Penguat Daya Gelombang Mikro (1)

TTG4D3 – Rekayasa Gelombang Mikro

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Outline

- Pendahuluan
- Macam-Macam Daya & Faktor Penguatan

Pendahuluan

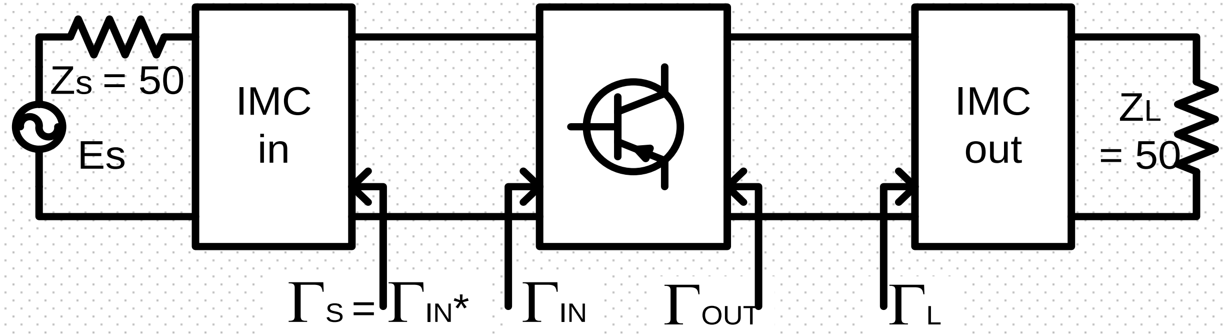
- Salah satu komponen yang terpenting dalam sebuah penguat adalah komponen aktif (transistor) yang memiliki nilai stabilitas berbeda-beda pada frekuensi kerja tertentu.
- Stabilitas adalah hal pertama yang harus diperhatikan dalam perancangan sebuah penguat. Stabilitas merupakan ketahanan transistor terhadap osilasi dalam rangkaian gelombang mikro yang dapat dihitung dengan data parameter S transistor tersebut.
- Dalam menganalisis kestabilan penguat, terdapat beberapa konstanta yang sering digunakan, yaitu:

1. Faktor kestabilan Rollet K

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2}{2|S_{21}S_{12}|}$$

2. Determinan dari parameter S

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$



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Pendahuluan

Faktor Kestabilan

Stabil tanpa syarat
(*unconditionally stable*)

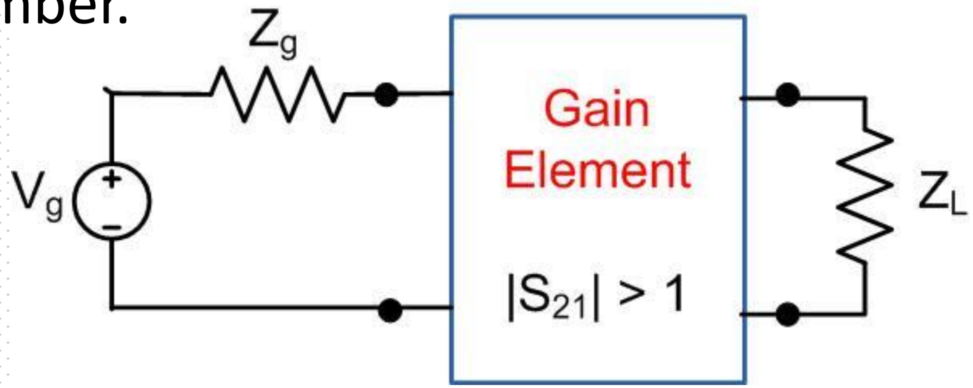
Yaitu apabila K>1 dan $|\Delta|<1$ dimana $|\Gamma_{in}|<1$ dan $|\Gamma_{out}|<1$. Pada kondisi ini transistor cocok digunakan sebagai penguat di mana penguat selalu stabil dengan pemilihan Γ_S dan Γ_L sembarang (di mana saja) pada *smith chart*.

Stabil bersyarat
(*potentially unstable*)

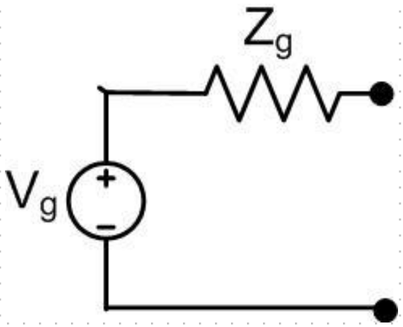
Yaitu apabila K<1 dan $|\Delta|>1$ atau K<1 dan $|\Delta|<1$. Kondisi ini lebih cocok digunakan untuk osilator karena impedansi sumber dan beban akan menyebabkan $|\Gamma_{in}|>1$ dan $|\Gamma_{out}|>1$. Pada kondisi ini lingkaran kestabilan berperan penting dalam pemilihan koefisien pantul sumber dan beban pada perancangan osilator supaya memenuhi syarat kondisi osilasi, yaitu $|\Gamma_{in}|>1$ dan $|\Gamma_{out}|>1$. Kondisi ini dapat juga digunakan sebagai penguat yaitu dengan syarat pemilihan Γ_S dan Γ_L yang berada pada daerah kestabilan sumber maupun beban pada *smith chart*.

Daya (1)

Sebelum diskusi tentang amplifier (penguat), harus didefinisikan terlebih dahulu tentang daya yang dialirkan. Misalkan ada komponen penguat yang dihubungkan dengan beban dan sumber.

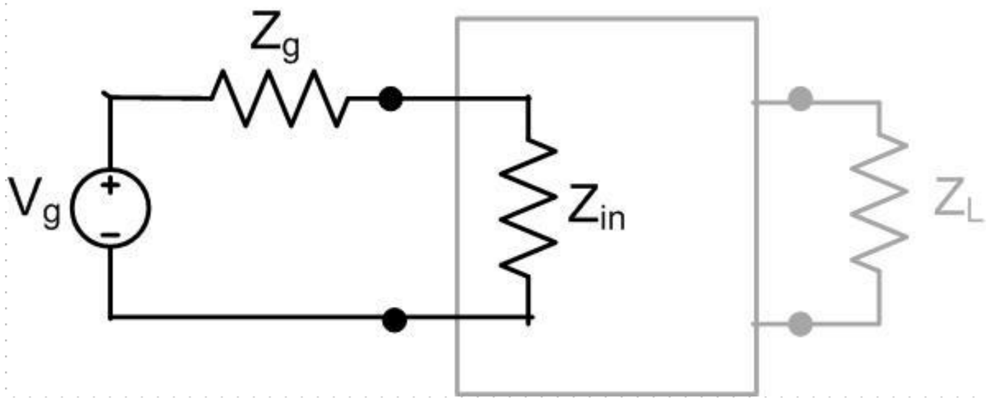


Pertama, power (daya) yang ada adalah **available power** (daya yg tersedia) yang berasal dari **sumber.**



P_{avs} = Available power dari sumber

Daya (2)



Daya yang datang ke port input komponen penguat

Daya yang dipantulkan dari port input komponen penguat

$$\mathbf{P_{in} = P_{inc} - P_{ref}}$$

$$= \frac{|\mathbf{b_S}|^2 - |\mathbf{a_S}|^2}{2\mathbf{Z_0}}$$

$$= \frac{|\mathbf{V_S}|^2}{8\mathbf{Z_0}} \frac{|1 - \Gamma_S|^2}{|1 - \Gamma_S \Gamma_{in}|^2} \left(1 - |\Gamma_{in}|^2\right)$$

$$= \frac{|\mathbf{V_S}|^2}{2\mathbf{Z_0}} \left| \frac{\mathbf{Z_0}}{\mathbf{Z_0} + \mathbf{Z_S}} \right|^2 \frac{1 - |\Gamma_{in}|^2}{|1 - \Gamma_S \Gamma_{in}|^2}$$

Daya yg diserap beban (port input komponen penguat)

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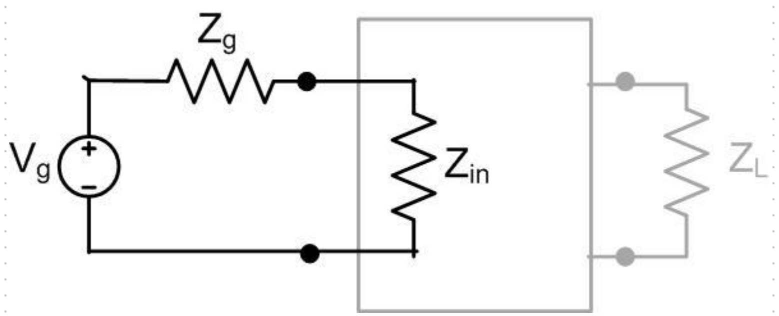
Daya (3)



P_{in} maks jika :

$$\frac{1 - |\Gamma_{in}|^2}{|1 - \Gamma_S \Gamma_{in}|^2}$$

maksimal

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$$\Gamma_{in} = \Gamma_S^*$$

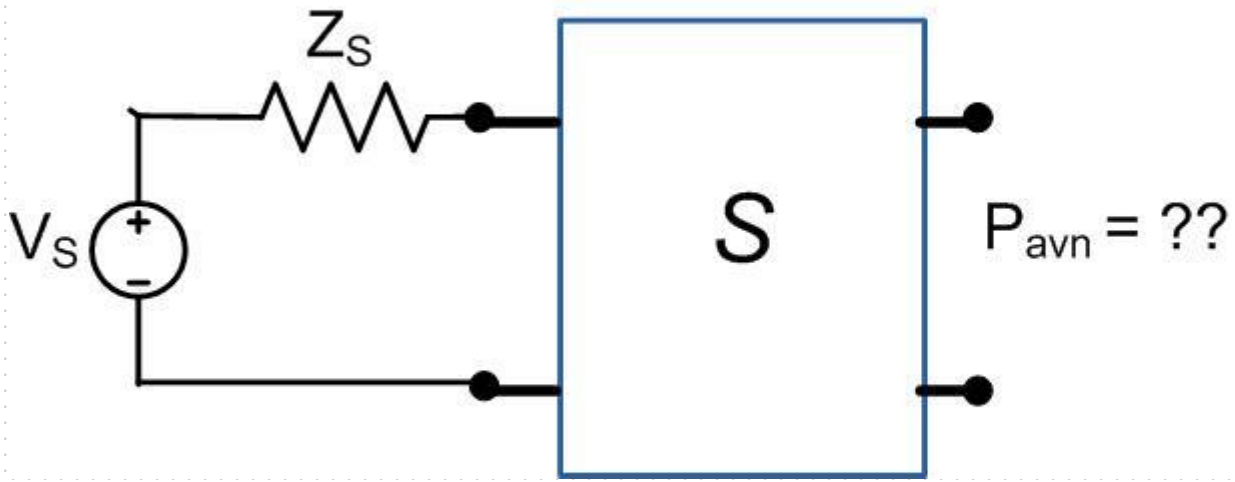
$$P_{avs} = P_{in}\big|_{\Gamma_{in} = \Gamma_S^*}$$

$$= \frac{|V_S|^2}{8Z_0} \frac{|1 - \Gamma_S|^2}{1 - |\Gamma_S|^2}$$

$$= \frac{|V_S|^2}{2Z_0} \left| \frac{Z_0}{Z_0 + Z_S} \right|^2 \frac{1}{1 - |\Gamma_S|^2}$$

$$= \frac{1}{2} |V_S|^2 \frac{1}{4\mathrm{Re}\{Z_S^*\}}$$

Daya (4)



Jika ada sebuah komponen dua port dihubungkan dengan sumber, bagaimana nilai Pavn?

Daya (5)

$$P_L = \frac{|b_2|^2 - |a_2|^2}{2Z_0}$$

$$= \frac{|V_{out}|^2}{8Z_0}\frac{|1-\Gamma_{out}|^2}{|1-\Gamma_{out}\Gamma_L|^2}\left(1-|\Gamma_L|^2\right)$$

$$= \frac{|V_S|^2}{8Z_0}\frac{|S_{21}|^2}{|1-\Gamma_S S_{11}|^2}\frac{|1-\Gamma_S|^2}{|1-\Gamma_{out}\Gamma_L|^2}\left(1-|\Gamma_L|^2\right)$$

P_L maks jika :

$$\frac{1-|\Gamma_L|^2}{|1-\Gamma_{out}\Gamma_L|^2}$$

maksimal

JIKA

$$\Gamma_L = \Gamma_{out}^*$$

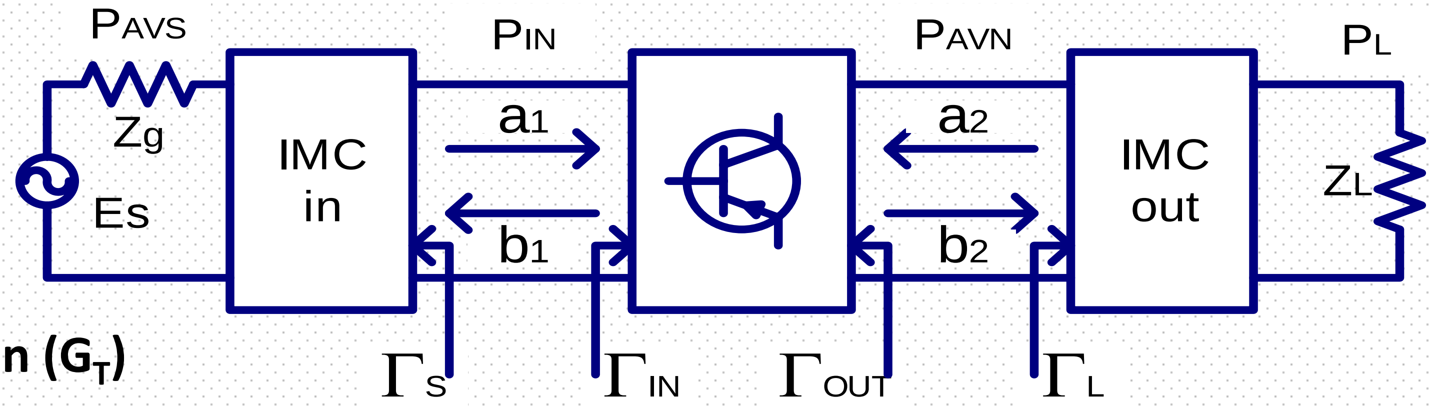
$$P_{avn} = P_L|_{\Gamma_L=\Gamma_{out}^*}$$

$$= \frac{|V_S|^2}{8Z_0}\frac{|S_{21}|^2}{|1-\Gamma_S S_{11}|^2}\frac{|1-\Gamma_S|^2}{|1-\Gamma_{out}\Gamma_{out}^*|^2}\left(1-|\Gamma_{out}|^2\right)$$

$$= \frac{|V_S|^2}{8Z_0}\frac{|S_{21}|^2}{|1-\Gamma_S S_{11}|^2}\frac{|1-\Gamma_S|^2}{\left(1-|\Gamma_{out}|^2\right)^2}\left(1-|\Gamma_{out}|^2\right)$$

$$= \frac{|V_S|^2}{8Z_0}\frac{|S_{21}|^2}{|1-\Gamma_S S_{11}|^2}\frac{|1-\Gamma_S|^2}{1-|\Gamma_{out}|^2}$$

Faktor Penguatan (1)



1. **Transducer Power Gain (G_T)**

$$G_T = \frac{P_L}{P_{avs}} = \frac{\text{Daya yang diberikan ke beban}}{\text{Daya yang tersedia pada sumber sinyal}}$$

2. **Operating Power Gain (G_P)**

$$G_P = \frac{P_L}{P_{in}} = \frac{\text{Daya yang diberikan ke beban}}{\text{Daya yang diberikan ke transistor}}$$

3. **Available Power Gain (G_A)**

$$G_A = \frac{P_{avn}}{P_{avs}} = \frac{\text{Daya tersedia dari transistor}}{\text{Daya yang tersedia pada sumber sinyal}}$$

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Faktor Penguatan (2)

1. **Transducer Power Gain (G_T)**

$$G_T = \frac{P_L}{P_{avs}} = \frac{\text{Daya yang diberikan ke beban}}{\text{Daya yang tersedia pada sumber sinyal}}$$

$$= \frac{|S_{21}|^2}{|1 - \Gamma_S\ S_{11}|^2} \frac{|1 - \ \Gamma_S|^2}{|1 - \Gamma_{out}\ \Gamma_L|^2} \left(1 - |\Gamma_L|^2\right) \frac{1 - \ |\Gamma_S|^2}{|1 - \Gamma_S|^2}$$

$$= \frac{|S_{21}|^2 \left(1 - \ |\Gamma_S|^2\right)\left(1 - |\Gamma_L|^2\right)}{1} \frac{1}{|1 - \Gamma_{out}\ \Gamma_L|^2\ |1 - \Gamma_S\ S_{11}|^2}$$

$$= \frac{|S_{21}|^2 \left(1 - \ |\Gamma_S|^2\right)\left(1 - |\Gamma_L|^2\right)}{1} \frac{1}{|1 - \Gamma_S\ \Gamma_{in}|^2\ |1 - \Gamma_L\ S_{22}|^2}$$

$$= \frac{|S_{21}|^2 \left(1 - \ |\Gamma_S|^2\right)\left(1 - |\Gamma_L|^2\right)}{|1 - \Gamma_S\ \Gamma_{in}|^2\ |1 - \Gamma_L\ S_{22}|^2}$$

Faktor Penguatan (3)

2. Operating Power Gain (G_P)

$$G_P = \frac{P_L}{P_{in}} = \frac{\text{Daya yang diberikan ke beban}}{\text{Daya yang diberikan ke transistor}}$$

$$= \frac{|S_{21}|^2}{|1 - \Gamma_S\ S_{11}|^2} \frac{|1 - \ \Gamma_S|^2}{|1 - \Gamma_{out}\ \Gamma_L|^2} \left(1 - |\Gamma_L|^2\right) \frac{|1 - \ \Gamma_S \Gamma_{in}|^2}{|1 - \Gamma_S|^2} \frac{1}{1 - \ |\Gamma_{in}|^2}$$

$$= \frac{|S_{21}|^2}{1 - \ |\Gamma_{in}\ |^2} \frac{1 - \ \ |\Gamma_L|^2}{|1 - \Gamma_{out}\ \Gamma_L|^2} \frac{1}{|1 - \ \Gamma_S\ S_{11}|^2} |1 - \ \Gamma_S \Gamma_{in}|^2$$

$$= \frac{|S_{21}|^2}{1 - \ |\Gamma_{in}\ |^2} \frac{1 - \ \ |\Gamma_L|^2}{|1 - \Gamma_{out}\ \Gamma_L|^2} \frac{1}{|1 - \ \Gamma_S\ S_{11}|^2} \frac{|1 - \ \Gamma_S S_{11}|^2\ |1 - \Gamma_{out}\ \Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}$$

$$= \frac{|S_{21}|^2}{1 - \ |\Gamma_{in}\ |^2} \frac{1 - \ \ |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}$$

Faktor Penguatan (4)

3. Available Power Gain (G_A)

$$\mathbf{G_A} = \frac{\mathbf{P_{avn}}}{\mathbf{P_{avs}}} = \frac{\textbf{Daya tersedia dari transistor}}{\textbf{Daya yang tersedia pada sumber sinyal}}$$

$$= \frac{|S_{21}|^2}{|1 - \Gamma_S\ S_{11}|^2} \frac{|1 - \ \Gamma_S|^2}{1 - |\Gamma_{out}|^2} \frac{1 - \ |\Gamma_S|^2}{|1 - \Gamma_S\ |^2}$$

$$= \frac{|S_{21}|^2}{|1 - \Gamma_S\ S_{11}|^2} \frac{|1 - \ \Gamma_S|^2}{1 - |\Gamma_{out}|^2}$$

Contoh (1)

A microwave transistor has the following S parameters at 10 GHz, with a 50 Ω reference impedance:

$S_{11} = 0,45 < 150^0$

$S_{12} = 0,01 < -10^0$

$S_{21} = 2,05 < 10^0$

$S_{22} = 0,40 < -150^0$

The source impedance is Z_S = 20 Ω and the load impedance is Z_L = 30 Ω.

Compute the power gain, the available gain and the transducer power gain.

Contoh (1)

Solution:

The reflection coefficients at the source and load are:

$$\Gamma_S = \frac{Z_S - Z_0}{Z_S + Z_0} = \frac{20 - 50}{20 + 50} = -0{,}429$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{30 - 50}{30 + 50} = -0{,}250$$

The reflection coefficients seen looking at the input and output of the terminated network are:

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\,\Gamma_L}{1 - S_{22}\,\Gamma_L} = 0{,}45 < 150^0 + \frac{(0{,}01 < -10^0)(2{,}05 < 10^0)(-0{,}250)}{1 - (0{,}40 < -150^0)(-0{,}250)}$$

$$= 0{,}455 < 150^0$$

$$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\,\Gamma_S}{1 - S_{11}\Gamma_S} = 0{,}40 < -150^0 + \frac{(0{,}01 < -10^0)(2{,}05 < 10^0)(-0{,}429)}{1 - (0{,}45 < 150^0)(-0{,}429)}$$

$$= 0{,}408 < -151^0$$

Contoh (1)

The power gain is:

$$G_P = \frac{|S_{21}|^2}{(1-\ |\Gamma_{in}|^2)} \frac{(1-\ \ |\Gamma_L|^2)}{|1-S_{22}\Gamma_L|^2} = \frac{(2{,}05)^2\,[1-(0{,}250)^2]}{[1-(0{,}455)^2]\,|1-(0{,}40 < -150^0\,)(-0{,}250\,)|^2}$$

=5,94

The available power gain is:

$$G_A = \frac{|S_{21}|^2}{(1-\ |\Gamma_{out}|^2)} \frac{(1-\ \ |\Gamma_S|^2)}{|1-S_{11}\Gamma_S|^2} = \frac{(2{,}05)^2\,[1-(0{,}429)^2]}{[1-(0{,}408)^2]\,|1-(0{,}45 < 150^0\,)(-0{,}429\,)|^2}$$

= 5,85

The transducer power gain is:

$$G_T = \frac{|S_{21}|^2(1-\ \ |\Gamma_S|^2)(1-\ \ |\Gamma_L|^2)}{|1-\Gamma_S\Gamma_{in}|^2|1-S_{22}\Gamma_L|^2}$$

$$= \frac{(2{,}05)^2\,[1-(0{,}429)^2][1-(0{,}250)^2]}{|1-(-0{,}429\,)(0{,}455 < 150^0\,)|^2|1-(0{,}40 < -150^0\,)(-0{,}250\,)|^2} = 5{,}49$$

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Referensi

- Microwave Engineering 3rd Edition, David M. Pozar.

Terima Kasih