ECEN 4797/5797

Introduction to Power Electronics

Lecture #30

Monday, November 2, 2009

Introduction to converter control systems

Loop gain plots and stability

Sections 9.1-9.4

Prof. Regan Zane

4797: Avg: 85.6%

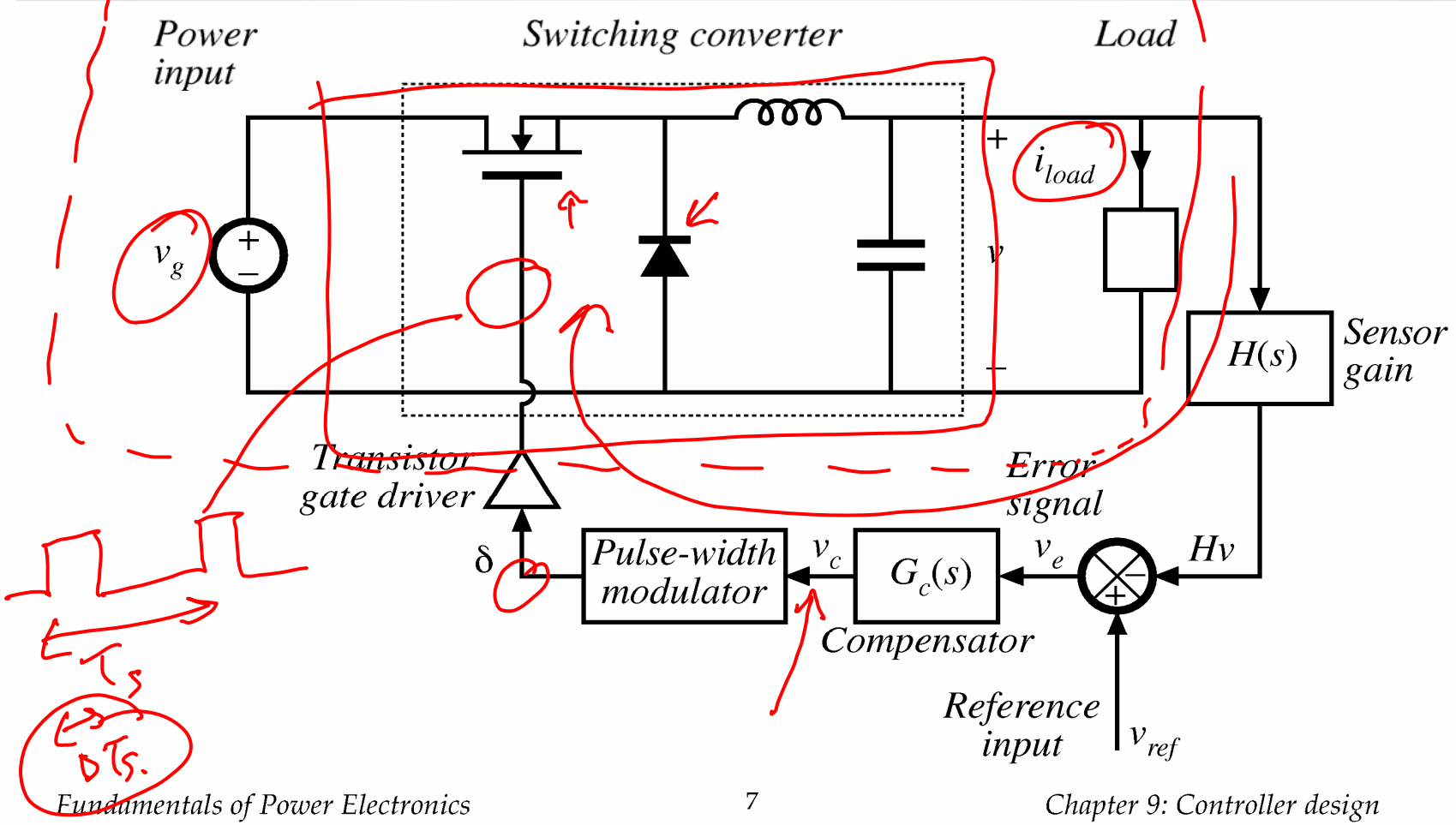
max: 100%

~~8979~~

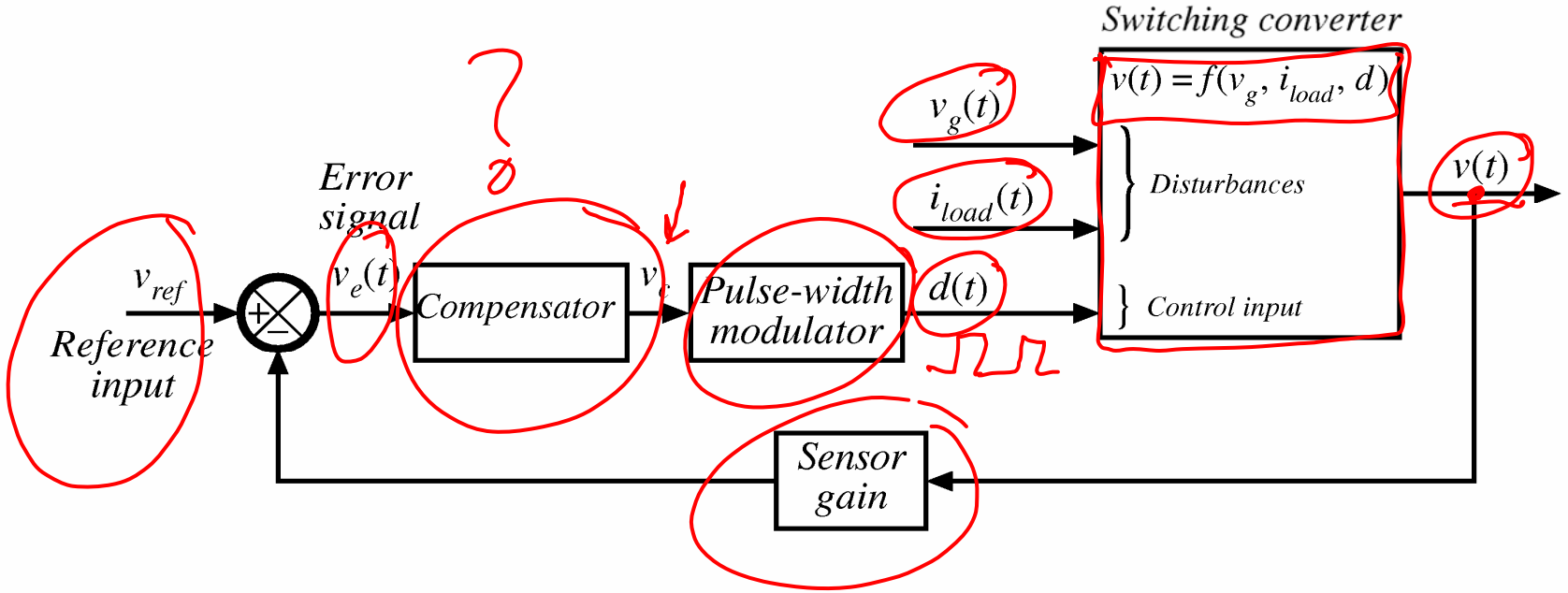
5797: { Avg 84.1%

max 105% ← $(t_1 + t_2) =$ ...

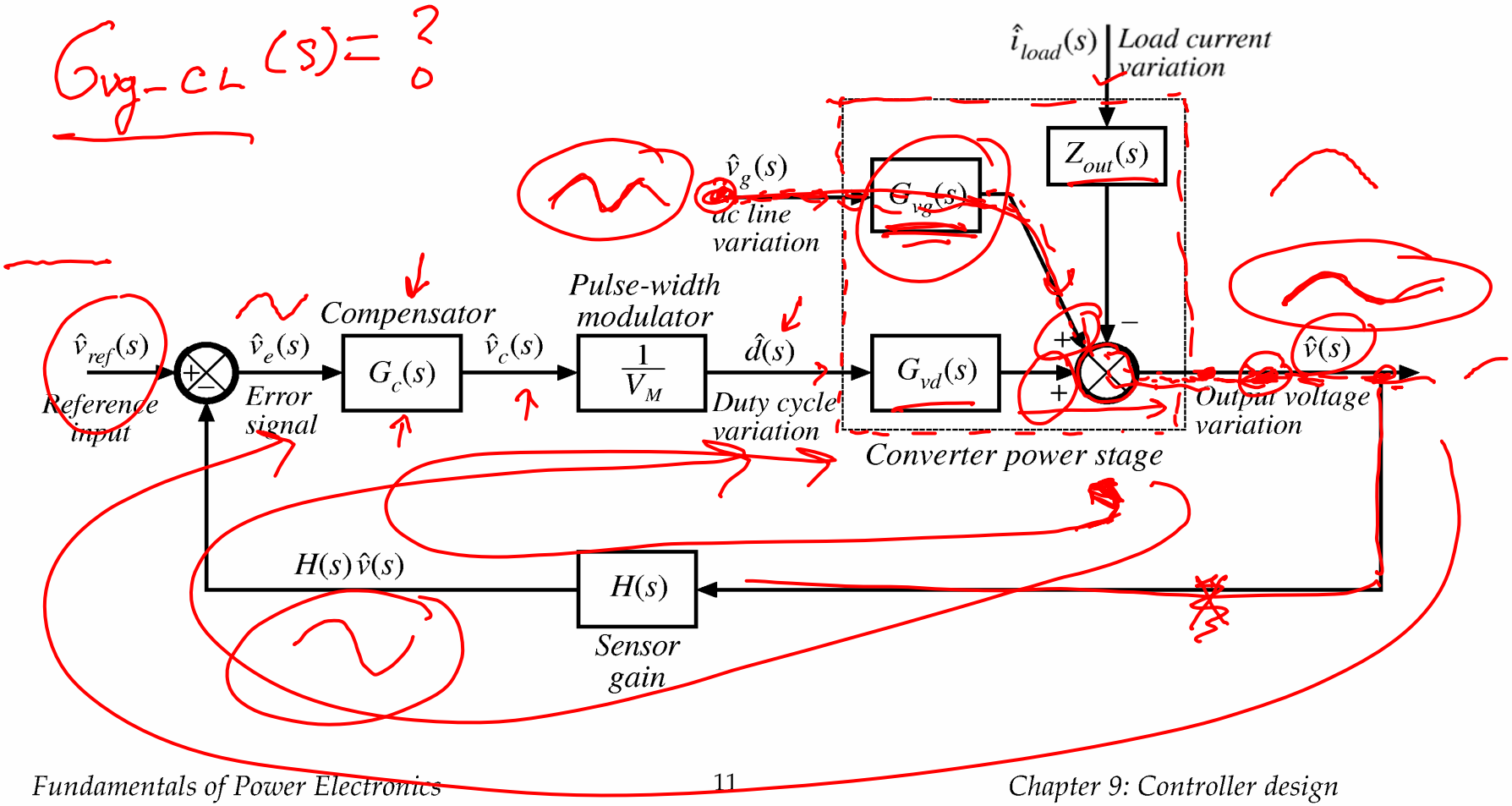
Negative feedback:
a switching regulator system

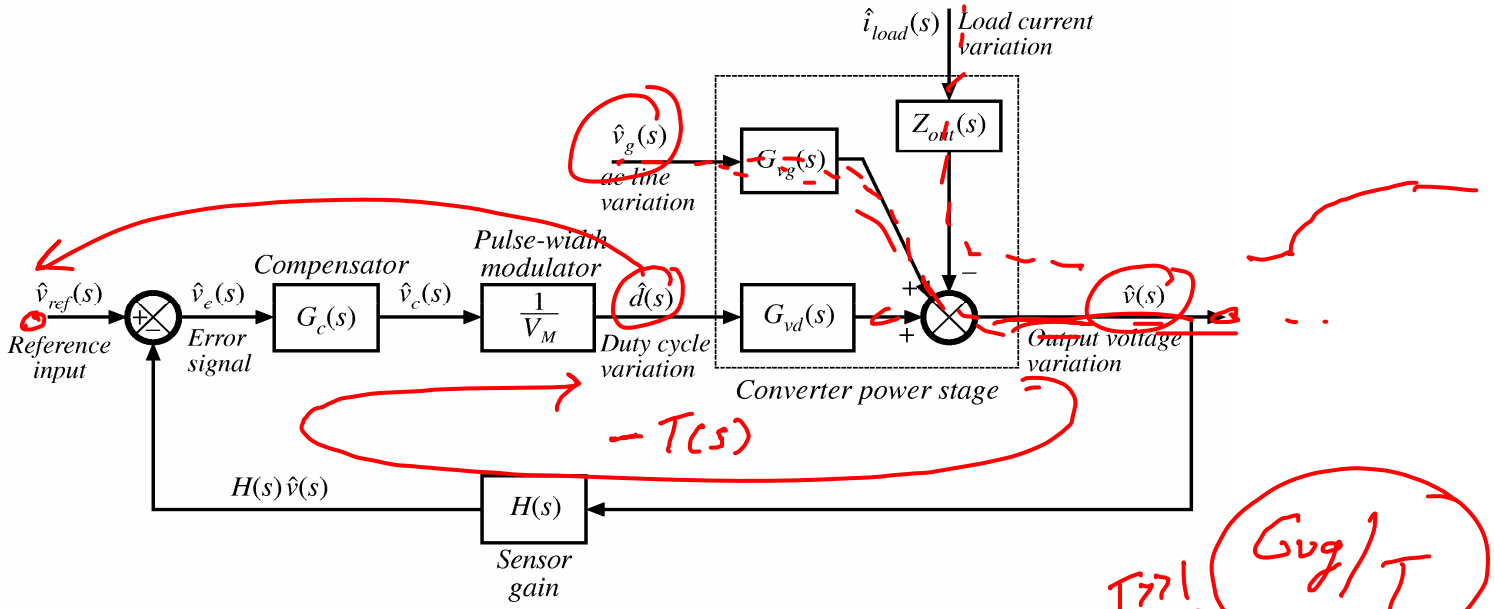


Negative feedback



Regulator system small-signal block diagram





$$\Rightarrow \boxed{G_{vg\text{-}CL}} = \frac{G_{vg}}{1+(HG_c\frac{1}{V_M}G_{vd})} = \frac{G_{vg}}{1+T} = \left(G_{vg}\cdot\frac{1}{1+T}\right)$$

$T \gg 1 \Rightarrow G_{vg}/T$

$T \ll 1 \Rightarrow G_{vg}$

$$\boxed{G_{v\_ref\_CL}} = \frac{G_c\frac{1}{V_M}\cdot G_{vd}}{1+T} = \left(\frac{1}{H}\cdot\frac{T}{1+T}\right)$$

$T \gg 1 \Rightarrow 1/H$

$T \ll 1 \Rightarrow T/H$

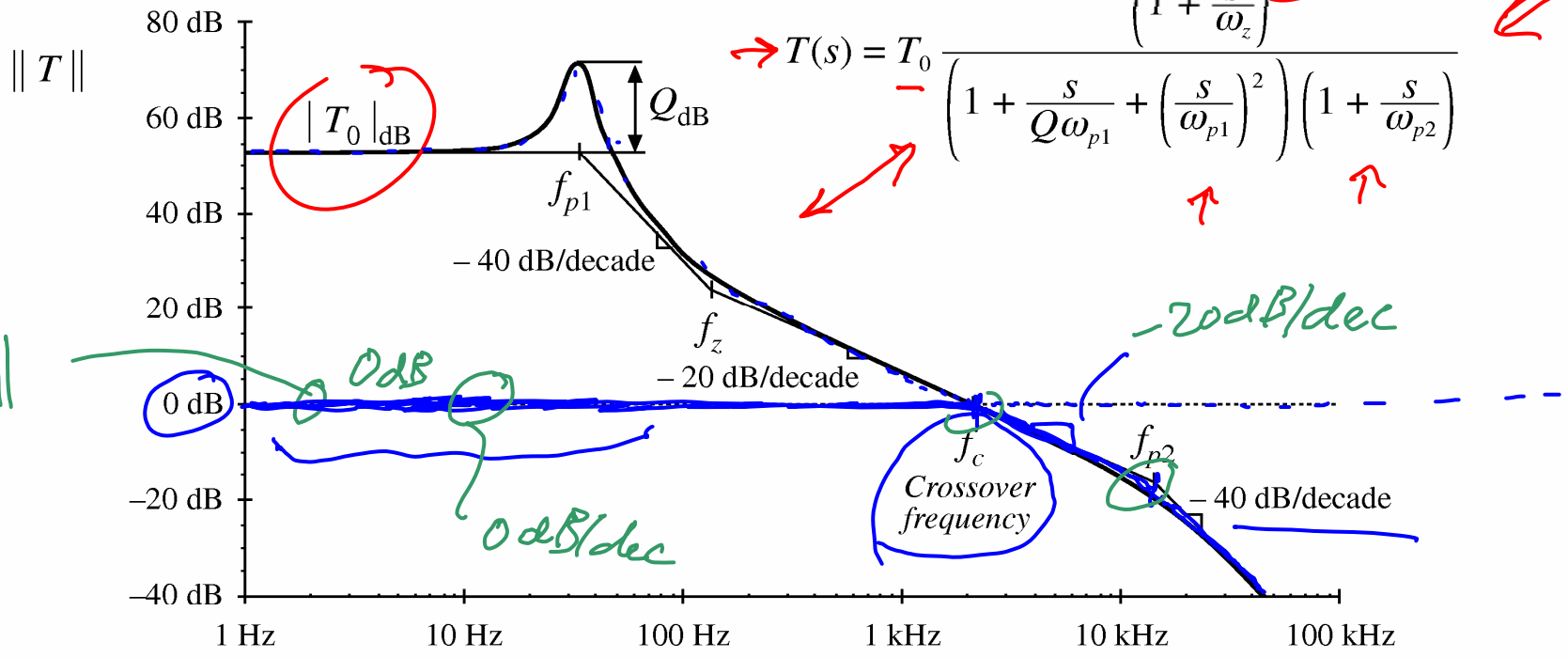
$$\boxed{Z_{out\_CL}} = \left(Z_{out}\cdot\frac{1}{1+T}\right)$$

$T \gg 1 \Rightarrow Z_{out}/T$

$T \ll 1 \Rightarrow Z_{out}$

9.3. Construction of the important quantities $1/(1+T)$ and $T/(1+T)$

Example

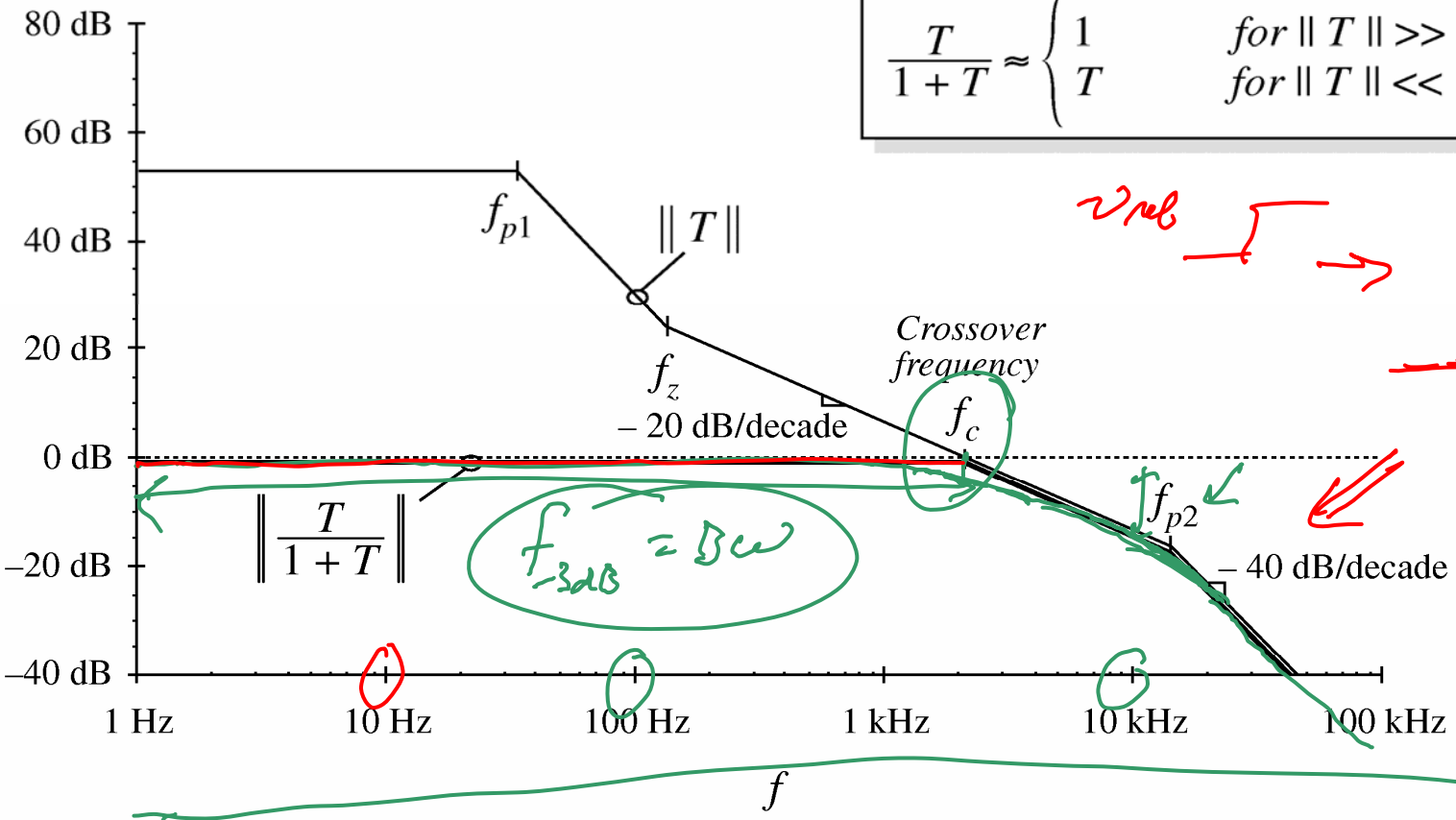


At the crossover frequency f_c, $\| T \| = 1$

Solve $G_{v\_vref\_CL}(s)$

$= \left(\frac{1}{H}\right) \cdot \frac{T}{1+T}$

$$\frac{T}{1+T} \approx \begin{cases} 1 & \text{for } \| T \| >> 1 \\ T & \text{for } \| T \| << 1 \end{cases}$$



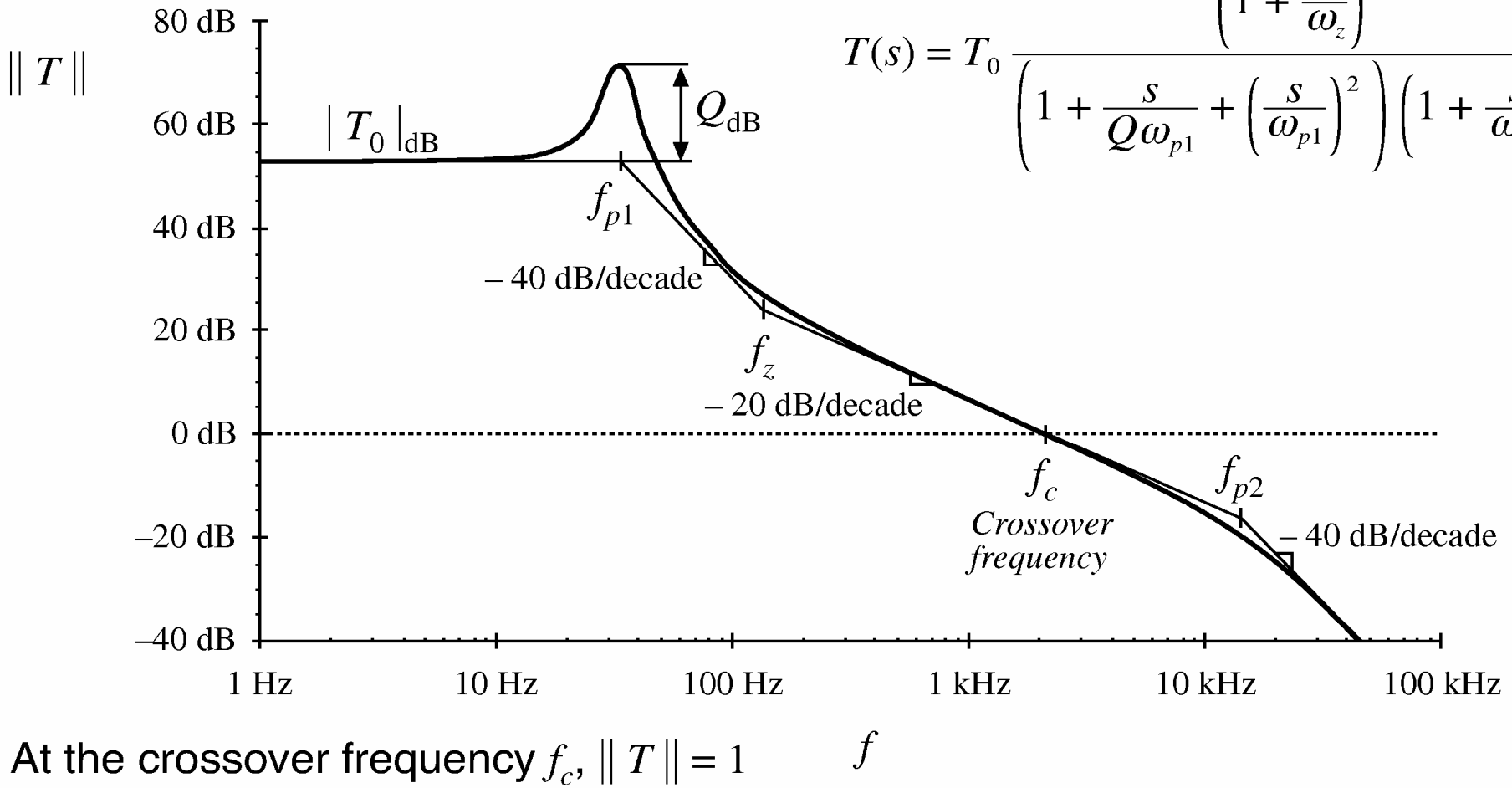
$$G_{v\_vref}(s) = \frac{1}{H} \cdot \frac{1}{(1 + s/\omega_c)(1 + s/\omega_{p2})}$$

T / (1+T), Example 2

T / (1+T)

Example

$$T(s) = T_0 \frac{\left(1 + \frac{s}{\omega_z}\right)}{\left(1 + \frac{s}{Q\omega_{p1}} + \left(\frac{s}{\omega_{p1}}\right)^2\right)\left(1 + \frac{s}{\omega_{p2}}\right)}$$

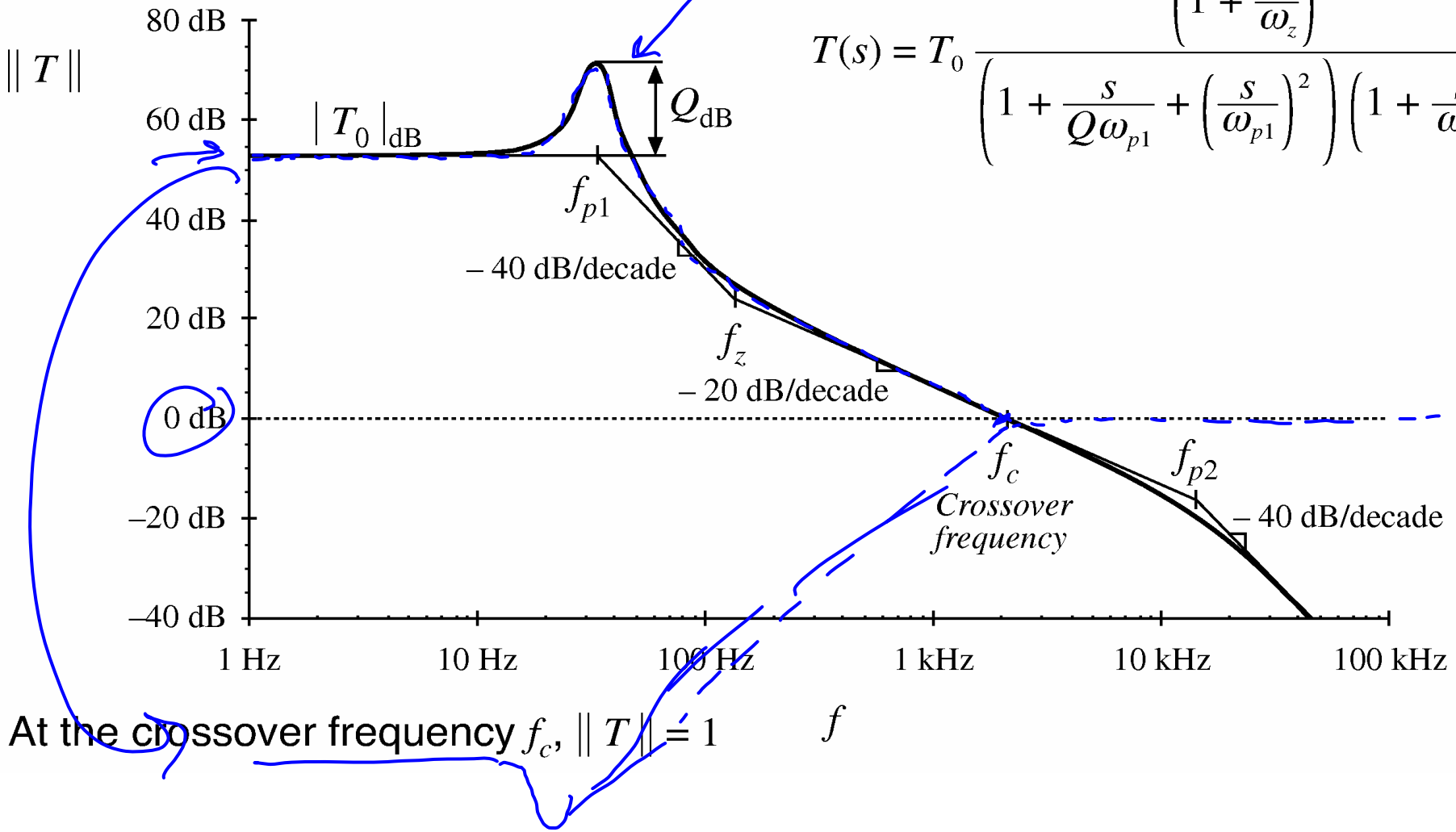


At the crossover frequency f_c, $\| T \| = 1$

1 / (1+T)

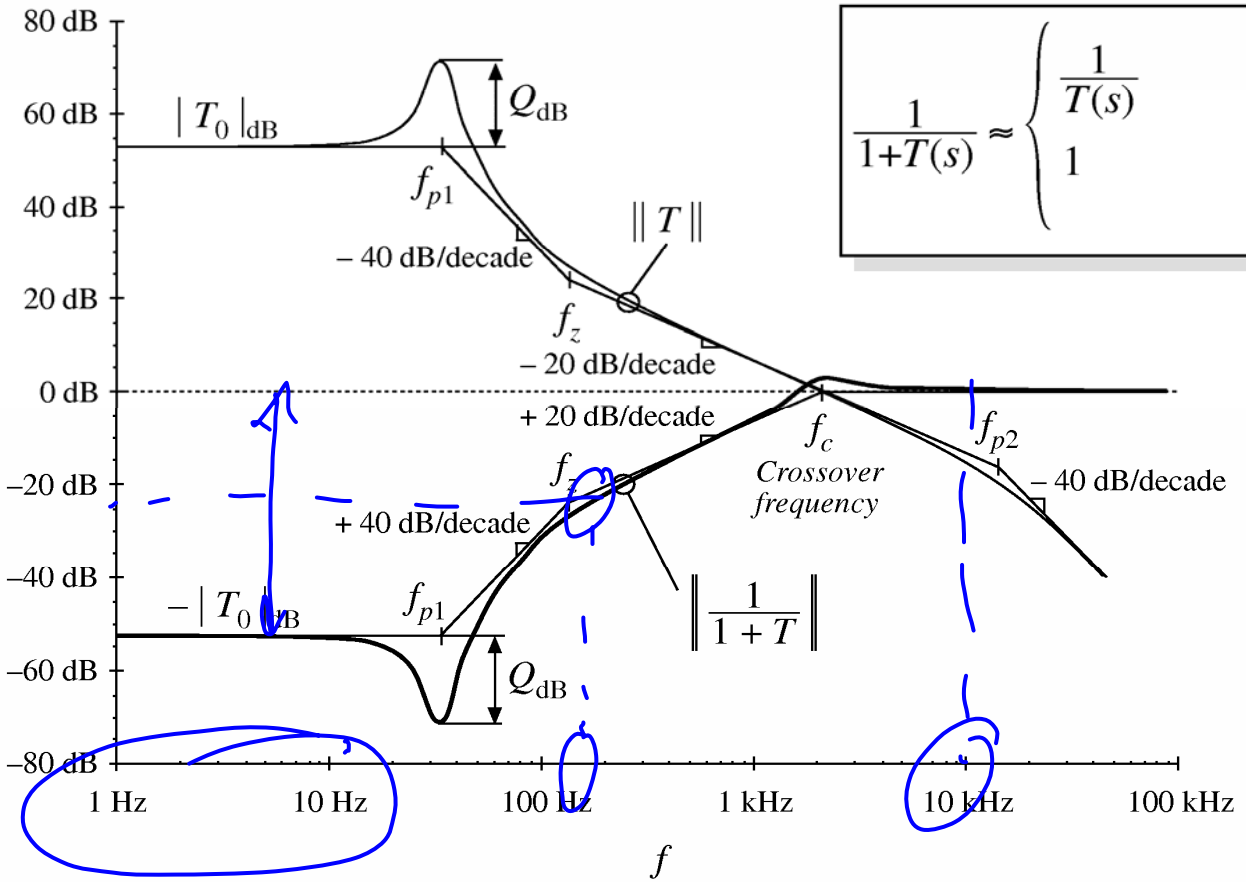
Example

$$T(s) = T_0 \frac{\left(1 + \frac{s}{\omega_z}\right)}{\left(1 + \frac{s}{Q\omega_{p1}} + \left(\frac{s}{\omega_{p1}}\right)^2\right)\left(1 + \frac{s}{\omega_{p2}}\right)}$$



At the crossover frequency f_c, $\| T \| = 1$

Same example: construction of 1 / (1+T)



Interpretation: how the loop rejects disturbances

Below the crossover frequency: $f < f_c$ and $\| T \| > 1$

Then $1/(1+T) \approx 1/T$, and disturbances are reduced in magnitude by $1/\| T \|$

Above the crossover frequency: $f > f_c$ and $\| T \| < 1$

Then $1/(1+T) \approx 1$, and the feedback loop has essentially no effect on disturbances

$$\frac{1}{1+T(s)} \approx \begin{cases} \frac{1}{T(s)} & \text{for } \| T \| >> 1 \\ 1 & \text{for } \| T \| << 1 \end{cases}$$

Terminology: open-loop vs. closed-loop

Original transfer functions, before introduction of feedback ("open-loop transfer functions"):

$$G_{vd}(s) \qquad G_{vg}(s) \qquad Z_{out}(s)$$

Upon introduction of feedback, these transfer functions become ("closed-loop transfer functions"):

$$\frac{1}{H(s)}\,\frac{T(s)}{1+T(s)} \qquad \frac{G_{vg}(s)}{1+T(s)} \qquad \frac{Z_{out}(s)}{1+T(s)}$$

The loop gain:

$$T(s)$$

T / (1+T), Example 2