Multi-Stage Amplifiers

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Some figures of this presentation were taken from the instructional resources of the following textbook:
A. S. Sedra and K. C. Smith, *Microelectronic Circuits*. New York, NY: Oxford University Press, 2003.

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Outline

- Introduction
- Basic properties of a general amplifier with *N* stages
- Type of coupling between stages
- Capacitive coupling
- Inductive coupling
- Direct coupling

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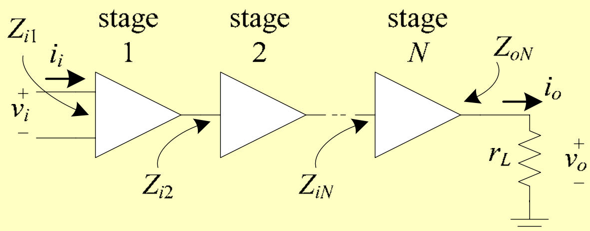
Introduction

- Most of the practical amplifiers consists of several amplification stages
- Input stages provide high input impedance and high noise immunity (CMRR)
- Intermediate stage provide most of the amplification gain
- Output stages provide low output impedance (for a voltage output), and adjust the DC levels

A General Amplifier with *N* Stages



$$Z_i = Z_{i1}$$

$$Z_o = Z_{oN}$$

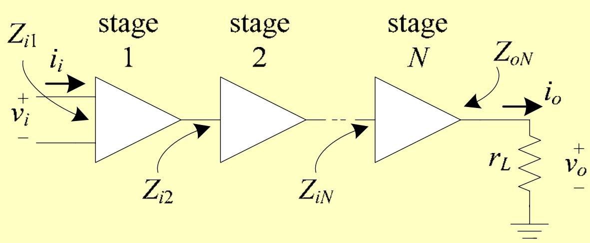
$$A_v = \frac{v_o}{v_i} = (A_{v1})(A_{v2})\ldots(A_{vN})$$

If the gain is expressed in dB:

$$A_{v\,dB} = 20\log\left|\frac{v_o}{v_i}\right| = 20\log[(|A_{v1}|)(|A_{v2}|)\ldots(|A_{vN}|)]$$

$$A_{v\,dB} = 20\log\left|\frac{v_o}{v_i}\right| = A_{v1dB} + A_{v2dB} + \cdots + A_{vN\,dB}$$

A General Amplifier with *N* Stages (cont)



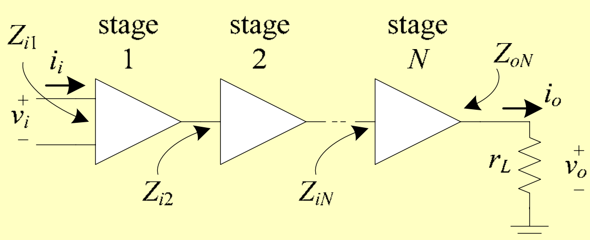
Similarly:

$$A_i = \frac{i_o}{i_i} = (A_{i1})(A_{i2})\ldots(A_{iN})$$

Total power gain:

$$A_v A_i = (\frac{i_o r_L}{i_i Z_i})(\frac{i_o}{i_i}) = \frac{\frac{1}{2} i_o^{\,2} r_L}{\frac{1}{2} i_i^{\,2} Z_i} = \frac{p_o}{p_i} = A_p$$

A General Amplifier with *N* Stages (cont)



Distortion Limits: DL^+, DL^-

Usually,

$DL^+ = DL^+_N$, and $DL^- = DL^-_N$

However, an intermediate stage can be saturated before the output stage

Types of Coupling between Amp. Stages

- Capacitive coupling
- Inductive coupling
- Direct coupling
- Optical coupling

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Capacitive Coupling

Advantages

☺ Makes independent the biasing point of each stage

☺ Can be ignored at mid and high frequencies

☺ It is suitable for discrete configurations

Disadvantages

☹ Affects the amplification at low frequencies

☹ Makes difficult impedance matching

☹ Large capacitors (electrolytic) are noisy

☹ Unsuitable for integrated circuits

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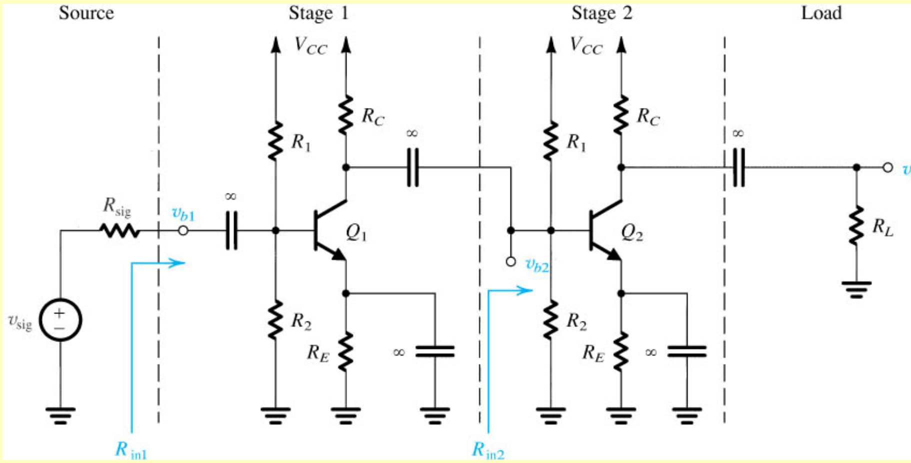
Capacitive Coupling – Example 1



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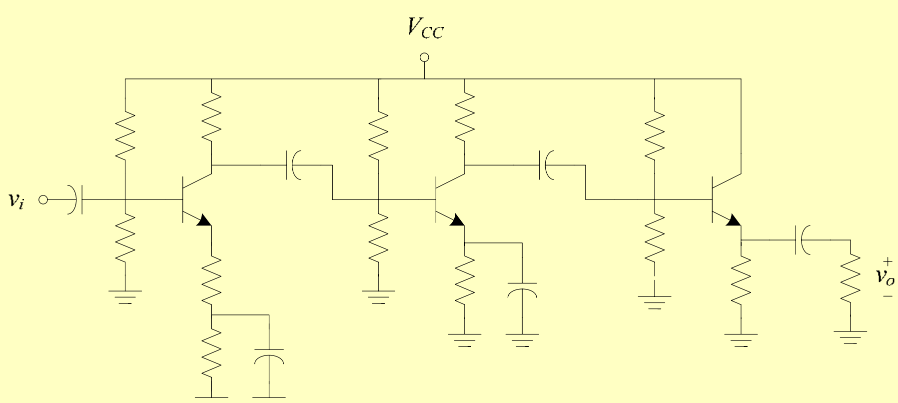
Capacitive Coupling – Example 2



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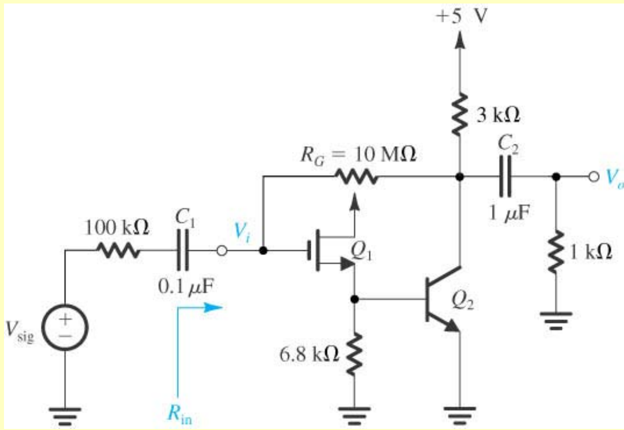
Capacitive Coupling – Example 3



Inductive Coupling

Advantages

☺ Makes independent the biasing point of each stage

☺ Produce electrical isolation (magnetic coupling)

☺ Facilitate impedance matching

☺ Allows a tuned coupling

Disadvantages

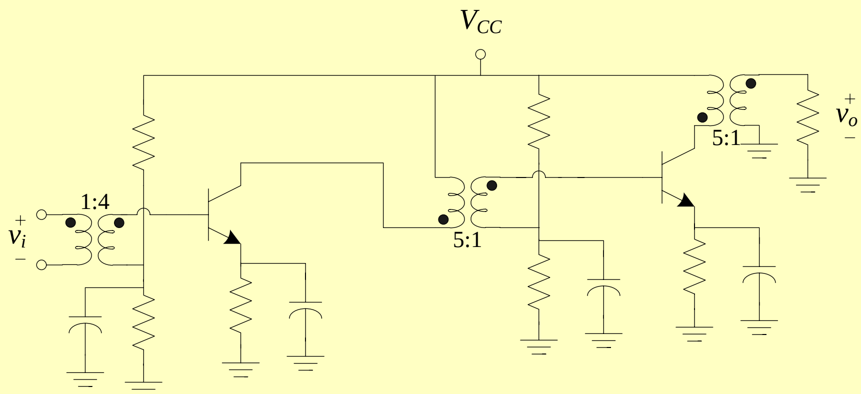
☹ Transformers are bulky, heavy and expensive

☹ Introduce non-linear effects

☹ Unsuitable for integrated circuits

☹ Affects amplification at low and high frequencies

Inductive Coupling – Example



Direct Coupling

Advantages

☺ Allow amplification of DC signals

☺ Low cost

☺ Ideal for integrated circuits

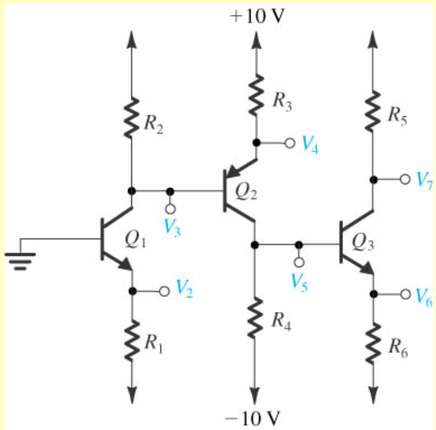
Disadvantages

☹ The bias point of each stage depends on the remaining stages

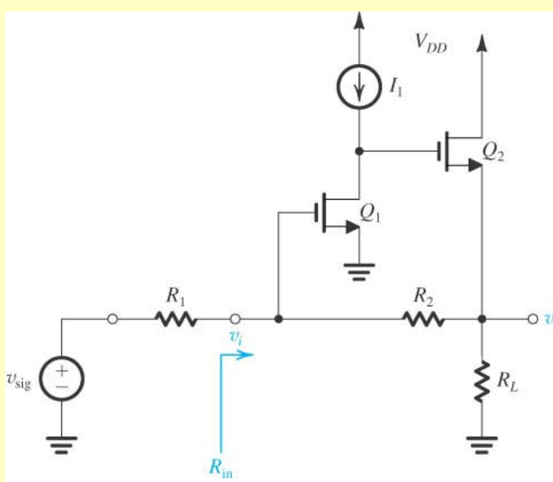
☹ Their design can be complicated

☹ Unsuitable for integrated circuits

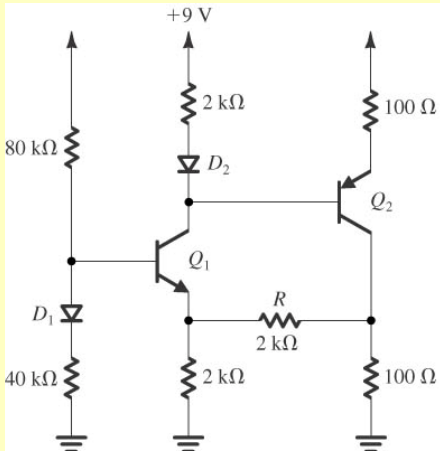
Direct Coupling – Example 1



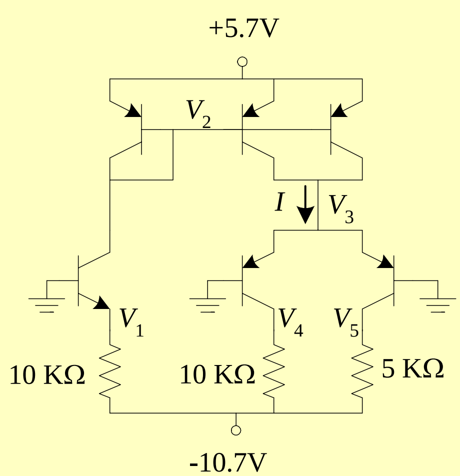
Direct Coupling – Example 2



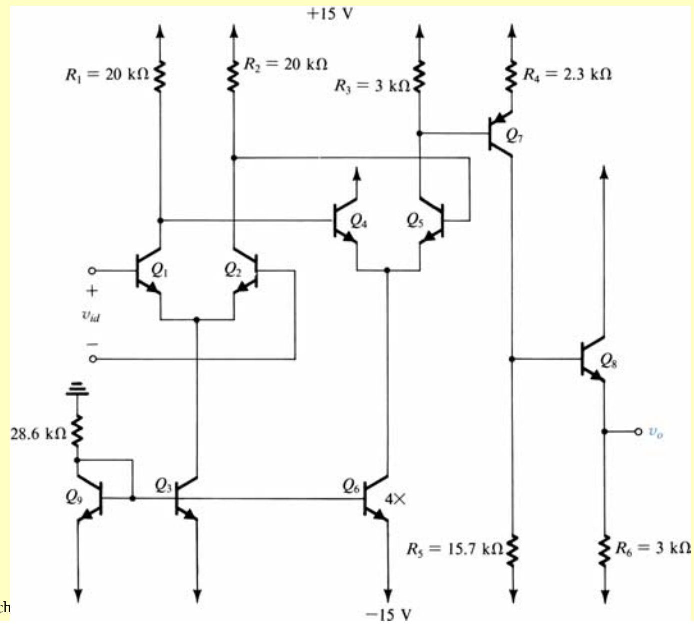
Direct Coupling – Example 3



Direct Coupling – Example 4



Direct Coupling – Example 5



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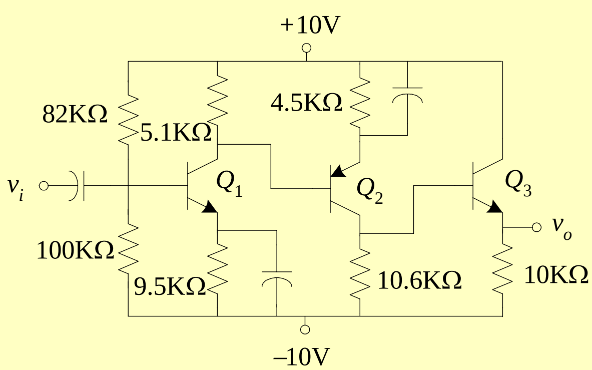
Direct Coupling – Example 6



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Direct Coupling – Example 7