Department of Computer Engineering
Faculty of Engineering
Prince of Songkla University

241-309

Advanced Analog and Digital Systems

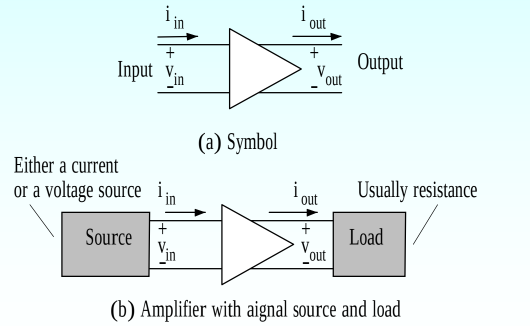
1

Chapter 1

Ideal Analog Amplifier

Analog Amplifier

"The amplifier is the circuit that accept its input either current or voltage signal, to increase the amplitude of this signal without altering its shape in anyway"



Ideal linear amplifier

Voltage gain

"The output voltage is equal to the input voltage multiplied by a constant"

$$v_{out} = A_v \times v_{in}$$

or

$$A_v = \frac{v_{out}}{v_{in}}$$

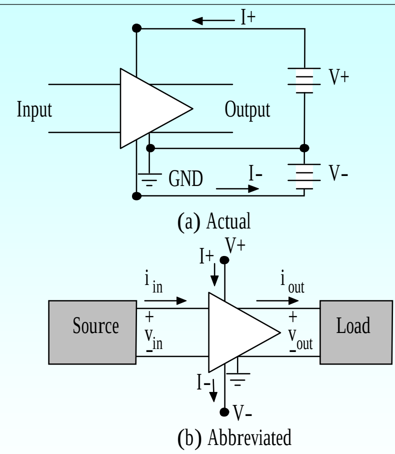
Current Gain

$$i_{out} = A_i \times i_{in}$$

or

$$A_i = \frac{i_{out}}{i_{in}}$$

Power Considerations

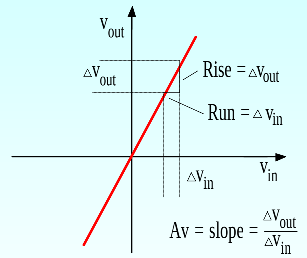


Power supply connections

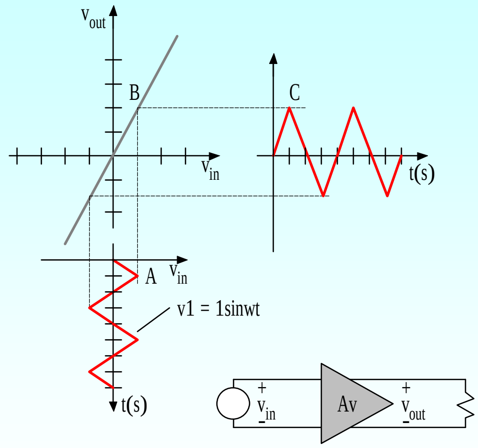
Linear Transfer Characteristics

Transfer characteristic curve dealing with devices or circuits that have more than two terminals. It displays how a signal is *transferred* from the input terminal pair to the output terminal pair.

Voltage Transfer Characteristic Curve



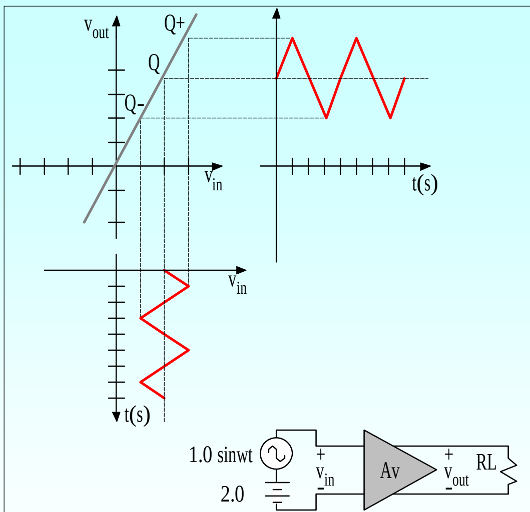
A general voltage transfer characteristic curve



Ideal voltage amplifier and Graphical solution for v_{out}

The amplifier which input consists of a DC source in series with an ac source

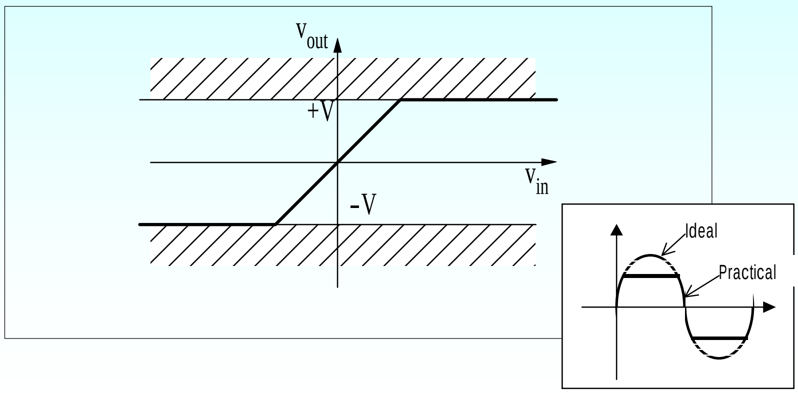
$$v_{in} = 2.0 + 1.0\sin wt$$
$$v_{out} = A_v \times v_{in} = 2.0(2.0 + 1.0\sin wt)$$
$$= 4.0 + 2.0\sin wt$$



Ideal voltage amplifier and Graphical solution for v_{out}

Output Voltage Limitations

In practical circuit, the input and output voltages must certainly be limited to some finite values. The output voltage cannot in general exceed the value of either DC power supply voltage.



Nonlinear Transfer Charateristics

Nonlinear Voltage Transfer Curve

Theoretical curve : obtained mathematically.

Actual curve : obtained by laboratory measurement.

the equation to describe FETs are

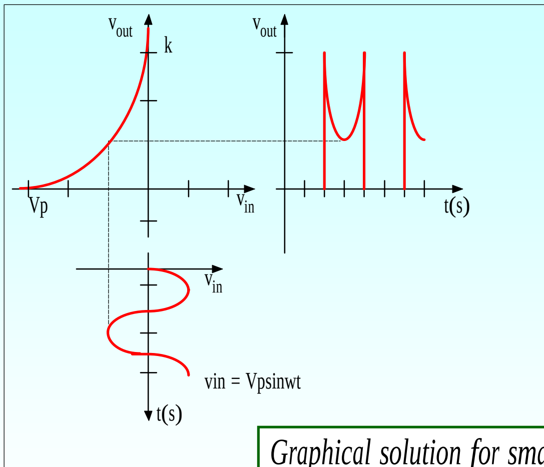
$$v_o = k(v_{in} - v_T)^2$$

or

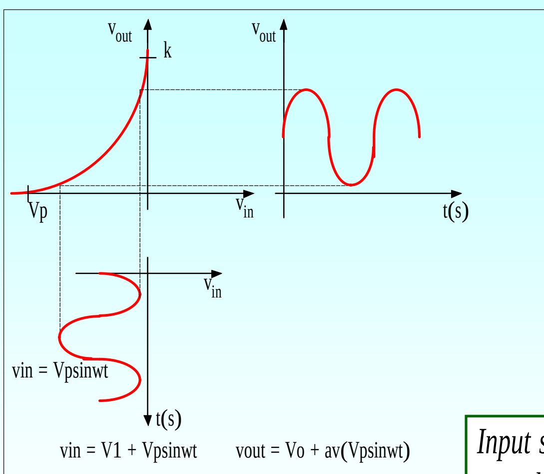
$$v_o = k(1 - \frac{v_{in}}{v_P})^2$$

k , v_P and v_T are all manufacturer's data sheet constants.

Graphical Interpretation

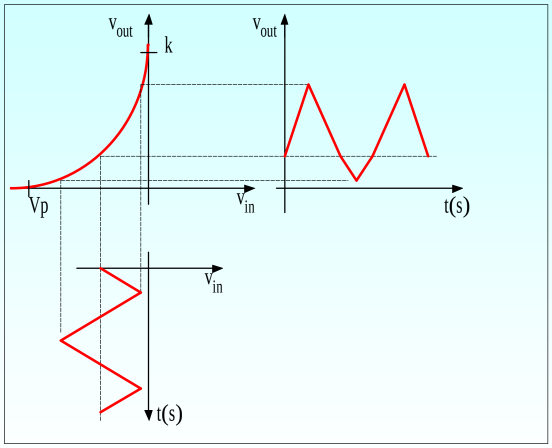


Graphical solution for small ac input voltage, $v_{in} = V_p \sin \omega t$ is applied to the amplifier

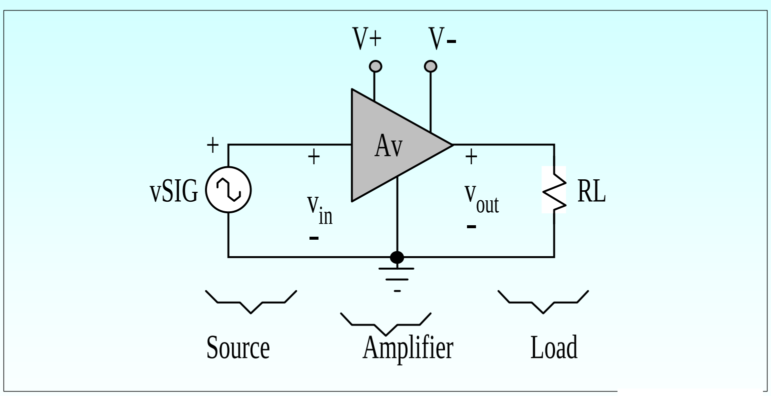


Input signal consists of a small ac voltage superposed on a DC voltage

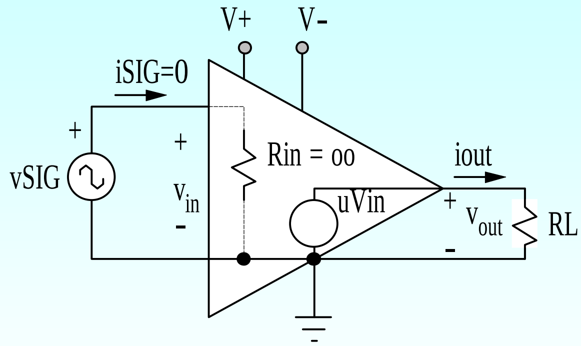
Output Distortion



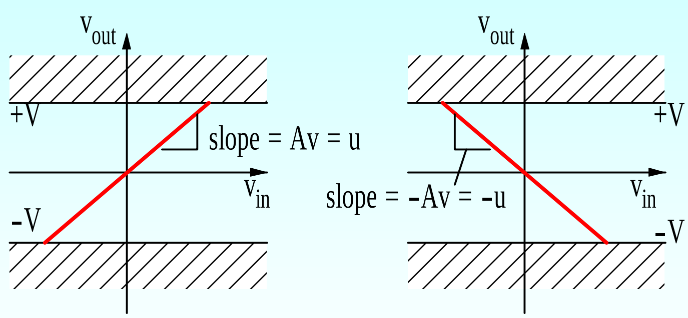
Linear Voltage Amplifier



Ideal Model

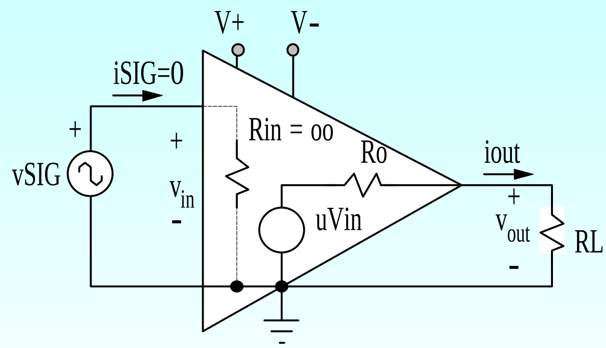


Linear voltage amplifier model



(a) Positive voltage gain (b) Negative voltage gain

Departures from Ideal

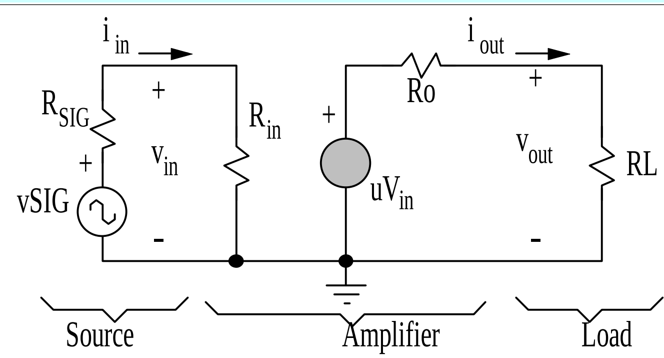


(a) Non-ideal linear voltage amplifier

$$v_{out} = m\ v_{in}\left(\frac{R_L}{R_O + R_L}\right)$$

$$A_v = \frac{v_{out}}{v_{in}} = m\left(\frac{R_L}{R_O + R_L}\right)$$

Source Resistance

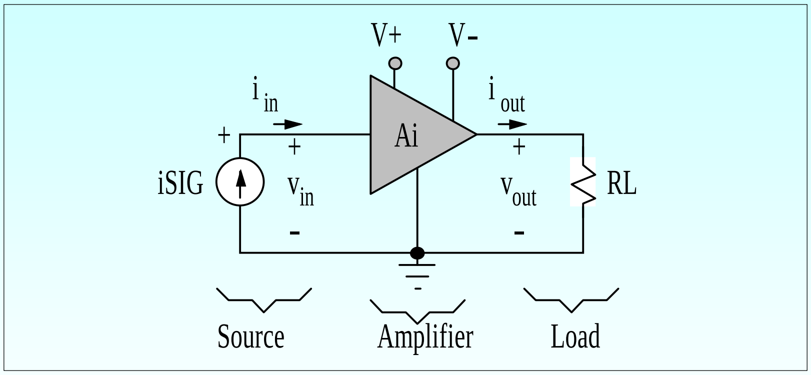


(a) Non-ideal linear voltage amplifier

$$v_{in} = v_{SIG}\left(\frac{R_{in}}{R_{SIG} + R_{in}}\right)$$

$$A_v = \frac{v_{out}}{v_{SIG}} = \left(\frac{R_{in}}{R_{SIG} + R_{in}}\right) \times m\left(\frac{R_L}{R_O + R_L}\right)$$

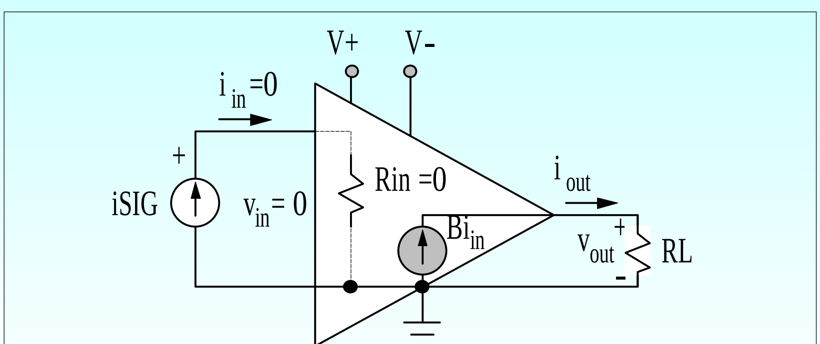
Linear Current Amplifier



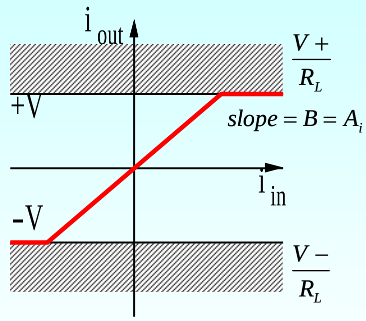
$$i_{out} = A_{in} \times i_{in}$$

$$A_{in} = \frac{i_{out}}{i_{in}}$$

Ideal Model

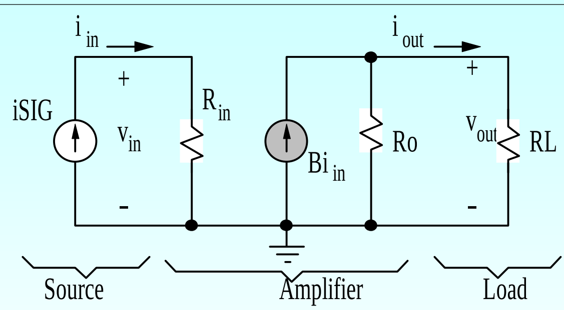


Linear current amplifier model



Current transfer characteristic.

Departures from the Ideal

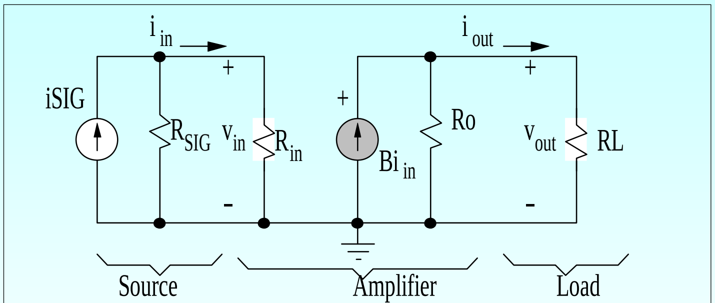


(a) Nonideal linear current amplifier

$$i_{out} = b\, i_{in}\left(\frac{R_O}{R_O + R_L}\right)$$

$$A_{in} = \frac{i_{out}}{i_{in}} = b\left(\frac{R_O}{R_O + R_L}\right)$$

Source Resistance



Nonideal linear current amplifier with source resistance

$$i_{in} = i_{SIG}\left(\frac{R_{SIG}}{R_{SIG}+R_{in}}\right)$$

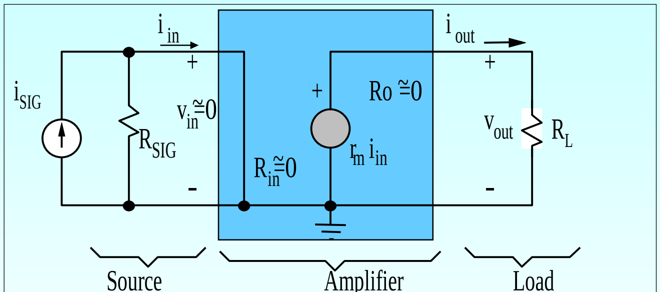
$$A_i = \frac{i_{out}}{i_{SIG}} = \left(\frac{R_{SIG}}{R_{SIG}+R_{in}}\right)\times b\left(\frac{R_O}{R_O+R_L}\right)$$

Linear Resistance and Conductance Amplifiers

Transconductance Amplifier : accept a input voltage signal and deliver current to a load connected to its output

Tranresistance Amplifier : accept a input current signal and provide voltage to a load connected to its output

Linear Resistance Amplifier



Resistance Amplifier

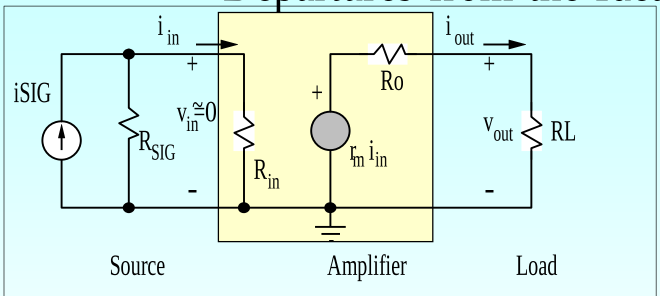
The output voltage is simply the value of current-dependent voltage source

$$v_{out} = r_m \times i_{in}$$

$$r_m = \frac{v_{out}}{i_{in}}$$

r_m = the ratio of output voltage to input current (V/A)

Departures from the Ideal



Linear Resistance Amplifier

From

$$A_r = \frac{v_{out}}{i_{SIG}}$$

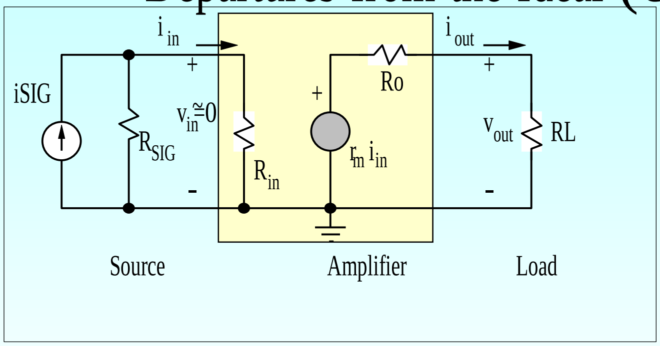
Current Divider rule thus

$$i_{in} = i_{SIG} \times \left(\frac{R_{SIG}}{R_{SIG} + R_{in}} \right)$$

and

$$r_m \times i_{in} = r_m \times i_{SIG} \times \left(\frac{R_{SIG}}{R_{SIG} + R_{in}} \right)$$

Departures from the Ideal (Cont')



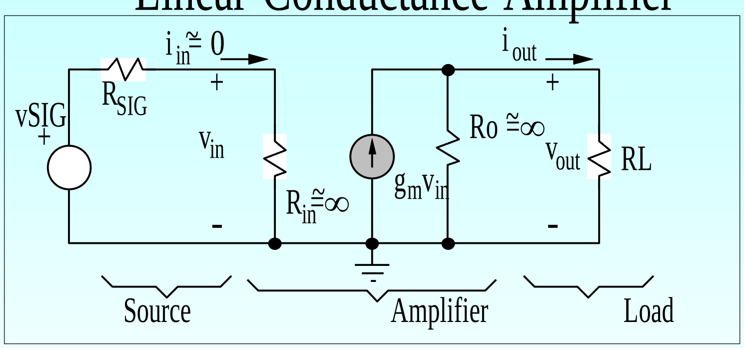
find v_{out} by using voltage divider Rule

$$v_{out} = r_m\, i_{in} \times \left(\frac{R_L}{R_O + R_L} \right)$$

so that

$$A_r = \frac{v_{out}}{i_{SIG}} = \left(\frac{R_{SIG}}{R_{SIG} + R_{in}} \right) \times r_m \times \left(\frac{R_L}{R_O + R_L} \right)$$

Linear Conductance Amplifier



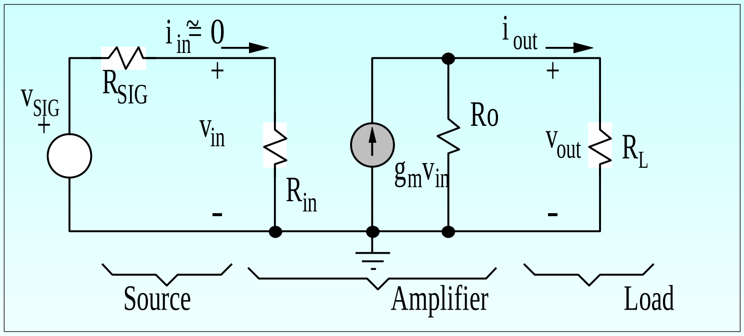
The output current i_{out} delivered to the load resistance R_L equals the current of voltage-dependent current source

$$i_{out} = g_m \times v_{in}$$

$$g_m = \frac{i_{out}}{v_{in}}$$

g_m = the ratio of output current to input voltage (A/V)

Departures from the Ideal



$$A_g = \frac{i_{out}}{v_{SIG}}$$

$$= \left(\frac{R_{in}}{R_{SIG} + R_{in}} \right) \times g_m \times \left(\frac{R_O}{R_O + R_L} \right)$$

Frequency Consideration

Decibel

The *bel(B)* was defined by the following equation to relate power levels P_1 and P_2 :

$$G = \log_{10}\left(\frac{P_2}{P_1}\right) \qquad \text{bel}$$

The *bel* was too large a unit of measurement for practical purpose, The *decibel* was defined such that 10 decibels = 1 bel

$$G_{dB} = 10\log_{10}\left(\frac{P_2}{P_1}\right) \qquad \text{dB}$$

from (for $Z_i = Z_L$)

$$P_1 = \frac{(V_1)^2}{R_i}$$

$$P_2 = \frac{(V_2)^2}{R_i}$$

so that (Voltage Gain in decibels)

$$\begin{aligned} G_{dB} &= 10\log_{10}\left(\frac{P_2}{P_1}\right) \qquad \text{dB} \\ &= 10\log_{10}\frac{(V_2)^2/R_i}{(V_1)^2/R_i} \\ &= 10\log_{10}\left(\frac{V_2}{V_1}\right)^2 \\ &= 20\log_{10}\left(\frac{V_2}{V_1}\right) \end{aligned}$$

For cascade stage

$$A_{vT} = A_{v1}\,A_{v2}\,A_{v3}\;\mathbf{K}\;A_{vn} \qquad \text{dB}$$

and

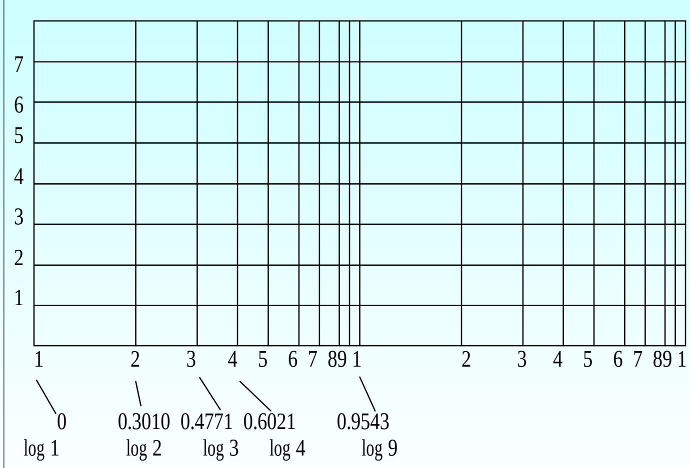
$$G_{vT} = G_{v1} + G_{v2} + G_{v3} + \mathbf{K} + G_{vn} \qquad \text{dB}$$

Applied to current consideration

for $P_2 = \dfrac{(I_2)^2}{R_L}$ and $P_1 = \dfrac{(I_1)^2}{R_L}$

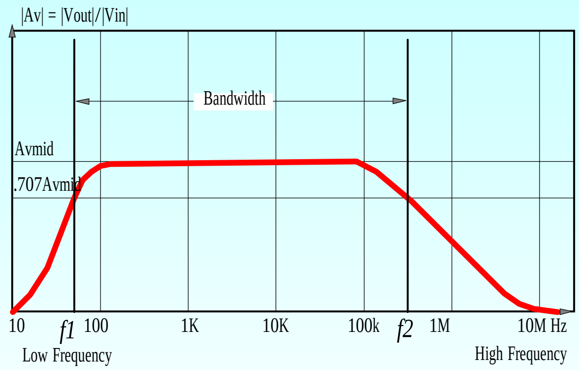
$$G_{dB} = 20\log_{10}\left(\frac{I_2}{I_1}\right) \qquad \text{dB}$$

$$G_{iT} = G_{i1} + G_{i2} + G_{i3} + \mathbf{K} + G_{in} \qquad \text{dB}$$



Semilog graph paper

General Frequency Conderations



Gain versus Frequency

Bandwidth (BW) = $f_2 - f_1$

f_1,f_2 : cut off frequency (or band, break, half-power frequency)

= 0.707A_{vmid} (Midband power output)

Bandwidth (BW) = $f_2 - f_1$

f_1,f_2 : cut off frequency (or band, break, half-power frequency) = 0.707A_{vmid} (Midband power output)

$$P_{omid} = \frac{|V_o^{\ 2}|}{R_o} = \frac{|A_{vmid} V_i|^2}{R_o}$$

at half-power frequency (0.707A_{vmid})

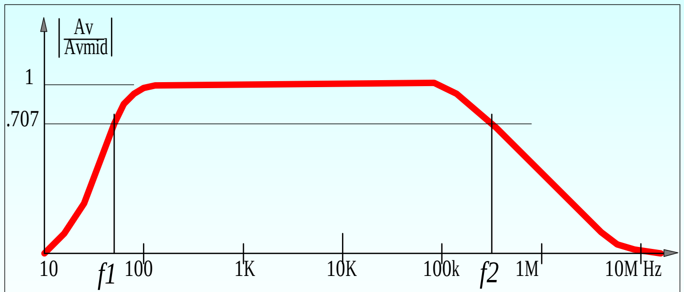
$$P_{oHPF} = \frac{|0.707 A_{vmid} V_i|^2}{R_o}$$

$$P_{oHPF} = \frac{0.5|A_{vmid} V_i|^2}{R_o}$$

$$P_{oHPF} = 0.5 P_{omid}$$

A decibel plot can be obtained by

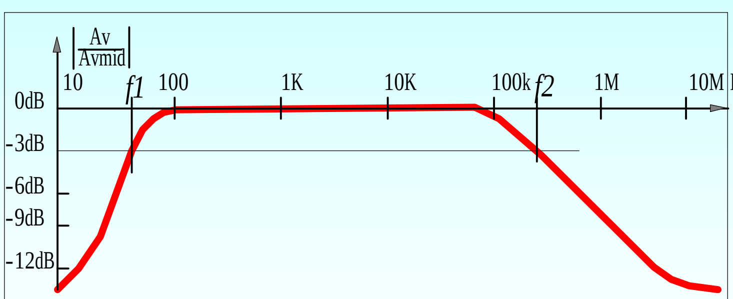
$$\left.\frac{|A_v|}{|A_{vmid}|}\right|_{dB} = 20\log_{10}\frac{|A_v|}{|A_{vmid}|}$$



Normalize Gain versus Frequency Plot

At midband frequency $20\log_{10}1 = 0$ and 0.707 = 1/2
the cut off frequency

$$20\log_{10}\frac{1}{2} = -3dB$$



Decibel lot of Normalize Gain versus Frequency Plot

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