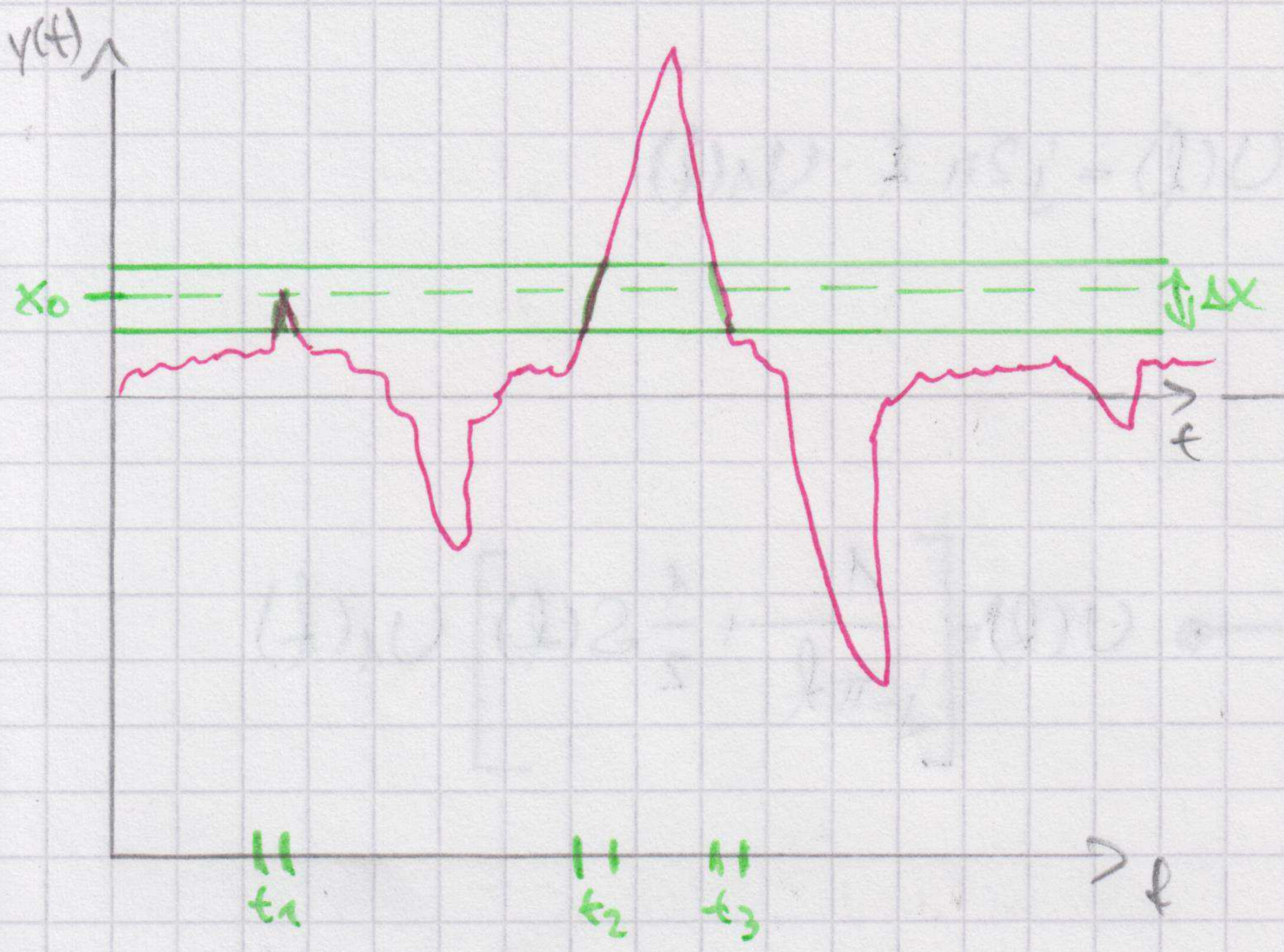
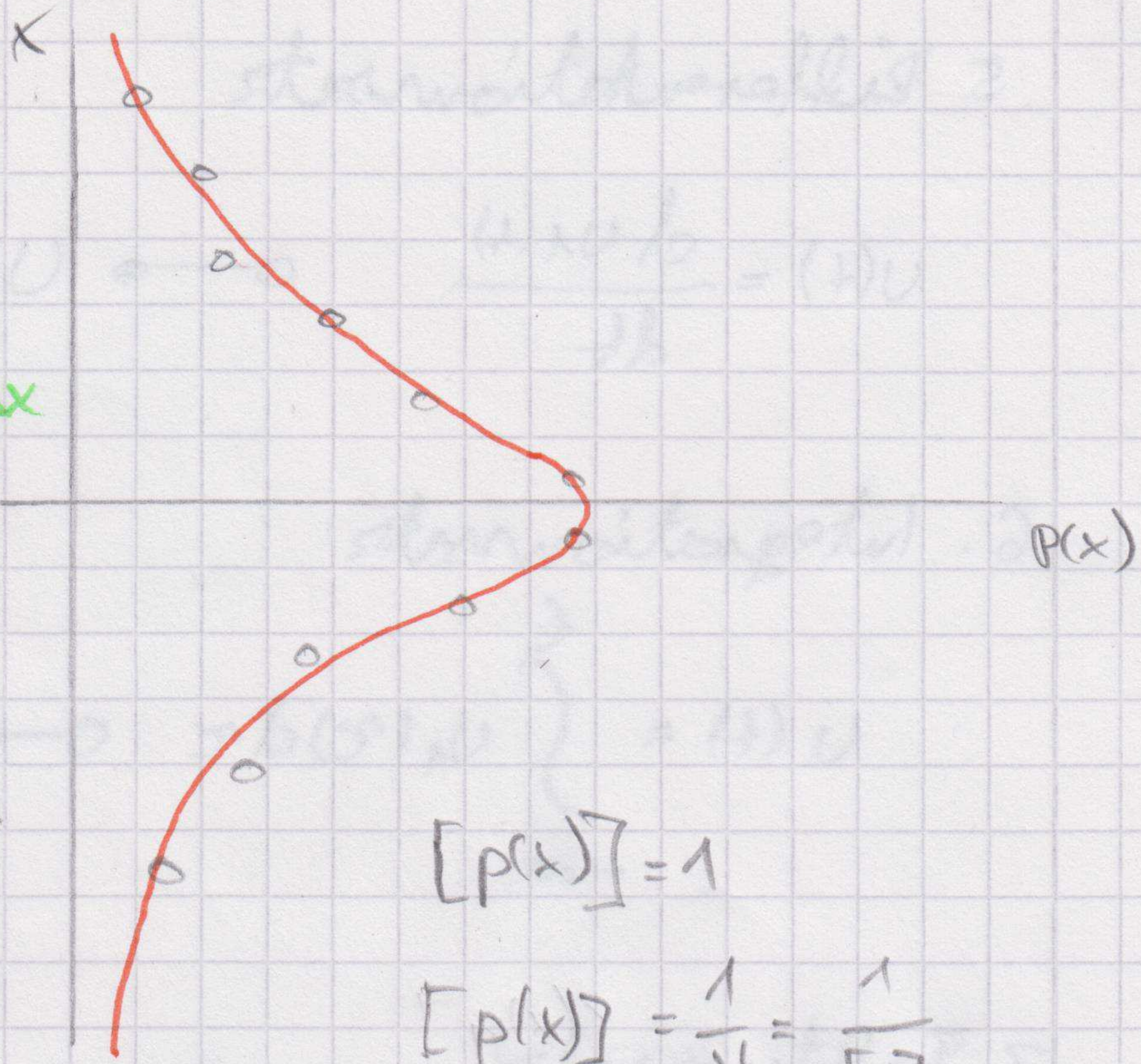




$$[p(x)] = 1$$

$$[p(x)] = \frac{1}{V} = \frac{1}{[x]}$$

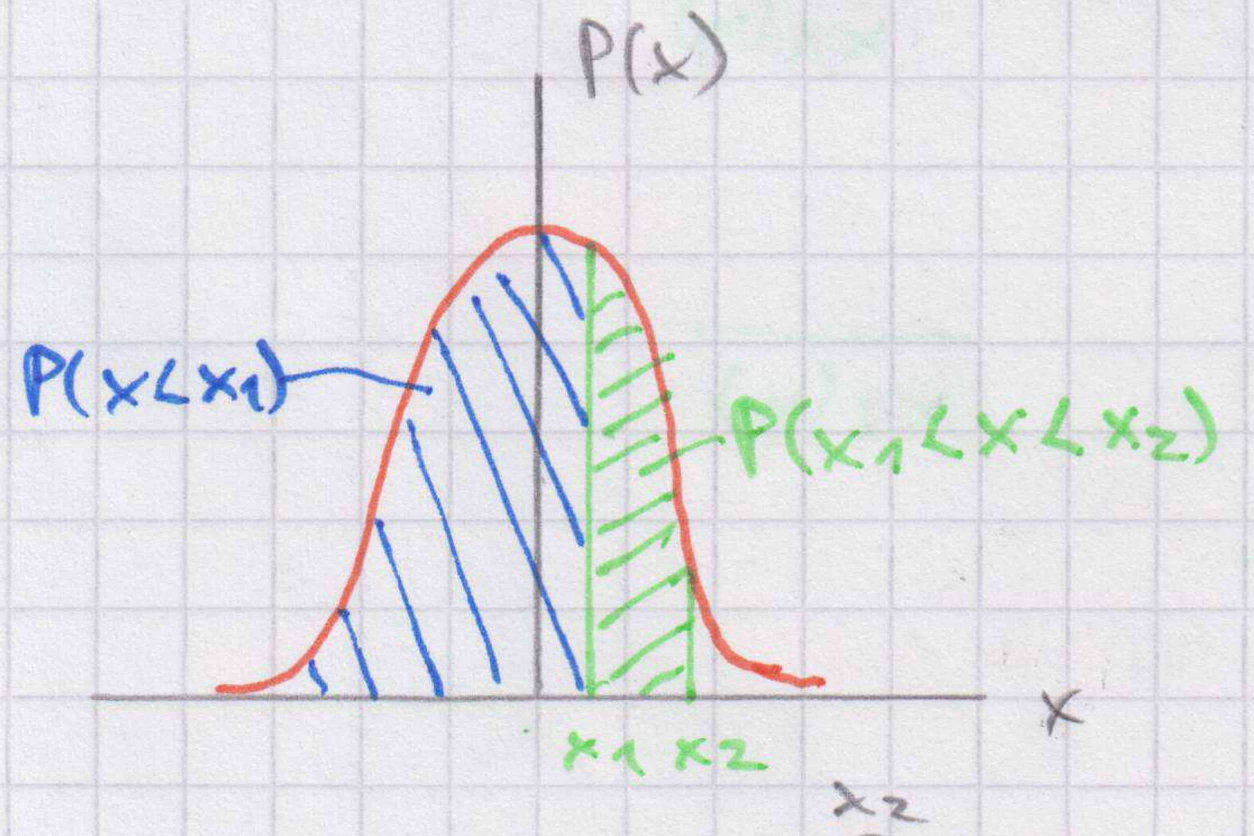
ges. Wahrscheinlichkeit für die Amplituden

$$P\left(x_0 - \frac{\Delta x}{2} < x(t) < x_0 + \frac{\Delta x}{2}\right) = \frac{t_1 + t_2 + t_3 + t \ldots}{\text{Gesamtzeit} (\to \infty)}$$

Grenzübergang für $\Delta x \to 0$ $\qquad$ $P(x) \to 0$

↳ Wahrscheinlichkeitsdichte

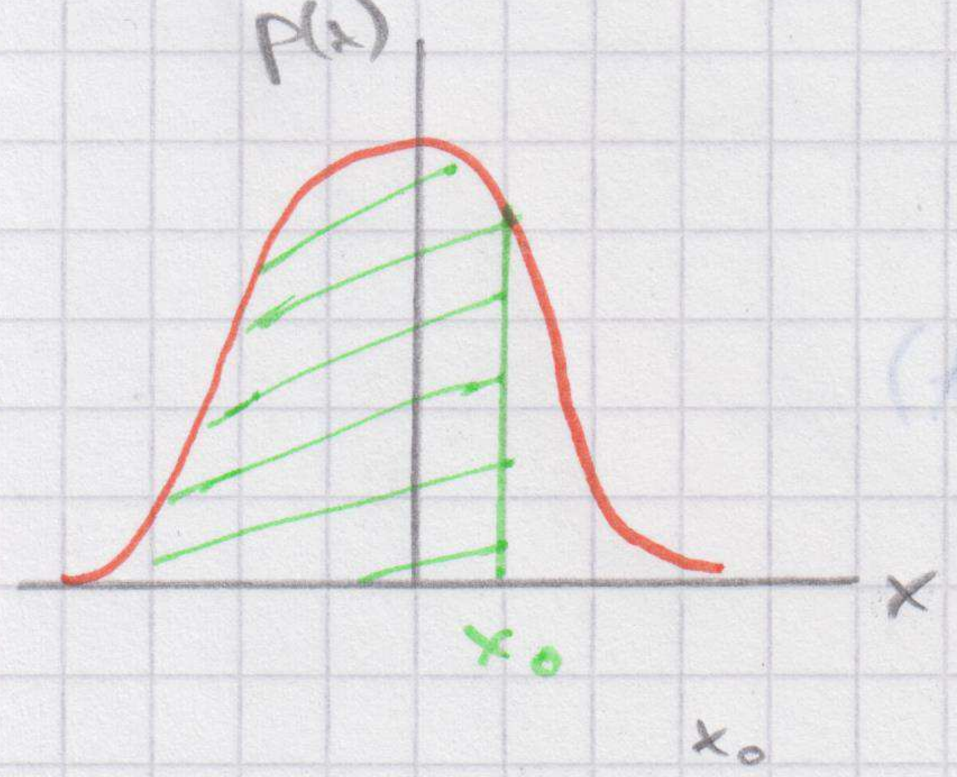
$$p(x) = \lim_{\Delta x \to 0} \frac{P\left(x_0 - \frac{\Delta x}{2} < x < x_0 + \frac{\Delta x}{2}\right)}{\Delta x}$$

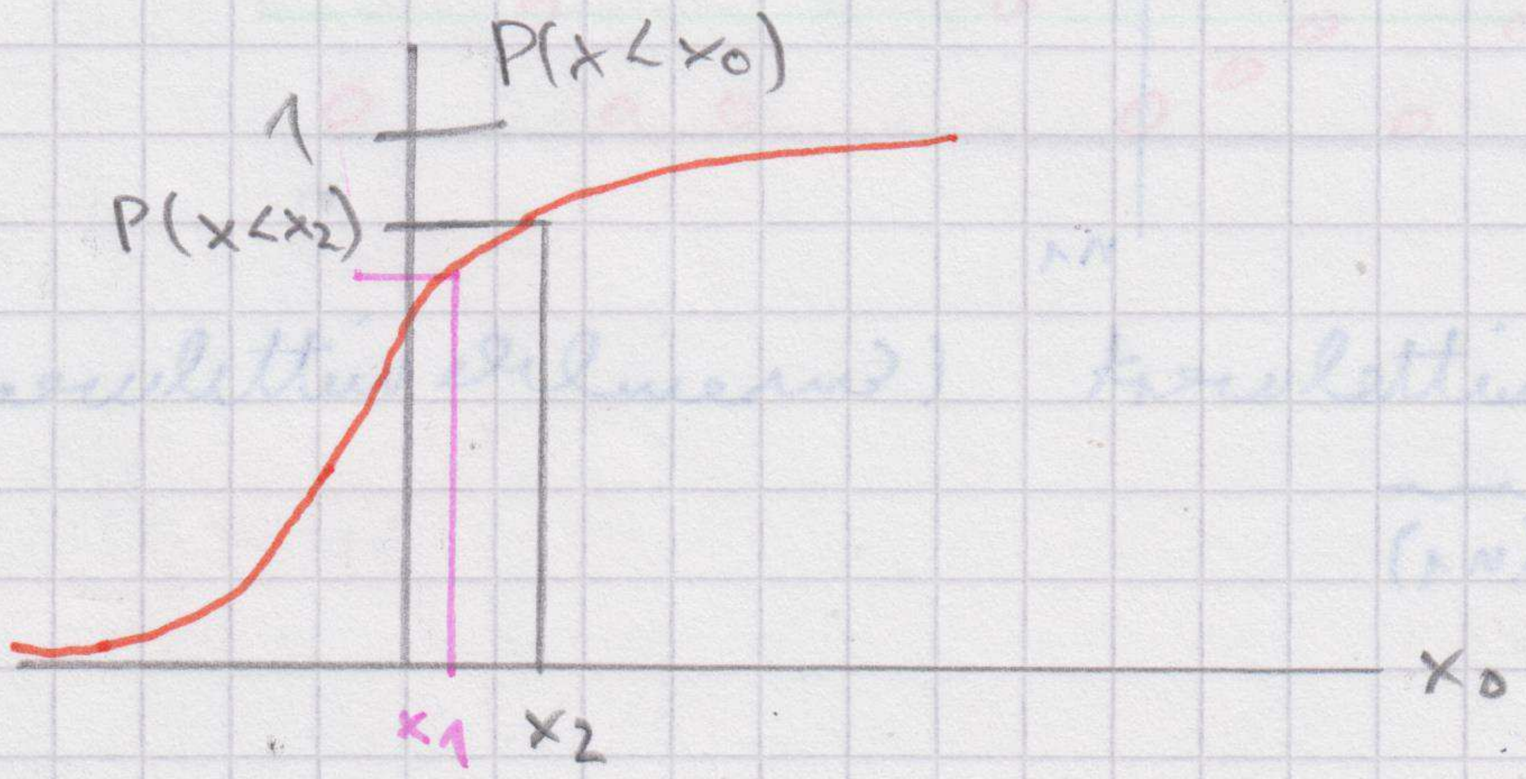


$$\sum_{i=1}^{\infty} p(x_1) = 1$$

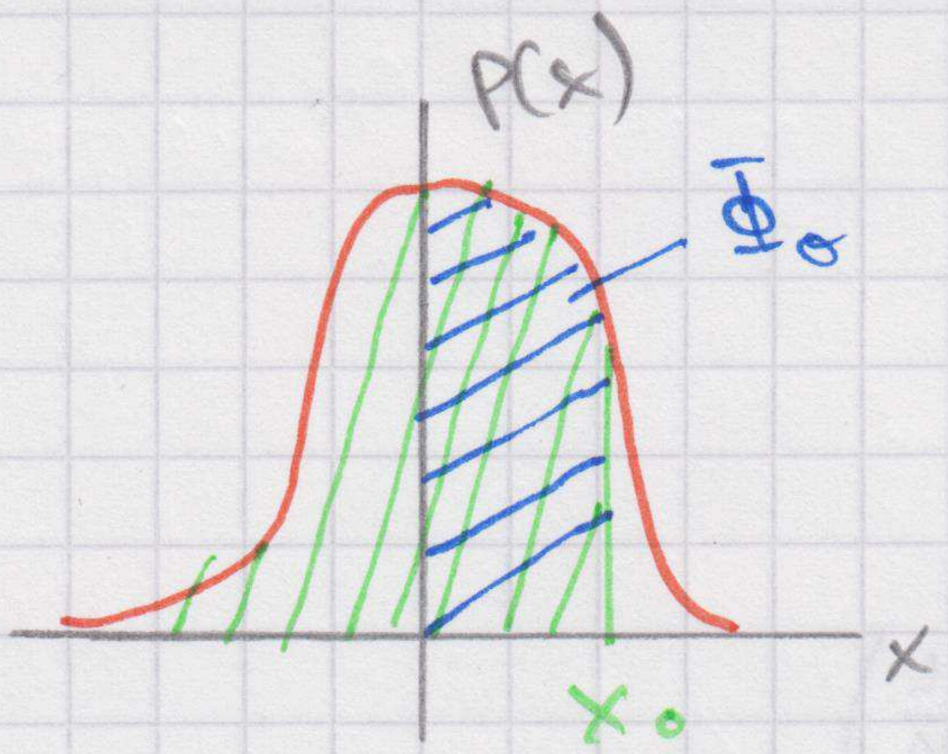
$$\int_{-\infty}^{\infty} p(x)\,dx = 1$$

$$P(x_1 < x < x_2) = \int_{x_1}^{x_2} p(x)\,dx = P(x < x_2) - P(x < x_1)$$





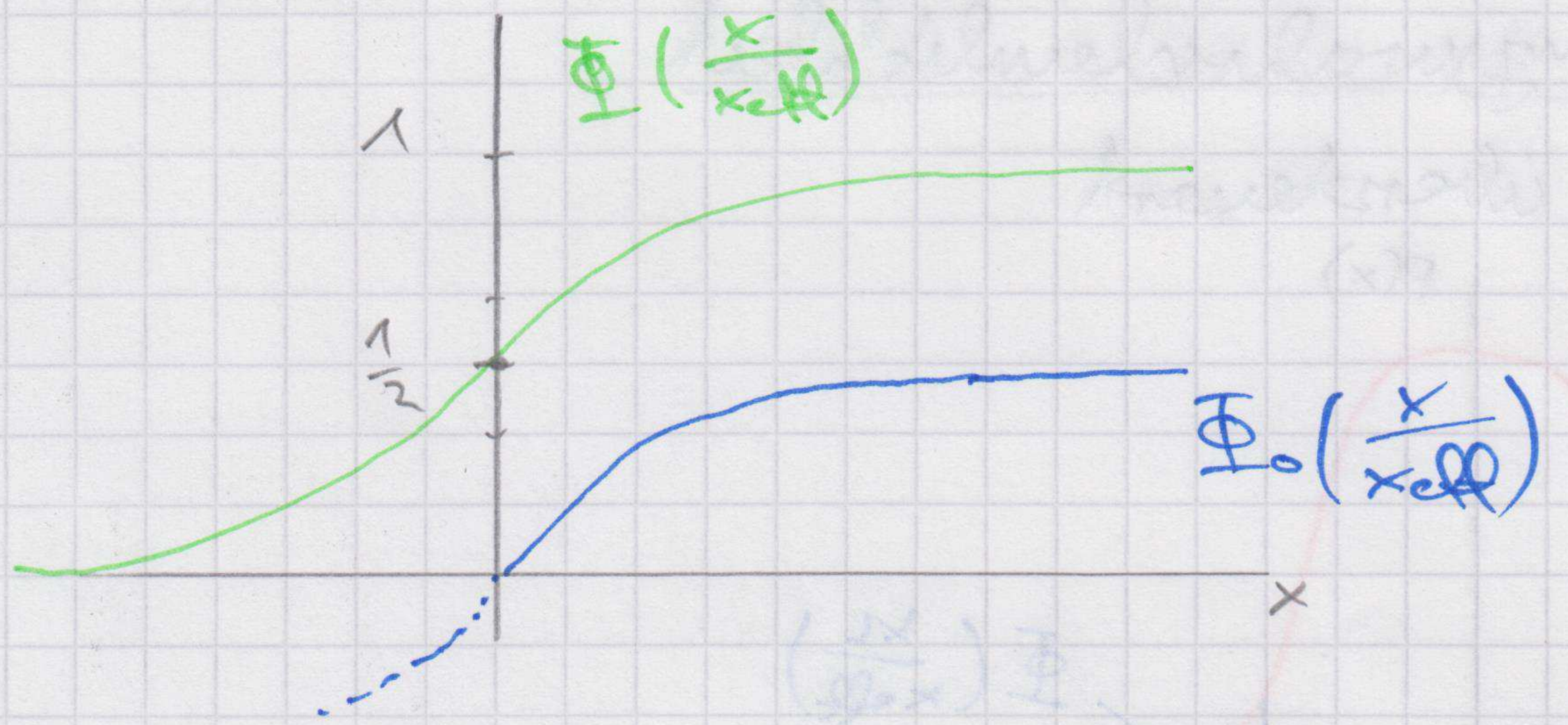
$$P(x < x_0) = \int_{-\infty}^{x_0} p(x)\,dx$$



Zentrierte Gaußverteilung
$(a = x_a = 0)$

$$P(x < x_0) = \int_{-\infty}^{x_0} \frac{1}{\sqrt{2\pi}\, x_{eff}}\, e^{-\frac{x^2}{2 x_{eff}^2}}\, dx = \int_{-\infty}^{x_0} p(x)\, dx$$

$$= \Phi\left(\frac{x_0}{x_{eff}}\right)$$ "Gauß'sches Fehlerintegral"



Einseitiges Gauß'sches Fehlerintegral

$$\Phi_0\left(\frac{x_0}{x_{eff}}\right) = \Phi\left(\frac{x}{x_{eff}}\right) - \frac{1}{2} = \int_0^{x_0} p(x)\, dx$$

Casio-Rechner:

$P(x) = \Phi(x)$

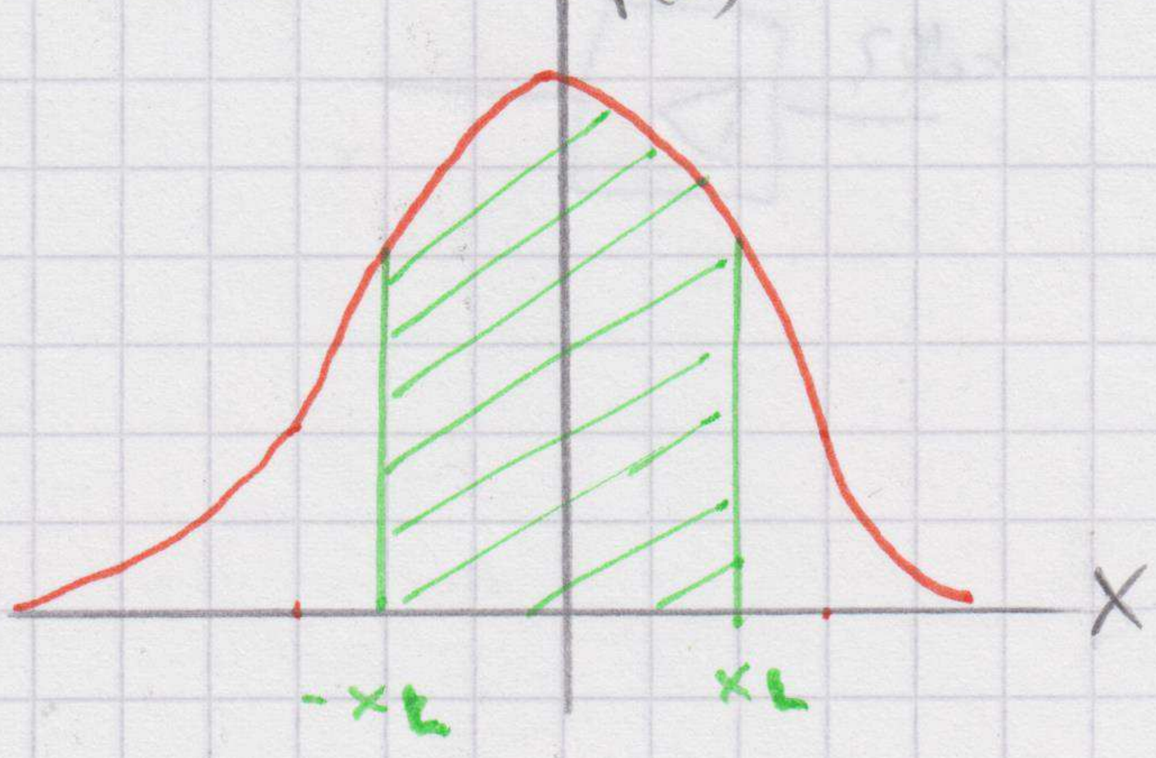
$Q(x) = |\Phi_0(x)|$

$R(x) = \Phi(-x)$

$$\Phi = \Phi_0 + \frac{1}{2}$$
$$\Phi_0(x) = -\Phi_0(-x)$$

Bereichswahrscheinlichkeit

Verstärker übersteuert nicht

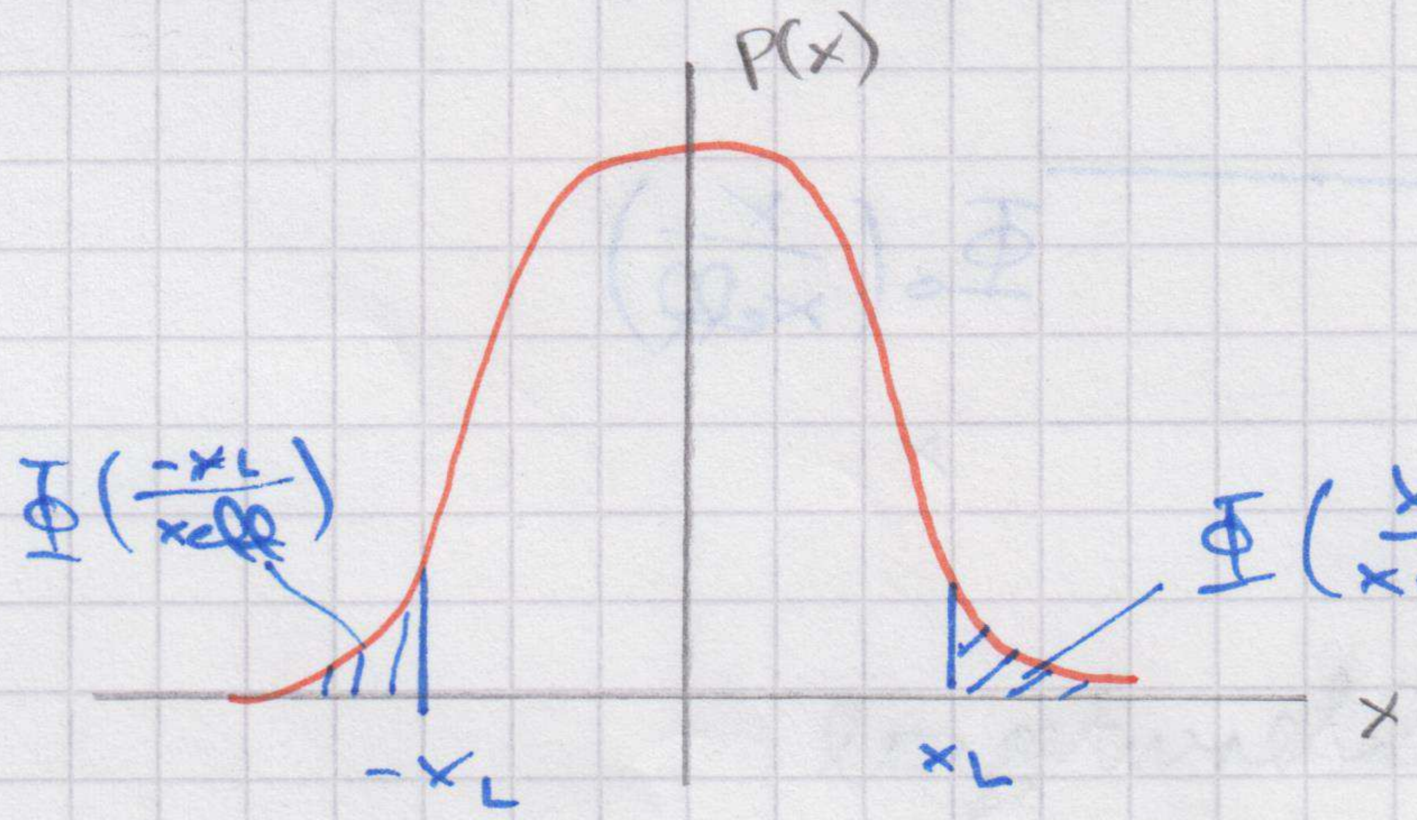


$$P(-x_L < x < x_L) = P(|x| < x_L)$$
$$= \int_{-x_L}^{x_L} p(x)\,dx$$
$$= \Phi\left(\frac{x_L}{x_{eff}}\right) - \Phi\left(\frac{-x_L}{x_{eff}}\right)$$
$$= \Phi_0\left(\frac{x_L}{x_{eff}}\right) - \Phi\left(\frac{-x_L}{x_{eff}}\right) = 2\,\Phi_0\left(\frac{x_L}{x_{eff}}\right)$$

<error function> $:= \mathrm{erf}\left(\frac{1}{\sqrt{2}} \cdot \frac{x_L}{x_{eff}}\right) \Leftarrow$ (Matheprogramme)

Überschreitungswahrscheinlichkeit

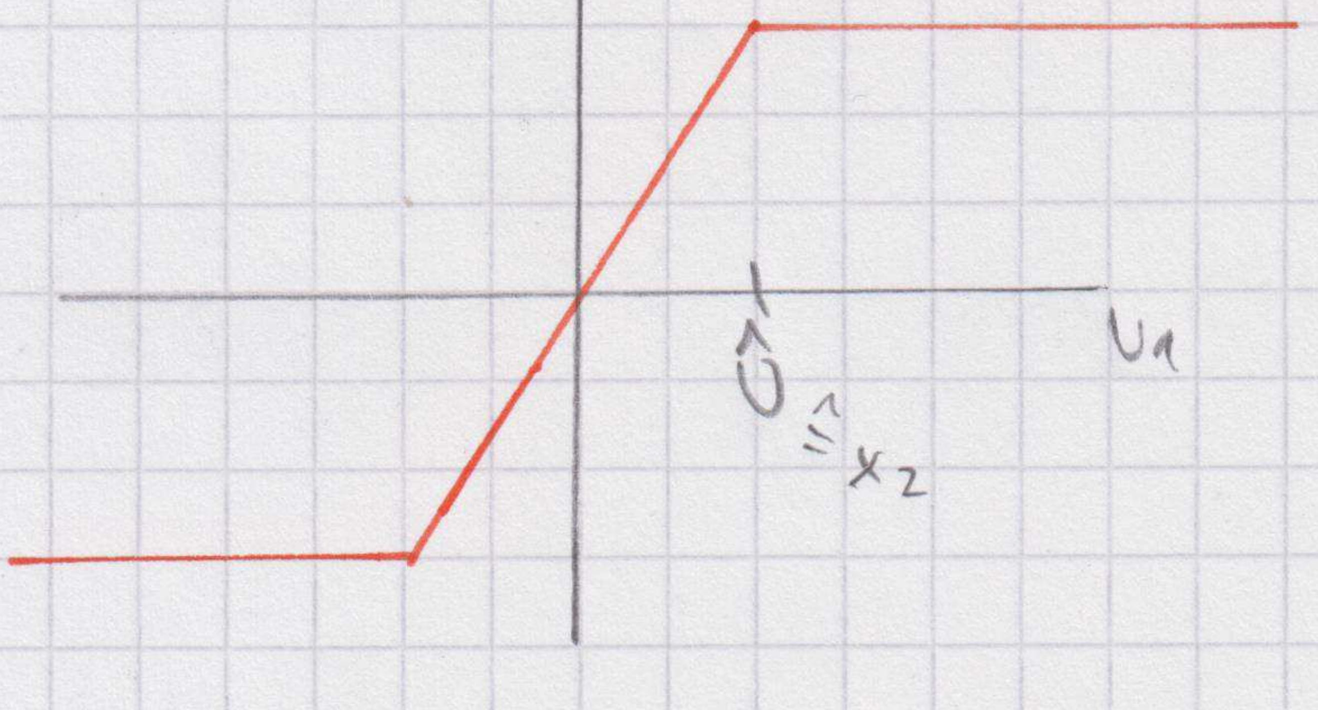
Verstärker übersteuert

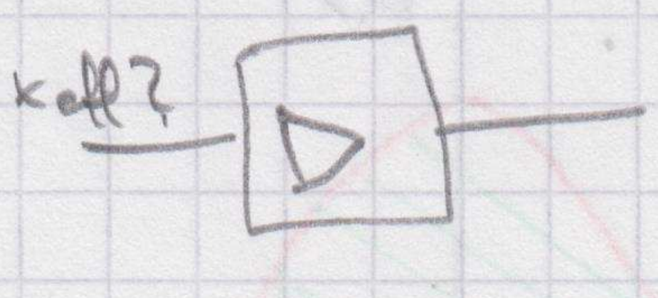


$$P(|x| > x_L) = \int_{-\infty}^{-x_L} p(x)\,dx + \int_{x_L}^{\infty} p(x)\,dx = 2\,\Phi\left(\frac{-x_L}{x_{eff}}\right)$$
$$= 1 - P(|x| < x_L) = 1 - 2\,\Phi_0\left(\frac{x_L}{x_{eff}}\right)$$
$$= \mathrm{erfc}\left(\frac{1}{\sqrt{2}} \cdot \frac{x_L}{x_{eff}}\right)$$

$\boxed{\mathrm{erfc}(x) = 1 - \mathrm{erf}(x)}$

Bsp: Übersteuerung eines Verstärkers





Übersteuerung $\leq 2\%$

|

Überschreitungswahrscheinlichkeit

$$P(x > \hat{U}) = 2\% = 0{,}02$$

$$\left.\begin{aligned} &\operatorname{erfc}\left(\frac{1}{\sqrt{2}} \cdot \frac{\hat{U}}{U_{n,eff}}\right) = 0{,}02 \\ &\frac{1}{\sqrt{2}} \cdot \frac{\hat{U}}{U_{n,eff}} \approx 1{,}645 \end{aligned}\right\} \text{aus Diagramm}$$

$$U_{n,eff} \approx \frac{\hat{U}}{1{,}645\sqrt{2}} = \frac{2V}{1{,}645 \cdot \sqrt{2}} \approx 0{,}86V$$

Mittelwerte

MW 1. Ordnung (Gleichanteil)

$$\overline{x(t)} = \lim_{T\to\infty} \frac{1}{T} \int_T x(t)\, dt = X_=$$

MW 2. Ordnung (Effektivwert^2)

$$\overline{x^2(t)} = \lim_{T\to\infty} \frac{1}{T} \int_T x^2(t)\, dt = x_{eff}^2$$

↓

Mittlere Gesamtleistung $P = \frac{x_{eff}^2}{R}$

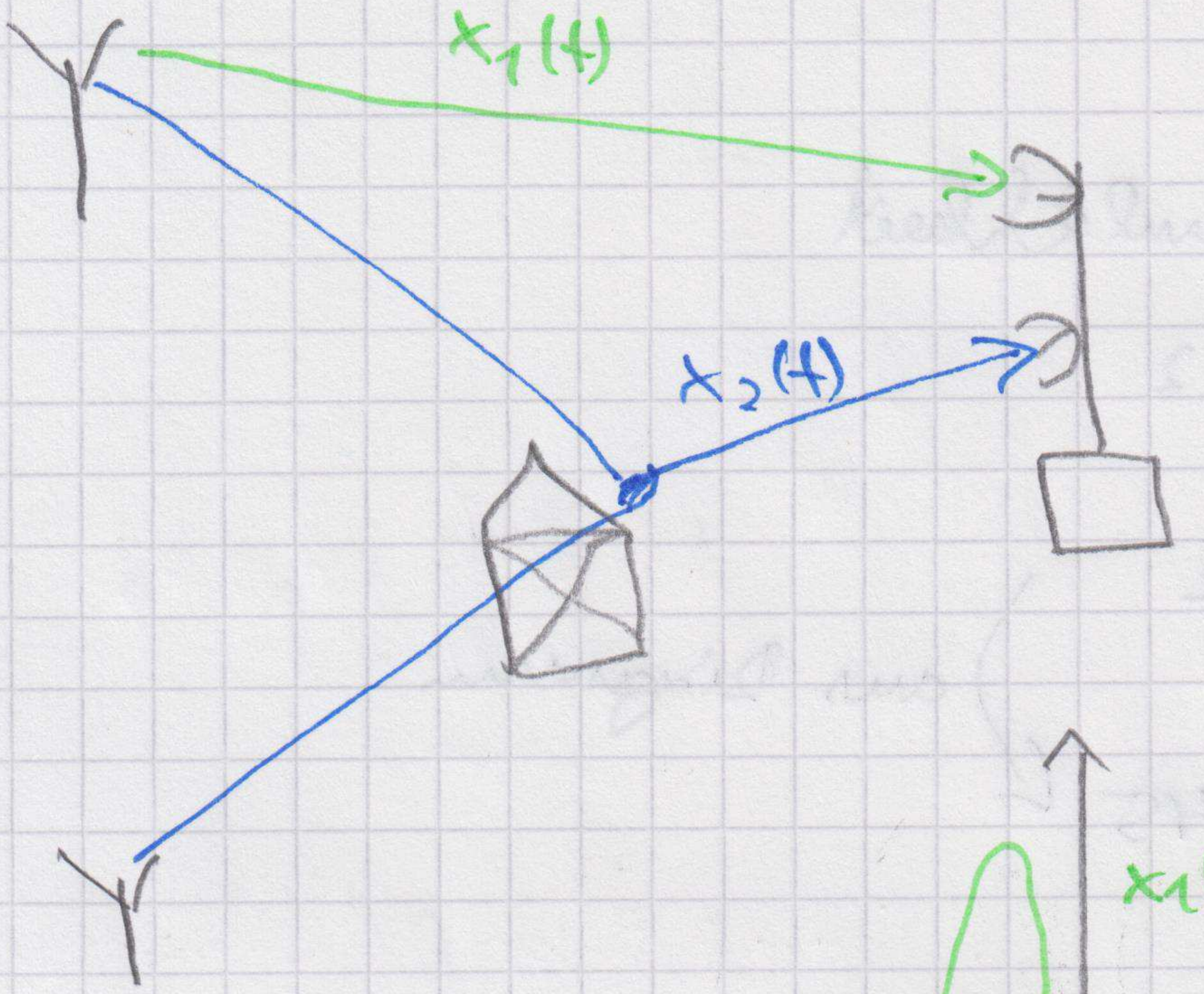
↳ Scharmittelwert / Ensemble

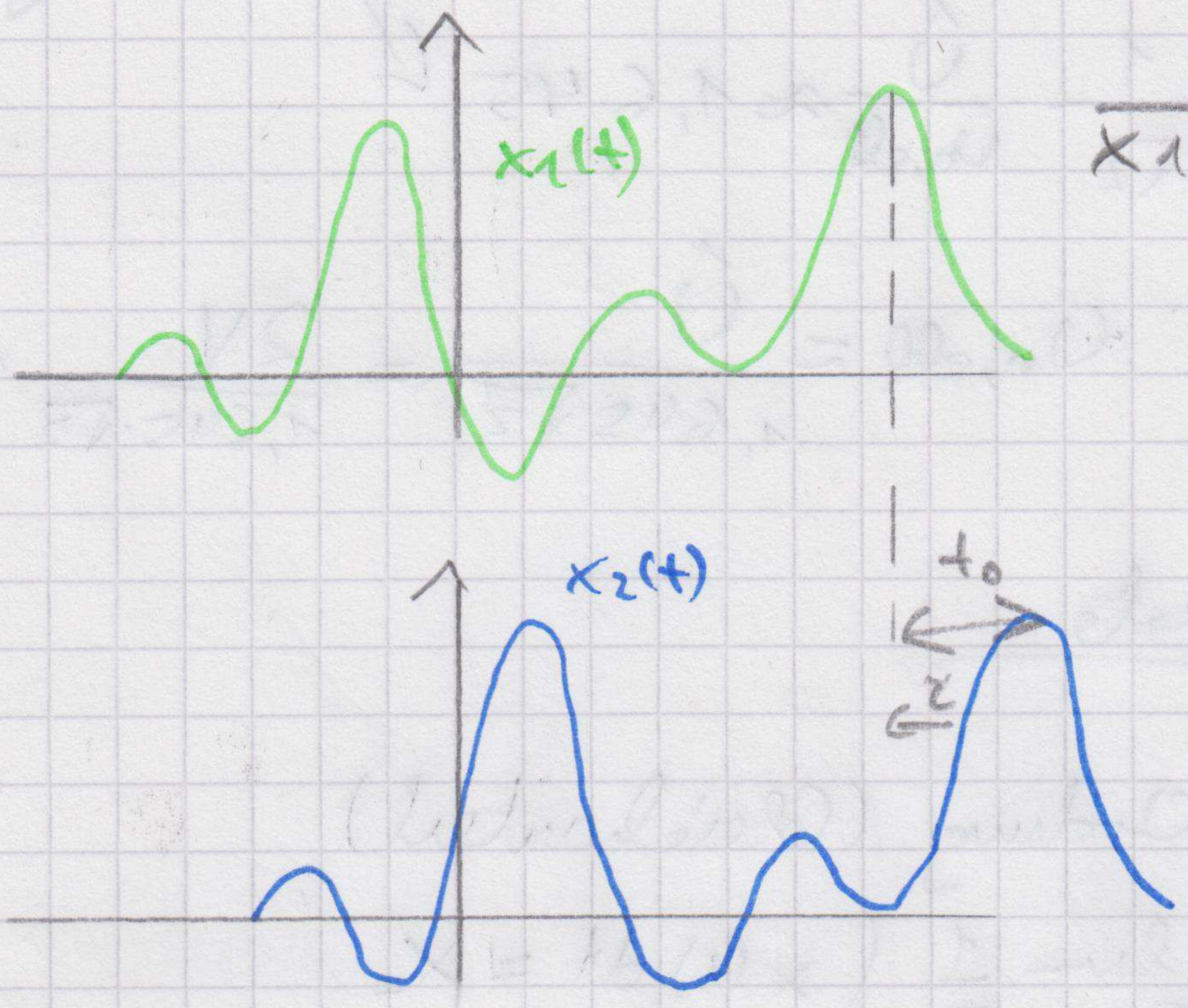
Moment 1. Ordnung

$$\widetilde{x(t)} = \int_{-\infty}^{\infty} x \cdot p(x)\, dx \qquad (= \overline{x(t)} \text{ weil ergodisch})$$

Moment 2. Ordnung

$$\widetilde{x^2(t)} = \int_{-\infty}^{\infty} x^2\, p(x)\, dx$$





$\overline{x_1(t)} = 0$

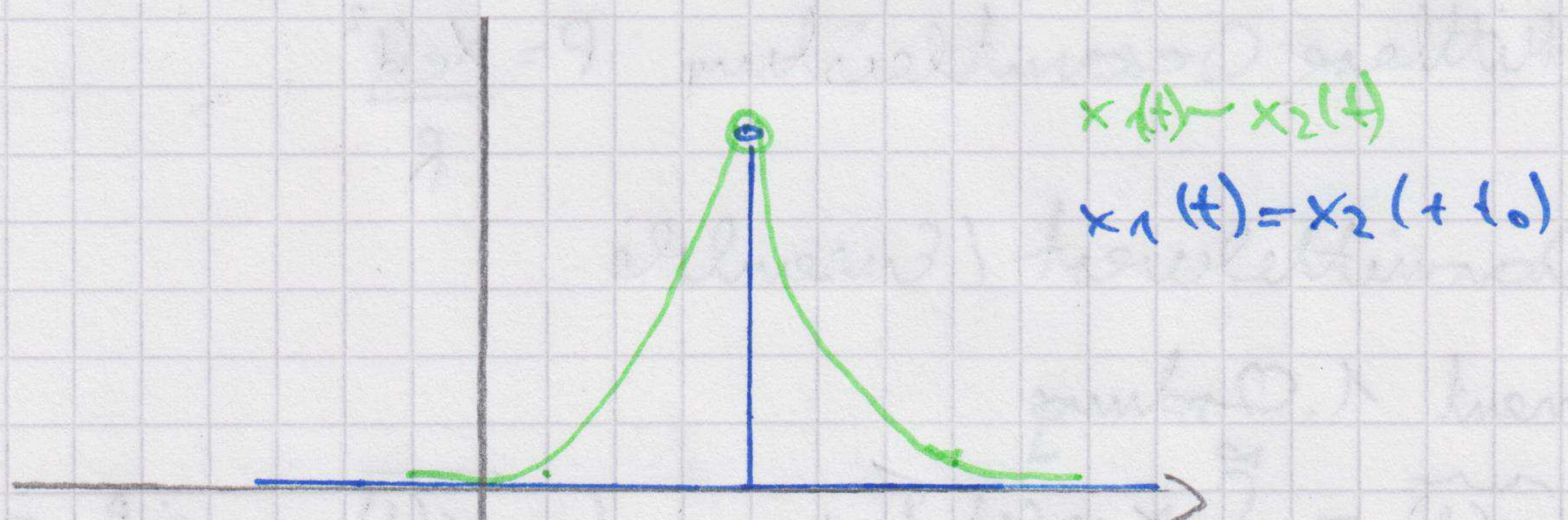
$\overline{x_2(t)} = 0$

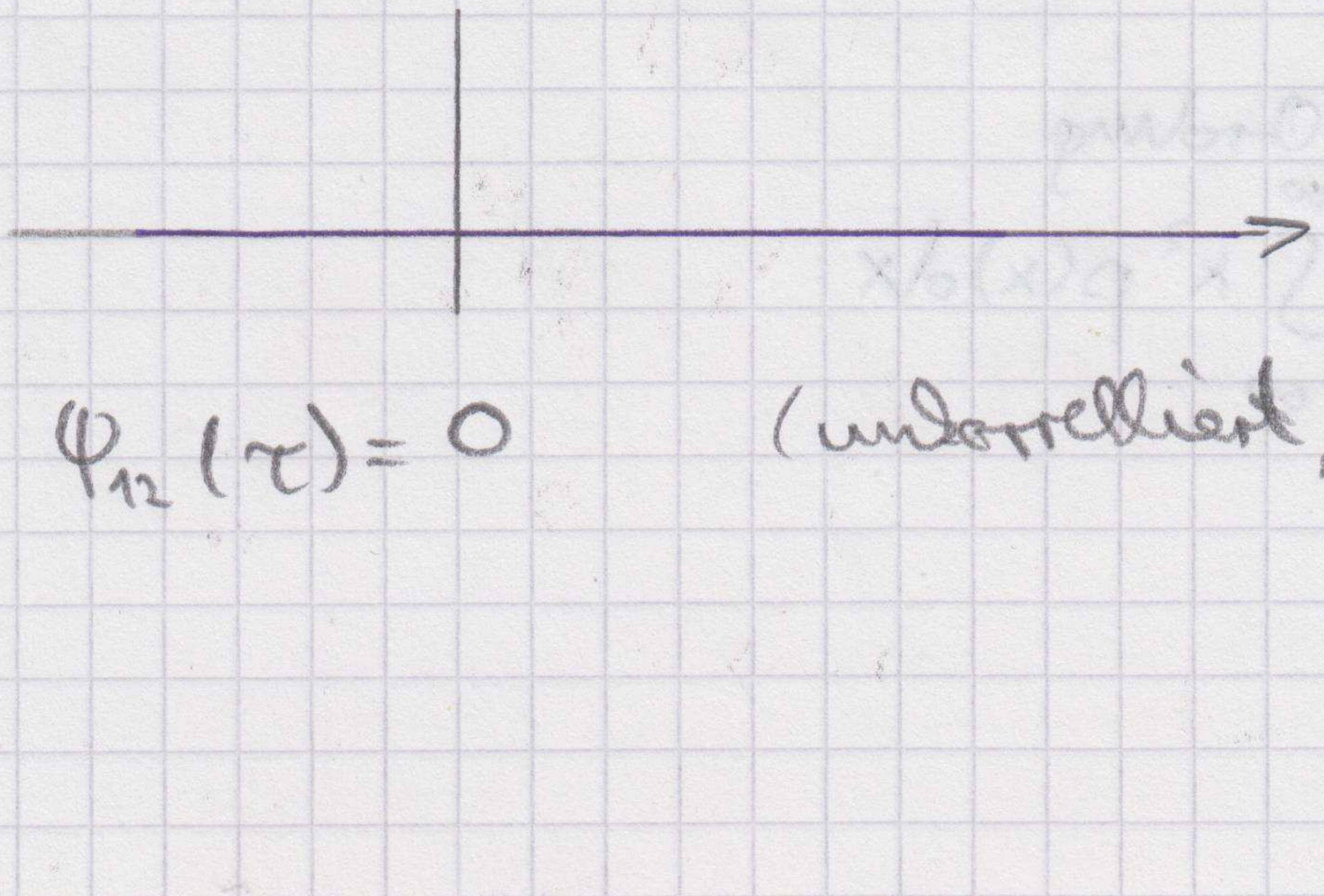
Bsp: $x_2(t) = x_1(t - t_0)$

$$\psi_{12}(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_T x_1(t)\, x_2(t+\tau)\, dt$$

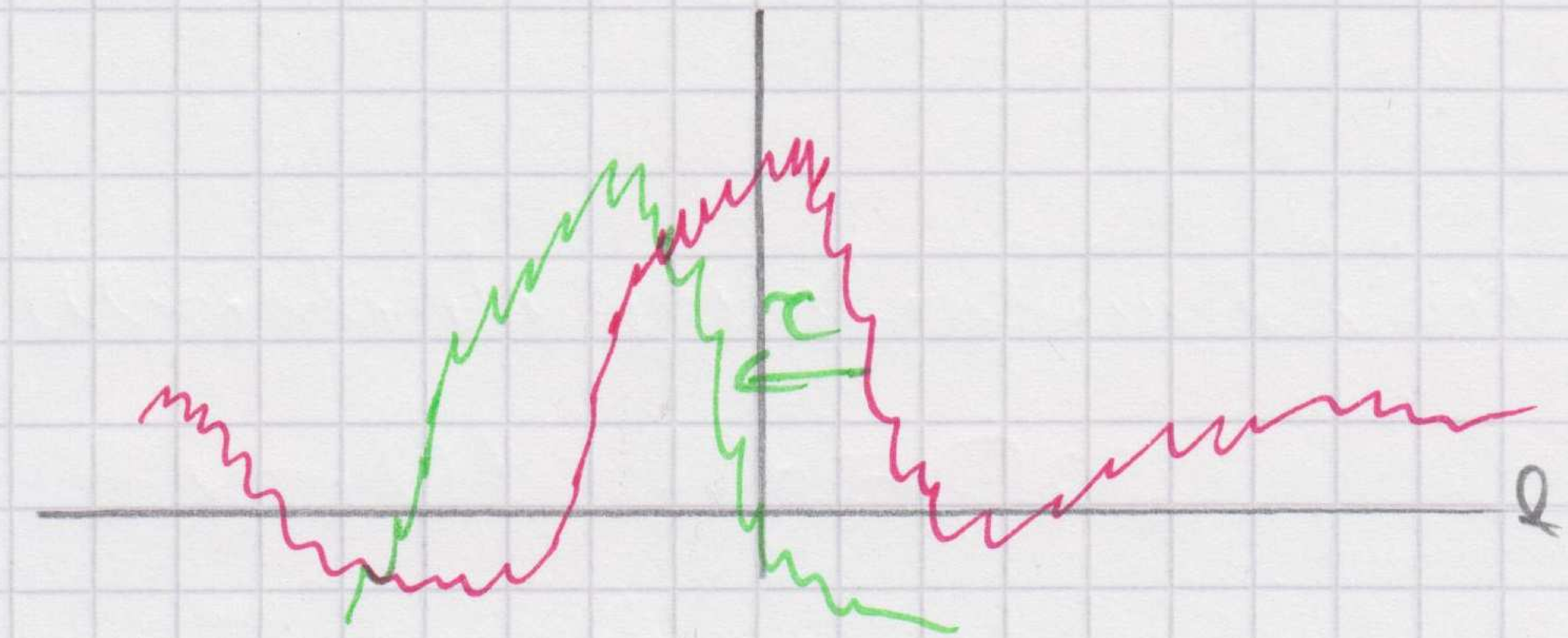
Kreuzkorrelationsfunktion

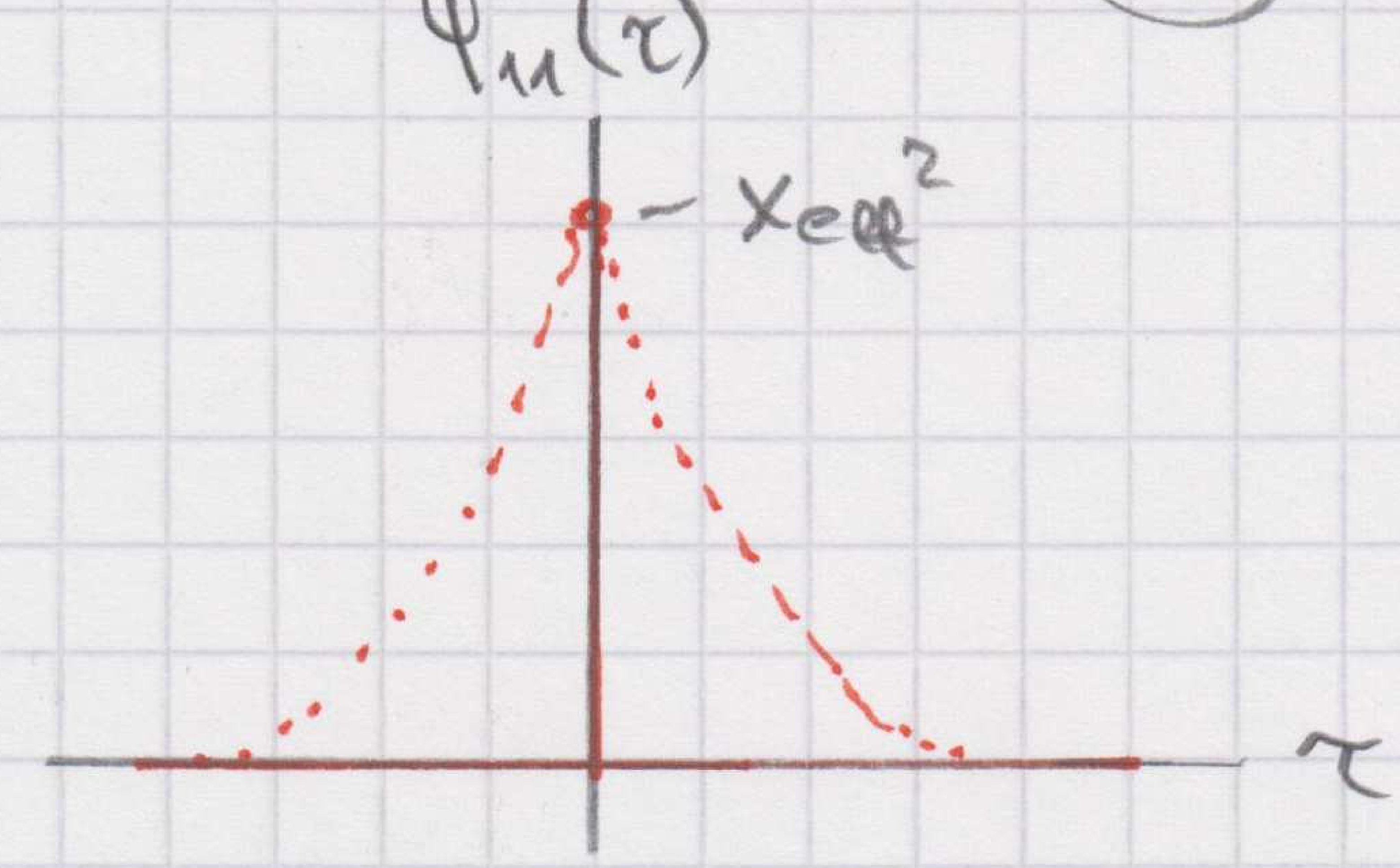
$$\overline{x_1(t)\, x_2(t+\tau)}$$

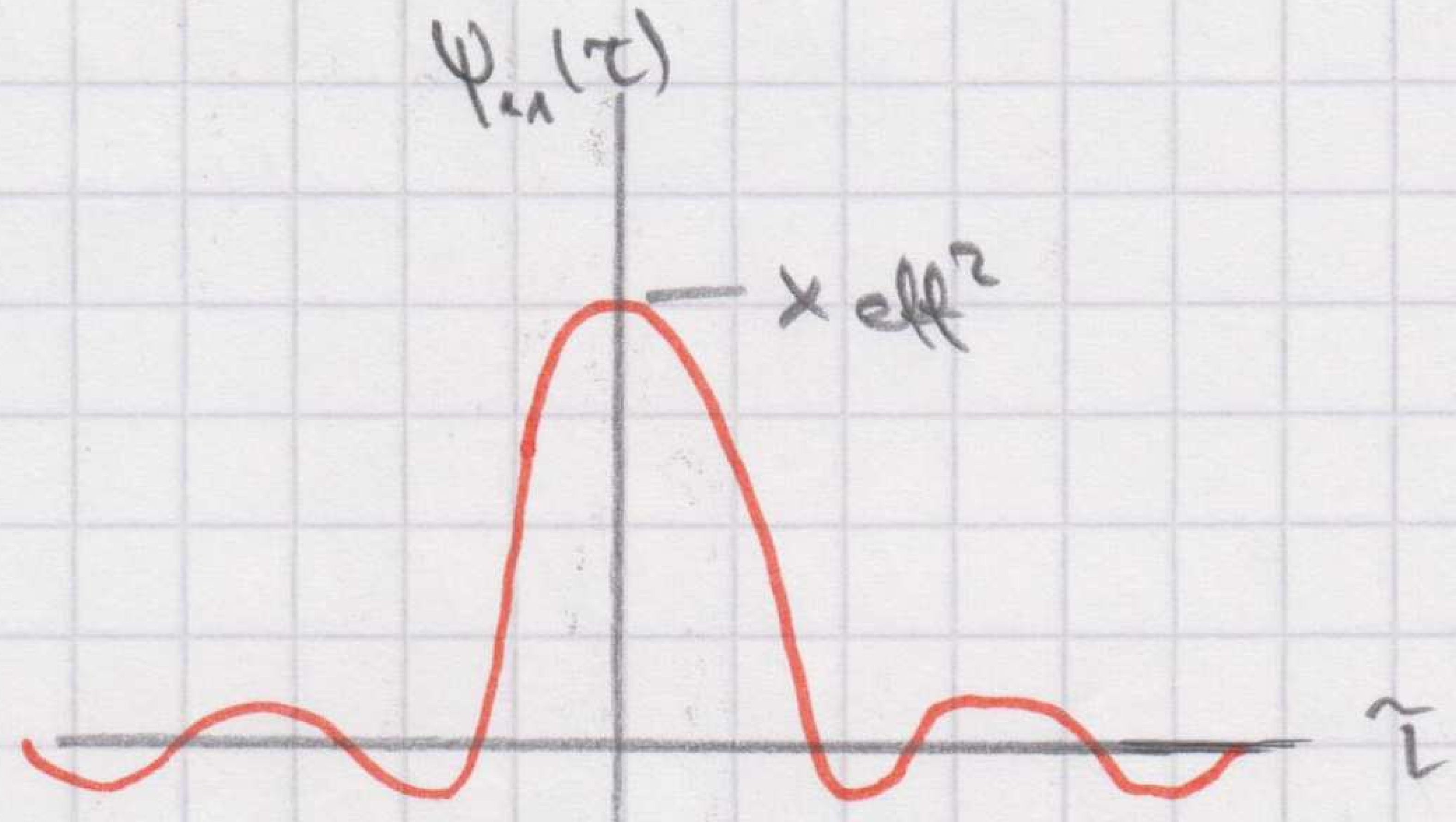




$\psi_{12}(\tau) = 0$ (unkorreliert, orthogonal)







Autokorrelationsfunktion:

$$\varphi_{11}(\tau) = \lim_{T\to\infty} \frac{1}{T}\int_T x(t)\,x(t+\tau)\,dt$$

$$= \overline{x(t)\,x(t+\tau)}$$

$$[\varphi_{11}(\tau)] = 1V^2$$

$$\varphi_{11}(0) = x_{eff}^2$$