2C-03

An Idea to Obtain the Open Loop Characteristics of OPAMP by Closed Loop Results

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Operational Amplifier Stability Research

Research Objective

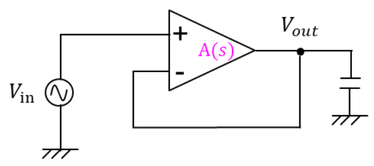
- Problem

Difficult to get open loop characteristics

- Our target

Provide an easy-to-use tool to obtain the open loop characteristics from the closed loop operation results

- Approach



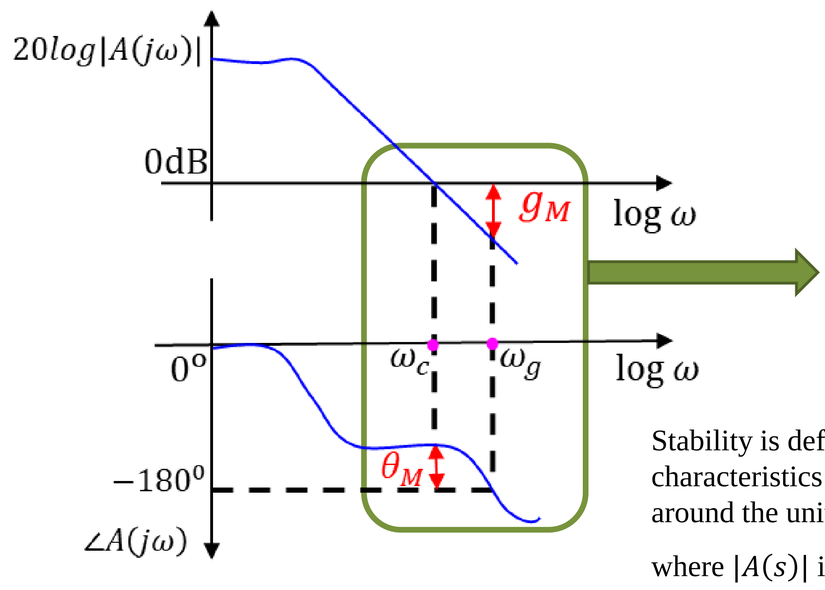
$$\frac{V_{out}}{V_{in}} = W(s) = \frac{A(s)}{1+A(s)}$$

Closed loop characteristics

$$A(s) = \frac{W(s)}{1-W(s)}$$

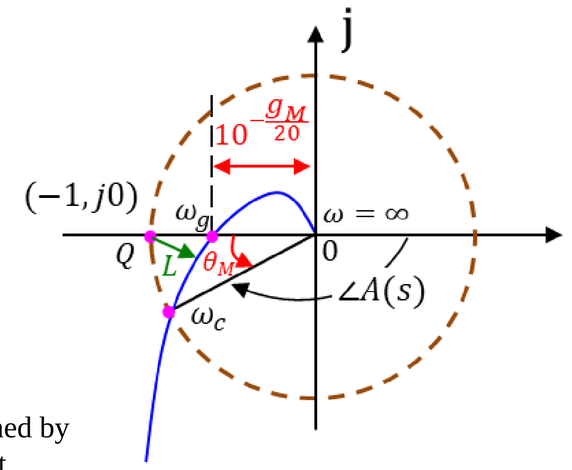
Open loop characteristics

Bode Plot



Stability is defined by characteristics at around the unit circle, where $|A(s)|$ is small

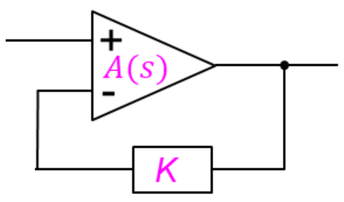
Nyquist Plot



L: minimum distance to point -1

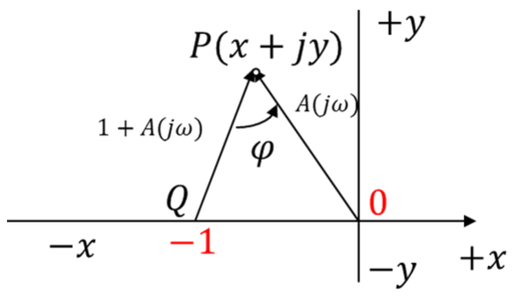
g_M: gain margin θ_M: phase margin

Closed loop $M \cdot \varphi$ locus in open loop Nyuist



Closed loop

Buffer connection condition: $K=1$



Nyquist plane of open loop transfer function $A(j\omega)$

$\overrightarrow{OP}: A(j\omega)$ $\overrightarrow{QP}: 1 + A(j\omega)$

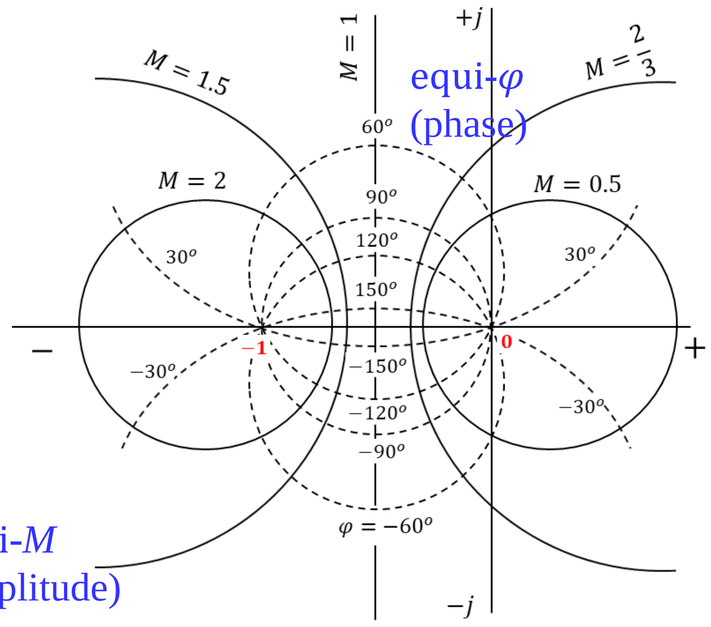
closed loop transfer function:

$$W(j\omega) = \frac{A(j\omega)}{1 + 1 * A(j\omega)} = \frac{\overrightarrow{OP}}{\overrightarrow{QP}} = Me^{j\varphi}$$

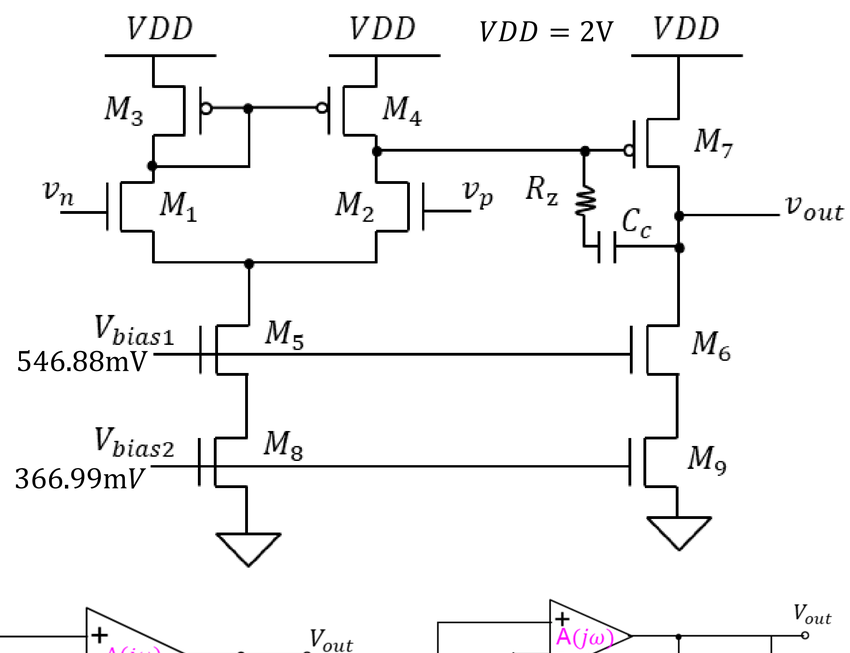
$$M = \frac{|\overrightarrow{OP}|}{|\overrightarrow{QP}|}, \varphi = \angle QPO \qquad M^2 = \frac{|\overrightarrow{OP}|^2}{|\overrightarrow{QP}|^2} = \frac{x^2+y^2}{(x+1)^2+y^2}$$

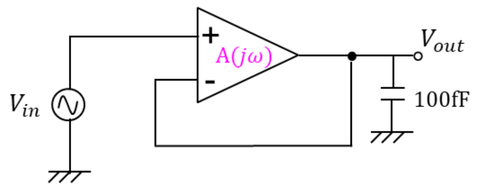
Equation of circumference

$$\{x + \frac{M^2}{M^2-1}\}^2 + y^2 = (\frac{M}{M^2-1})^2$$

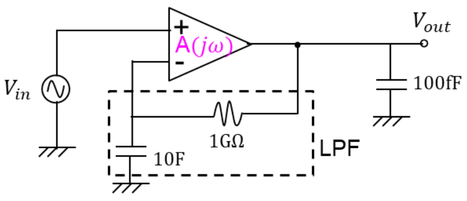


Operational amplifier





Proposed method

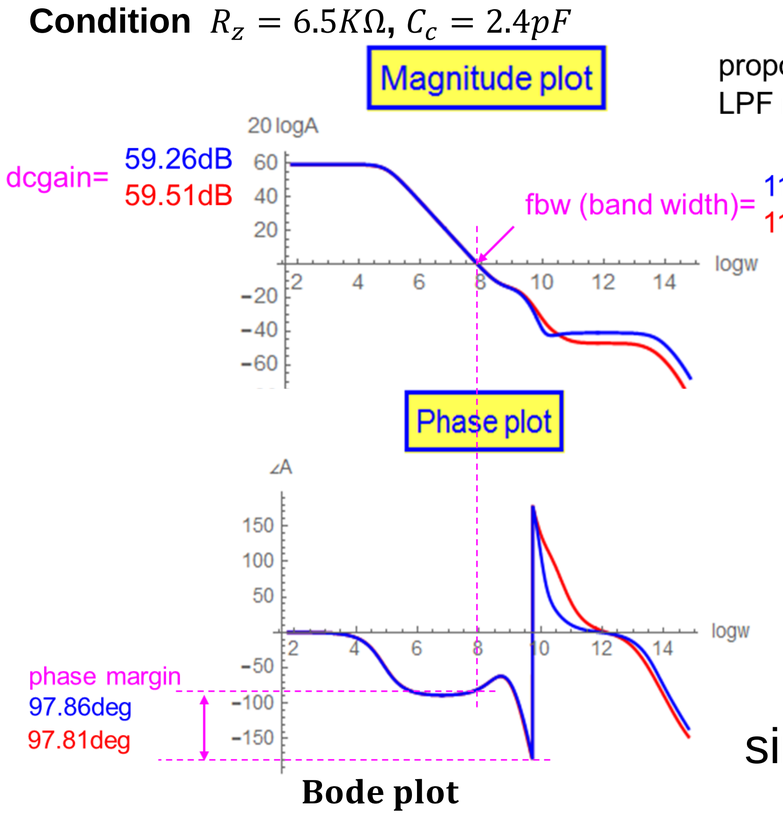


LPF(Low pass filter) method

By using different axes on the same complex plane, closed loop and open loop characteristics become a single plot.

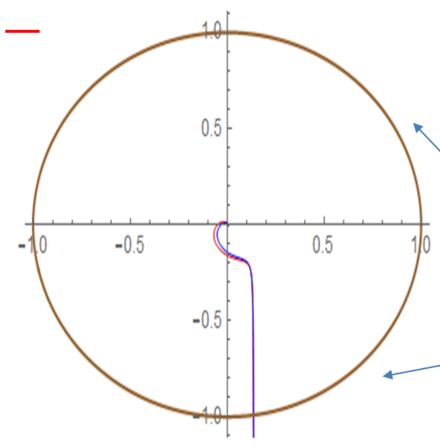
Simulation Result

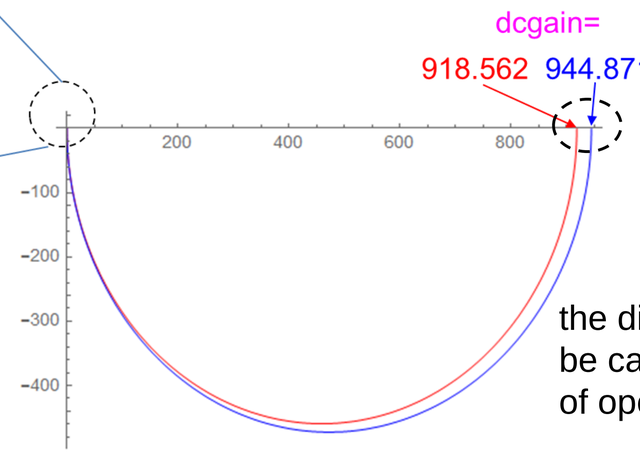
Condition $R_z = 6.5K\Omega$, $C_c = 2.4pF$



Bode plot

proposed method —
LPF method —





Nyquist plot

results are close even at low frequency in simulation

the difference of DC gain be caused by the difference of operation point

simulation results are consistent

Conclusion

- Tried the conversion method for obtain the open loop characteristics (opamp stability etc.) from closed loop operation results
- The effectiveness of this method be shown by practical example

Future work

- Apply to more other practical examples
- Provide an easy-to-use tool for anyone