EE285 Electronics I

Amplifiers – Part2

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Multistage Amplifiers

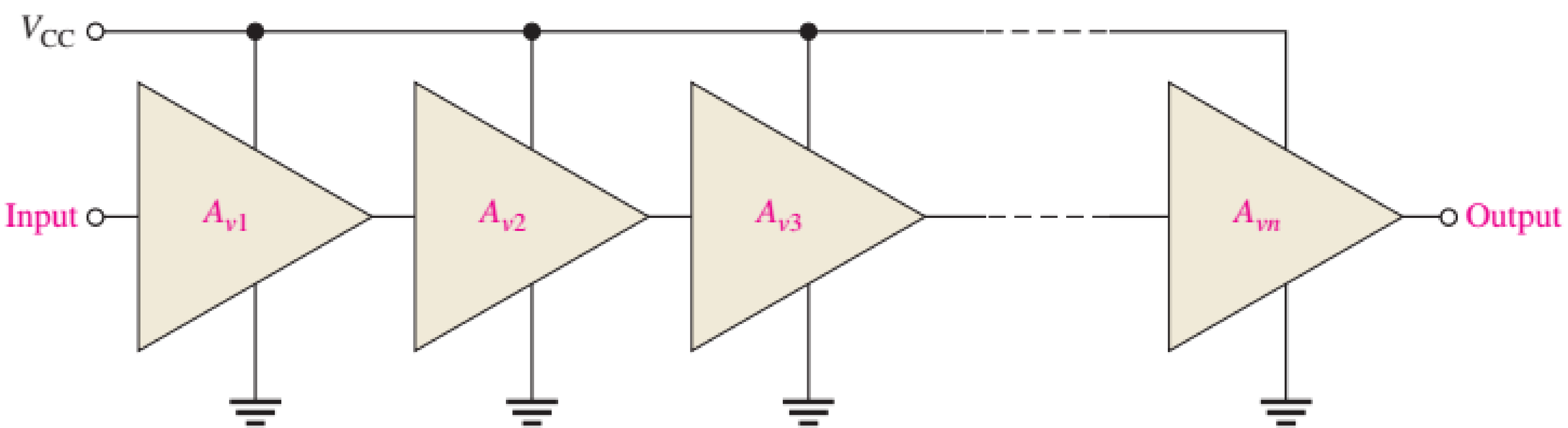
- Two or more amplifiers can be connected in a **cascaded** arrangement with the output of one amplifier driving the input of the next.
- Each amplifier in a cascaded arrangement is known as a **stage.**
- The basic purpose of a multistage arrangement is to increase the overall voltage gain.

Multistage Amplifiers

- **Multistage Voltage Gain**
  - The overall voltage gain, A'_v , of cascaded amplifiers, as shown in Figure, is the product of the individual voltage gains.

$$A'_v = A_{v1}A_{v2}A_{v3} \cdot \cdot \cdot A_{vn}$$

  - where *n* is the number of stages



Multistage Amplifiers

- Amplifier voltage gain is often expressed in **decibels** (dB) as follows:

$$A_{v(\mathrm{dB})} = 20 \log A_v$$

- This is particularly useful in **multistage** systems because the overall voltage gain in dB is the *sum* of the individual voltage gains in dB

$$A'_{v(\mathrm{dB})} = A_{v1(\mathrm{dB})} + A_{v2(\mathrm{dB})} + \cdots + A_{vn(\mathrm{dB})}$$

Multistage Amplifiers

- A certain cascaded amplifier arrangement has the following voltage gains: A_{v1}=10, A_{v2}=15 and A_{v3}=20. What is the overall voltage gain? Also express each gain in decibels (dB) and determine the total voltage gain in dB.

$$A'_v = A_{v1}A_{v2}A_{v3} = (10)(15)(20) = \mathbf{3000}$$

$$A_{v1(\text{dB})} = 20 \log 10 = \mathbf{20.0\ dB}$$

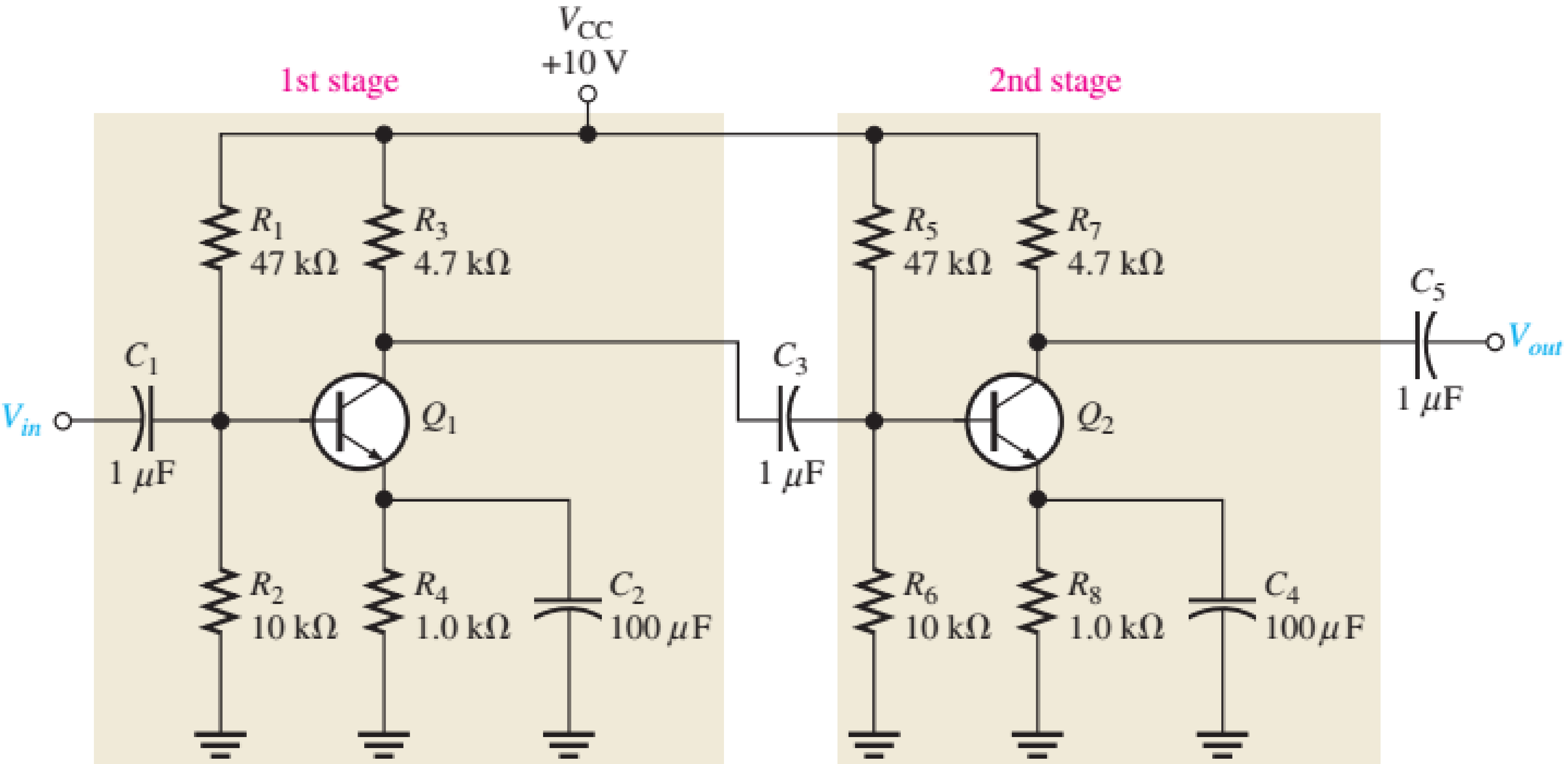
$$A_{v2(\text{dB})} = 20 \log 15 = \mathbf{23.5\ dB}$$

$$A_{v3(\text{dB})} = 20 \log 20 = \mathbf{26.0\ dB}$$

$$A'_{v(\text{dB})} = 20.0\text{ dB} + 23.5\text{ dB} + 26.0\text{ dB} = \mathbf{69.5\ dB}$$

Multistage Amplifiers

- **Capacitively-Coupled Multistage Amplifier**
  - Figure shows a two-stage capacitively coupled amplifier



$\beta_{DC} = \beta_{ac} = 150$ for Q_1 and Q_2

Multistage Amplifiers

- Notice that both stages are identical common-emitter amplifiers with the output of the first stage capacitively coupled to the input of the second stage.

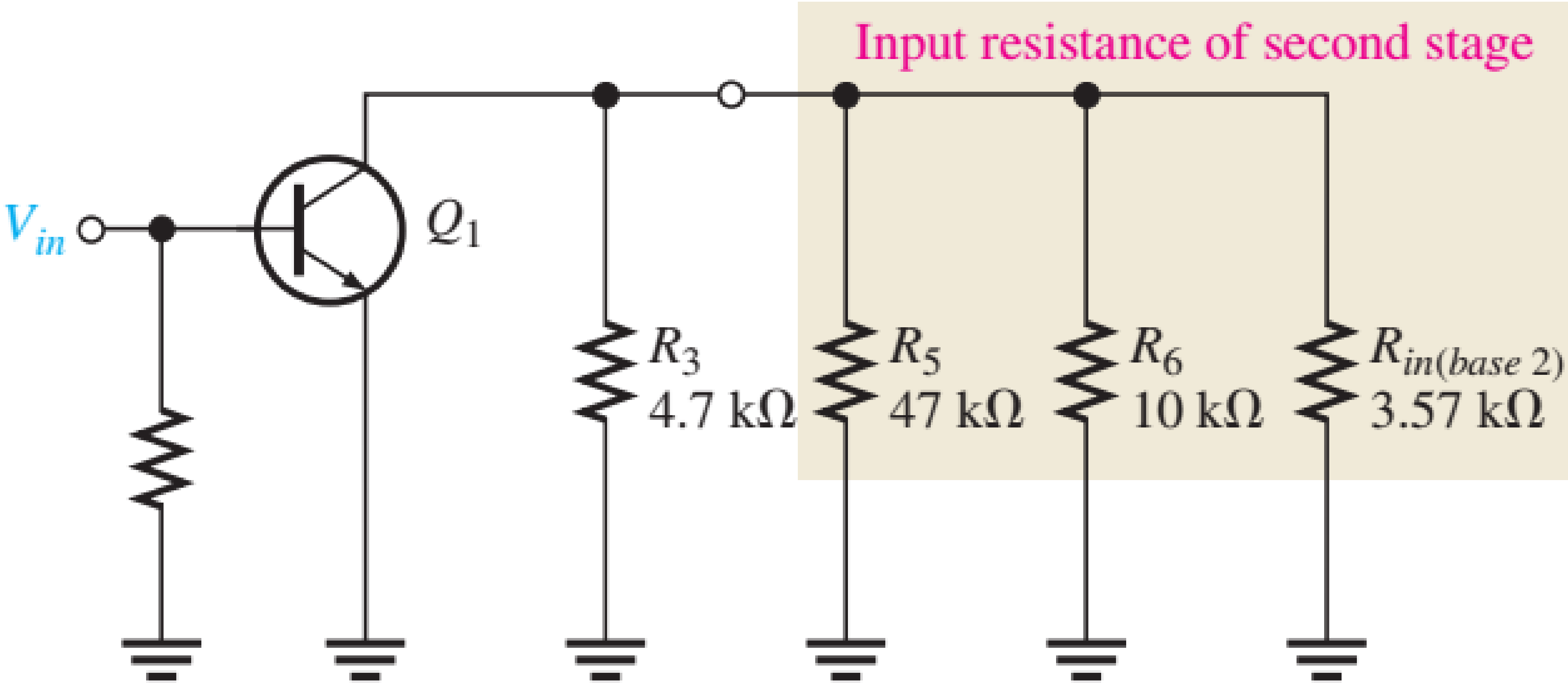
- Capacitive coupling prevents the dc bias of one stage from affecting that of the other but allows the ac signal to pass without attenuation because $X_C \approx 0\Omega$ at the frequency of operation.

- ***Loading Effects***
  - In determining the voltage gain of the first stage, you must consider the loading effect of the second stage. Because the coupling capacitor C_3 effectively appears as a short at the signal frequency, the total input resistance of the second stage presents an ac load to the first stage

Multistage Amplifiers

- Looking from the collector of Q_1, the two biasing resistors in the second stage, R_5 and R_6, appear in parallel with the input resistance at the base of Q_2
- In other words, the signal at the collector of Q_1 "sees" R_3, R_5, R_6, and $R_{in(base2)}$ of the second stage all in parallel to ac ground
- Thus, the effective ac collector resistance of Q_1 is the total of all these resistances in parallel, as shown in Figure

Multistage Amplifiers



Multistage Amplifiers

- The voltage gain of the first stage is reduced by the loading of the second stage because the effective ac collector resistance of the first stage is less than the actual value of its collector resistor, R_3.

  Remember that $A_V = \frac{R_C}{r'_e}$

- ***Voltage Gain of the First Stage***
  - The ac collector resistance of the first stage is

    $$R_{c1} = R_3 || R_5 || R_6 || R_{in(base2)}$$

  - $R_{in(base2)} = \beta_{ac} r'_e$
  - $r'_e = \frac{25\ mV}{I_E}$, thus I_E should be calculated to find R_{C1}

Multistage Amplifiers

- Theveninizing the bias circuit and applying Kirchhoff's voltage law to the base-emitter circuit, of the DC equivalent circuit
- $R_{TH} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(47k\Omega)(10k\Omega)}{47k\Omega + 10k\Omega} = 8.25k\Omega$
- $V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} = \left(\frac{10k\Omega}{47k\Omega + 10k\Omega}\right) 10\text{V} = 1.75\text{V}$
- $I_E = \frac{V_{TH} - V_{BE}}{R_E + {R_{TH}}/{\beta_{DC}}} = \frac{1.75V - 0.7V}{1k\Omega + {8.25k\Omega}/{150}} = 0.995\ mA$
- $r_e' = \frac{25\ mV}{I_E} = \frac{25\ mV}{0.995\ mA} = 25.13\Omega$
- $R_{in(base2)} = \beta_{ac} r_e' = 150 \cdot 25.13 = 3.77k\Omega$
- $R_{c1} = R_3 || R_5 || R_6 || R_{in(base2)} = 4.7k\Omega || 47\text{k}\Omega || 10k\Omega || 3.77k\Omega$

Multistage Amplifiers

- $R_{c1} = R_3 || R_5 || R_6 || R_{in(base2)} = 4.7k\Omega || 47\text{k}\Omega || 10k\Omega || 3.77k\Omega$
- $\quad = 1.67k\Omega$

- Therefore, the base-to-collector voltage gain of the first stage is
- $A_{V1} = \frac{R_{c1}}{r'_e} = \frac{1.67k\Omega}{25.13\Omega} = 66.45$

- ***Voltage Gain of the Second Stage***
  - The second stage has no load resistor, so the ac collector resistance is R_7, and the gain is
  - $A_{V2} = \frac{R_7}{r'_e} = \frac{4.7k\Omega}{25.13\Omega} = 187.03$
  - Compare this to the gain of the first stage, and notice how much the loading from the second stage reduced the gain

Multistage Amplifiers

- ***Overall Voltage Gain***
  - The overall amplifier gain with no load on the output is
  - $A'_V = A_{V1} \cdot A_{V2} = 66.45 \cdot 187.03 \approx 12428$
  - If an input signal of 100µV, for example, is applied to the first stage and if there is no attenuation in the input base circuit due to the source resistance, an output from the second stage of $100\mu V \cdot 12428 = 1.24V$ will result
  - The overall voltage gain can be expressed in dB as follows:
  - $A'_{V(dB)} = 20log_{10}(12428) = 81.89\ dB$

Multistage Amplifiers

- ***DC Voltages in the Capacitively Coupled Multistage Amplifier***
  - Since I_E = 0.995 mA,
  - $V_E = I_E R_4 = 0.995\, mA \cdot 1\, k\Omega = 0.995\, V$
  - $V_B = V_E + 0.7V = 1.695\, V$
  - Since $I_C \approx I_E$
  - $V_C = V_{CC} - I_C R_3 = 10V - 0.995\, mA \cdot 4.7k\Omega = 5.32\, V$

"Have the courage to follow your heart and intuition. They somehow know what you truly want to become."

- Steve Jobs