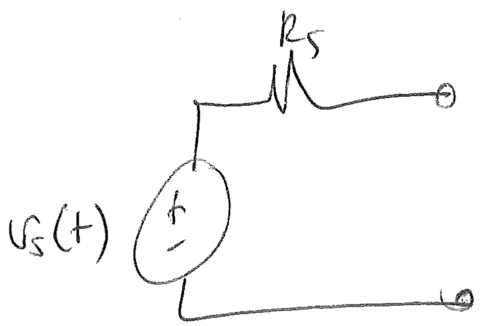
Electronics I.

Chapter 1.1

Signals

- → Different instruments produce signals.
  ex. microphones, sensors, electrical monitors, ...
  ↳ TRANSDUCERS (physical to electrical signals)
- → Signal processing is needed to analyze or use the signal in meaningful ways.

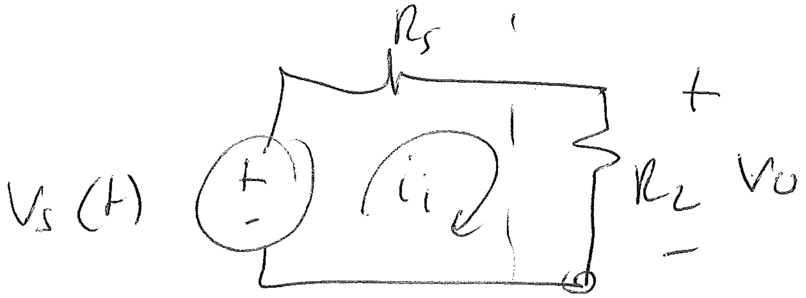
- → Two representations of signals in electrical domain.



Thevenin

Norton.

- → When these signals are processed a load is applied.

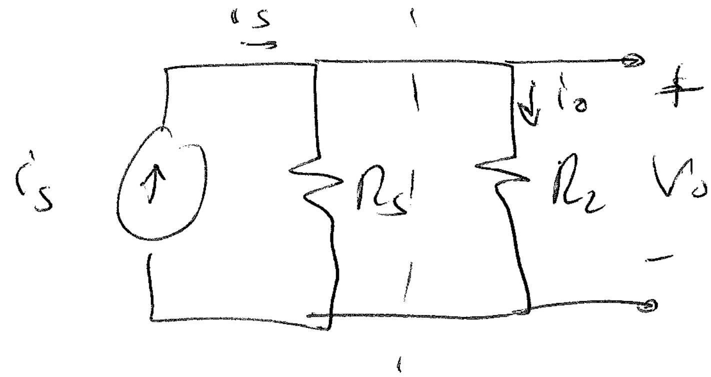


$$i_1 = \frac{V_S(t)}{R_S + R_L}$$

$$V_O = \frac{V_S}{R_S + R_L} \cdot R_L$$

$$V_O = V_S \frac{R}{R_S + R_L}$$

for $V_O = V_S$ $\quad R_L \gg R_S$ or $R_S \to 0$



$$i_o = \frac{v_o}{R_L}$$

$$V_o = \frac{i_s}{(R_s \parallel R_L)} = i_s \frac{R_L R_s}{R_L + R_s}$$

$$i_o = \frac{i_s}{\cancel{R_L}} \frac{\cancel{R_L} R_s}{R_L + R_s} = i_s \frac{R_s}{R_L + R_s}$$

for $i_s = i_o$ $R_s \gg R_L$ or $R_s \to \infty$

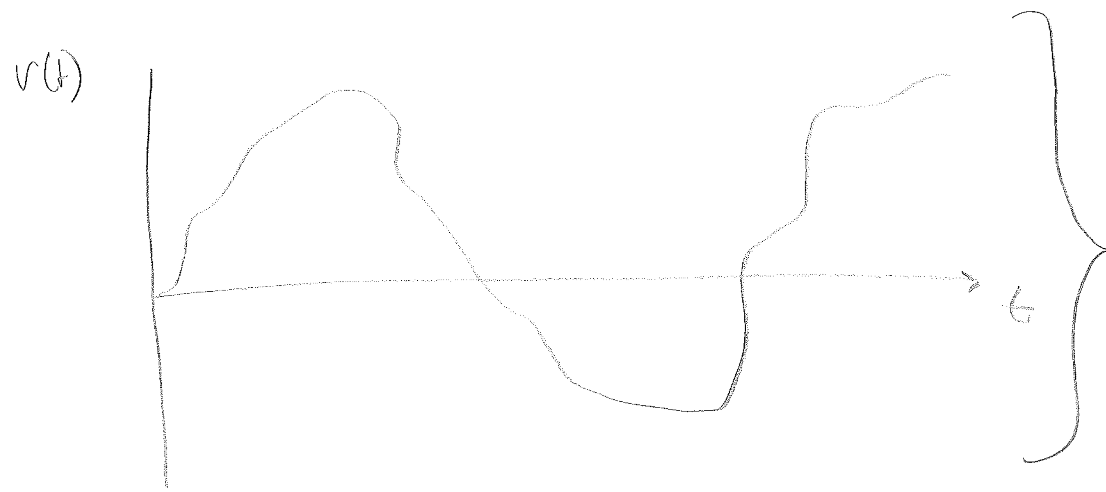
Not much control over R_s.

Design R_L to minimize or eliminate signal strength loss.

when source is connected to a load.

Electronics 1.

1.3 Analog and digital signals



Analog signal

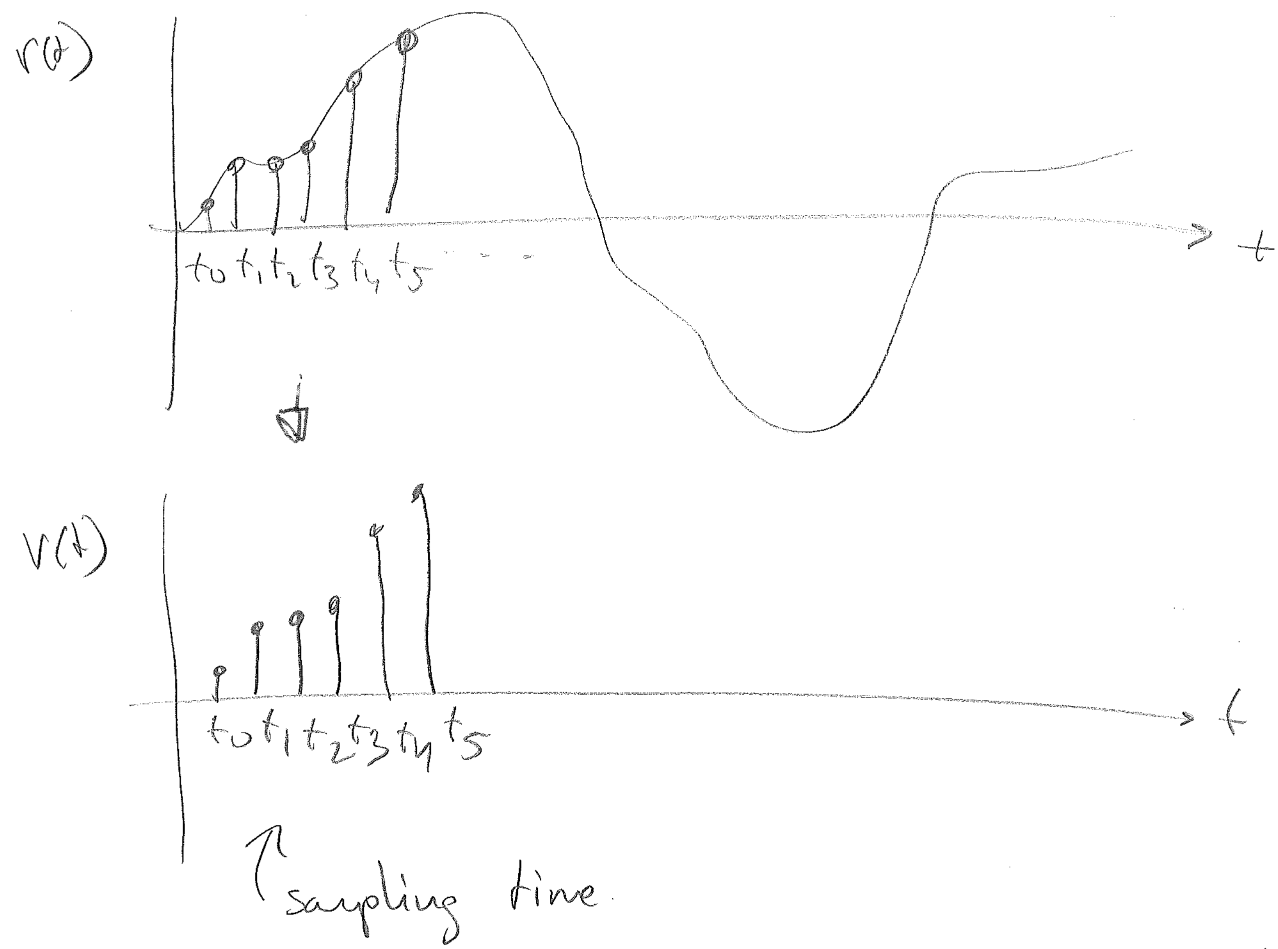
Analog signal: Such a signal is analogous to the physical signal it represents.

* the magnitude of the signal can take on any value.
* the amplitude of the analog signal exhibits a continuous variation over its range of activity.
* Majority of signals in the world around us are analog

→ Electronic circuits that process such signals are known as $\boxed{\text{analog circuits.}}$

Digital signal

Signal representation using a sequence of numbers, each numbers representing the signal magnitude at an instant of time



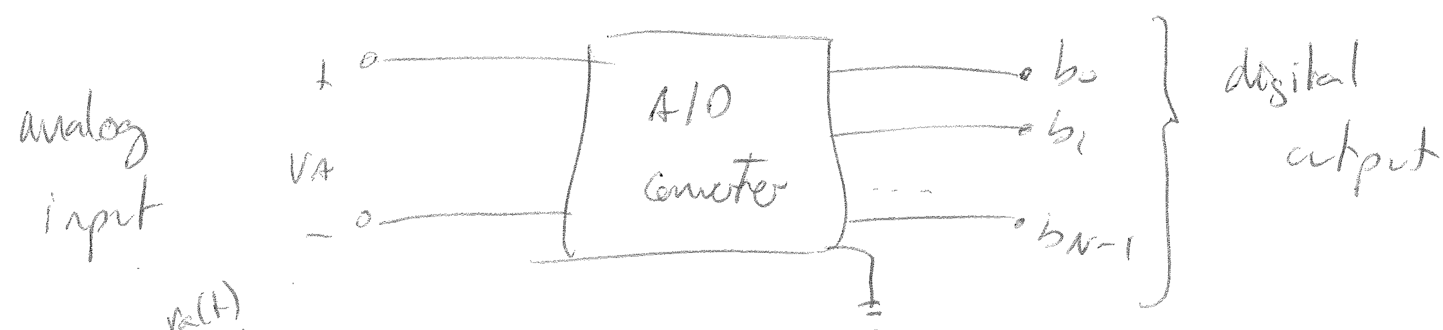
→ Signal is defined only at the sampling instants. It's no longer a continuous function of time but rather, it is a discrete-time signal

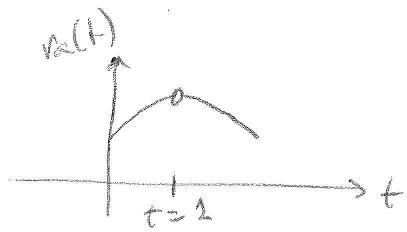
→ The signal becomes digitized or quantized or discretized if only a finite number of digits is ~~use~~ used.

→ ~~B~~ Finite number of binary digits used to represent signal.

→ Binary system is convenient because only two values are possible: 0 or 1. These can be represented by

0 volts,	5 volts	CMOS
−5 V,	0 V	PMOS
0,	3.3 V	Some ~~Advanced~~
0,	1.8V	Advanced.
0,	15V	old analog
0,	12V	old analog
−12V,	12V	old analog





~~$V_A = 5.0135$ V~~

$V_A = 5V$

101

→ Digital processing is ~~easier than easily~~ ~~are~~ easily accomplished w/ few building blocks.

→ Analog signals are still important. Mixed-signals.

Chapter 1.4 Amplifiers

Signal amplification.

Amplifier as a circuit building block.

→ consider only external characteristics for now.

→ ~~Transducers (sensors~~

Weak signals (μV or mV) need amplification.

- sensors
- antennas
- mphones
-

↳ Processing of weak signals is unreliable.

→ Amplification must be (ideally) linear.

→ changes in shape of original signal are called distortion.

$$\therefore \quad v_o(t) = A \cdot v_i(t)$$

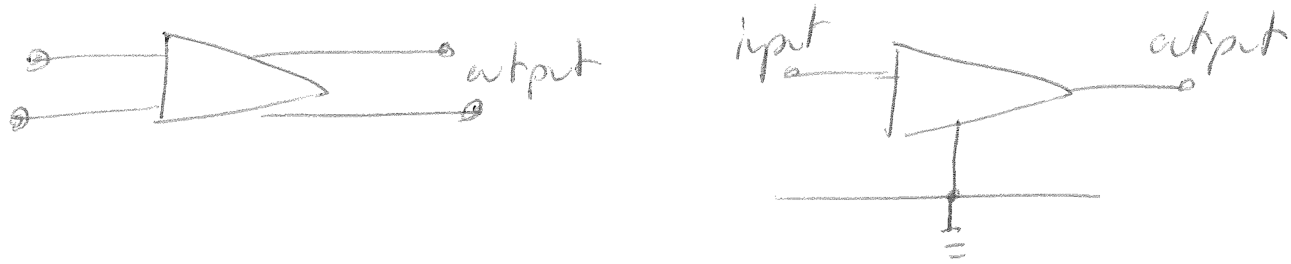
A – amplifier gain.

ex: (1) Preamplifier in house stereo is a voltage amplifier.

(2) Power amplifiers provide large current gains but modest voltage gains. Drives speaker in home stereo.

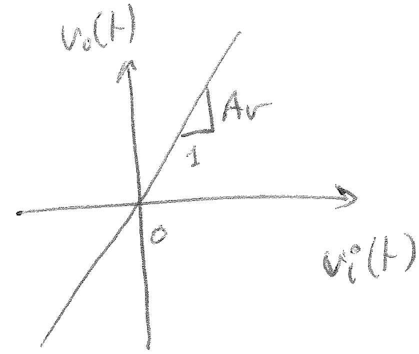
→ small voltage signal is converted to large voltage signal.
amplified

1.4.2. Amplifier circuit symbol.

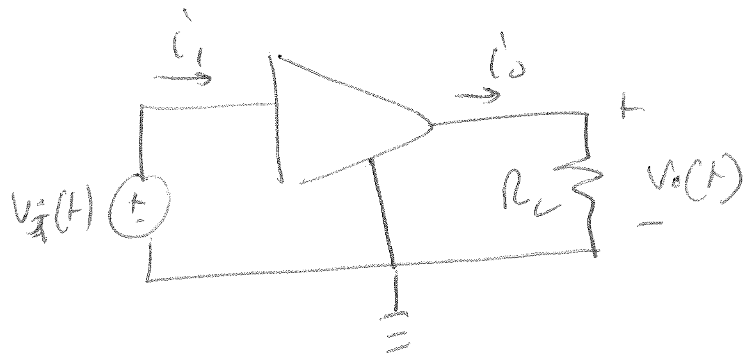


w/ common ground terminal.

1.4.3 Voltage gain



Voltage gain $\rightarrow$ $A_v = \frac{v_o}{v_i}$



1.4.4 Power gain and current gain

Amplifiers increase signal power (transformers do not).

Power gain $\rightarrow$ $A_p = \frac{\text{load power } (P_L)}{\text{input power } (P_i)} = \frac{v_o i_o}{v_i i_i}$

Current gain $\rightarrow$ $A_i = \frac{i_o}{i_i}$

And. $A_p = A_i \cdot A_v$

1.4.5 Expressing gain in decibels

→ Gain is expressed either dimensionless & or as emphasys on units (V/V) or (A/A) or (W/W)

→ Also with a logarithmic measure:

To convert from power to V or i?

Voltage gain in decibels = $20 \cdot \log |A_v|$ dB

Current " " " = $20 \cdot \log |A_i|$ dB

Power " " " = $10 \cdot \log |A_p|$ dB.

↳ original definition of deciBell (10 x log)

Gain Av can be negative is there is a 180° phase difference between input + output. Not that the amplifier attenuates signal.

Examples.

v_i (V)	v_o (V)	A_v (V/V)	$20 \log \lvert A_v \rvert$ dB
1mV	1mV	1	0
1mV	2mV	2	6.02
1mV	10mV	10	20
1mV	100mV	100	40
1mV	1V	1000	60
1V	0.5V	0.5	-6.02
1V	0.1V	0.1	-20
1V	0.01V	0.01	-40
1V	0.001V	0.001	-60

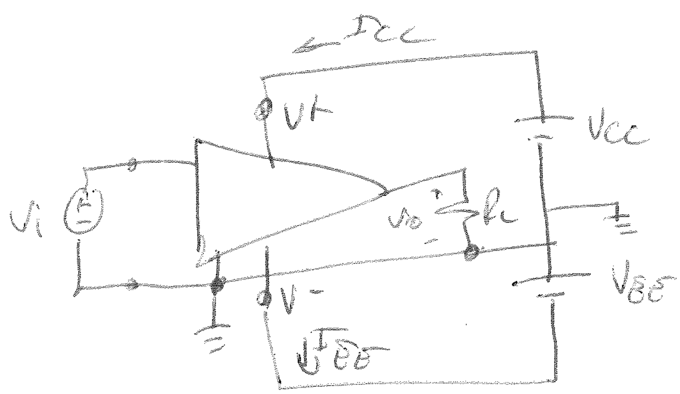
A negative gain in dB indicates that the signal is attenuated

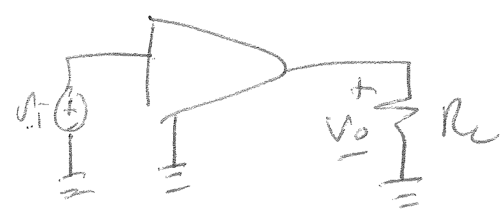
1.4.6 Amplifier power supplies

? Where does the additional power to amplify the signal come from?

→ Amplifier needs DC power supplies for proper operation.

→ DC sources supply power to the load and also power needed for internal operations (dissipated power)





Power supplied → $P_{dc} = V_{CC} I_{CC} + V_{EE} I_{EE}$

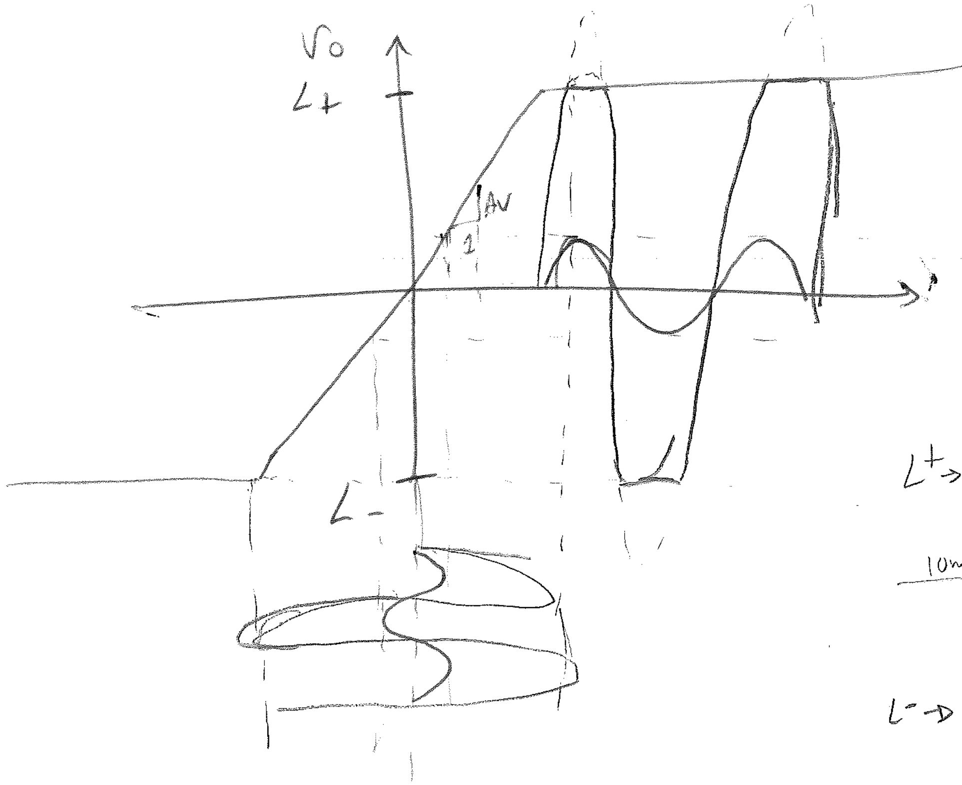
Power balance → $P_{dc} + P_I = P_L + P_{dissipated}$

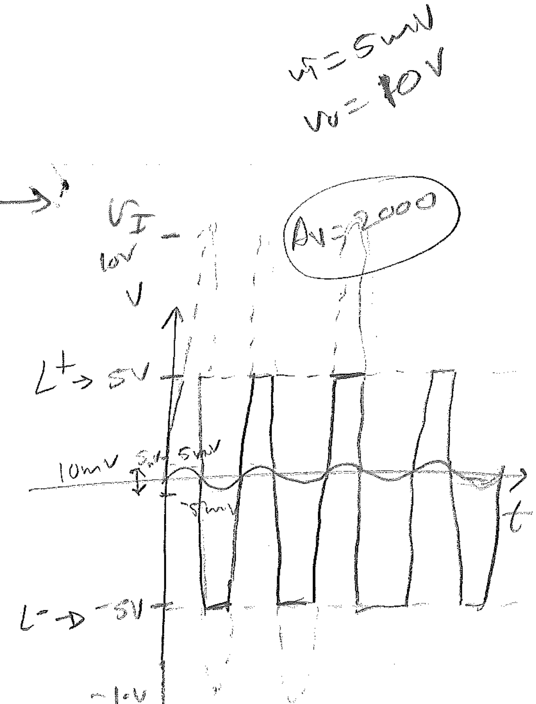
Power Efficiency $= \eta \equiv \frac{P_L}{P_{dc}} \times 100$

↳ Important parameter for power amplifiers.

~~1.5 - Circuit models for Amplifiers~~

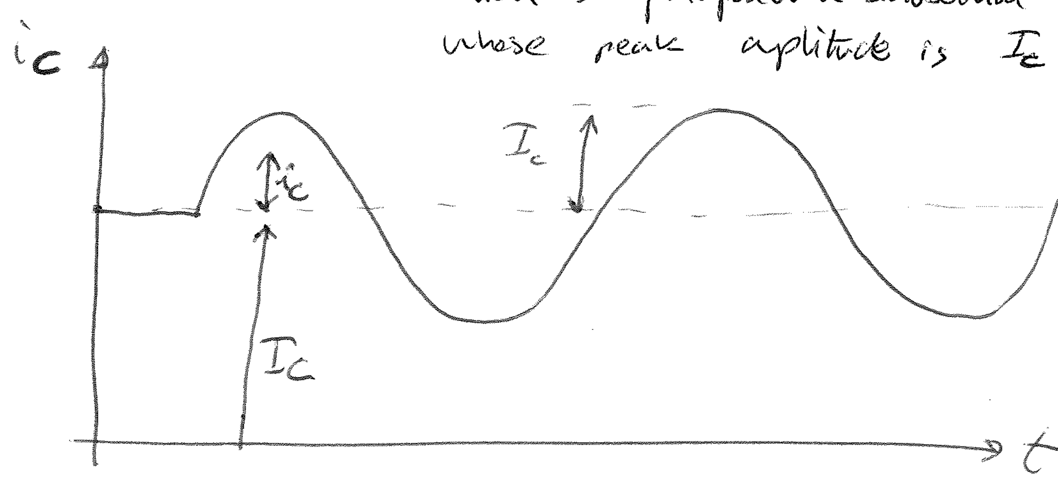
1.4.7. Amplifier saturation





1.4.8 Symbol convention

$i_C(t)$ consists of a dc component I_C on which is superimposed a sinusoidal component $i_c(t)$ whose peak amplitude is I_c



$$i_C(t) = I_C + i_c(t)$$

total instaneous current

dc component

sinusoidal component ~~instaneous~~

Symbol convention:

→ Total instantaneous quantities: lower-case symbol w/ uppercase subscript.

$v_C(t)$, $v_{DS}(t)$

→ DC quantities: upper-case symbols w/ uppercase subscripts.

I_C, V_{DS}

→ Incremental signal quantities: lower case symbol w/ lower-case subscript.

$i_c(t)$, $v_{gs}(t)$

→ Sine wave signals: amplitude by uppercase symbol w/ lower case subscripts.

I_c, V_{gs}

→ Power supplies: upper case letter w/ a double-letter upper case subscript.

V_{CC}, V_{DD}, I_{CC}, I_{DD}

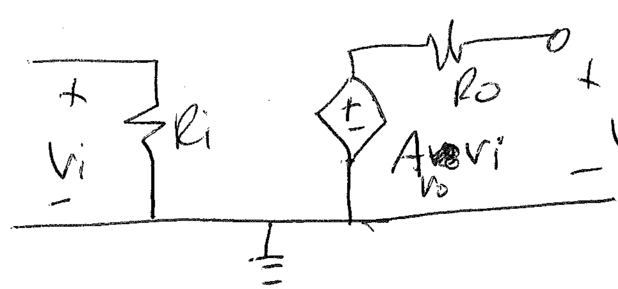
current drawn from power supplies.

1.5 Circuit Models for Amplifiers

Models to represent either single transistor amplifiers or more complex (20 or more transistors/ devices) amplifiers.

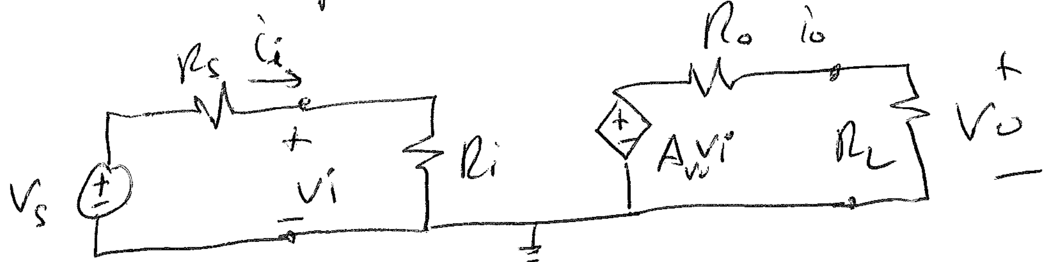
1.5.1 Voltage amplifier model

Circuit model for voltage amplifier



A_{vo} → gain factor of ~~open~~ amplifier. open circuit voltage gain of amplifier.

with input signal source and load.



$$V_o = A_{vo} V_i \frac{R_L}{R_L + R_o}$$

gain of circuit → $A_v = \frac{V_o}{V_i} = \frac{A_{vo} V_i}{V_i} \frac{R_L}{R_L + R_o} = A_{vo} \frac{R_L}{R_L + R_o}$

gain factor of amplifier.

for max gain $A_v = A_{vo}$

and $R_o = 0$ or $R_L \gg R_o$

→ Also range of value for which A_v is valid.

Also $v_i = v_s \frac{R_i}{R_i + R_s}$

$\therefore$ for $v_i = v_s \rightarrow R_i >> R_s$ or $R_i \rightarrow \infty$

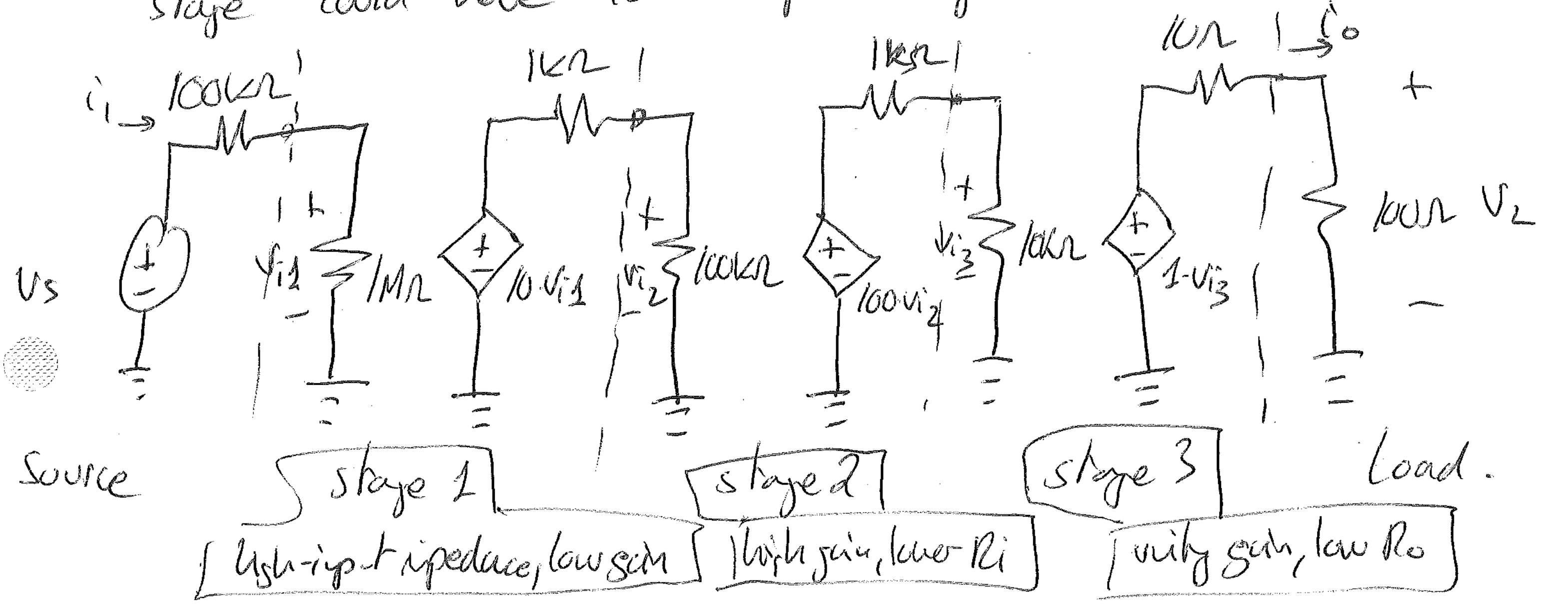
~~Also design~~

Overall gain: $\frac{v_o}{v_s} = A_{vo} \frac{R_i}{R_i + R_s} \cdot \frac{R_L}{R_L + R_o}$

Buffer amplifiers ~~are~~ sometimes used when R_s is large and signal attenuation results. $\boxed{A_{vo} = 1}$ ~~to increase~~ Also called unity gain amplifiers they provide high input resistance and low output impedance to increase total power.

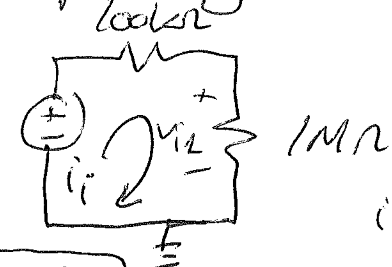
1.5.2 Cascade Amplifiers.

Cascade of two or more stages, each with different characteristics. First stage usually has large input impedance and last stage could have low output impedance.



Evaluate $\frac{v_L}{v_s}$, current gain and power gain.

$V = IR$



Solution

Fraction of v_s at input of 1st stage:

$$\frac{v_{i1}}{v_s} = \frac{1M\Omega}{1M\Omega + 100k\Omega} = 0.909 \text{ V/V}$$

$$i_1 = \frac{v_s}{100k + 1M\Omega}$$

$$v_{i1} = i_1 \cdot 1M\Omega$$

$$v_{i1} = \frac{v_s}{100k + 1M\Omega} \cdot 1M\Omega$$

$$\frac{v_{i1}}{v_s} = \frac{1M\Omega}{100k + 1M\Omega}$$

Voltage gain of 1st stage:

$$A_{v1} = \frac{v_{i2}}{v_{i1}} = \frac{10 \cdot \cancel{v_{i1}}}{\cancel{v_{i1}}} \cdot \frac{100k\Omega}{100k\Omega + 1k\Omega}$$

$$A_{v1} = \cancel{9.9\text{ V/V}}\ 9.9 \text{ V/V}$$

Voltage gain of 2nd stage:

$$A_{v2} = \frac{v_{i3}}{v_{i2}} = \frac{100 \cdot v_{i2}}{v_{i2}} \cdot \frac{10k\Omega}{10k\Omega + 1k\Omega} = 90.9 \text{ V/V}$$

Voltage gain of output stage (3rd)

$$A_{v3} = \frac{v_L}{v_{i3}} = \frac{1 \cdot \cancel{v_{i3}}}{\cancel{v_{i3}}} \cdot \frac{100\Omega}{100\Omega + 100\Omega} = 0.909 \text{ V/V}$$

Total gain of 3 stages in cascade:

$$A_v = \frac{v_L}{v_{i1}} = A_{v1} \cdot A_{v2} \cdot A_{v3} = 818 \text{ V/V}$$

or $20 \cdot \log 818 = 58.3 \text{ dB}$

cont'd

(cont'd)

Voltage gain from source to load.

$v_{i1} = 0.909 \cdot v_s$

~~$v_s = 0.909 \cdot v_{i1}$~~

$$\frac{v_L}{v_s} = \frac{A_v \cdot v_{i1}}{v_s}$$

$$= 0.909 \cdot 818 = 743.6 \text{ V/V}$$

$$\text{or } 57.4\,dB = 20 \cdot \log(743.6)$$

Current gain:

$$A_i = \frac{i_o}{i_i} = \frac{v_L/100\Omega}{v_{i1}/1M\Omega} = 10^4 \cdot \frac{v_L}{v_{i1}} = (10^4)(818)$$

$$= 8.18 \times 10^6 \text{ A/A}$$

$$\text{or } 138.3\,dB = 20 \cdot \log(8.16 \times 10^6)$$

Power gain:

$$A_p = \frac{P_L}{P_i} = \frac{v_L \cdot i_o}{v_{i1} \cdot i_1}$$

$$A_p = A_v \cdot A_i = (818)(8.18 \times 10^6) = 66.9 \times 10^8 \text{ W/W}$$

$$\text{or } 10 \cdot \log(66.9 \times 10^8) = 98.3\,dB.$$

$$\text{or } A_p(dB) = \frac{1}{2}\left[A_v(dB) + A_i(dB)\right]$$

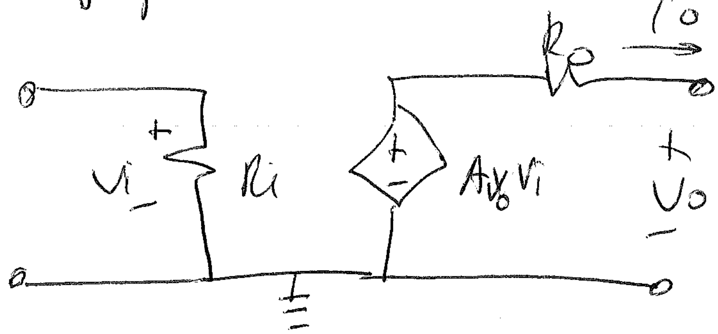
1.5.3 Other amplifiers types.

Table 1.1 (page 28)

~~current~~

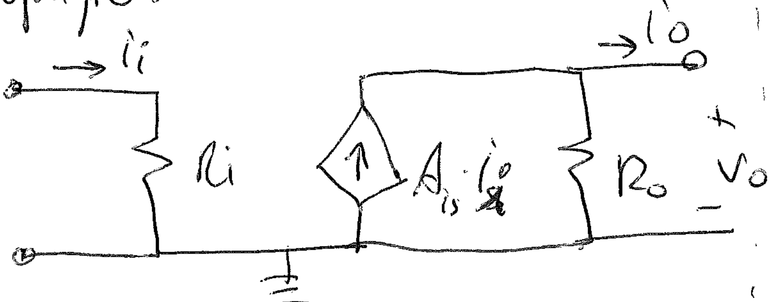
	Gain Parameter	Ideal Characteristics

voltage amplifier:



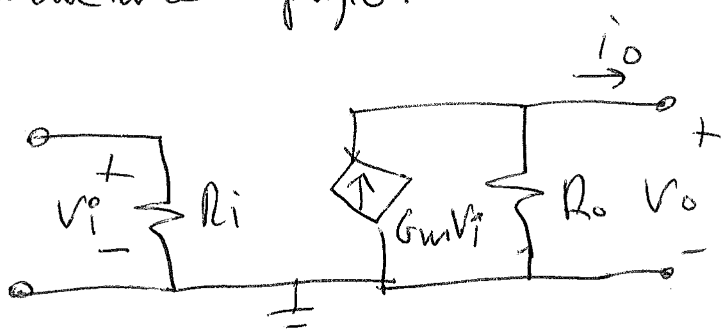
open-circuit voltage gain $A_{vo} = \frac{v_o}{v_i}\Big|_{i_o=0}$ $\left(\frac{V}{V}\right)$ | $R_i = \infty$, $R_o = 0$

Current amplifier:



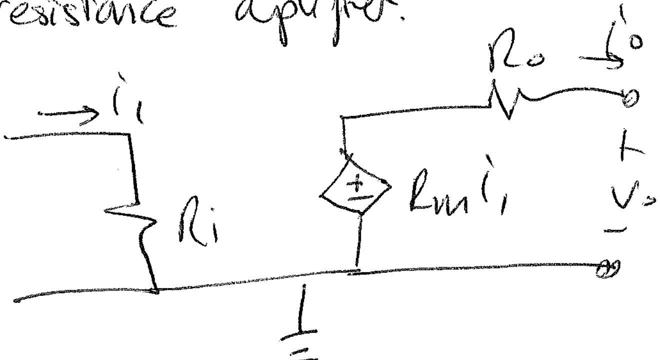
short-circuit current gain $A_{is} = \frac{i_o}{i_i}\Big|_{v_o=0}$ $\left(\frac{A}{A}\right)$ | $R_i = 0$, $R_o = \infty$

Transconductance amplifier.



short-circuit transconductance $G_m = \frac{i_o}{v_i}\Big|_{v_o=0}$ (A/V) | $R_i = \infty$, $R_o = \infty$

Transresistance amplifier.



open-circuit transresistance $R_m = \frac{v_o}{i_i}\Big|_{i_o=0}$ (V/A) | $R_i = 0$, $R_o = 0$

Hw#1 1.43, 1.46, 1.47,