Analysis and Design of Operational Amplifier Stability Based on Routh-Hurwitz Method

○王建龍

Gopal Adhikari　小林春夫　築地伸和　平野繭　栗原圭汰

群馬大学大学院　理工学府電子情報部門

長浜顕仁　野田一平　吉井宏治

リコー電子デバイス（株）

群馬大学
GUNMA UNIVERSITY

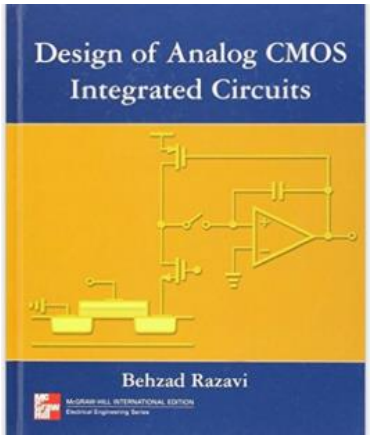
Research Background (Stability Theory)

- **Electronic Circuit Design Field**
  - Bode plot (>90% frequently used)
  - Nyquist plot (源代裕治、電子回路研究会 2015年7月)

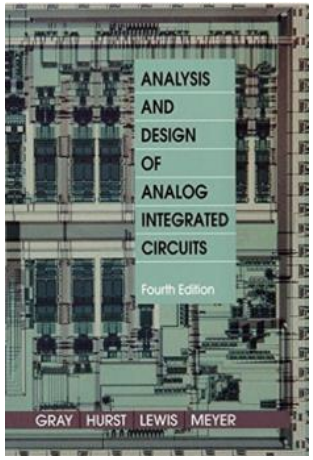
- **Control Theory Field**
  - Bode plot
  - Nyquist plot
  - Nicholas plot
  - Routh-Hurwitz stability criterion
    ⇨ Very popular in control theory field
    but rarely seen in electronic circuit books/papers
  - Lyapunov function method
  - :

Electronic Circuit Text Book

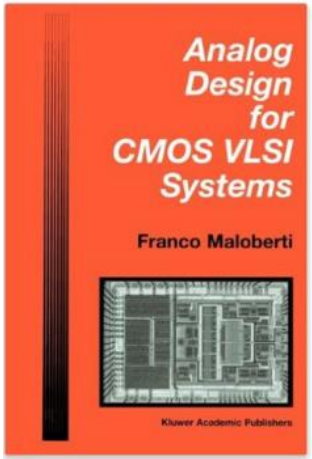
We were NOT able to find out any electronic circuit text book which describes Routh-Hurwitz method
for operational amplifier stability analysis and design !



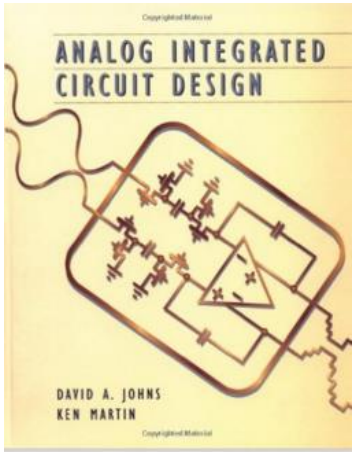
Razavi



Gray



Maloberti

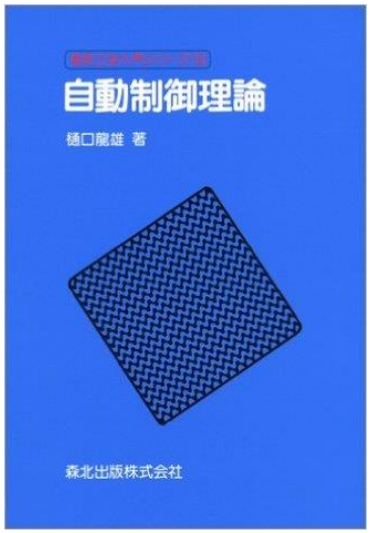


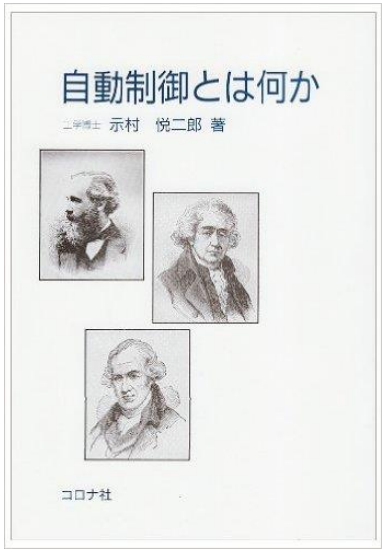
Martin

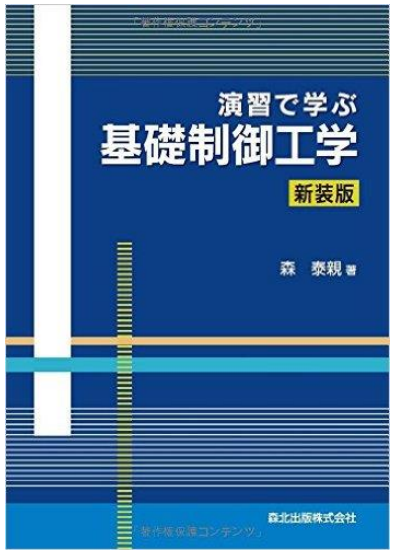
None of the above describes Routh-Hurwitz.
Only Bode plot is used.

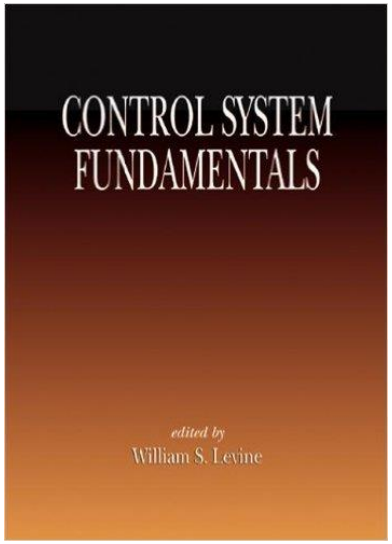
Control Theory Text Book

Most of control theory text books
describe Routh-Hurwitz method
for system stability analysis and design !









Contents

- Stability Criteria
  - Nyquist Criterion and Bode Plot

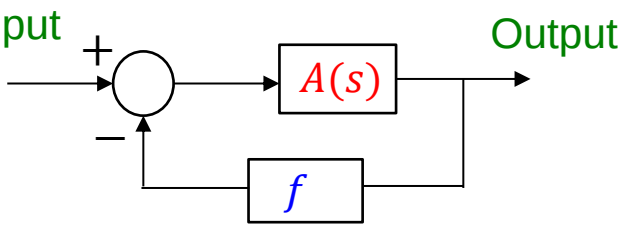
Harry Nyquist
1889-1976 (Sweden)

Hendrik Wade Bode
1905-1982 (蘭)

Transfer Function and Stability

- Transfer function of closed-loop system

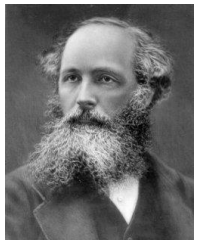
$$G(s) = \frac{A(s)}{1 + fA(s)} = \frac{N(s)}{D(s)}$$



- Suppose

$$N(s) = b_m s^m + b_{m-1} s^{m-1} + \cdots + b_1 s + b_0$$

$$D(s) = a_n s^n + a_{n-1} s^{n-1} + \cdots + a_1 s + a_0$$



J. Maxwell

A. Stodola

- System is stable if and only if

Maxwell and Stodola found out !!

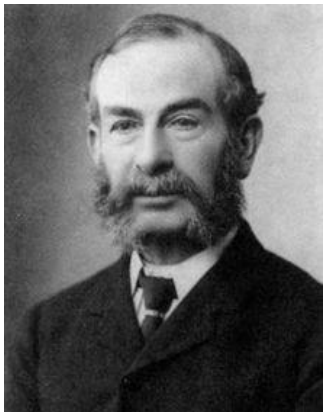
real parts of all the roots s_p of the following are negative:

Characteristic equation $D(s) = a_n s^n + a_{n-1} s^{n-1} + \cdots + a_1 s + a_0 = 0$

- To satisfy this, what are the conditions for $a_n, a_{n-1}, \cdots a_1, a_0$?

Routh and Hurwitz solved this problem independently !!

Routh and Hurwitz



Edward Routh
1831- 1907（英）

1876

Routh test

Great
Mathematicians !

Adolf Hurwitz
1859 - 1919（独）

1895

Hurwitz matrix

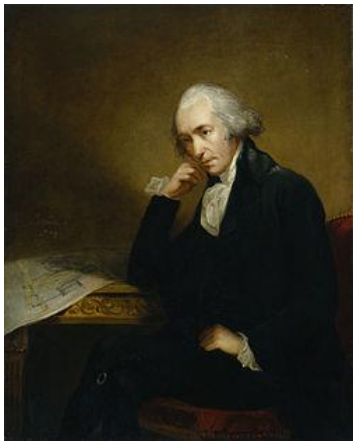
Very different algorithms,
but later it was proved that both are the same results.

Discover Truth

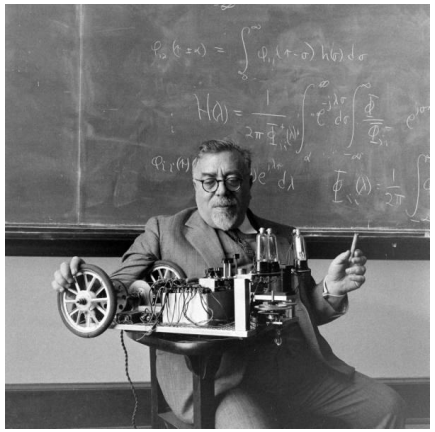
Final Statement

- Control theory is
  theoretical basis of analog circuit design.

- “Feedback” is the most important concept there.



James Watt
1736 - 1819



Nobert Wiener
1894 - 1964

Harold Black
1898-1983

John Ragazzini
1912-1988