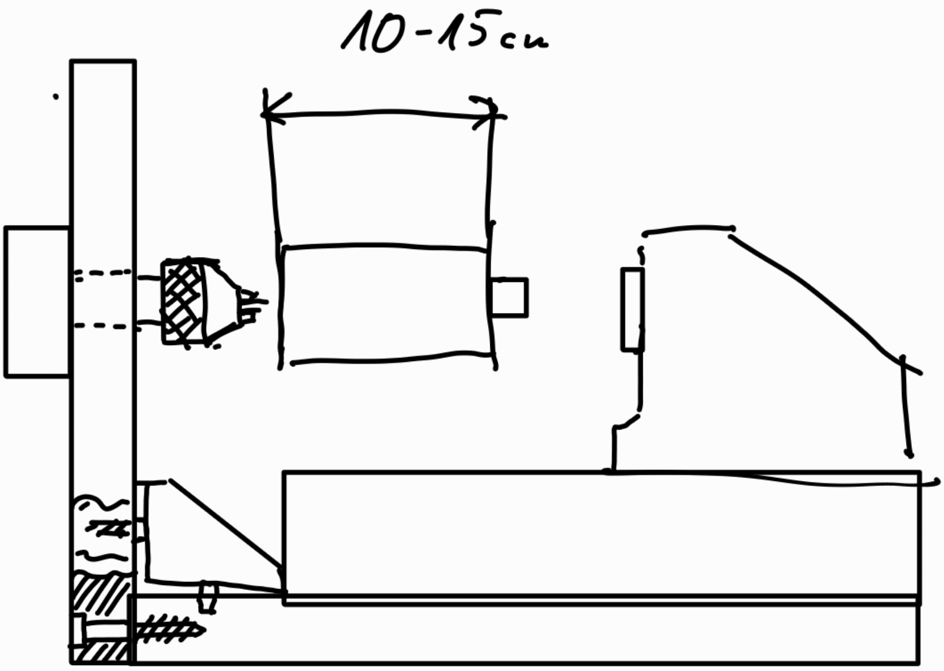
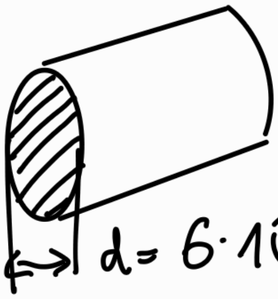


Spannsystem — 42 AWG $6\cdot10^{-2}$ mm – $5\cdot10^{-1}$ mm

bis 28.04

Resistance:
6.046 Ω/m



$d = 6\cdot10^{-5}$ m

$\frac{F}{g} = m$

Tensile strength max: 210 MPa

Tensile strength Yield: 40-80 MPa

Dehngrenze

Maximale Kraft

d	Spannung
0,02 - 0,06	7,0 - 30 g
0,06 - 0,16	40 - 200 g
0,1 - 0,4	70 - 600 g

$$F_{max} = \frac{\pi d^2}{\cancel{4}} \cdot \cancel{40} \cdot 10^6$$

$$= \underline{\pi\, 36 \cdot 10^{-10}} \cdot 10^7$$

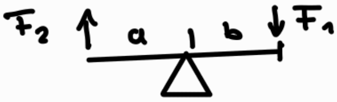
$$= \pi\, 3{,}6\ 10^{-2}$$

$$\approx 10^{-1}\ N = 100\ mN$$

$$- 200\ mN \nearrow \text{bei } 80\ MPa$$

$$\frac{(5\cdot10^{-4})^2 \cdot \pi\ 80\cdot10^6}{4}$$

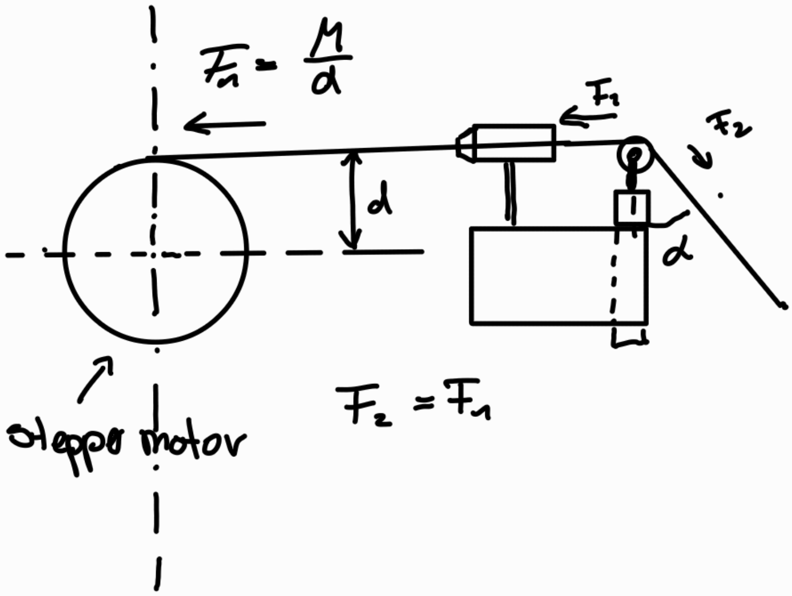
bei $5\cdot10^{-4}$ m | $25\ 10^{-8} \cdot \frac{\pi}{4}\ 20\cdot 10^{6}$ → $15{,}7$ N



$M = F_1 \cdot b$

$M = F_2 \cdot a$

$F_2 = \frac{F_1 b}{a} \to \frac{M}{a} = F$



$\Rightarrow$

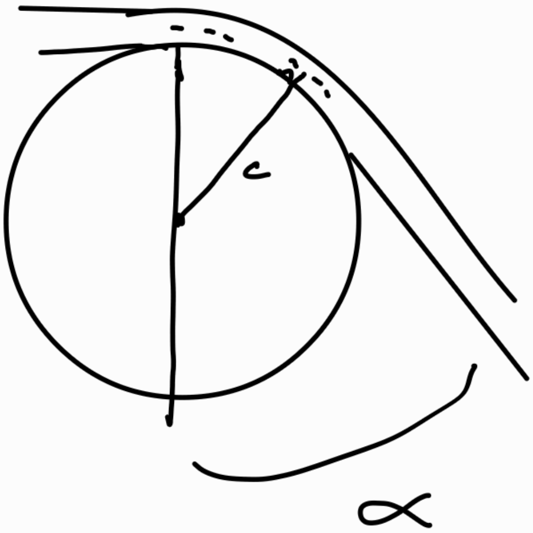
Biegespannung der Rollen

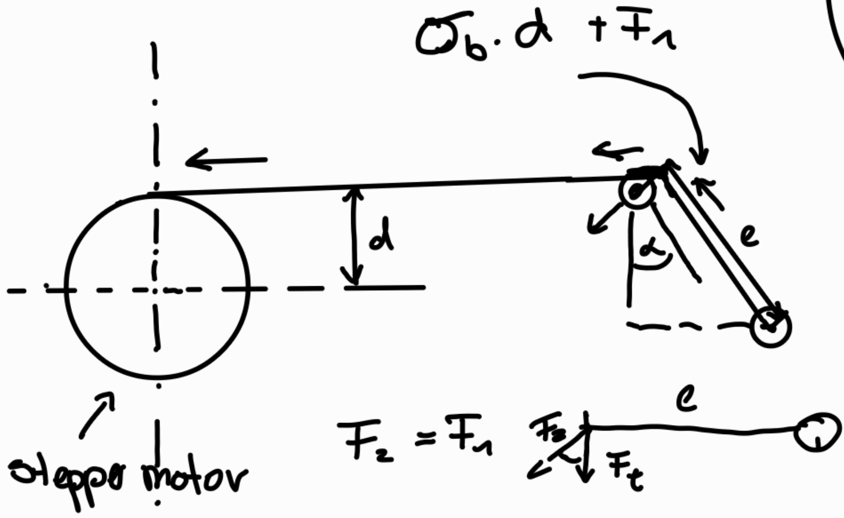
$r = 10^{-2}\,m$

$M = F_1 \cdot r$

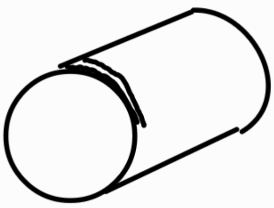
$\sigma_b = \frac{M_b}{W}$

$\sigma = \frac{\delta\ D}{D}$





$M = F_t \cdot e$



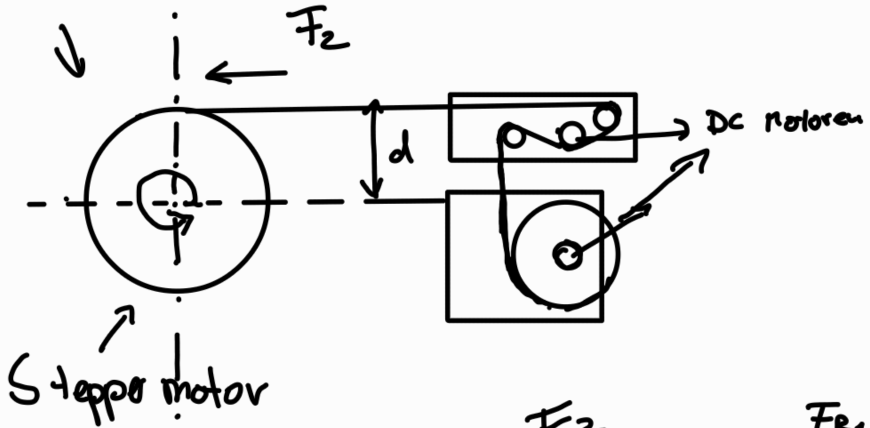
Wheel encoder

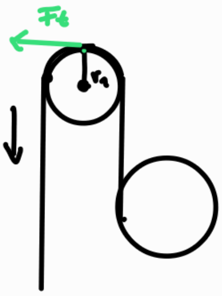
$\sigma_x = \frac{F_x}{A}$

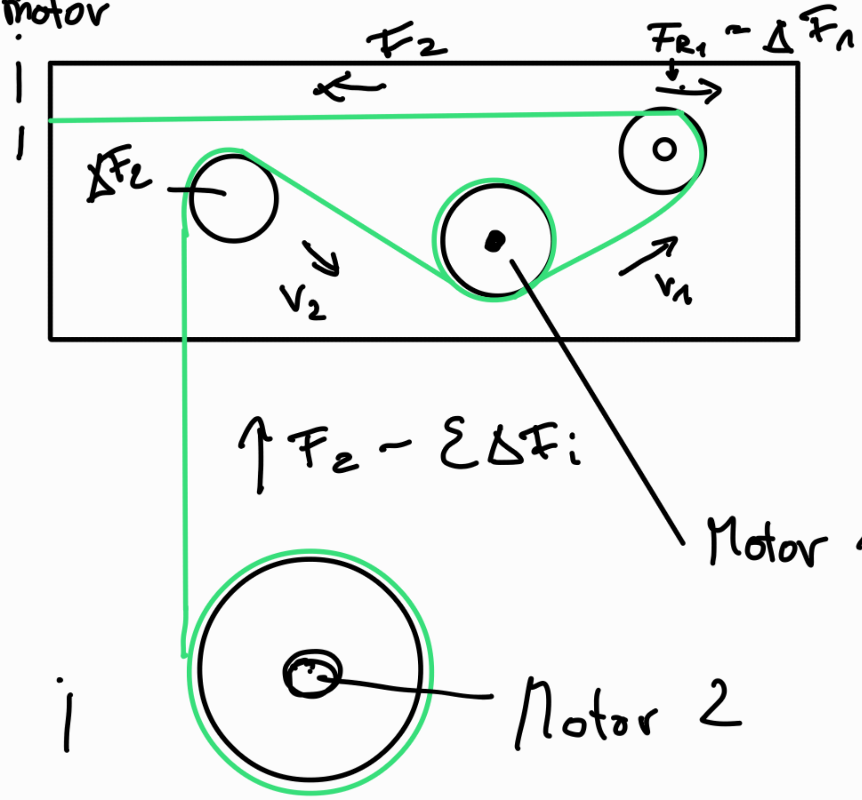
$\vec{M} = \vec{r} \times \vec{F}$ $\frac{M}{r} = F_2$

$M = I\omega \Rightarrow \frac{F_r}{I} = \omega$

$M = F_r r_1$







Grundspannung

$\sigma_G = \frac{\sum \Delta F_i}{A}$

$r \;\Big|\;$ Wälzlager $\eta = 97\%$

$\frac{F}{F + \Delta F}$

Shopping List:

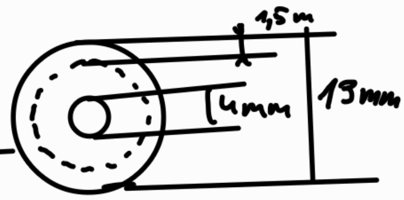
RPM-controll

2x DC Motoren → mit IC L298 Bridge

Piezo-Drucksensor – wahrscheinlich teuer und zu ungenau

Drehmomentsensor

Einfachere Umsetzung mit Feder



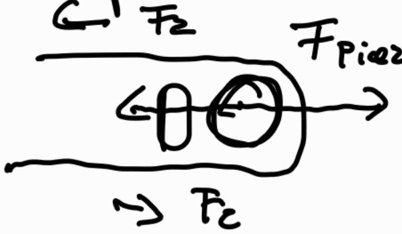
Rillenkugellager → vorzugsweise aus Kunststoff

→ z.B. V624ZZ ⇒ V-Nut

ca. 8 €

Piezoelement → Ladung → Stromfluss aufgrund Kraft ein Wirkung

Vereinfacht



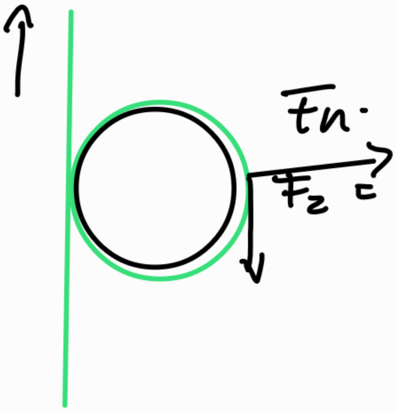
$F_{piezo} = 2F_z$

$\frac{F_{piezo}}{2} = F_z$

↗ über einem bestimmten Schwellen wert

↓

Motor1 regelt die Geschwindigkeit nach → schneller



$F_z - F_{verlust} =$

$s = \sqrt{x_1^2 + x_2^2 - 2x_1x_2\cos(\gamma)}$

$F_s = -k\Delta s$

$\Delta s = s - s_0$

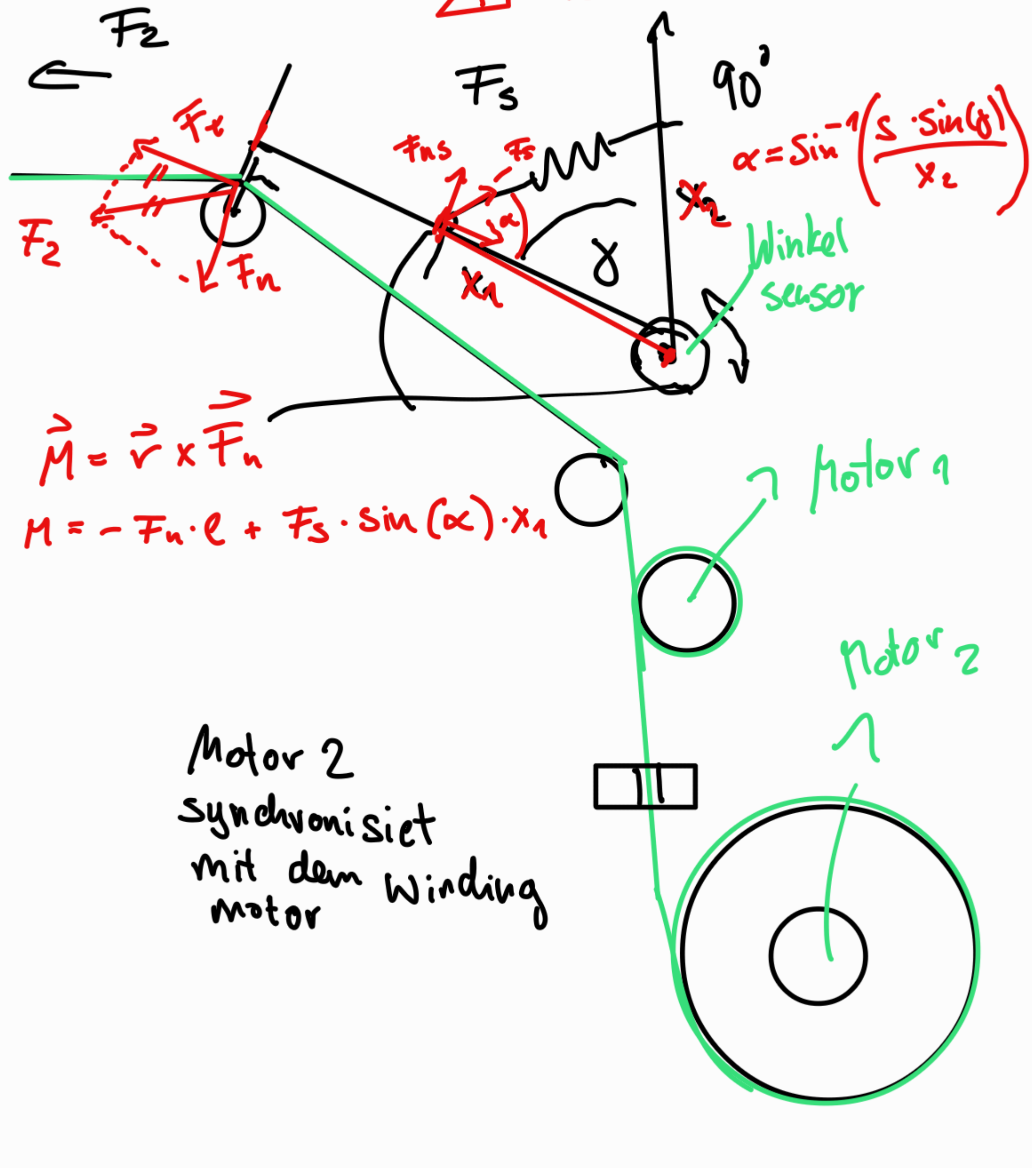
$\frac{G}{H} = \sin$

Proximity sensor for spring pos → back tension controll

Rotary Sensor for main tension control

Stepper direction

Servo pulse and direction



$\alpha = \sin^{-1}\left(\frac{s \cdot \sin(\gamma)}{x_2}\right)$

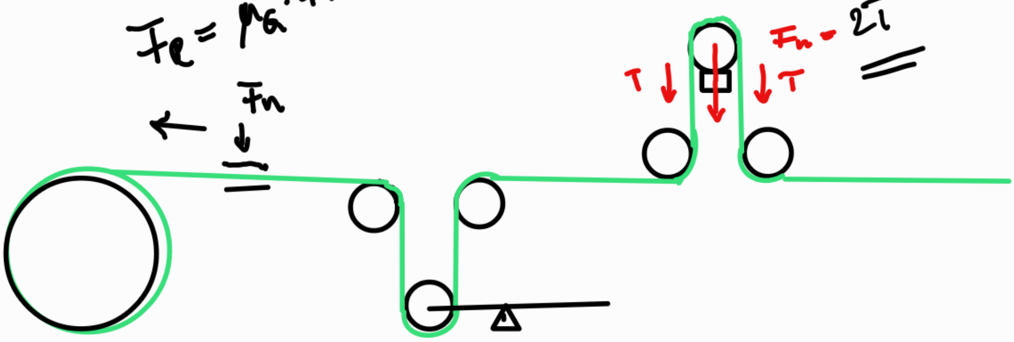
$\vec{M} = \vec{r} \times \vec{F_n}$

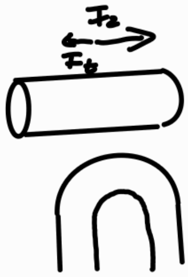
$M = -F_n \cdot l + F_s \cdot \sin(\alpha) \cdot x_1$

$F_n = 2T$

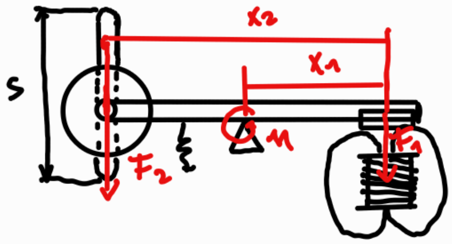
Motor 2 synchronisiert mit dem Winding motor

$$F_R = \mu_G \cdot F_N \Rightarrow \sigma = \frac{F_R}{\pi r_{Draht}^2} \approx 100\text{-}200 \text{ mN}$$



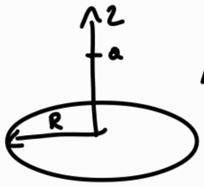


$$d\vec{l} = \frac{\partial}{\partial s}\vec{r}(s)$$



$F_1 = -F_{GE} - F_M$

$F_1 = F_M$



$$B = \frac{\mu I}{4\pi}\int \frac{d\vec{l} \times |\vec{r} - \vec{r}(s)|}{|\vec{r} - \vec{r}(s)|}$$

$$\vec{r}(s) = \begin{pmatrix} R\cos(\theta) \\ R\sin(\theta) \\ 0 \end{pmatrix} \Rightarrow \frac{\partial}{\partial s} = R \cdot \begin{pmatrix} -\sin(\theta) \\ \cos(\theta) \\ 0 \end{pmatrix}$$

$$F_2 = 2T$$

$$T_{max} = 200 \text{ mN}$$

$$M = F_M \cdot x_1$$

$$M = F_2 \cdot (x_2 - x_1)$$

$$F_M \cdot x_1 = F_2 (x_2 - x_1)$$

$$F_2 = \frac{x_1}{x_2 - x_1} F_M$$

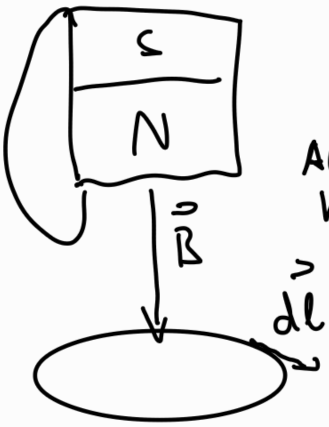
$$\vec{B} = \frac{\mu I}{4\pi} R^2 \int_0^{2\pi} \frac{\begin{pmatrix} -\sin(\theta) \\ \cos(\theta) \\ 0 \end{pmatrix} \times \begin{pmatrix} \cos\theta \\ \sin(\theta) \\ a \end{pmatrix}}{\left|R\begin{pmatrix} \cos\theta \\ \sin(\theta) \\ a \end{pmatrix}\right|^{3/2}} d\theta$$

$$= \frac{\mu I R^2}{4\pi} \int_0^{2\pi} \frac{\begin{pmatrix} a\cos\theta \\ +a\sin\theta \\ -(\sin^2(\theta) + \cos(\theta)^2) \end{pmatrix}}{(R^2 + a^2)^{3/2}}$$

$$B_z = \frac{\mu I R^2}{4\pi} \int^{2\pi} \frac{-1}{(R^2 + a^2)^{3/2}}$$

$$B_z = \frac{\mu I}{2} \frac{R^2}{(R^2 + a^2)^{3/2}} \Rightarrow \frac{\mu I n}{2} \frac{R^2}{(R^2 + a^2)^{3/2}}$$

$$F_L = I \int d\vec{l} \times \vec{B}$$



Annähernd konstant

$$\vec{l} = \begin{pmatrix} R\cos\alpha \\ R\sin\alpha \\ 0 \end{pmatrix}$$

$$\vec{B} = \begin{pmatrix} 0 \\ 0 \\ -B_H \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ -\mu\mu_0 H \end{pmatrix}$$

$$H = \frac{1}{\mu\mu_0}\vec{B}$$

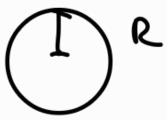
$$d\vec{l} = \begin{pmatrix} R\sin\alpha \\ -R\cos\alpha \\ 0 \end{pmatrix} d\alpha$$

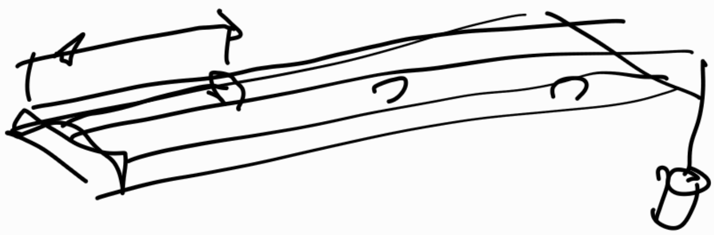
$$\vec{F}_L = I \int \begin{pmatrix} R\sin\alpha \\ -R\cos\alpha \\ 0 \end{pmatrix} \times \begin{pmatrix} 0 \\ 0 \\ -\mu\mu_0 H \end{pmatrix} d\alpha$$

$$\vec{F}_L = I \int_0^{2\pi} \begin{pmatrix} +\mu\mu_0 H \cdot R\cos\alpha \\ \mu\mu_0 H \cdot R\sin\alpha \\ 0 \end{pmatrix} d\alpha$$

1 Stepper   Holding Torque = 150 Ncm

$M = 350\,g \cdot cm^2$





$M = m_1 + m_2$

$F_{ges} = M \cdot a$

$F_{ges} = \sum F_i$

red. Masse

$T = \mu g$

$F_g = -g m_2$

$T = m_1 a_x$

$\sum F_y = T - m_2 g$ ← F_g

$-m_2 a_2 = T - m_2 g$

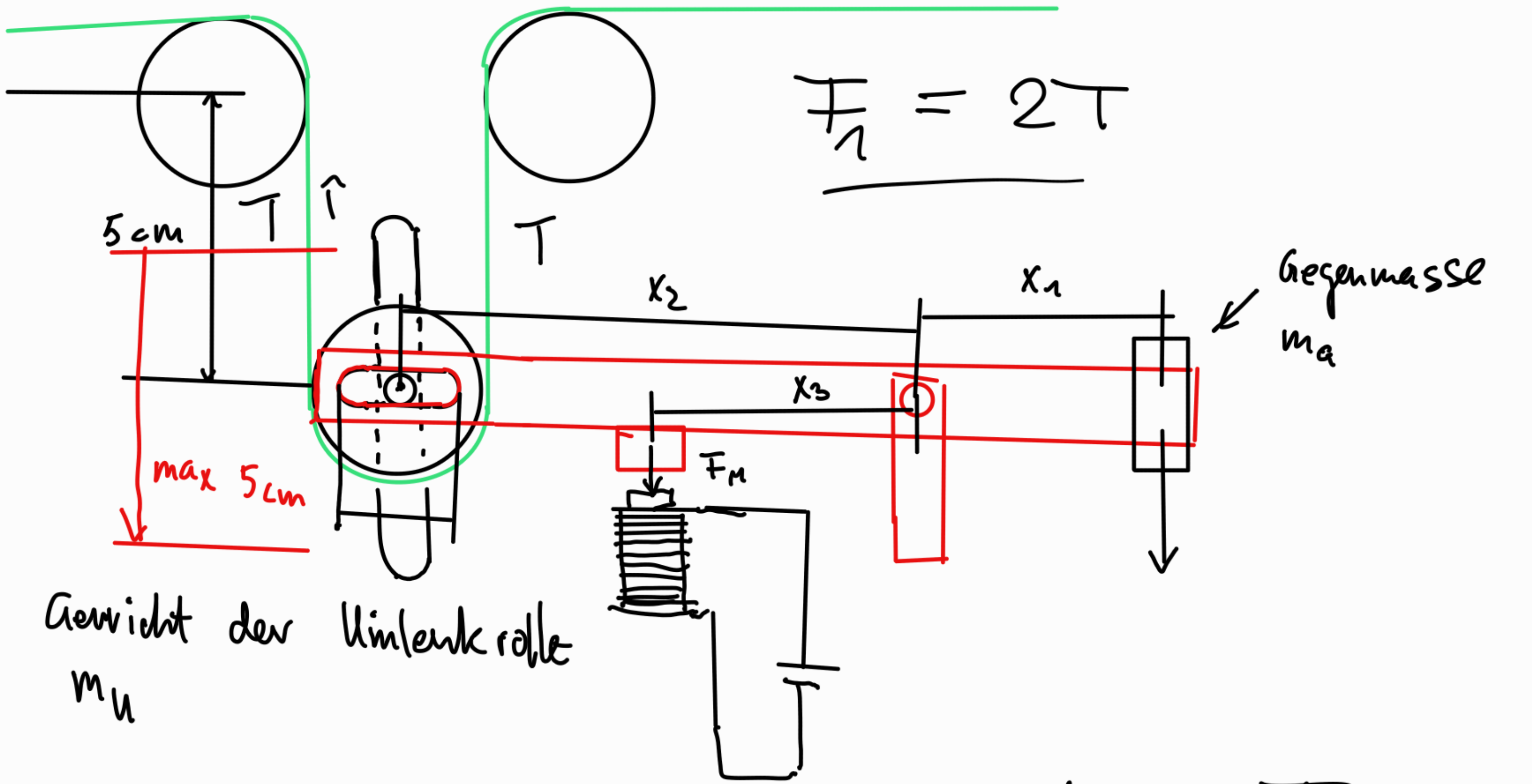
$T = m_2(g - a_y)$

$m_1 a = m_2 (g - a)$

$m_1 a + m_2 a = m_2 g$

$a = \frac{m_2 \cdot g}{m_1 + m_2}$

Finales Konzept:



$$\underline{F_1 = 2T}$$

$$M_1 = F_{ga} \cdot x_1 + F_1 \cdot x_1$$

$$M_2 = F_M \cdot x_3 + F_{gu} \cdot x_2$$

$$M = M_1 + M_2$$

$$M_M = F_M \cdot x_3$$

$$M_M = F_1 \cdot x_2$$

$$F_1 = \frac{x_3}{x_2} F_M$$

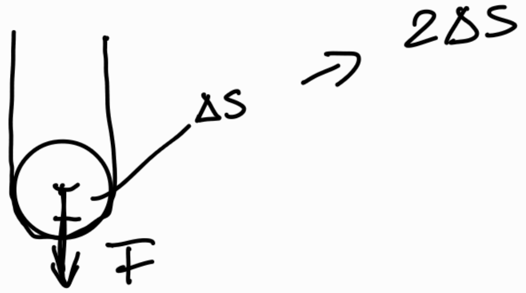
$$F_1 = \underbrace{F_{gu} + \frac{x_1}{x_2} F_{ga}} + \frac{x_3}{x_2} F_M = 2T$$

Piezo $\Rightarrow$ U $\longrightarrow$ PID

$F_M \propto I$

PID $\longrightarrow$ $I \pm \Delta I$ $\longrightarrow$ F_M $\longrightarrow$ Piezo

$V(t)$ - Drahtgeschwindigkeit



$B \propto x$

Abstand des Magneten!

für $M=0$ $M = F_{gU} \cdot x_2 = F_{gA} \cdot x_1$

$$F_{gA} = \frac{x_2}{x_1} F_{gU}$$

$$M_1 = F_{gA} \cdot x_1$$

$$M_2 = F_{gU} \cdot x_2 + F_M \cdot x_3$$

Grundspannung 20g

$M_1 = F_{gA} \cdot x_1 \Rightarrow F_2 = \frac{x_1}{x_2} F_{gA}$

$$0{,}4\ N = F_{gU} - F_2$$

$$2T = 0{,}4\ N = F_{gU} - \frac{x_1}{x_2} F_{gA}$$

$$\frac{(F_{gU} - 0{,}2) \cdot x_2}{F_{gA}} = x_1$$

$$x_1 = \frac{(F_{gU} - 2T)\, x_2}{F_{gA}}$$