Amplifier Gain and Decibel Representation

Dr. Francis M. fernandez

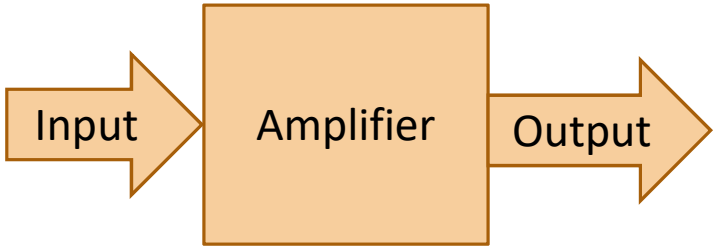
What is gain?

- Gain of an amplifier or network is the ratio of output to input.
- Gain is defined for power, voltage and current as below.

$$Power\ gain, A_{P(ratio)} = \frac{P_{output}}{P_{input}}$$

$$Voltage\ gain, A_{V(ratio)} = \frac{V_{output}}{V_{input}}$$

$$Current\ gain, A_{I(ratio)} = \frac{I_{output}}{I_{input}}$$



Bel and Decibel

- Bel was initially defined for power loss in telephone networks but later extended to represent gain of amplifiers as well.
- Power gain in bel is defined as the common logarithm (base 10) of power ratio.

$$Power\ gain\ in\ Bel,\ A_{P(Bel)} = \log_{10} \frac{P_{output}}{P_{input}}$$

- Later a modified representation – ***Decibel*** was adopted and is represented as

$$Power\ gain\ in\ Decibel,\ A_{P(dB)} = 10 \log_{10} \frac{P_{output}}{P_{input}}$$

Decibel Representation Examples

Input Power P_{I}	Output Power P_{O}	Ratio Gain $A_P = \frac{P_O}{P_I}$	Gain in *dB* $A_{P(dB)} = 10 \log_{10} \frac{P_O}{P_I}$
10	1000	100	20 *dB*
10	100	10	10 *dB*
10	10	1	0 *dB*
10	1	0.1	-10 *dB*

- Negative decibel gain indicates attenuation

Voltage Gain

- Relation between power and voltage in a network

$$\text{Power, } P = \frac{V^2}{R}$$

Assuming constant load impedance, power is proportional to square of voltage

Then, $$\text{Power gain, } A_{P(ratio)} = \frac{V_{out}^{\,2}/R}{V_{in}^{\,2}/R} = \left(\frac{V_{out}}{V_{in}}\right)^2 = A_V^{\,2}$$

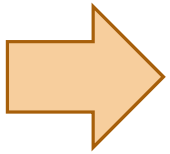
$$\text{Corresponding decibel voltage gain, } A_{V(dB)} = 10 \log A_V^{\,2}$$

ie. $$\text{Voltage gain, } A_{V(dB)} = 20 \log A_V$$

where $$A_V = \frac{V_{out}}{V_{in}}$$

Current Gain

- Relation between power and current in a network



$$\text{Power, } P = I^2 R$$

Assuming constant load impedance, power is proportional to square of current

Then,
$$\text{Power gain, } A_{P(ratio)} = \frac{I_{out}{}^2 R}{I_{in}{}^2 R} = \left(\frac{I_{out}}{I_{in}}\right)^2 = A_I{}^2$$

$$\text{Corresponding decibel current gain, } A_{I(dB)} = 10 \log A_I{}^2$$

ie.
$$\text{Current gain, } A_{I(dB)} = 20 \log A_I$$

where $A_V = \dfrac{I_{out}}{I_{in}}$

Example 1

An amplifier has the following details:

- Input voltage: 1 V, Output voltage: 10 V
- Input impedance 10 ohms
- Output impedance 10 ohms

Calculate the gain

$$\text{Voltage gain, } A_V = \frac{V_{out}}{V_{in}} = \frac{10}{1} = 10$$

$$\text{Input current, } I_{in} = \frac{V_{in}}{R_{in}} = \frac{1}{10} = 0.1 \text{ A}$$

$$\text{Output current, } I_{out} = \frac{V_{out}}{R_{out}} = \frac{10}{10} = 1 \text{ A}$$

$$\text{Current gain, } A_I = \frac{I_{out}}{I_{in}} = \frac{1}{0.1} = 10$$

Decibel voltage gain, $A_{V(dB)} = 20 \log A_V = 20 \log 10 = 20\ dB$

Decibel current gain, $A_{I(dB)} = 20 \log A_I = 20 \log 10 = 20\ dB$

Input Power, $P_{in} = \frac{V_{in}^{\ 2}}{R_{in}} = \frac{1^2}{10} = 0.1\ \text{W}$

Output power, $P_{out} = \frac{V_{out}^{\ 2}}{R_{out}} = \frac{10^2}{10} = 10\ \text{W}$

Decibel power gain, $A_{P(dB)} = 10 \log A_P = 10 \log \frac{10}{0.1} = 20\ dB$

Example 2

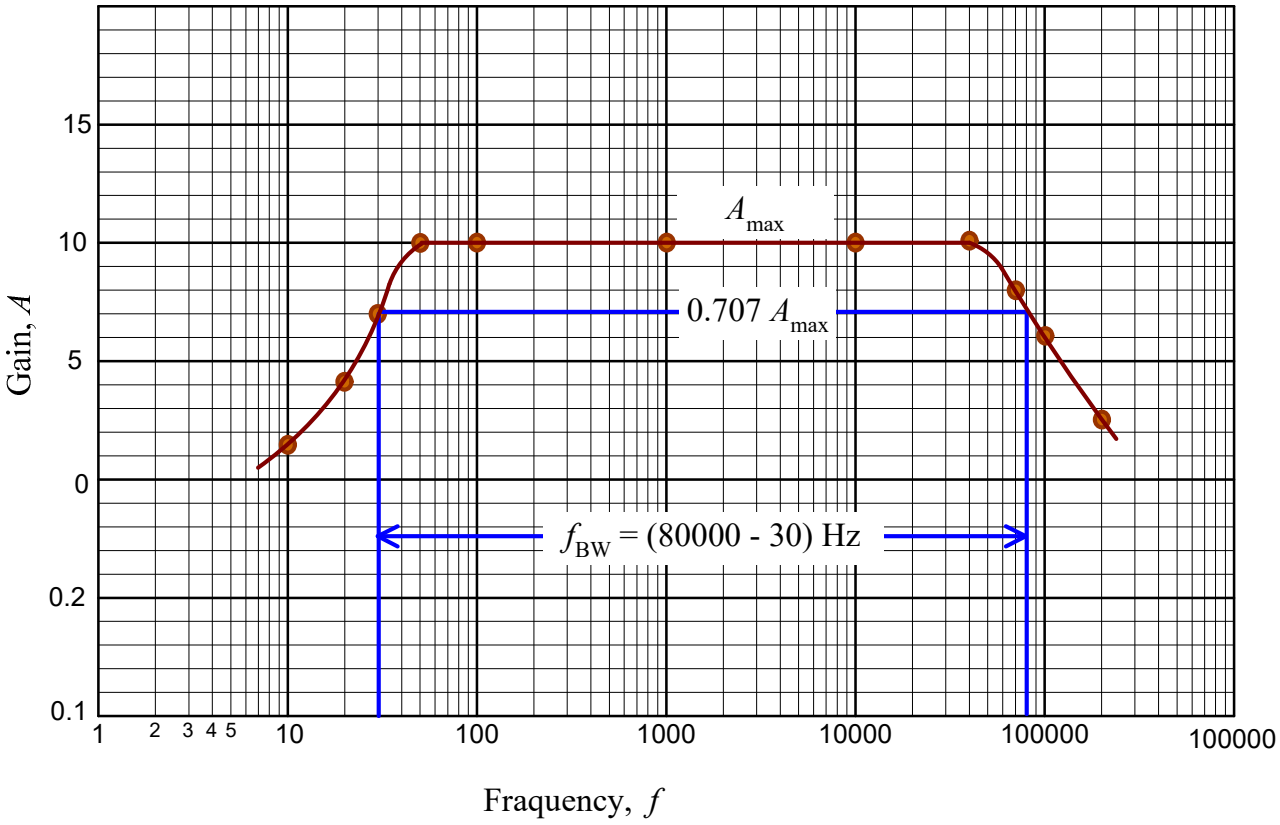
An amplifier yielded the following output voltage at when the input frequency is changed from 10 Hz to 200 kHz. Input is 10 mV sine wave. Plot the gain in ratio and decibel. Also find the bandwidth.

Frequency (Hz)	Output Voltage (V)
10	14
20	42
30	70
50	100
100	100
1,000	100
10,000	100
40,000	100
70,000	80
100,000	60
200,000	25

Solution:

Frequency *f* (Hz)	Output Voltage *Vo* (mV)	Ratio Gain *A* (V_o / V_i)	Gain (dB) 20 log *A*
10	14	1.4	2.9
20	42	4.2	12.5
30	70	7.0	16.9
50	100	10	20.0
100	100	10	20.0
1,000	100	10	20.0
10,000	100	10	20.0
40,000	100	10	20.0
70,000	80	8	18.0
100,000	60	6	15.5
200,000	25	2.5	8.0

Plot of Ratio Gain



Plot of Decibel Gain