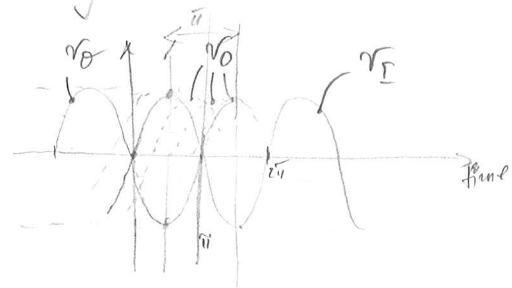
$\boxed{\text{Ch 8}}$ PART I

What is instability?
How to address it? → Frequency compensation techniques.

Stability is determined by how the loop-gain $T(jf)$ varies with frequency!

- Imagine that increasing f T becomes real an negative.
- Assume normally a noninverting amplifier
- in this case the negative feedback becomes positive



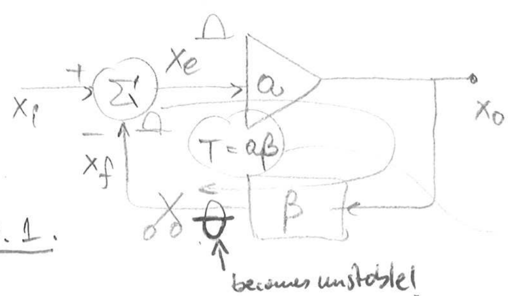
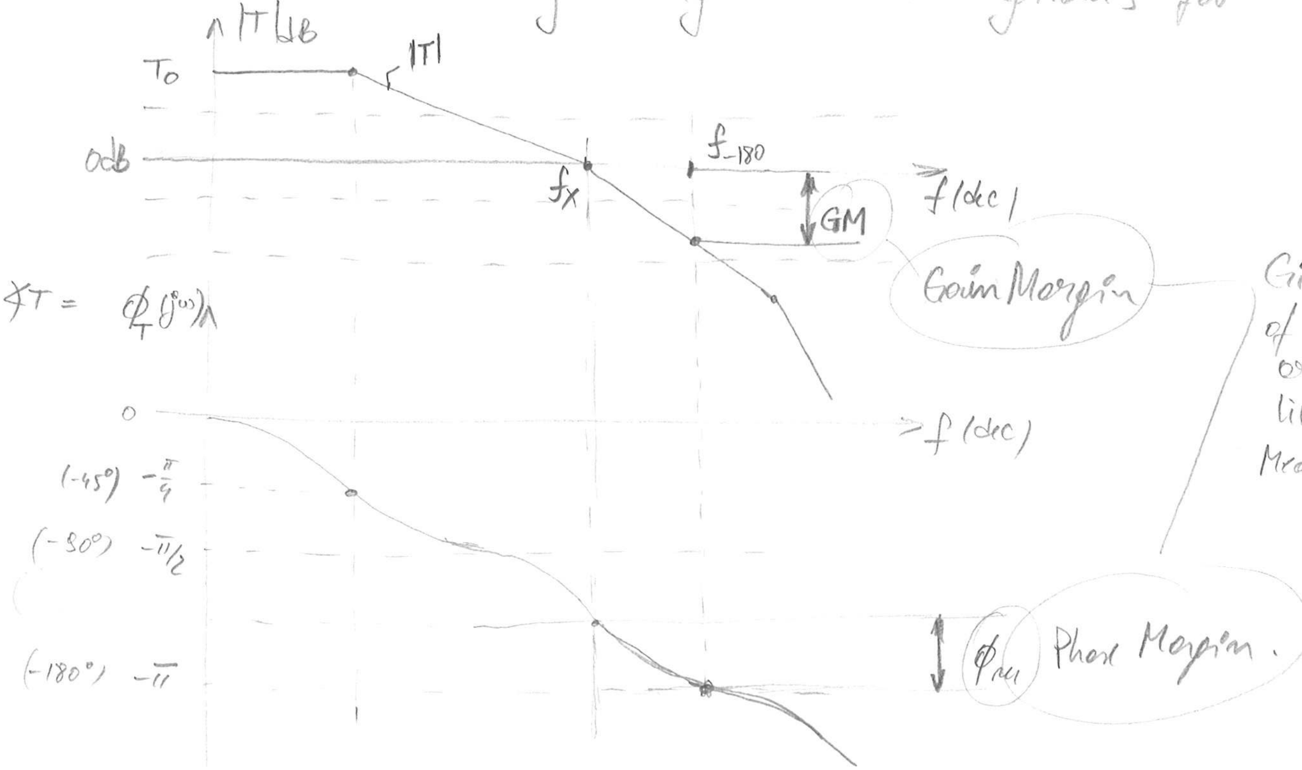


Fig. 1.

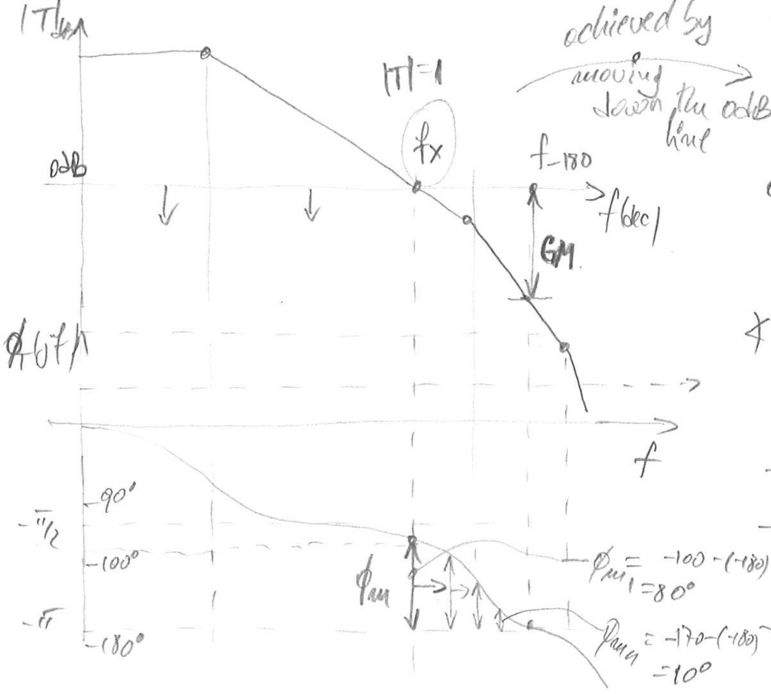
If $T = a\beta$ become real and negative, that is we have a phase lag (or shift) of 180° (π)

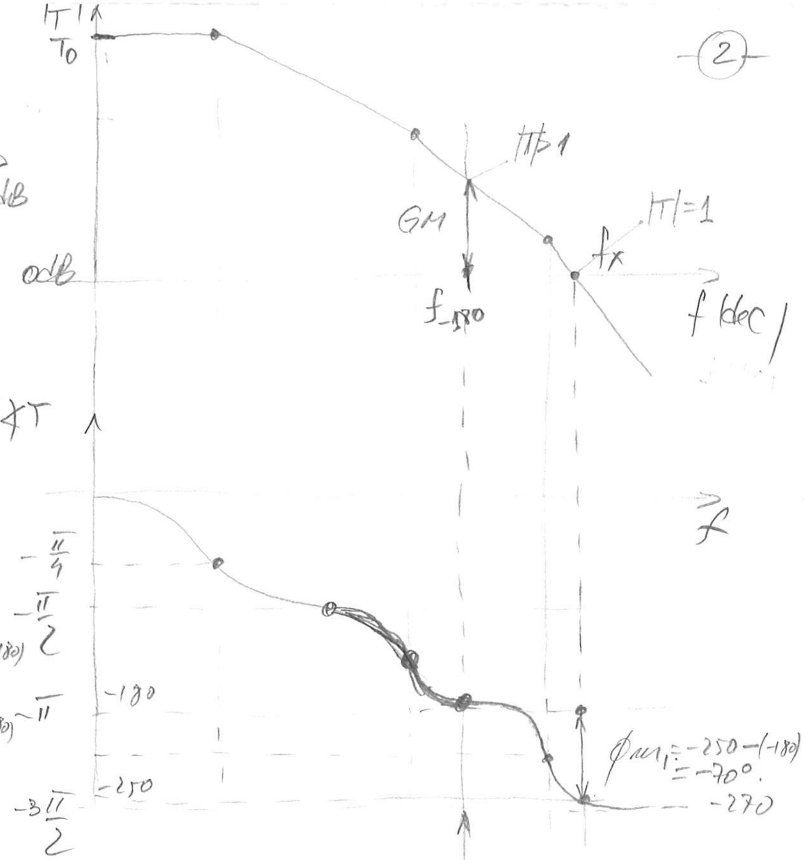
This is visualized nicely using the Bode diagrams for T:



Give us measures of how far we are from situations like in fig. 1. Measures to asses instability or stability.

In other words:





This is fine, OK. stable!

$$\phi_m = ∢T(jf_x) - (-180^\circ) = 180^\circ + ∢T(jf_x)$$

This is NOT OK unstable!

freq. for which $|T|>1$ and $∢T = -180^\circ$ => Neg. feedback becomes positive!

Unstable	Stable
$T>1$	$T<1$
$\phi < -180^\circ$	

Will grow and saturate due to nonlinearities.

$$\boxed{A(jf_{-180}) = \frac{a(jf_{-180})}{1+T(jf_{-180})}}$$

Imagine the 0dB line moving down until

$f_x = f_{-180}$, $|T|=1$, $\phi = -180$ => $A(jf_{-180}) \to \infty$

Oscillations emerge with zero input!

In conclusion: For phase -180° and less we need $|T|$ to be <1 for stability. Otherwise circuit will become unstable (oscillates or saturates)

Where f_x is located is crucial!

$$\boxed{GM = 20 \log \frac{1}{|T(jf_{-180})|}}$$

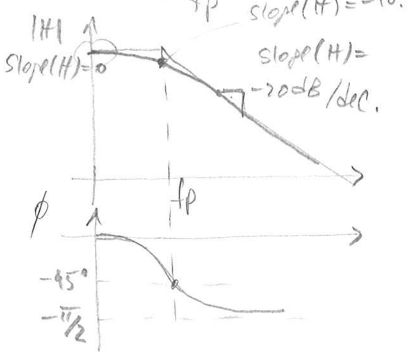
$$\phi_m = ∢T(jf_x) - (-180^\circ) = \boxed{180 + ∢T(jf_x) = \phi_m}$$

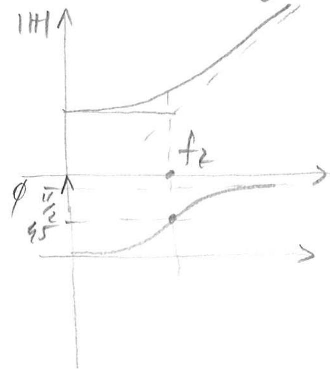
Typical values are 45° or more commonly 60°!

c) $\phi_m = 60^\circ$ we want $|T(jf_{-120})| = 1$ => we can find, by trial and error, $\boxed{f_{-120} = 512\ kHz}$ => $\boxed{T_0 = 5760}$ down from $T_0 = 10^4$.

The rate of closure $\boxed{ROC}$

$H = \dfrac{1}{1 + j\,f/f_p}$ $\qquad$ $H = 1 + j\,f/f_z$





$\measuredangle H = 0$ $\quad$ $\measuredangle H = -45$ $\quad$ $\measuredangle H = -90$ $\quad$ $\measuredangle H = 0$ $\quad$ $\measuredangle H = 45$ $\quad$ $\measuredangle H = 90$

Slope $|H| = 0$ $\quad$ Slope $|H| = -10$ $\quad$ Slope $H = -20$ $\quad$ ...

=> Empirical formula $\boxed{\measuredangle H \cong 4.5 \times \text{Slope}(|H|)}$

Valid if roots of H(s) are real, negative and well separated.

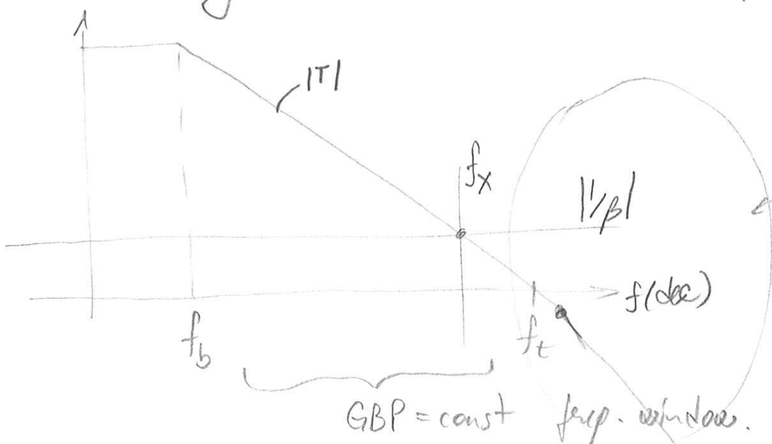
This formula is useful to quickly asses $|T|$ and $\measuredangle T$.
Assume $|a|$ and $|1/\beta|$ have been plotted. Assess their slope at f_x (the cross over frequency) => New definition: Rate of Closure $\boxed{ROC}$

$$\boxed{ROC \triangleq \Big|\text{Slope}(|a|) - \text{Slope}(|1/\beta|)\Big|_{f=f_x}}$$

Use to quickly estimate ϕ_m

Useful:
- ROC ≅ 20dB/dec => $\phi_m \cong 90^\circ$
- ROC ≅ 30dB/dec => $\phi_m \cong 45^\circ$
- ROC ≅ 40 => $\phi_m \cong 0^\circ$ ← oscillator
- ROC > 40 => $\phi_m < 0^\circ$

8.2 Stability in constant GBP OpAmp Circuits



Higher order poles => we have additional phase lag.

=> $\measuredangle a(jf_t) \cong -120°C$ => $\phi_m \cong 60°$

Here $\measuredangle a(jf) \leq -90°$ => $\boxed{\text{Stable, } \phi_m \cong 90°}$

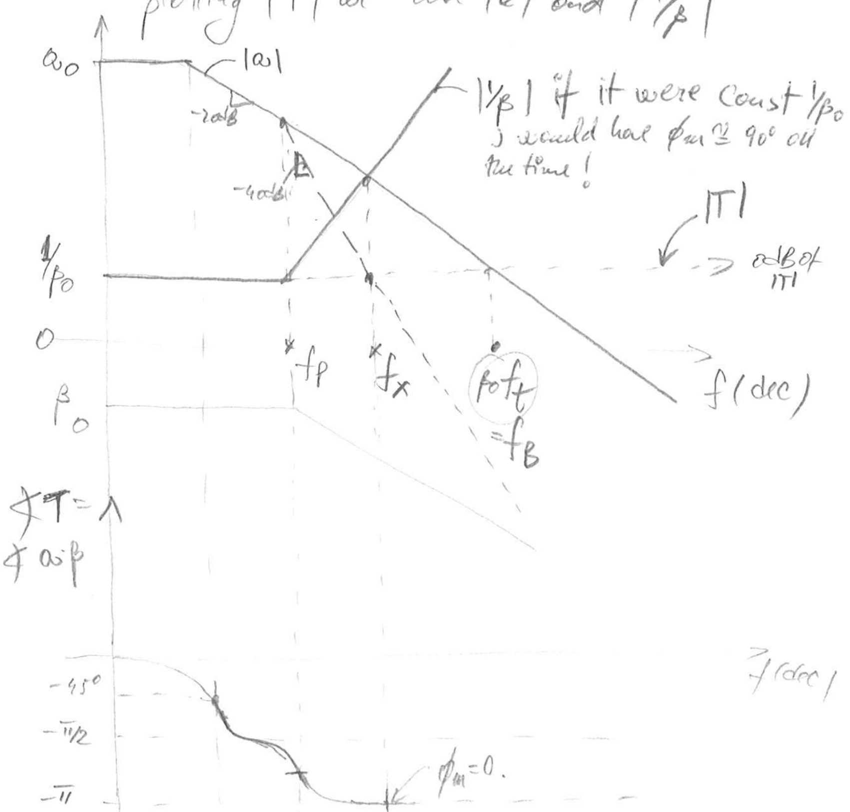
Unconditionally as long as β (feedback network) does not contain reactive elements!

→ if it does => instability may occur => we have to take measures to ensure stability!

Of special concern is a $\boxed{\text{feedback pole!}}$

$$\beta(jf) = \frac{\beta_0}{1 + j\, f/f_p}$$

pole for β is zero for $1/\beta$ because in plotting $|T|$ we use $|a|$ and $|1/\beta|$



For $f_p (f_z) \ll f_B = \beta_0 f_t$

Slope$(|a|) \cong -20$ dB/dec

Slope$(|1/\beta|) \cong 20$ dB/dec } =>

=> ROC $\cong$ 40dB/dec => $\boxed{\phi_m = 0°}$ ☹

$\boxed{\text{Next time will look at stabilization techniques}}$