Operational Amplifier Stability Research

Research Objective

Stability Criteria

Nyquist stability Criteria
- \( G(s) \) precedes \( P(s) \)
- Feedback system is stable
- Greater spacing between \( G(s) \) and \( P(s) \)
- More stable

Routh-Hurwitz stability Criterion
- Characteristic equation: \( \frac{a_n s^n + a_{n-1} s^{n-1} + \cdots + a_1 s + a_0}{b_m s^m + b_{m-1} s^{m-1} + \cdots + b_1 s + b_0} = 0 \)
- Sufficient and necessary condition:
  (i) \( a_i > 0 \) for \( i = 1, \ldots, n \)
  (ii) All values of Routh table’s first columns are positive.

Equivalence at Mathematical Foundations

Two Examples

Ex.1 \( G(s) = \frac{K(1 + h s)}{1 + a_1 s + a_2 s^2} \) One Zero, Two Poles

Stability Condition

Based on Routh-Hurwitz Criterion
- \( K > a_2 \): At condition: \( b_1 > 0 \)
- \( K < a_2 \): At condition: \( b_1 < 0 \)
- \( a_1 b - a_2 > 0 \): At condition: \( b_2 > 0 \)
- \( a_1 b - a_2 < 0 \): At condition: \( b_2 < 0 \)

Ex.2 \( G(s) = \frac{K(1 + h s)}{1 + a_1 s + a_2 s^2 + a_3 s^3} \) One Zero, Three Poles

Based on Nyquist Criterion
- \( \angle \omega = 0 \) at \( \omega = \infty \)

Example Verification

Example I

Closed-loop transfer function:
- \( H(s) = \frac{A_0 (1 + b_1 s)}{1 + (fA) + (fA s^2) + a_2 s^2} \)
- Explicit stability condition of parameters:
  \( a_i + fA b_i = R_1 C_i + R_2 C_i (R_1 + R_2) C_i + (fA_{ns} - fA_{nc}) R_1 R_2 C_i > 0 \)

Case (1): \( C_1 = 150 \Omega \)
- Consistency of Bode Plots and R-H Results

Case (2): \( C_1 = 79.57 \Omega \)
- Consistency of R-H Results

Case (3): \( C_1 = 10 \Omega \)
- Consistency of Bode Plots and R-H Results

Example II

Closed-loop transfer function:
- \( H(s) = \frac{A_0 (1 + b_1 s)}{1 + fA_0 + (fA_0 s) + a_2 s^2} \)
- Explicit stability condition of parameters:
  \( (a_i + fA_{ns}) p_0 - d (1 + fA_{ns}) > 0 \)

At condition:
- \( X = R_1 C_i + R_2 C_i (R_1 + R_2) C_i + (fA_{ns} - fA_{nc}) R_1 R_2 C_i \)
- \( Y = R_1 R_2 C_i (C_i + 1) + (fA_{ns} - fA_{nc}) R_1 R_2 C_i \)

Case (1): \( X > Y \)
- Consistency of Bode Plots and R-H Results

Case (2): \( X > Y \)
- Consistency of Bode Plots and R-H Results

Case (3): \( X = Y \)
- Consistency of R-H Results

Summary

- Equivalence between Nyquist and R-H stability criteria
- Equivalency of mathematical foundations
- R-H method, explicit circuit parameter conditions
- Consistency with Bode plot method, LTSpice simulation

Conclusion

R-H method can be used with conventional Bode plot method.