Amplifiers: Two frequent examples

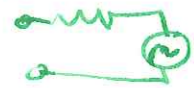
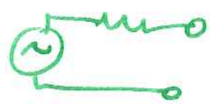
transducer → amp → measure

function generator → amp → power output

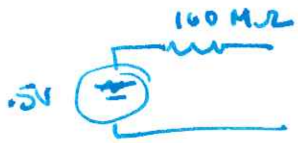
Typical Public Address System

combines two: microphone → amp → speaker

Claim: the important characteristics of amp are:
① input impedance, ② output impedance, ③ gain

Note: thevenin says the input terminals = 
and we expect the voltage on inputs (with nothing connected) should be negligible. On output thevenin says same:  but here we expect big output voltages — typically the output (open circuit gain) will be a multiple of what is on the input terminals: $V_{out} = A\, V_{in}$ ← "gain" perhaps in dB

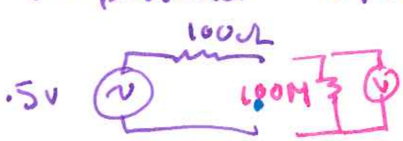
Eg "glass electrode" transducer used to measure pH:



If this is attached to a typical DMM with input impedance ~1 MΩ

the measured voltage will be $\frac{1}{101} \cdot .5 = .005$
ie a huge error!

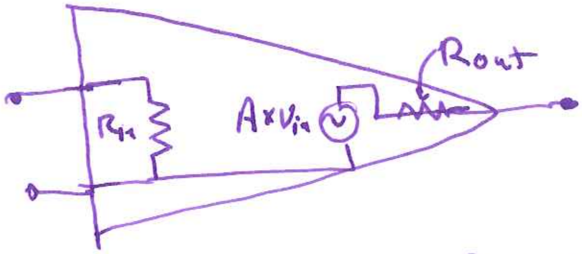
Eg – on the other hand in 200 you measured (in the Helmholtz lab) AC magnetic fields with a little "pick up" coil whose impedance < 100 Ω



measure: $\frac{100 \times 10^6}{100 \times 10^6 + 100} \cdot .5V = .5V$

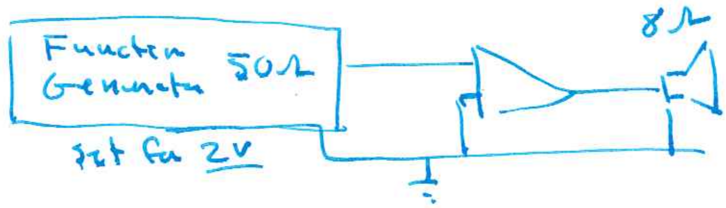
Remark: A low impedance transducer like this is a good candidate for an "impedance matching" transformer – using a transformer we could boost the voltage 10x and change the impedance 100x → 10K. 10K is still negligible compared to 1 MΩ so we would still get essentially 100% voltage transfer. However in the 200 lab there was no reason to boost voltage as they were already large enough to easily measure.

Generic Amp:



Remark: it turns out that $R_{in} \to \infty$ & $R_{out} \to 0$ are good characteristics of amp.

Eg:



Say: $R_{in} = 150\Omega$

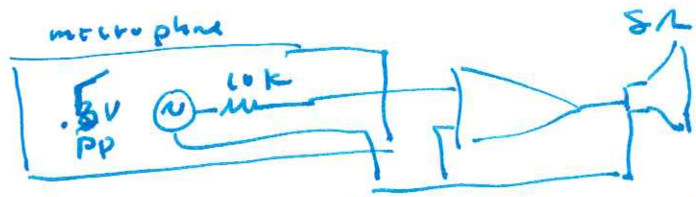
$R_{out} = 16\Omega$

$A = 30\,dB$

$= 10^{30/20}$

$= 31.6$

$$V_{out} = \left(\frac{150}{200} \cdot 2V\right) \times 31.6 \times \left(\frac{8}{24}\right) = 15.8$$



$R_{in} = 1M\Omega$

$R_{out} = 1\Omega$

$A = 30\,dB$

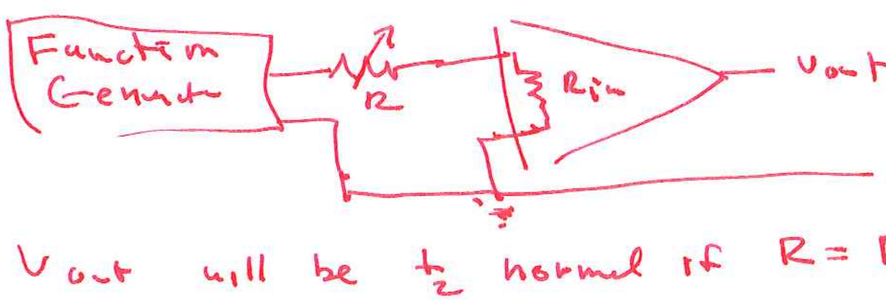
$$V_{out} = \left(\frac{10^6}{10^6 + 10^4}\,\frac{.5}{2\sqrt{2}}\right) \times 31.6 \cdot \left(\frac{8}{9}\right) = 4.9V$$

In lab we will commonly measure R_{in}, R_{out} & A.

Can measure R_{out} as was discussed RE Thevenin

$R_{out} = \dfrac{R}{\frac{V}{\Delta V} - 1}$ where ΔV is the "droop" from using a load R.

IF $R_{in} \gg$ Function generators 50Ω output impedance.

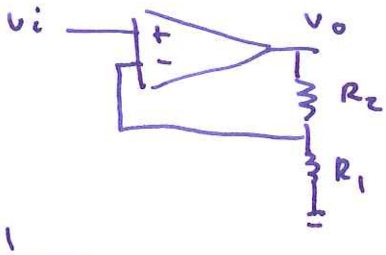


Vout will be $\frac{1}{2}$ normal if $R = R_{in}$

In general: $R_{in} = R\left(\frac{V}{\Delta V} - 1\right)$

An ideal op-amp: $R_{in} = \infty$, $R_{out} = 0$, $A = \infty$

Eg



$$v_- = \frac{R_1}{R_1+R_2} V_o$$

$$A(v_+ - v_-) = V_o$$

$$A\left(v_+ - \frac{R_1}{R_1+R_2} v_o\right) = v_o$$

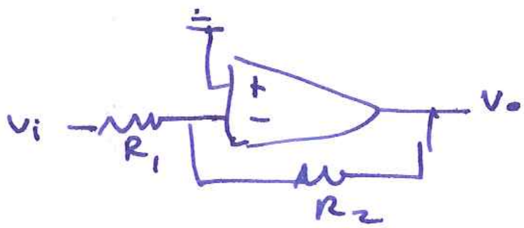
$$v_i = v_+ = \left(\frac{1}{A} + \frac{R_1}{R_1+R_2}\right) v_o$$

$$\frac{v_i}{\left(\frac{1}{A} + \frac{1}{1+R_2/R_1}\right)} = v_o$$

$$\text{gain} = \frac{1}{\left(\frac{1}{A} + \frac{1}{1+R_2/R_1}\right)}$$

$$\xrightarrow[A\to\infty]{} 1 + \frac{R_2}{R_1}$$

Eg



$$\frac{v_i - v_-}{R_1} = \frac{v_- - v_o}{R_2}$$

$$v_o = -A v_-$$

$$\frac{v_i}{R_1} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right) v_- - \frac{v_o}{R_2} = -\frac{1}{R_2}\left[-\left(1+\frac{R_2}{R_1}\right) v_- + v_o\right]$$

$$= -\frac{1}{R_2}\left[\left(1+\frac{R_2}{R_1}\right)\frac{1}{A} + 1\right] v_o$$

$$\frac{-\frac{R_2}{R_1} v_i}{\left(1 + \frac{1}{A}\left(1+\frac{R_2}{R_1}\right)\right)} = v_o$$

$$\text{gain} = \frac{-R_2/R_1}{\left(1+\frac{1}{A}\left(1+\frac{R_2}{R_1}\right)\right)} \rightarrow \frac{-R_2}{R_1}$$

Easier to remember Golden Rules

① No input currents ② $v_+ = v_-$ "virtual ground"