STABILITY

INEL 4202 - Spring 2013 - M. Toledo
ECE Dept. UPRM

Stability

Basics

- Basic feedback equation:

$$A_f(s) = \frac{a(s)}{1 + \beta(s)a(s)}$$

  Thus, feedback moves the poles of the amplifier's transfer function.

- Poles of A_f are roots of $1+\beta a$. Thus, feedback moves the poles of the amplifier's transfer function.

- The idea is to determine information about the stability of A_f from the loop gain $T(s) = \beta(s)a(s)$.

Nyquist Theorem

Let ω_{180° be the frequency at which the loop gain's phase angle is -180°. If

$$|\, T(j\omega_{180^\circ})\, | = |\, \beta(j\omega_{180^\circ}) A(j\omega_{180^\circ})\, | > 1$$

then the amplifier is unstable. Otherwise, it is stable.

Nyquist theorem allows us to answer questions about the stability of A_f by analyzing the loop gain βA.

Phase and Gain Margin

- Gain margin: decibels below zero of $| T(j\omega_{180^\circ}) |$.

- Phase margin: degrees above -180° at the frequency ω_{0dB} at which $| T(j\omega_{0dB}) | = 1$, or 0 db.

$$\phi_m = 180 + \angle T(j\omega_{0dB})$$

Note that $\angle T(j\omega_{0dB})$ is usually negative.

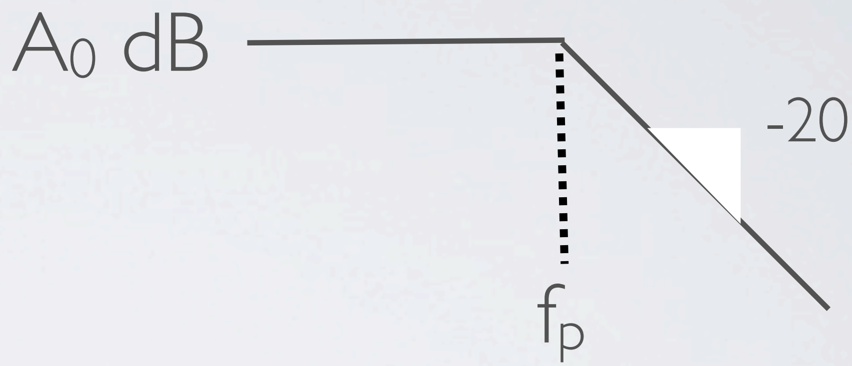
- The amplifier is unstable if the gain and phase margins are negative. If the margins are positive or zero the amplifier is *stable* or *marginally stable*, respectively.

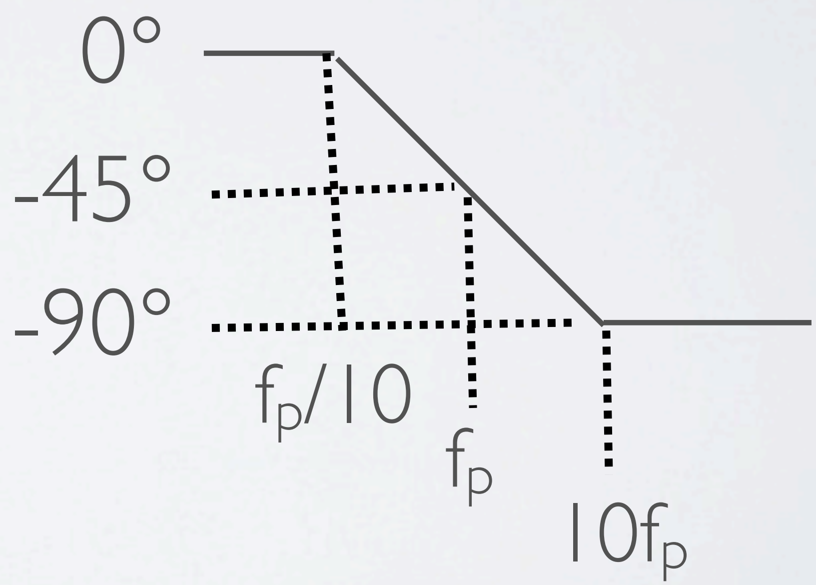
$A_{dB}=20 \log A$

1 decada = 10*frec.
1 octava = 2*frec

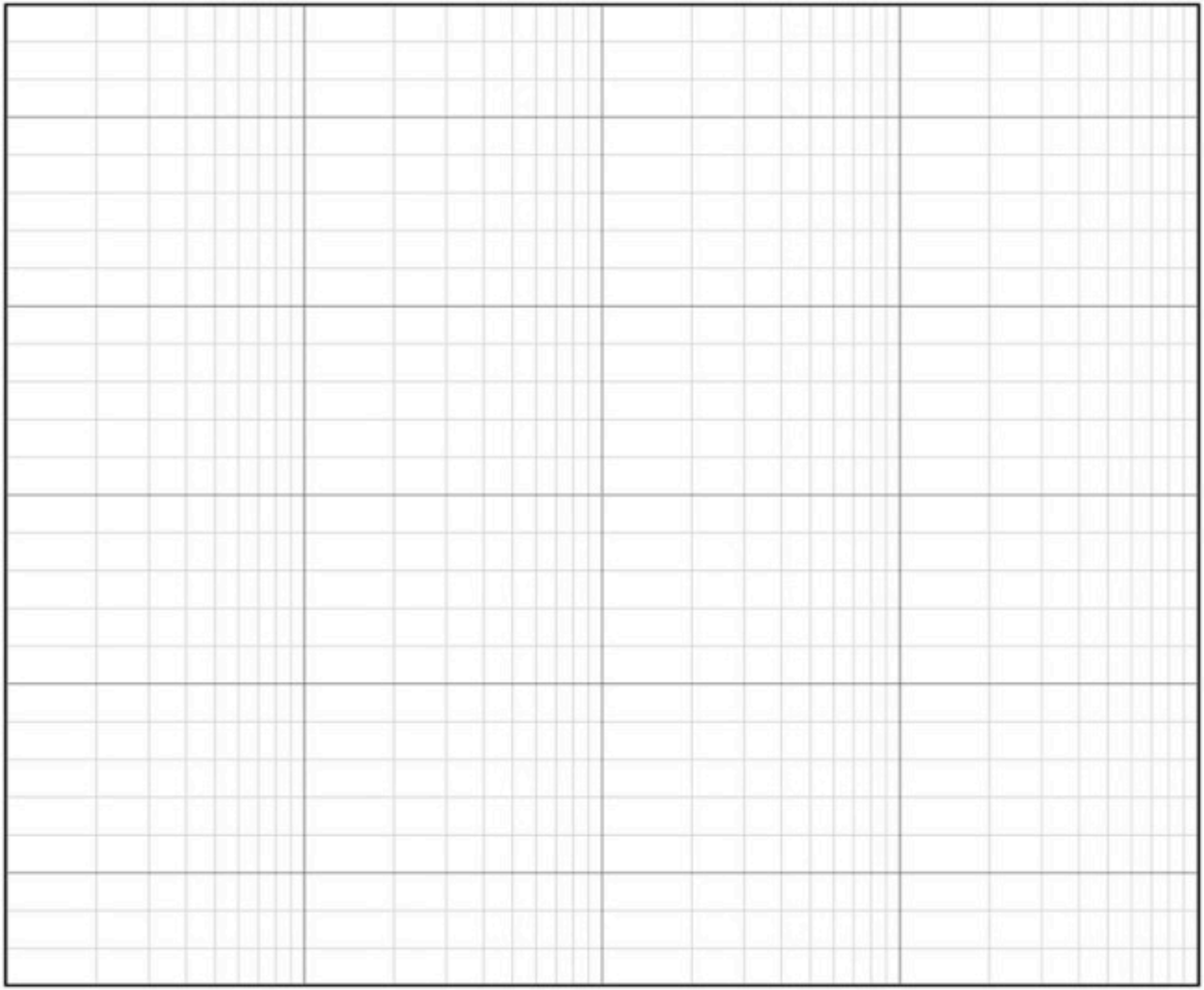
$$\frac{A_0}{1 + j\,\frac{f}{f_p}}$$

f/f_p	ϕ
0.1	5.7°
1	45°
10	84.3°





An amplifier with dc gain equal to 1000V/V will be used in a feedback configuration. The amplifier transfer function displays single poles at 1kHz and 10kHz. Find the phase margin Φ_m if the circuit will use a feedback network with β=1/2.

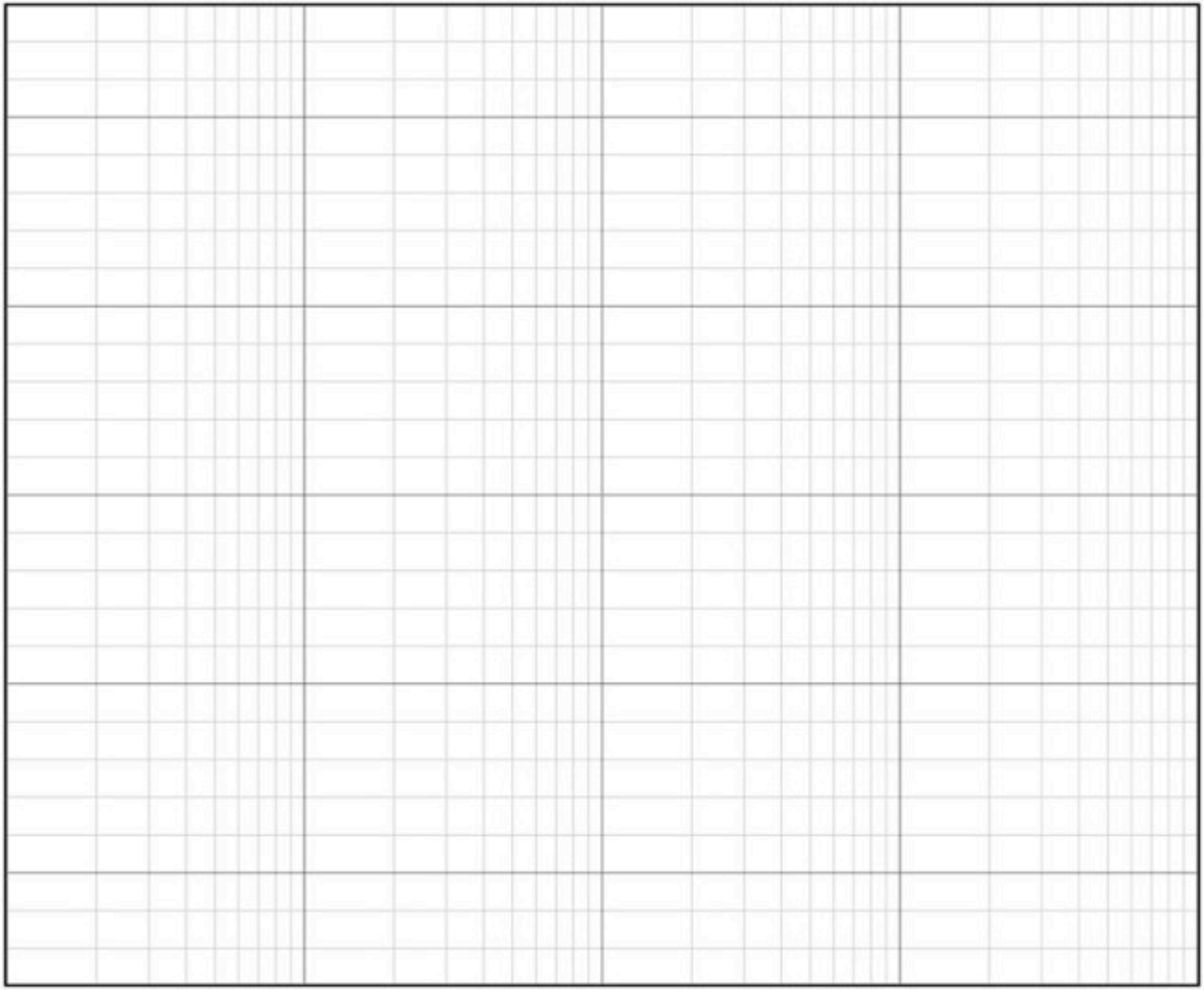


12.65 A 3-pole amplifier has a loop gain given by

$$T(f) = \frac{10^5 \times \beta}{\left(1 + j\frac{f}{5\times10^2}\right)\left(1 + j\frac{f}{10^4}\right)^2}$$

(a) determine the frequency f_{180} at which the phase is -180 degrees. (b) At f_{180} determine the value of β such that $|T(f_{180})| = 1$.

Extra: c) find the the value of β such that the phase margin is 45 degrees; (d) repeat for a phase margin of 60 degrees; (e) sketch the magnitude and phase bode plots of the amplifier's gain.

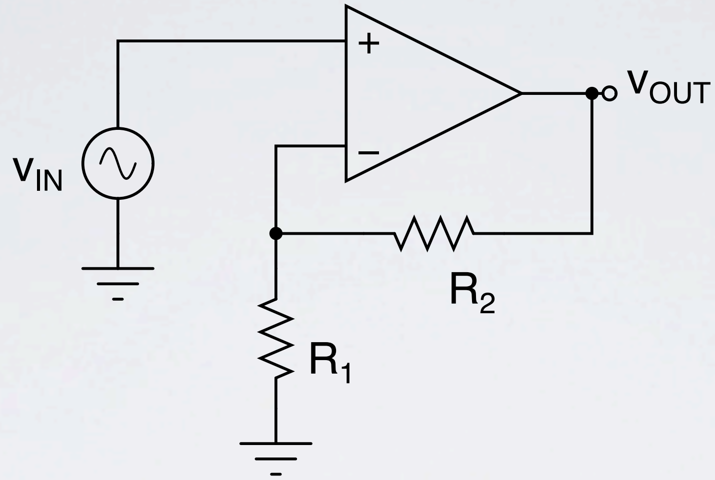


Example: An op amp with $a_0 = 10^3$ V/V and two pole frequencies at $f_1 = 100$kHz and $f_2 = 2$MHz is connected as a unity-gain voltage follower. Find φ_m.

Example: An amplifier has 3 identical poles at a frequency f_1 and is placed in a negative-feedback loop with a frequency independent feedback factor β. Find an expression for $f_{-180°}$ as well as the corresponding value of T.

Example: (a) Verify that the circuit with loop gain $T_0 = 10^2$ and three pole frequencies $f_1 = 100$kHz, $f_2 = 1$MHz and $f_3 = 2$MHz is unstable. (b) Reduce T_0 so that φ_m=45°. (c) repeat for φ_m=60°.

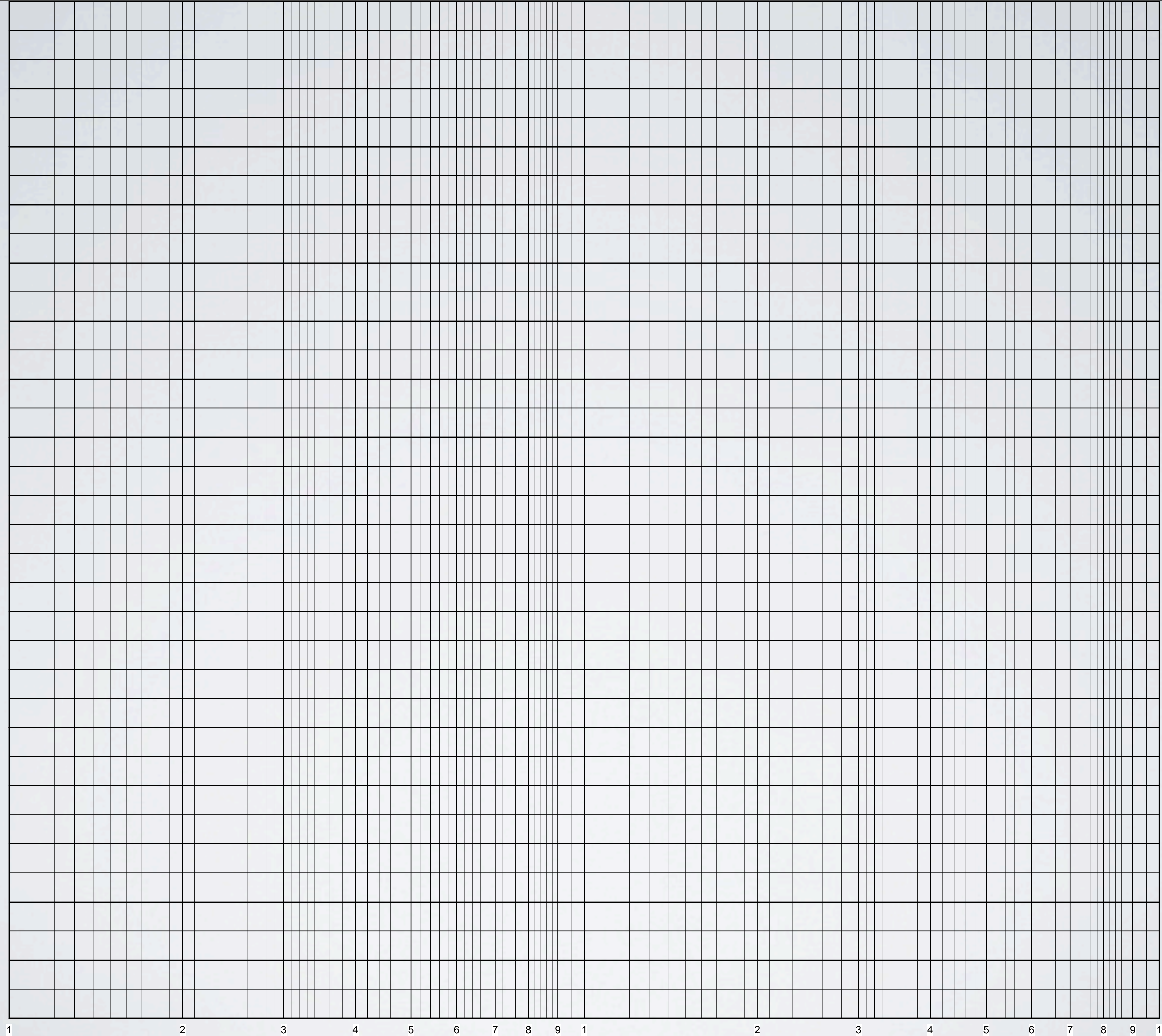
III. (33 pts.) In the following amplifier, the opamp has an open-loop d.c. gain of 10^4 and 4 poles at 1MHz, 10MHz, 10MHz and 200MHz. Find the smallest ratio R_2/R_1 for which the amplifier is stable.



An amplifier has a low-frequency gain of 200 and its transfer function has three poles at 1*MHz*, 2*MHz* and 4*MHz*.

(a) Sketch the bode plot.

(b) The amplifier is placed in a negative feedback loop with a feedback network with a frequency independent factor $\beta = 0.025$. Is the amplifier stable? Use your estimate of the phase or gain margin to justify your answer.


1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1

The response of an op amp can be approximated with a dominant pole frequency f_1 and a high-frequency pole f_2 to account for higher order roots. (a) Assuming $a_0 = 10^5$ V/V, $f_1 = 10$Hz, and $\beta = 1$ V/V, find the phase margin φ_m if $f_2 = 1$MHz. (b) Find f_2 for $\varphi_m = 45°$ and for $\varphi_m = 60°$.