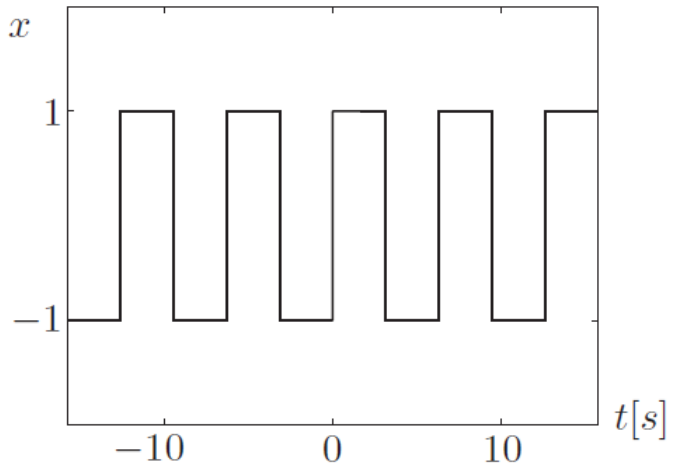


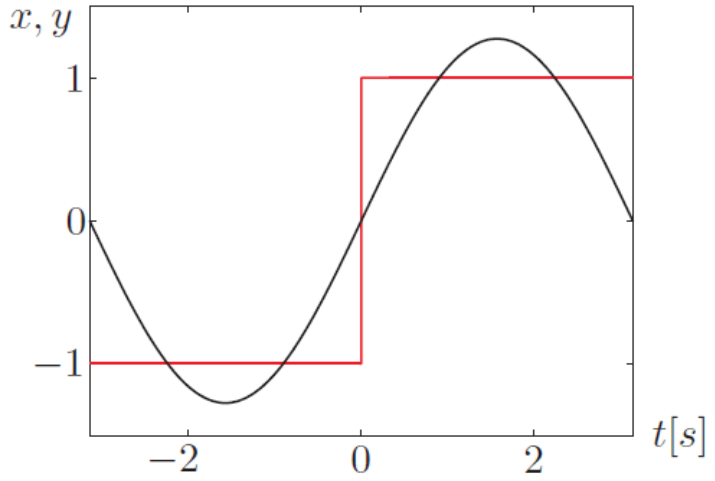



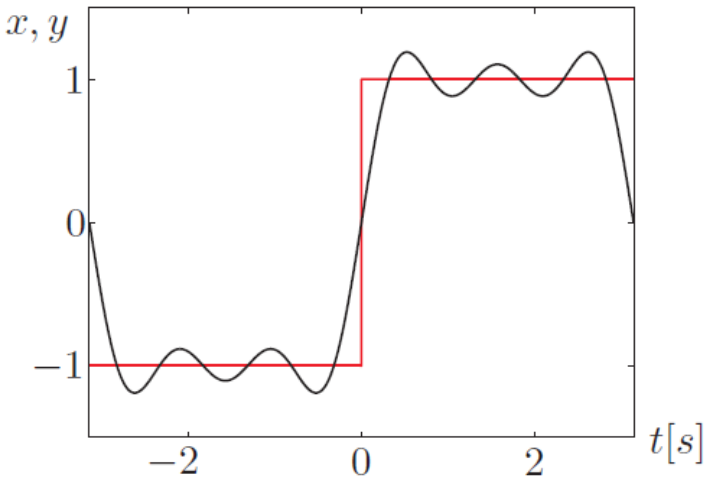



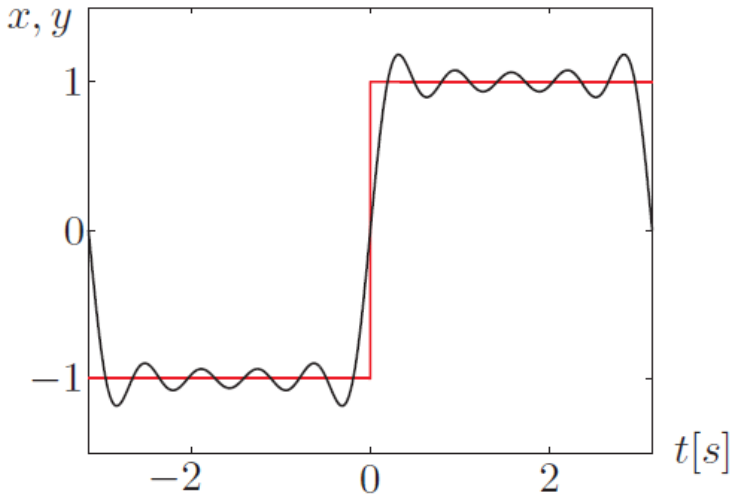



# Fourier series

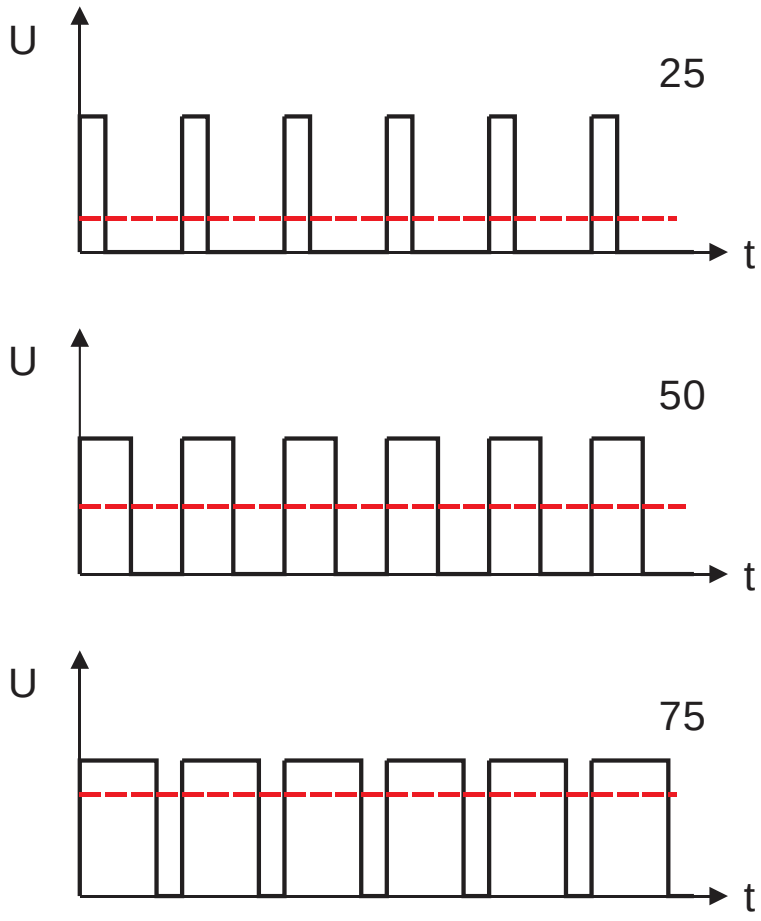


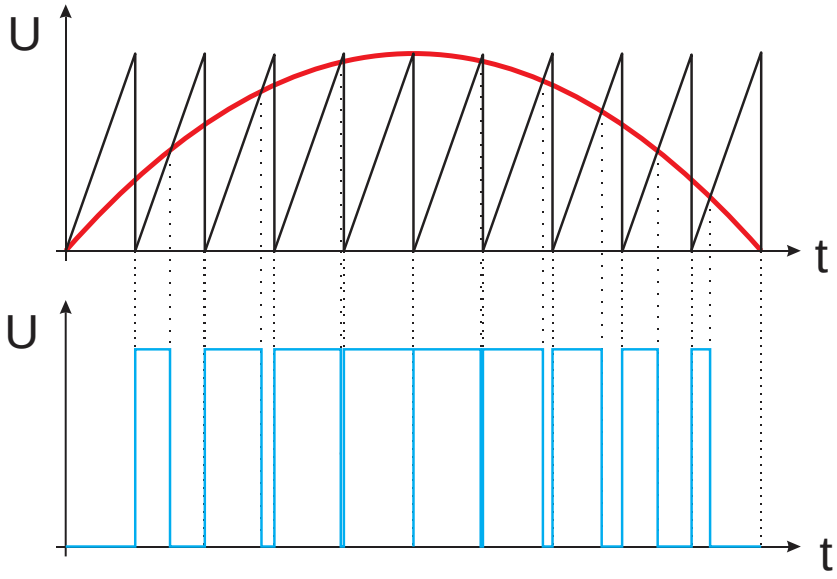



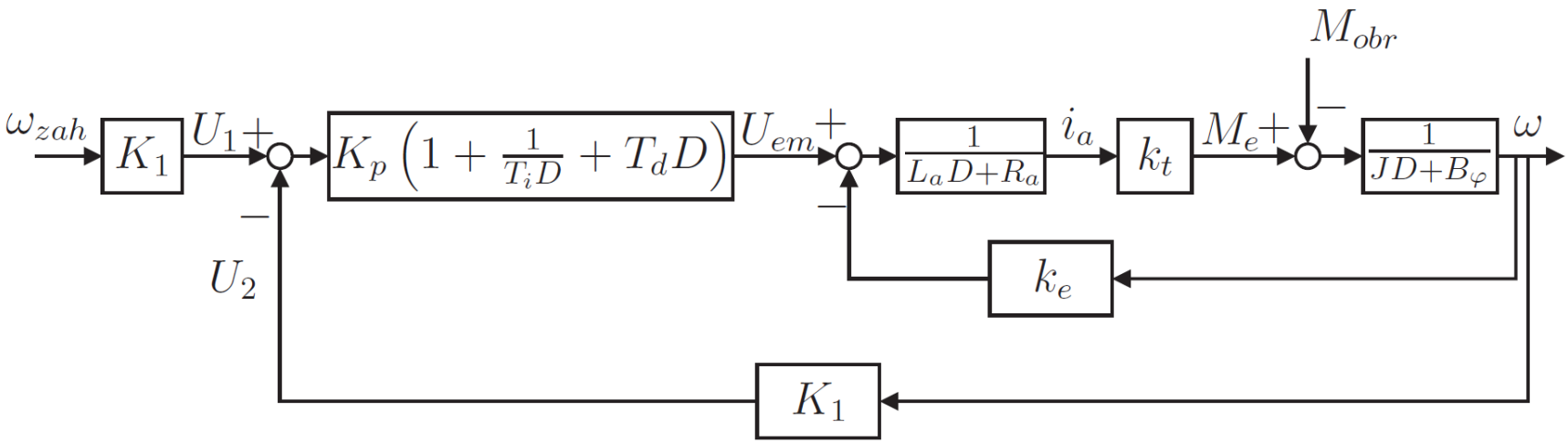



# PWM signal

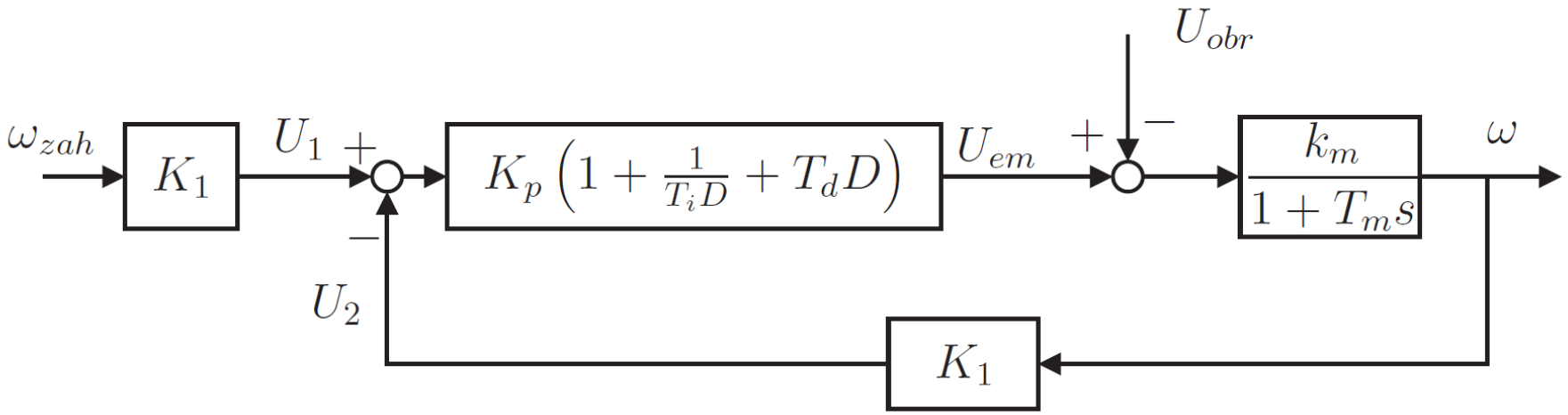


# DC electric motor as part of the control system



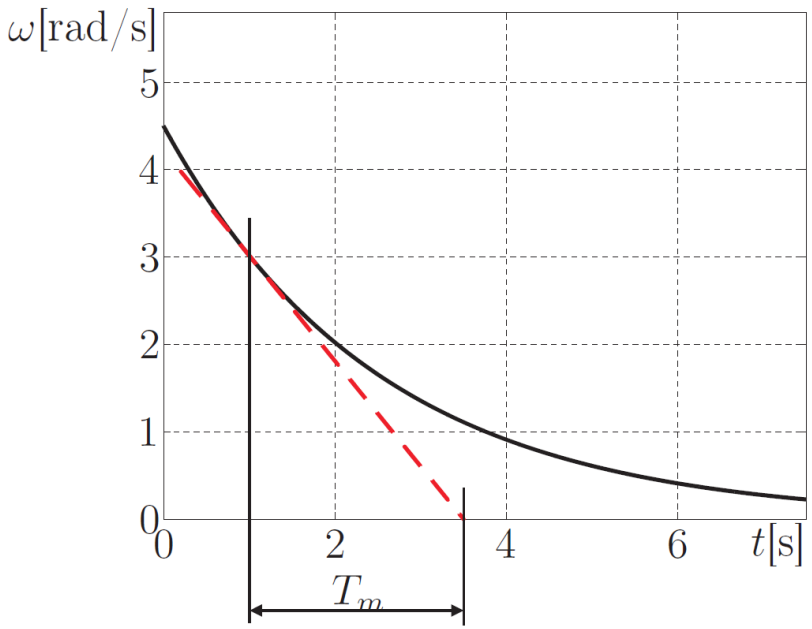
# Simplification




$$P(D) = \frac{\Omega(s)}{U_{em}(s)} = \frac{k_m}{1+T_m s}$$

# Determination of parameters (impulse transition function)

$$\Omega(s) = P(s) \cdot U_{em}(s) = \frac{k_m}{1 + T_m s} \cdot 1$$




$$\omega(t) = \frac{k_m}{T_m} e^{-\frac{t}{T_m}} \qquad \dot{\omega}(t) = -\frac{k_m}{T_m^2} e^{-\frac{t}{T_m}}$$

$$t = t_0 + \Delta t$$

$$\omega(\Delta t) = \omega(t_0) + \dot{\omega}(t_0)\,\Delta t = \frac{k_m}{T_m} e^{-\frac{t_0}{T_m}} - \frac{k_m}{T_m^2} e^{-\frac{t_0}{T_m}}\,\Delta t$$

$$\omega(\Delta t) = 0$$

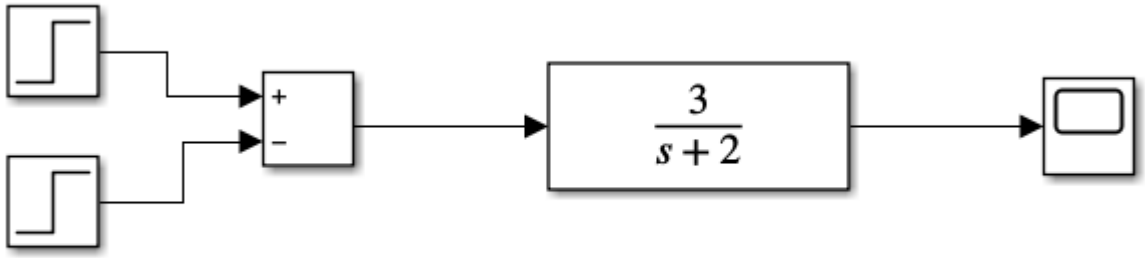
$$\frac{k_m}{T_m} e^{-\frac{t_0}{T_m}} - \frac{k_m}{T_m^2} e^{-\frac{t_0}{T_m}}\,\Delta t = 0 \quad \Rightarrow \quad \Delta t = T_m$$

$$\lim_{t \to 0} f(t) = \lim_{s \to \infty} sF(s)$$

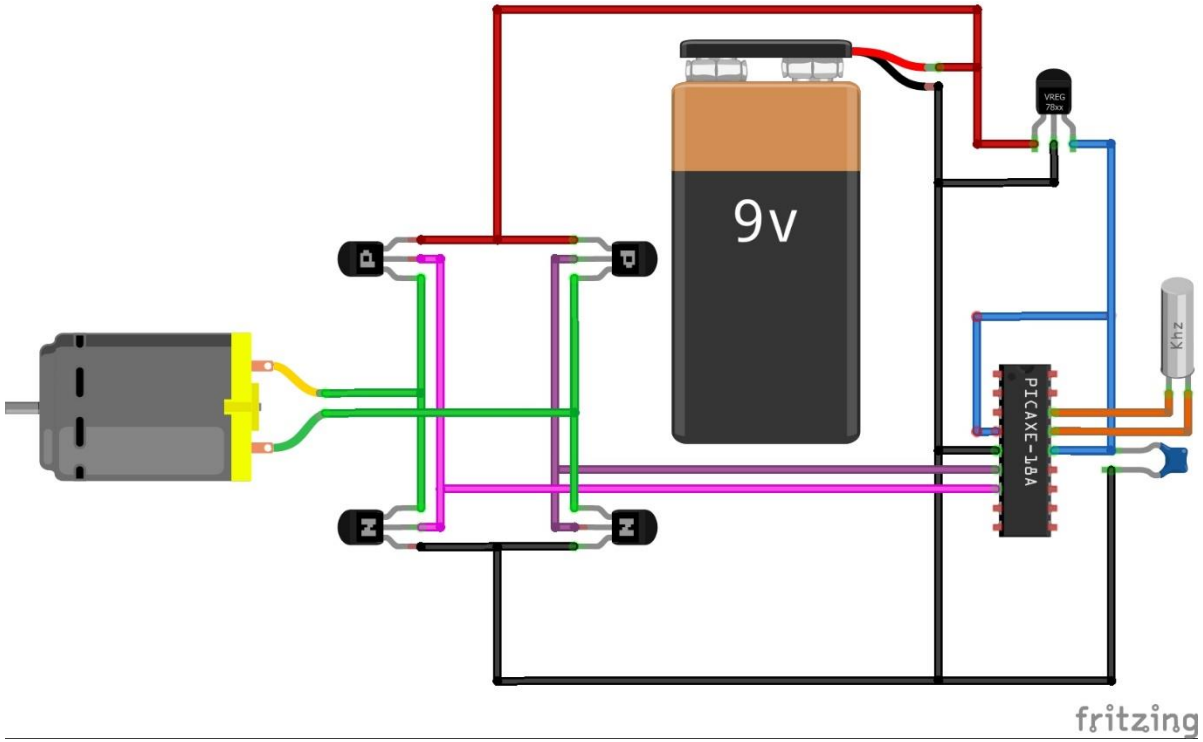
$$\omega(0) = \lim_{t \to 0} \omega(t) = \lim_{s \to \infty} s\Omega(s) = \lim_{s \to \infty} s \frac{k_m}{1 + T_m s} U_{em}(s)$$

$$\omega(0) = \frac{k_m}{T_m}$$

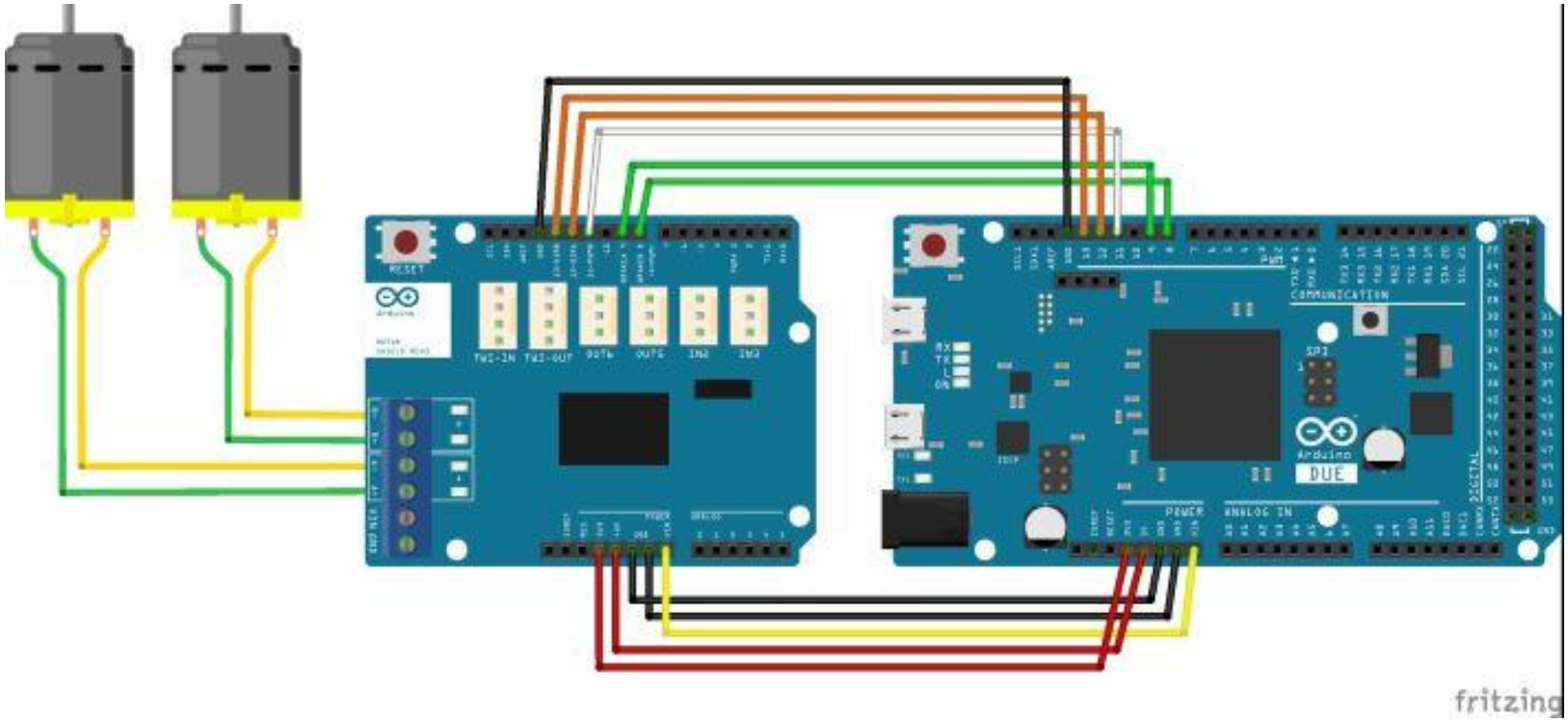
# Example in Simulink



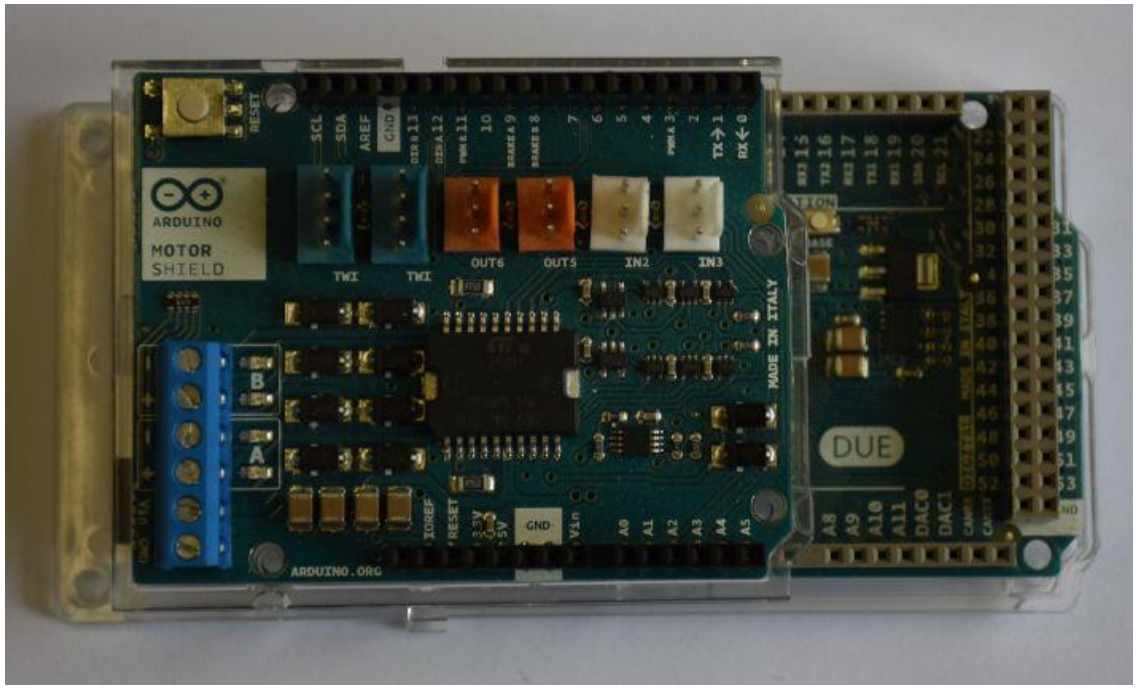
# PIC microcontroller and DC motor



# Arduino Shield DC



# Arduino shield - installation



# Example program

```
void setup() {
  //Setup Channel A
  pinMode(12, OUTPUT); //Initiates Motor Channel A pin
  pinMode(9, OUTPUT); //Initiates Brake Channel A pin
}

void loop(){
  //forward @ full speed
  digitalWrite(12, HIGH); //Establishes forward direction of Channel A
  digitalWrite(9, LOW);   //Disengage the Brake for Channel A
  analogWrite(3, 255);   //Spins the motor on Channel A at full speed
  delay(3000);
  digitalWrite(9, HIGH); //Engage the Brake for Channel A
  delay(1000);
  //backward @ half speed
  digitalWrite(12, LOW); //Establishes backward direction of Channel A
  digitalWrite(9, LOW);   //Disengage the Brake for Channel A
  analogWrite(3, 123);   //Spins the motor on Channel A at half speed
  delay(3000);
  digitalWrite(9, HIGH); //Engage the Brake for Channel A
  delay(1000);
}
```