



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Common collector and Common Drain Amplifiers

Flow of Discussion (Bottom-up) – *Building blocks*

- **System/ Sub-systems** (*for specific application*)
 - **Modules** (*performing specific tasks*)
 - **Building blocks** (*having specific characteristics*)
 - **Components** (*devices/circuit elements*)
- **Week 5:**
 - **Common Collector (CC) and Common Drain (CD) amplifiers**
 - **biasing, operation, analysis and design.**
 - **Common Base (CB) and Common Gate (CG) amplifier**
 - **biasing, operation, analysis and design.**



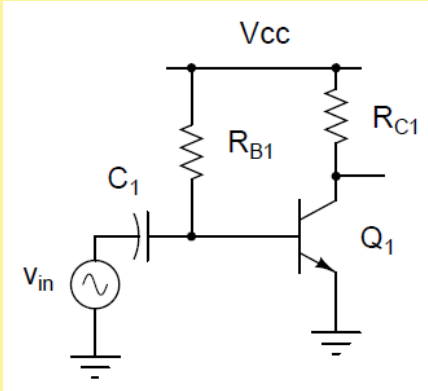
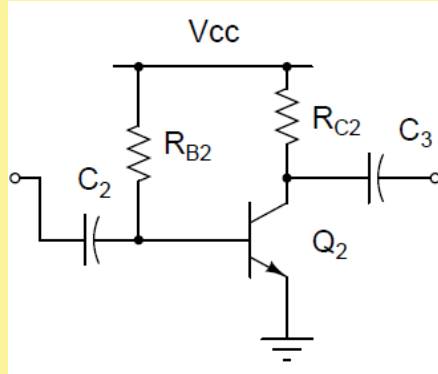
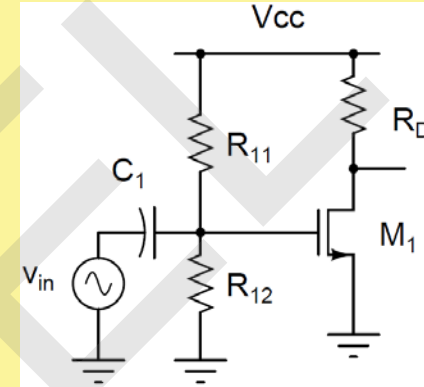
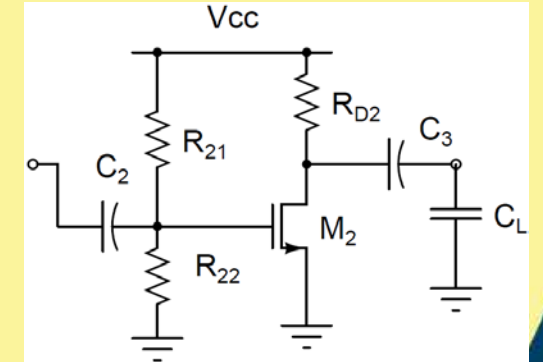
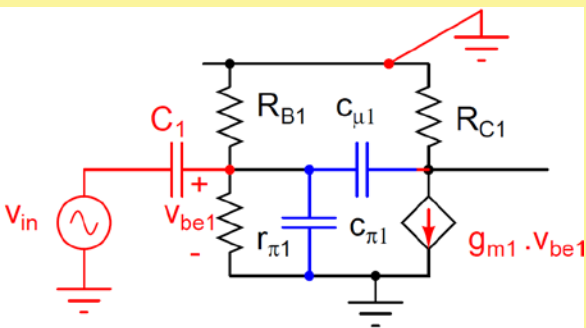
CONCEPTS COVERED

Concepts Covered:

- ☐ Motivation of using CC and CD amplifiers
- ☐ Basic operation and Biasing of CC and CD amplifiers
- ☐ Analysis for voltage gain, impedance and input capacitance

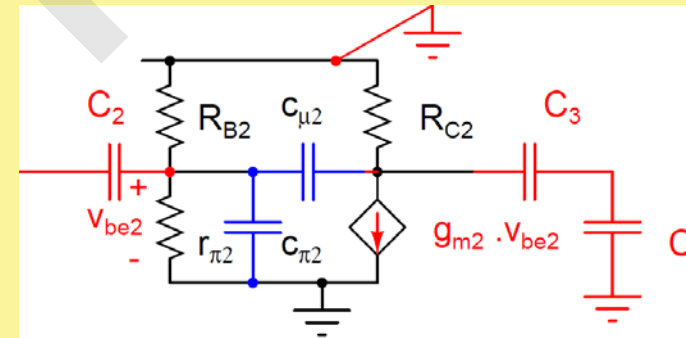


Recapitulation of cascading CE-CE (and CS-CS) amplifier

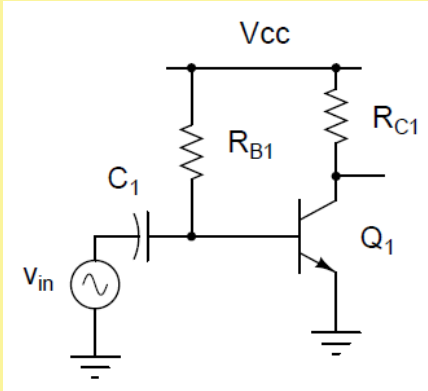
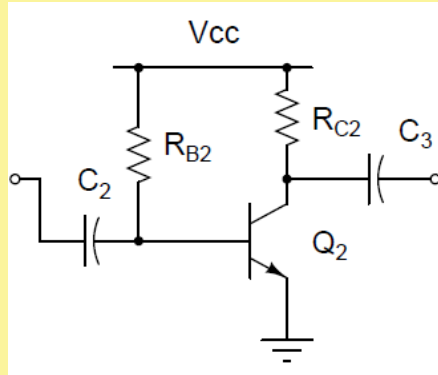
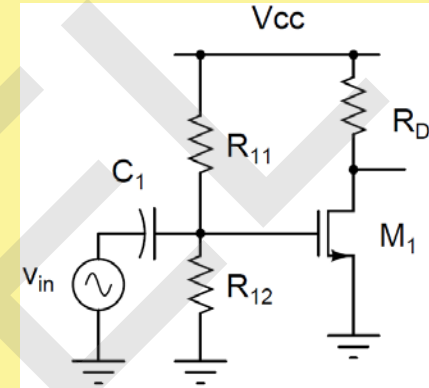
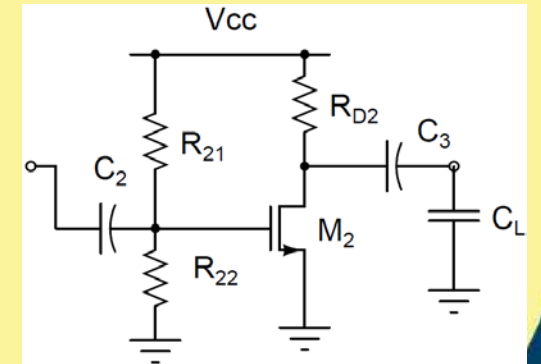
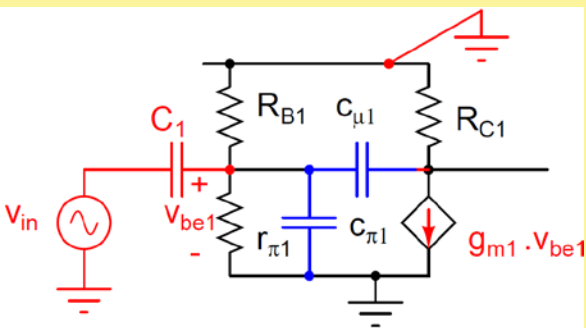
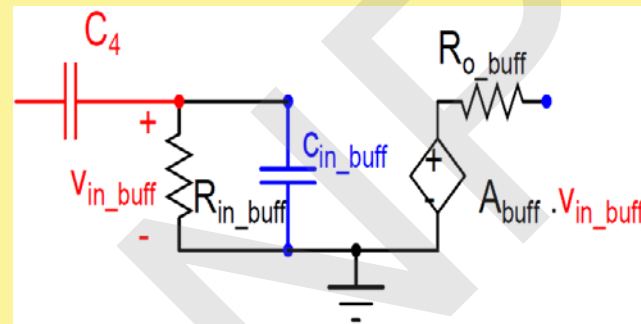
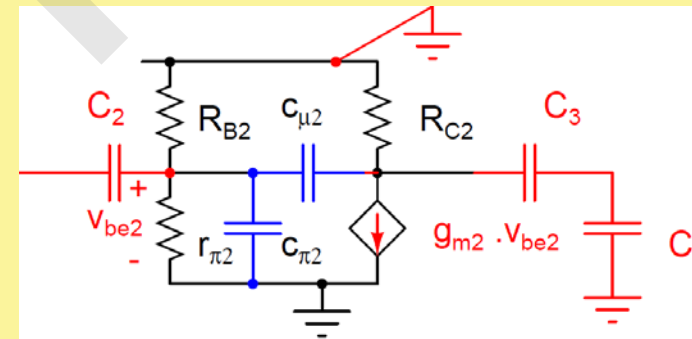
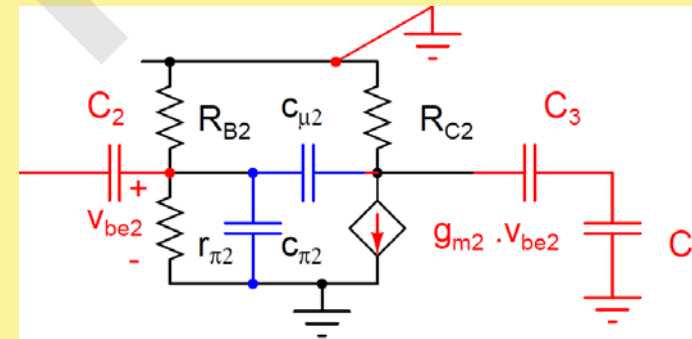


Affects:

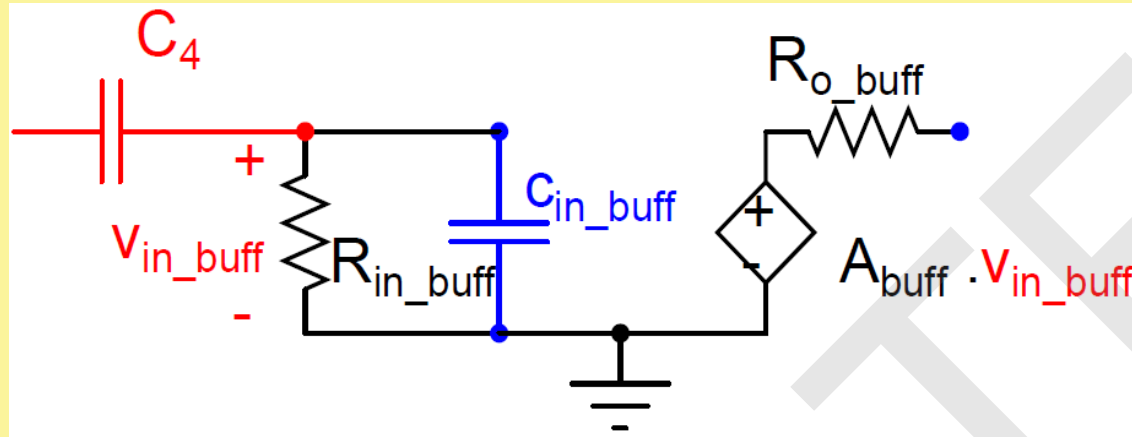
- Overall voltage gain
- Upper cutoff frequency
- Solution: Use BUFFER



Recapitulation of cascading CE-CE (and CS-CS) amplifier

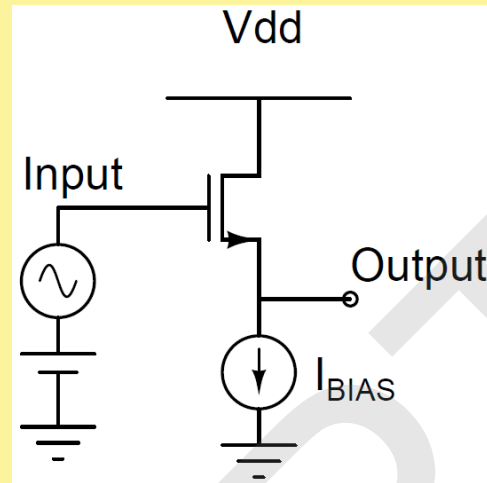
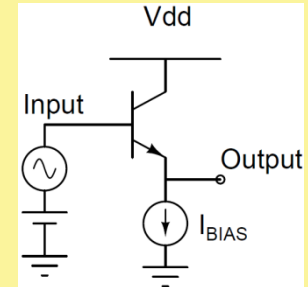


Necessary features of a Buffer (Voltage mode)



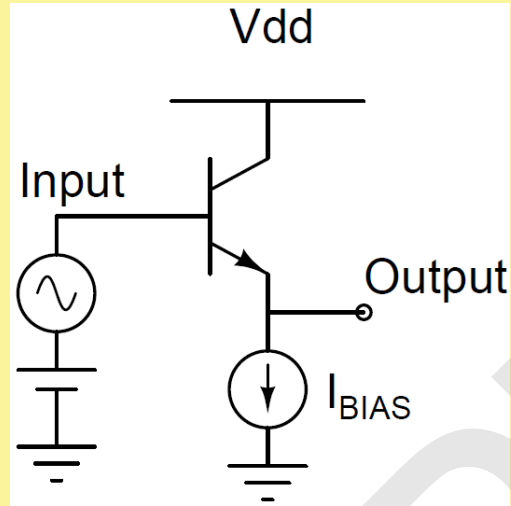
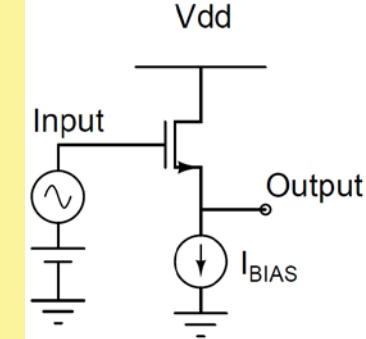
- **Low Output resistance**
- **High Input resistance**
- **Low Input capacitance**
- **Low Voltage attenuation**
- *Leading to Common collector and Common drain*

Basic operation and biasing of CC and CD amplifiers



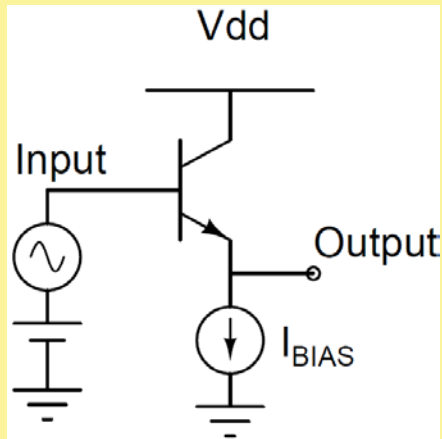
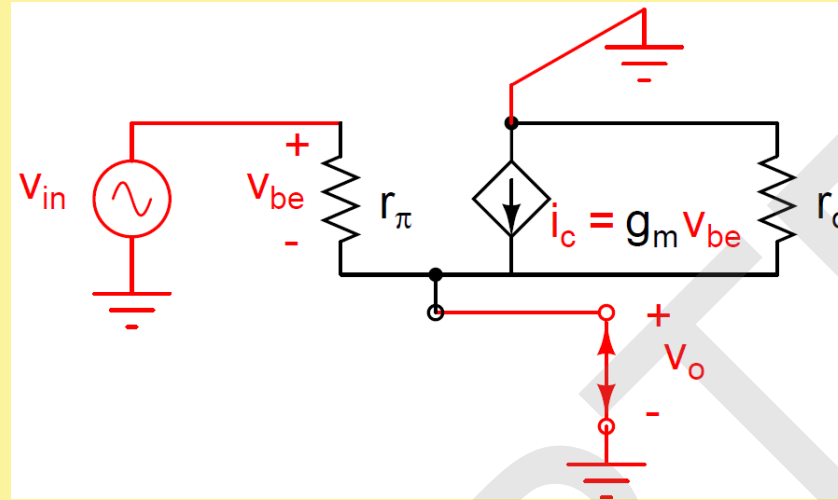
- **Ideal biasing**
- **Biasing at the emitter / source terminal**
- **Collector / Drain connection**
- **Biasing at the Base / Gate terminal**

Basic operation and biasing of CC and CD amplifiers (contd.)



- **Ideal biasing**
- **Biasing at the emitter / source terminal**
- **Collector / Drain connection**
- **Biasing at the Base / Gate terminal**

Small signal analysis of **CC** amplifier



$$\frac{(v_{in} - v_o)}{r_{\pi}} + g_m(v_{in} - v_o) = \frac{v_o}{r_o}$$

$$v_o = v_{in} \cdot \frac{(g_m \cdot r_{\pi} + 1) \cdot r_o}{(g_m \cdot r_{\pi} + 1) \cdot r_o + r_{\pi}}$$

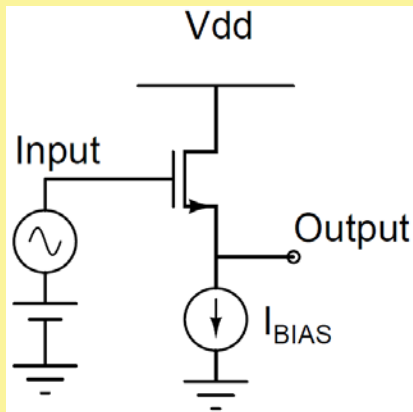
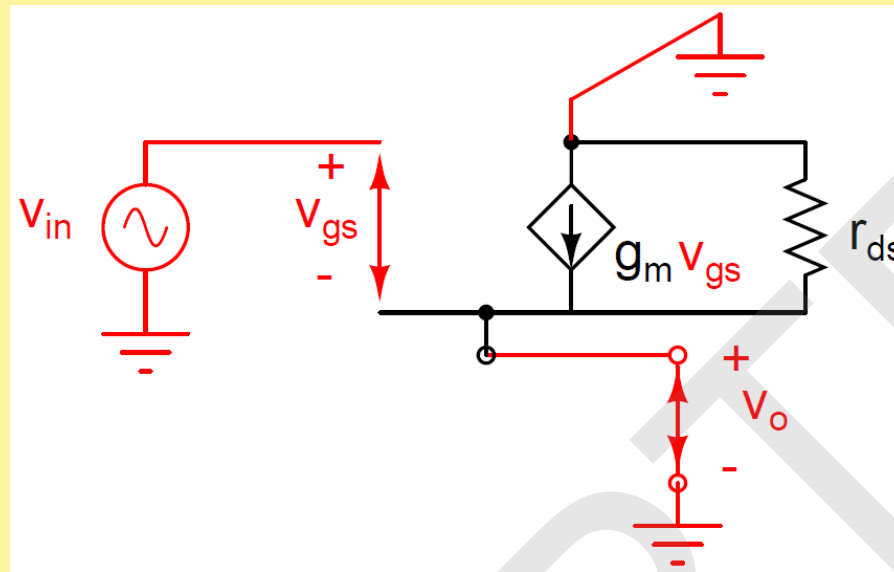
• **Input resistance:**

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{v_{in}}{(v_{in} - v_o)/r_{\pi}} = (g_m \cdot r_{\pi} + 1) \cdot r_o + r_{\pi}$$

• **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_{\pi} + 1) \cdot r_o}{(g_m \cdot r_{\pi} + 1) \cdot r_o + r_{\pi}}$$

Small signal analysis of **CD** amplifier



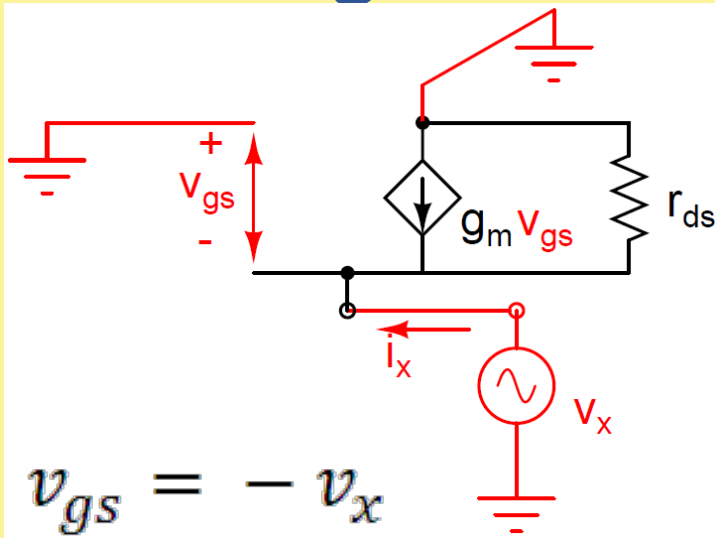
$$v_o = r_{ds}(g_m v_{gs}) = r_{ds} g_m (v_{in} - v_o)$$

$$v_o = v_{in} \cdot \frac{(g_m \cdot r_{ds})}{(g_m \cdot r_{ds} + 1)}$$

- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_{ds})}{(g_m \cdot r_{ds} + 1)}$$

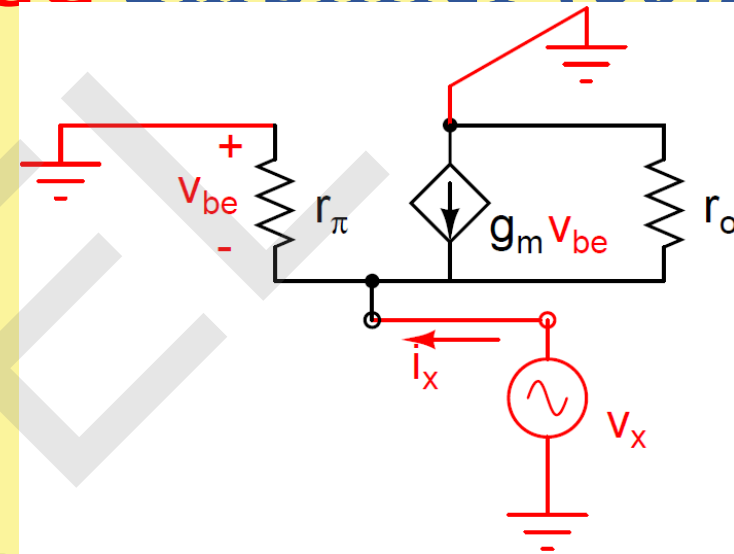
Small signal analysis of **CD** and **CC** amplifier (contd.)



Output Resistance:

$$i_x = \frac{v_x}{r_{ds}} + g_m \cdot v_x$$

$$R_o = \frac{v_x}{i_x} = \frac{1}{\left(g_m + \frac{1}{r_{ds}}\right)}$$

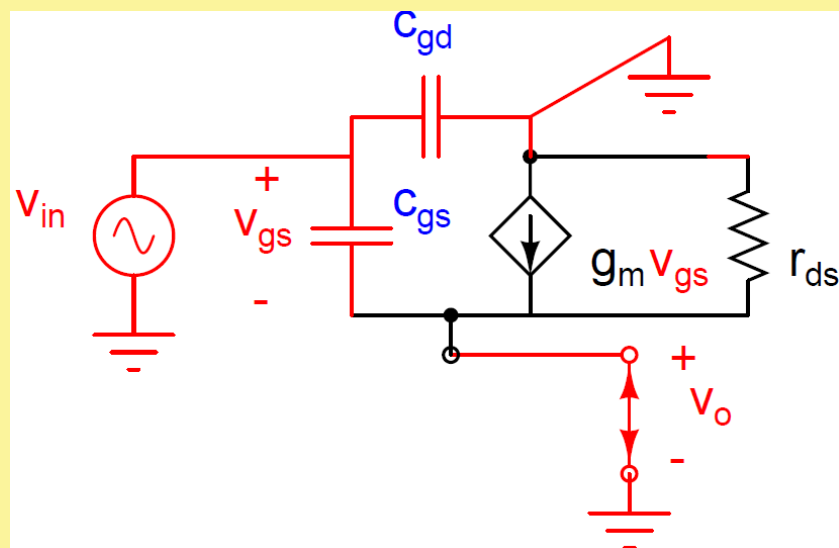


$$v_{be} = -v_x$$

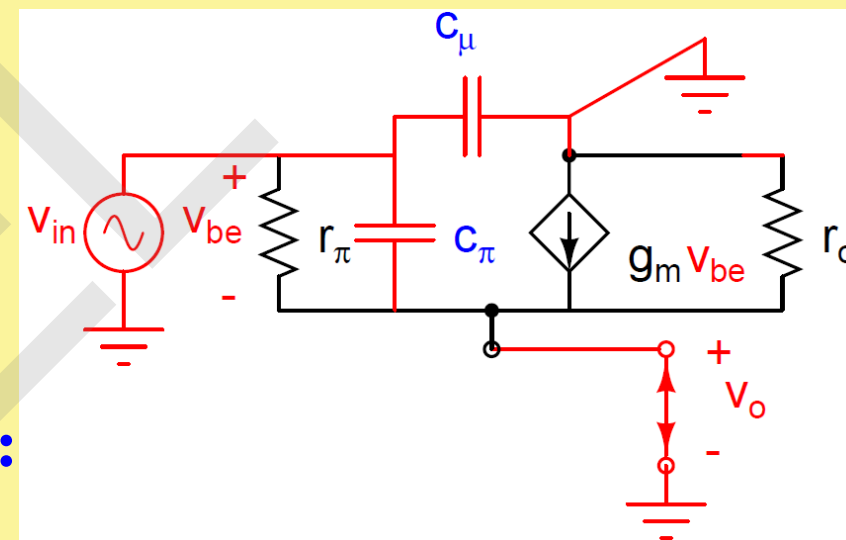
$$i_x = g_m \cdot v_x + \frac{v_x}{r_o} + \frac{v_x}{r_\pi}$$

$$R_o = \frac{v_x}{i_x} = \frac{1}{\left(g_m + \frac{1}{r_o} + \frac{1}{r_\pi}\right)}$$

Small signal analysis of **CD** and **CC** amplifier (*contd.*)



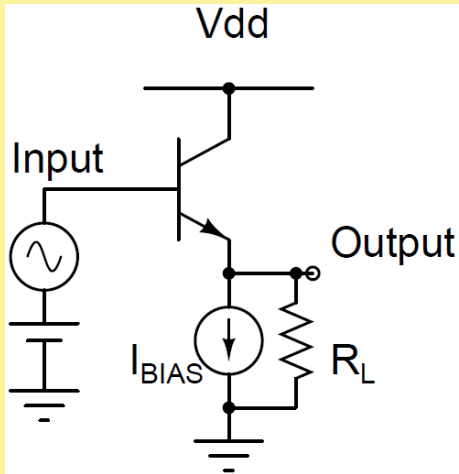
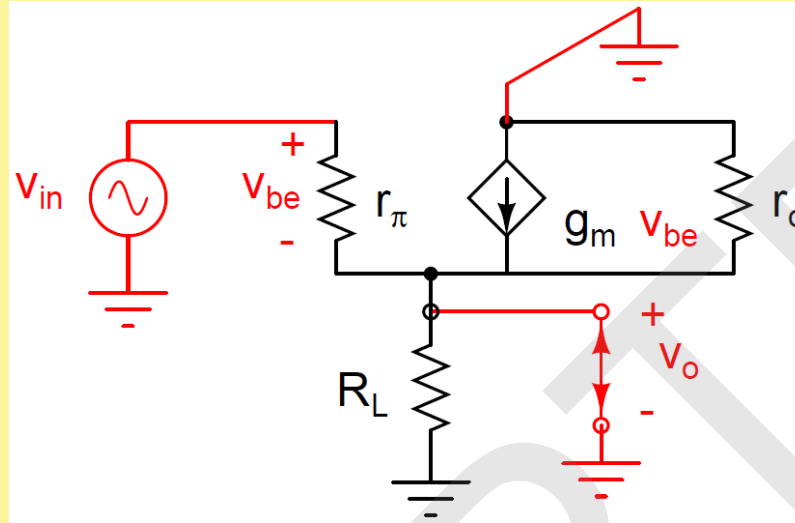
Input Capacitance:



$$\begin{aligned}
 c_{in} &= c_{gs}(1 - A_v) + c_{gd} \\
 &= c_{gs} \left(1 - \frac{(g_m \cdot r_{ds})}{(g_m \cdot r_{ds} + 1)} \right) + c_{gd} \\
 &= \frac{c_{gs}}{(g_m \cdot r_{ds} + 1)} + c_{gd}
 \end{aligned}$$

$$\begin{aligned}
 c_{in} &= c_{\pi}(1 - A_v) + c_{\mu} \\
 &= \frac{c_{\pi} \cdot r_{\pi}}{(g_m \cdot r_{\pi} + 1)r_o + r_{\pi}} + c_{\mu}
 \end{aligned}$$

Small signal analysis of more realistic **CC** amplifier



$$C_{in} = \frac{C_{\pi} \cdot r_{\pi}}{(g_m \cdot r_{\pi} + 1) \cdot (R_L || r_o) + r_{\pi}} + C_{\mu}$$

- **Input resistance:**

$$R_{in} = (g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L) + r_{\pi}$$

- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L)}{(g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L) + r_{\pi}}$$

Conclusion

Conclusion:

- ☐ CC and CD amplifiers works as buffer in voltage mode amplification
- ☐ Basic operation and biasing has been discussed
- ☐ Analysis for gain, impedance and input capacitance has been discussed
- ☐ *Numerical examples and Design of CC and CD to be covered*





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*Thank
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(contd.)***

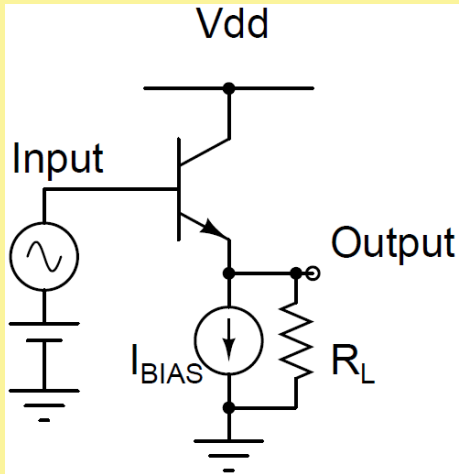
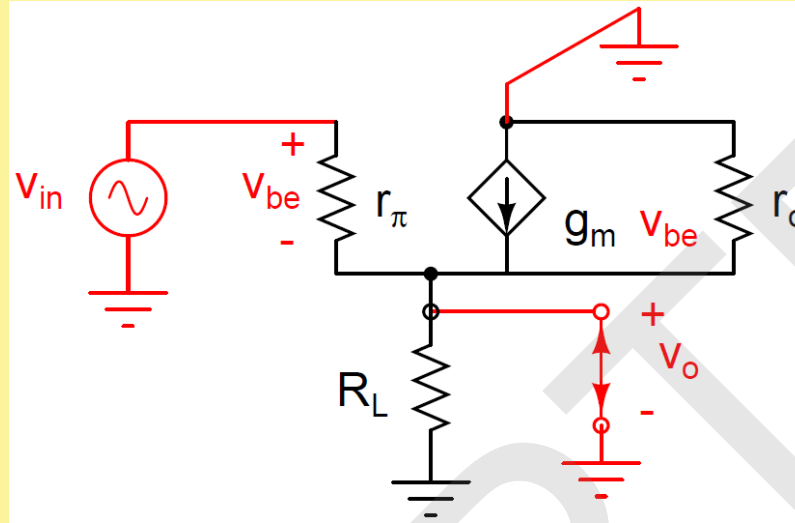
CONCEPTS COVERED

Concepts Covered:

- ☐ Motivation of using CC and CD amplifiers
- ☐ Basic operation and Biasing of CC and CD amplifiers
- ☐ Analysis for voltage gain, impedance and input capacitance considering realistic components
 - ☐ R_L
 - ☐ R_s
 - ☐ R_c / R_D
- ☐ Design guidelines
- ☐ Numerical examples



Small signal analysis of more realistic **CC** amplifier (*including R_L*)



- **Input capacitance:**

$$C_{in} = \frac{C_{\pi} \cdot r_{\pi}}{(g_m \cdot r_{\pi} + 1) \cdot (R_L || r_o) + r_{\pi}} + C_{\mu}$$

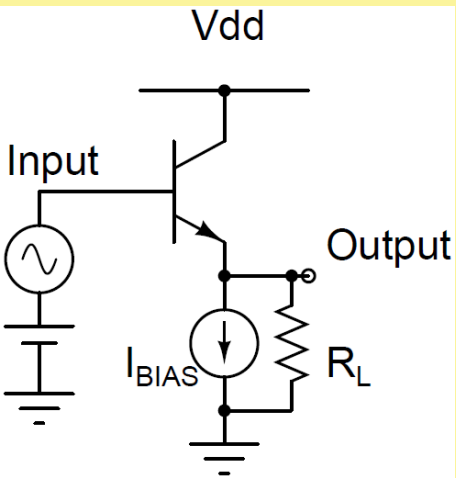
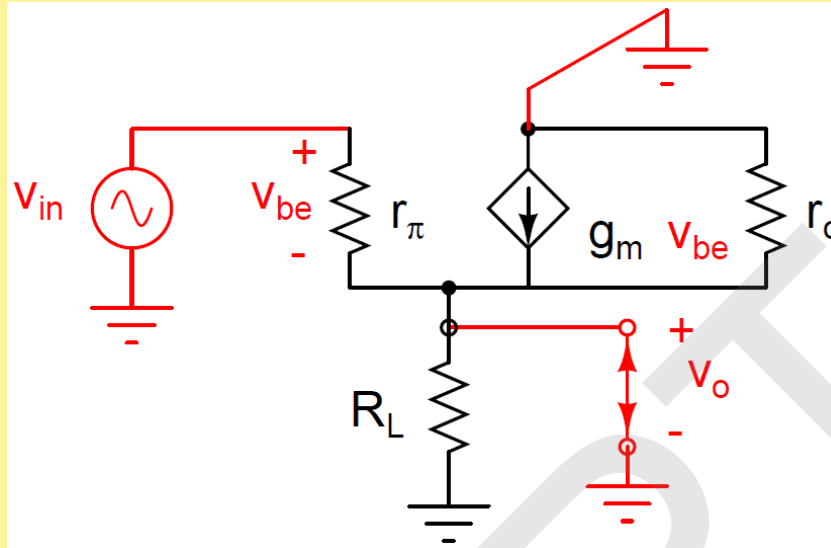
- **Input resistance:**

$$R_{in} = (g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L) + r_{\pi}$$

- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L)}{(g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L) + r_{\pi}}$$

Small signal analysis of more realistic **CC** amplifier (*including R_L*)



$$C_{in} = \frac{C_{\pi} \cdot r_{\pi}}{(g_m \cdot r_{\pi} + 1) \cdot (R_L || r_o) + r_{\pi}} + C_{\mu}$$

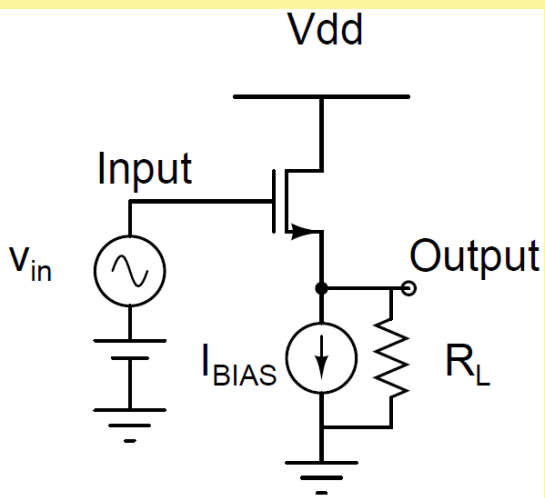
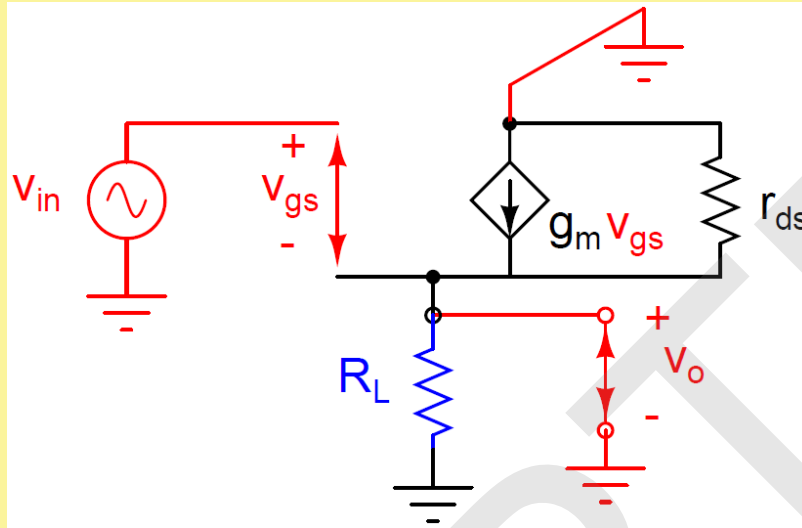
$$R_{in} = (g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L) + r_{\pi}$$

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L)}{(g_m \cdot r_{\pi} + 1) \cdot (r_o || R_L) + r_{\pi}}$$

• Output resistance:

$$R_o = \frac{v_x}{i_x} = \frac{1}{\left(g_m + \frac{1}{r_o} + \frac{1}{r_{\pi}} + \frac{1}{R_L} \right)}$$

Small signal analysis of more realistic **CD** amplifier (*including R_L*)



• Voltage gain:

$$\frac{v_o}{v_{in}} = \frac{g_m \cdot (r_{ds} || R_L)}{\{g_m \cdot (r_{ds} || R_L) + 1\}}$$

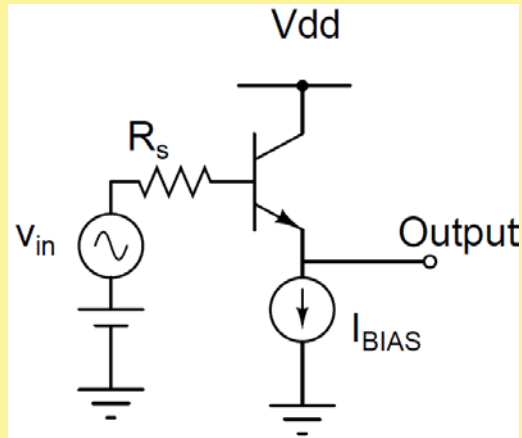
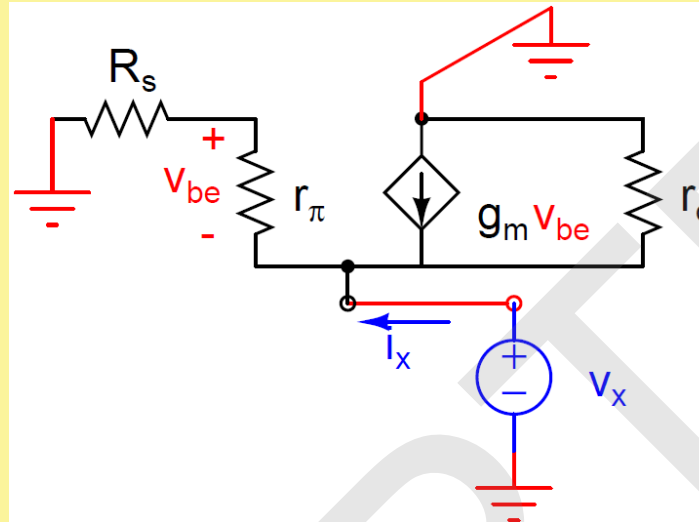
• Input resistance:

$$R_o = \frac{1}{\left(g_m + \frac{1}{r_{ds}} + \frac{1}{R_L}\right)}$$

• Input capacitance :

$$c_{in} = c_{gs}(1 - A_v) + c_{gd} = \frac{c_{gs}}{\{g_m \cdot (r_{ds} || R_L) + 1\}} + c_{gd}$$

Small signal analysis of more realistic **CC** amplifier (*with R_s*)



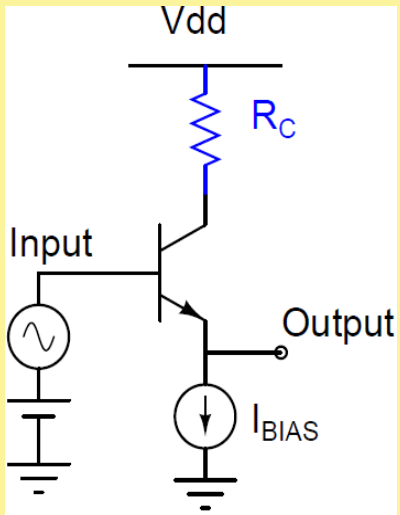
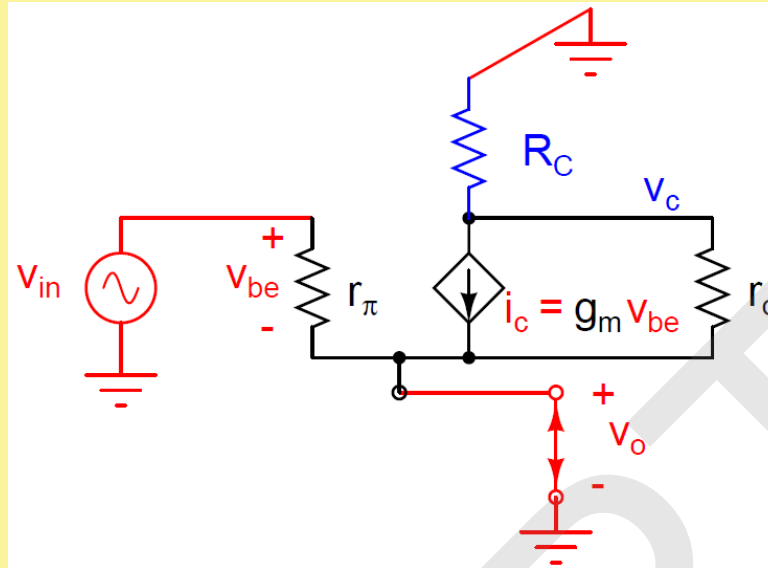
• **Output resistance:**

$$v_{be} = -v_x \cdot \frac{r_\pi}{(R_s + r_\pi)}$$

$$i_x = g_m \cdot v_x \cdot \frac{r_\pi}{(R_s + r_\pi)} + \frac{v_x}{r_o} + \frac{v_x}{(R_s + r_\pi)}$$

$$R_o = \frac{v_x}{i_x} = \frac{1}{\left\{ \frac{g_m \cdot r_\pi}{(R_s + r_\pi)} + \frac{1}{r_o} + \frac{1}{(R_s + r_\pi)} \right\}}$$

Small signal analysis of more realistic **CC** amplifier (*including R_c*)



• **Voltage gain:**

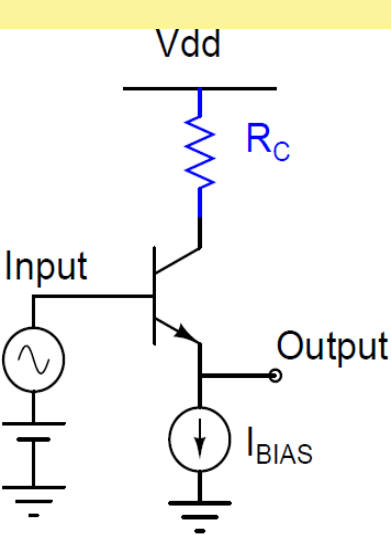
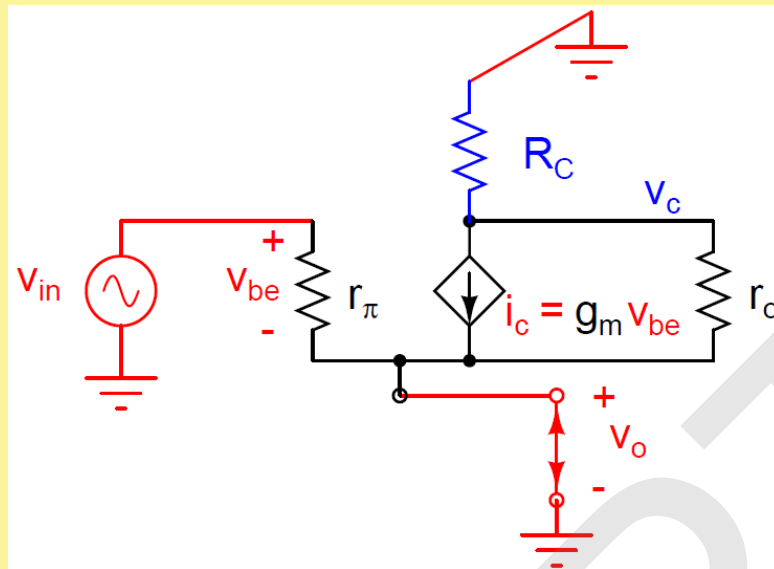
$$v_{be} = (v_{in} - v_o) \quad v_c = R_c \frac{(v_{in} - v_o)}{r_{\pi}}$$

$$\frac{(v_o - v_c)}{r_o} = \frac{(v_{in} - v_o)}{r_{\pi}} + g_m(v_{in} - v_o)$$

$$v_o \left\{ 1 + g_m \cdot r_o + \frac{R_c}{r_{\pi}} + \frac{r_o}{r_{\pi}} \right\} = v_{in} \left\{ g_m \cdot r_o + \frac{R_c}{r_{\pi}} + \frac{r_o}{r_{\pi}} \right\}$$

$$v_o = v_{in} \cdot \frac{(R_c + r_o + g_m \cdot r_{\pi} \cdot r_o)}{(r_{\pi} + R_c + r_o + g_m \cdot r_{\pi} \cdot r_o)}$$

Small signal analysis of more realistic **CC** amplifier (*including R_C*)



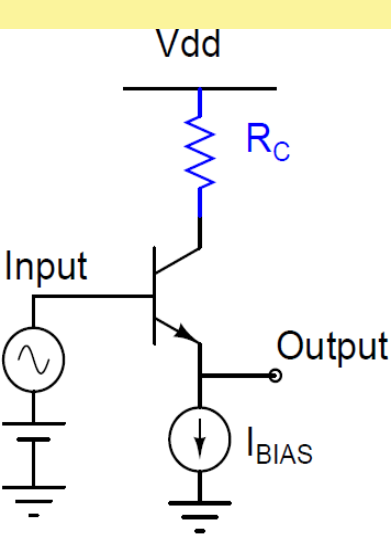
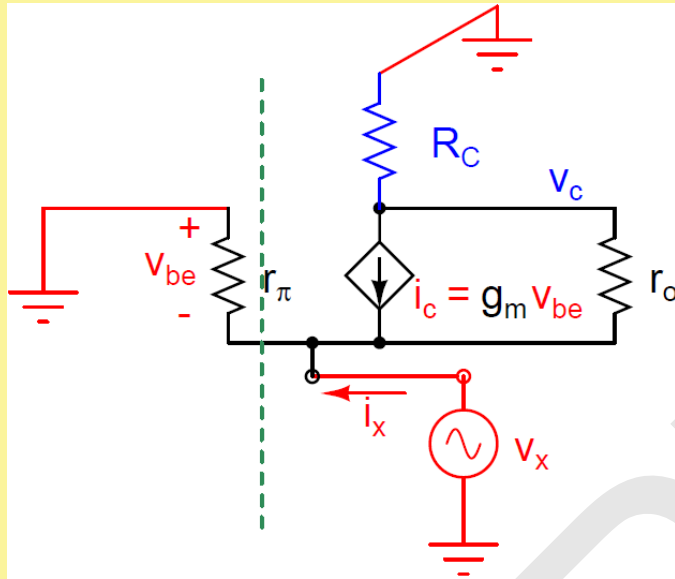
• Input resistance:

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{v_{in}}{(v_{in} - v_o)/r_{\pi}} = \frac{r_{\pi}}{\left(1 - v_o/v_{in}\right)}$$

$$v_o = v_{in} \cdot \frac{(R_C + r_o + g_m \cdot r_{\pi} \cdot r_o)}{(r_{\pi} + R_C + r_o + g_m \cdot r_{\pi} \cdot r_o)}$$

$$R_{in} = (r_{\pi} + R_C + r_o + g_m \cdot r_{\pi} \cdot r_o)$$

Small signal analysis of more realistic **CC** amplifier (*including R_C*)



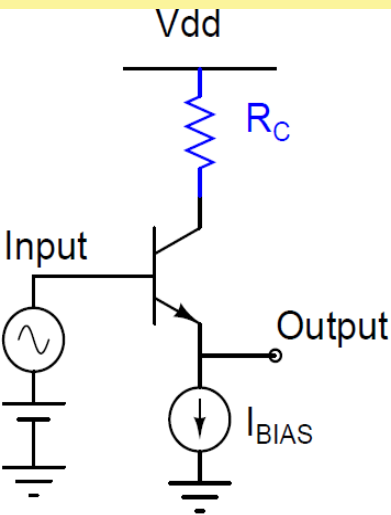
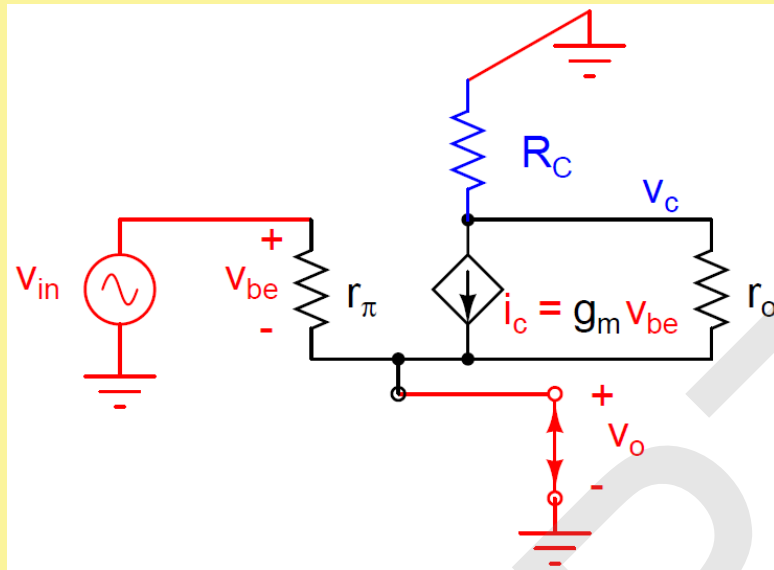
• **Output resistance:**

$$i_x = g_m \cdot v_x + \frac{(v_x - R_C i_x)}{r_o}$$

$$\frac{v_x}{i_x} = \frac{(R_C + r_o)}{(1 + g_m \cdot r_o)}$$

$$R_{out} = r_{\pi} \parallel \left\{ \frac{(R_C + r_o)}{(1 + g_m \cdot r_o)} \right\}$$

Small signal analysis of more realistic **CC** amplifier (*including R_c*)



• Input Capacitance:

$$v_o = v_{in} \cdot \frac{(R_c + r_o + g_m \cdot r_\pi \cdot r_o)}{(r_\pi + R_c + r_o + g_m \cdot r_\pi \cdot r_o)}$$

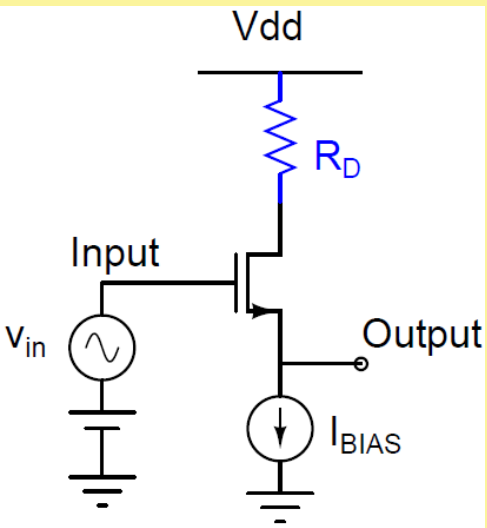
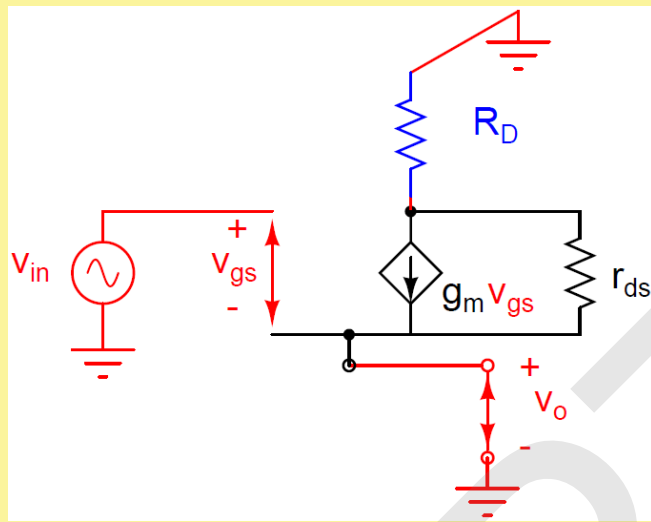
$$v_c = R_c \frac{(v_{in} - v_o)}{r_\pi} = \frac{R_c v_{in}}{r_\pi} \cdot \left\{ 1 - \frac{v_o}{v_{in}} \right\}$$

$$= v_{in} \cdot \frac{R_c}{(r_\pi + R_c + r_o + g_m \cdot r_\pi \cdot r_o)}$$

$$c_{in} = c_\pi(1 - A_{vE}) + c_\mu(1 - A_{vC})$$

$$= c_\pi \cdot \frac{r_\pi}{(r_\pi + R_c + r_o + g_m \cdot r_\pi \cdot r_o)} + c_\mu \cdot \frac{(R_c + r_o + g_m \cdot r_\pi \cdot r_o)}{(r_\pi + R_c + r_o + g_m \cdot r_\pi \cdot r_o)}$$

Small signal analysis of more realistic **CD** amplifier (*including R_D*)



• Voltage gain:

$$v_o = v_{in} \cdot \frac{(R_c + r_o + g_m \cdot r_{\pi} \cdot r_o)}{(r_{\pi} + R_c + r_o + g_m \cdot r_{\pi} \cdot r_o)}$$

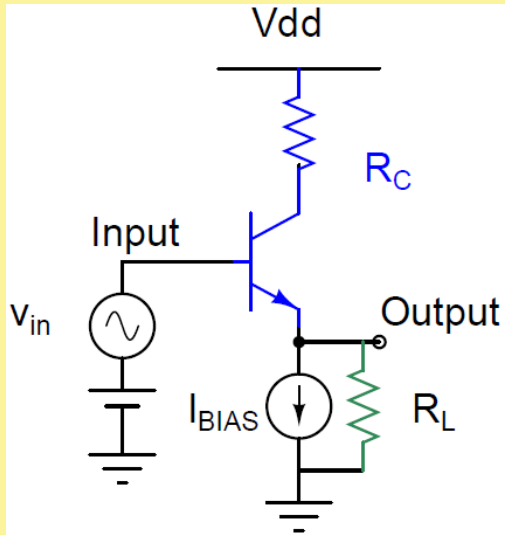
• Output resistance:

$$R_{out} = r_{\pi} \parallel \left\{ \frac{(R_c + r_o)}{(1 + g_m \cdot r_o)} \right\}$$

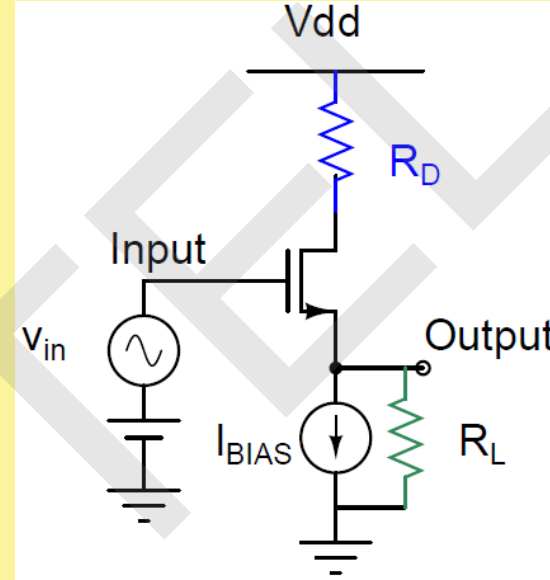
• Input Capacitance:

$$\begin{aligned} c_{in} &= c_{\pi}(1 - A_{vE}) + c_{\mu}(1 - A_{vC}) \\ &= c_{\pi} \cdot \frac{r_{\pi}}{(r_{\pi} + R_c + r_o + g_m \cdot r_{\pi} \cdot r_o)} + c_{\mu} \cdot \frac{(R_c + r_o + g_m \cdot r_{\pi} \cdot r_o)}{(r_{\pi} + R_c + r_o + g_m \cdot r_{\pi} \cdot r_o)} \end{aligned}$$

Exercise: Small signal analysis of more realistic **CC / CD** amplifier (including R_L and R_C/R_D)



- Output resistance:
- Input Capacitance:



- Voltage gain:

Conclusion:

- ☐ CC and CD amplifiers works as voltage mode buffer
- ☐ Basic operation and biasing has been discussed
- ☐ Analysis for gain, impedance and input capacitance has been discussed
- ☐ Analysis for voltage gain, impedance and input capacitance considering realistic components
 - ☐ R_L
 - ☐ R_s
 - ☐ R_c / R_D
- ☐ Numerical examples and Design of CC and CD to be covered

Conclusion





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*Thank
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(contd.)***

CONCEPTS COVERED

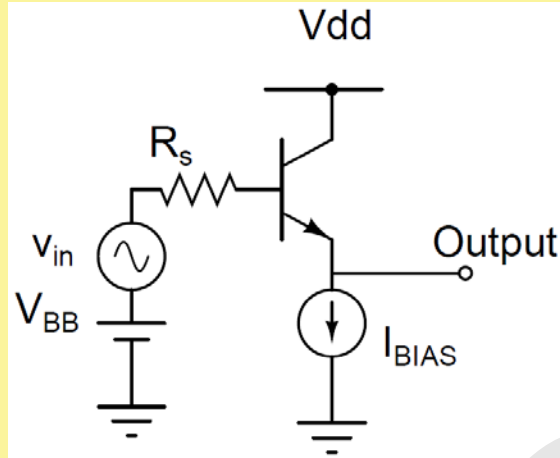
Concepts Covered:

- ☐ Motivation of using CC and CD amplifiers
- ☐ Basic operation and Biasing of CC and CD amplifiers
- ☐ Analysis for voltage gain, impedance and input capacitance considering realistic components
 - ☐ R_L
 - ☐ R_s
 - ☐ R_c / R_D
- ☐ Numerical examples
- ☐ Design guidelines



Numerical example: *CC amplifier*

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$

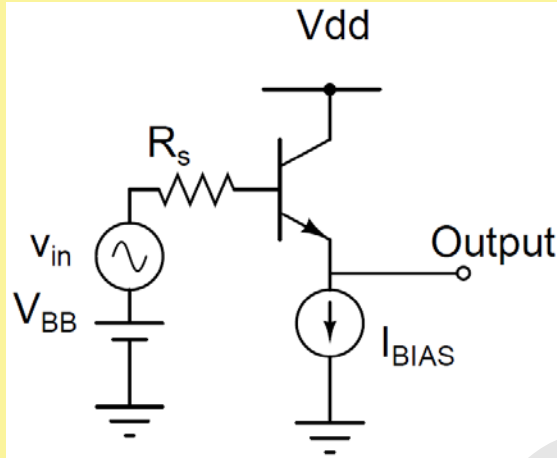


- $V_{dd} = 10 \text{ V}$
- $V_{BB} = 6 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $I_{BIAS} = 0.5 \text{ mA}$
- $R_s \approx 0 \Omega$

- **Find:**
 - Opt. point
 - Values of small signal pars.
 - Voltage gain,
 - Input Imp.
 - Output Imp.
 - Input Cap.
 - Upper cutoff freq.

Numerical exercise: *CC amplifier*

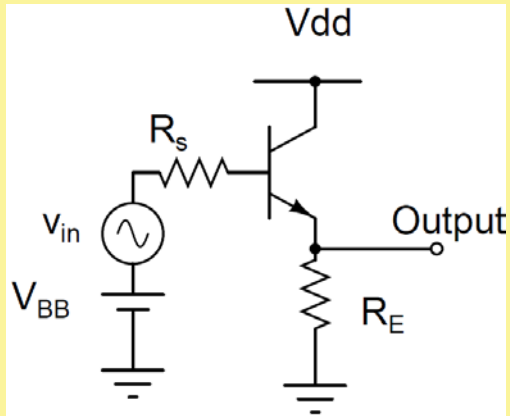
- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$
- $V_{dd} = 10 \text{ V}$
- $V_{BB} = 6 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $I_{BIAS} = 0.5 \text{ mA}$
- $R_s \approx 100 \text{ k}\Omega$



- **Find:**
 - Opt. point
 - Values of small signal pars.
 - Voltage gain,
 - Input Imp.
 - Output Imp.
 - Input Cap.
 - Upper cutoff freq.

Numerical example: *CC amplifier*

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$
- $V_{dd} = 10 \text{ V}$
- $V_{BB} = 6 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $R_E = 10.8 \text{ k}\Omega$
- $R_s \approx 100 \text{ k}\Omega$

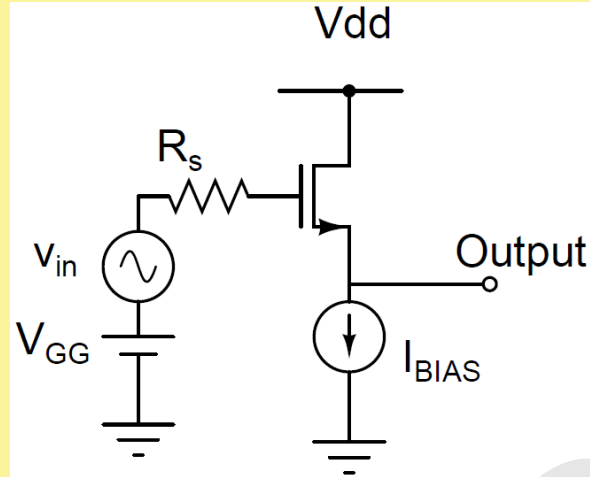


• Find:

- Opt. point
- Values of small signal pars.
- Voltage gain,
- Input Imp.
- Output Imp.
- Input Cap.
- Upper cutoff freq.

Numerical example: *CD amplifier*

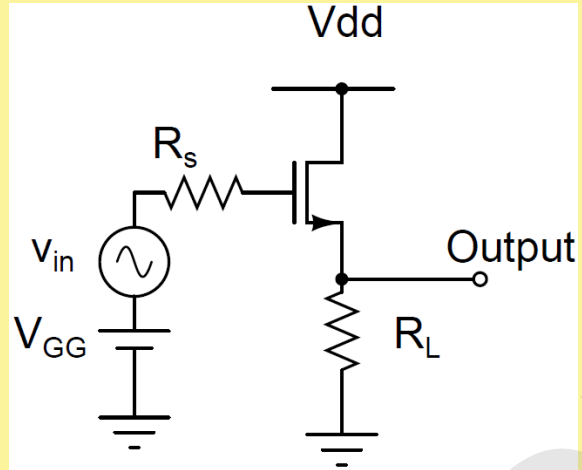
- $V_{th} \approx 1 \text{ V}$
- $KW/L = 2 \text{ mA/V}$
- $\lambda = 0.01 \text{ /V}$
- $C_{gs} = 10 \text{ pF}$
- $C_{gd} = 2 \text{ pF}$
- $V_{dd} = 10 \text{ V}$
- $V_{GG} = 6 \text{ V}$
- $C_L = 100 \text{ pF}$
- $I_{BIAS} = 1 \text{ mA}$
- $R_s \approx 10 \text{ k}\Omega$



- **Find:**
 - Opt. point
 - Values of small signal pars.
 - Voltage gain,
 - Output Imp.
 - Input Cap.
 - Upper cutoff freq.

Numerical example: *CD amplifier*

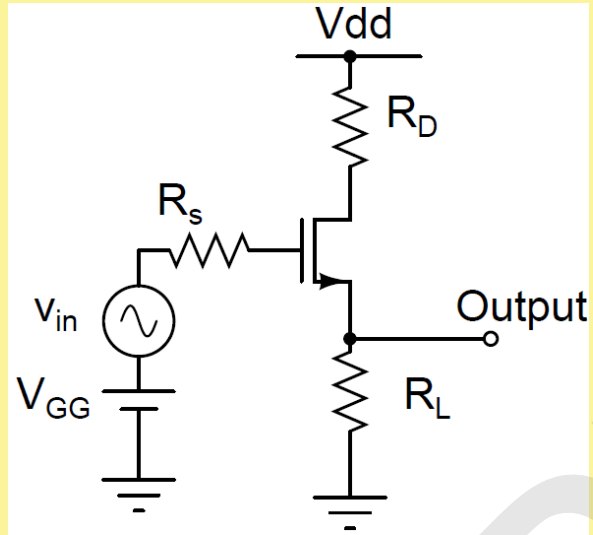
- $V_{th} \approx 1 \text{ V}$
- $KW/L = 2 \text{ mA/V}$
- $\lambda = 0.01 \text{ /V}$
- $C_{gs} = 10 \text{ pF}$
- $C_{gd} = 2 \text{ pF}$
- $V_{dd} = 10 \text{ V}$
- $V_{GG} = 6 \text{ V}$
- $C_L = 100 \text{ pF}$
- $R_L = 4 \text{ k}\Omega$
- $R_s \approx 10 \text{ k}\Omega$



- **Find:**
 - Opt. point
 - Values of small signal pars.
 - Voltage gain,
 - Output Imp.
 - Input Cap.
 - Upper cutoff freq.

Numerical example: *CD amplifier*

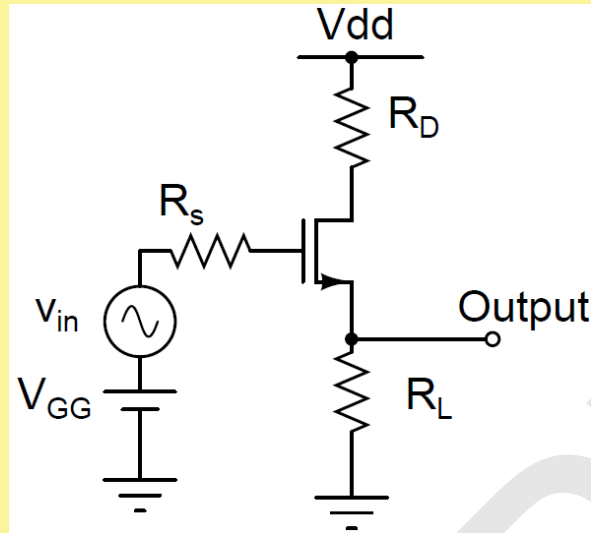
- $V_{th} \approx 1\text{ V}$
- $KW/L = 2\text{ mA/V}$
- $\lambda = 0.01\text{ /V}$
- $C_{gs} = 10\text{ pF}$
- $C_{gd} = 2\text{ pF}$
- $V_{dd} = 10\text{ V}$
- $V_{GG} = 6\text{ V}$
- $C_L = 100\text{ pF}$
- $R_D = 4\text{ k}\Omega$
- $R_L = 4\text{ k}\Omega$
- $R_s \approx 10\text{ k}\Omega$



- **Find:**
 - Opt. point
 - Values of small signal pars.
 - Voltage gain,
 - Output Imp.
 - Input Cap.
 - Upper cutoff freq.

Design guidelines: *CD amplifier*

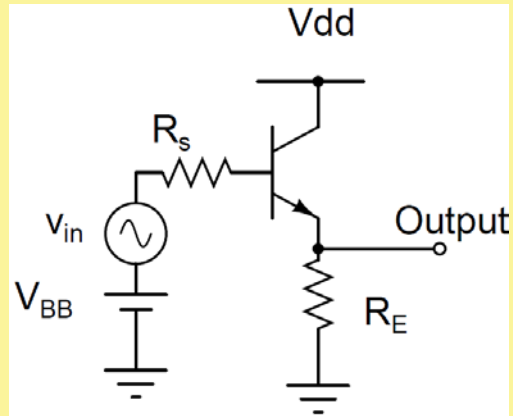
- $V_{th} \approx 1\text{ V}$
- $KW/L = 2\text{ mA/V}$
- $\lambda = 0.01\text{ /V}$
- $C_{gs} = 10\text{ pF}$
- $C_{gd} = 2\text{ pF}$
- $V_{dd} \approx 10\text{ V}$
- $C_L = 100\text{ pF}$
- $R_s \approx 10\text{ k}\Omega$
- $V_{GG} = ?$
- $R_D = ?$
- $R_L = ?$



- Opt. point
- Values of small signal pars.
- Voltage gain,
- Output Imp.
- Input Cap.
- Upper cutoff freq.

Design guidelines: *CC amplifier*

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$



- $V_{DD} = 10 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $R_s \approx 100 \text{ k}\Omega$

- $R_E = ?$
- $V_{BB} = ?$

- Opt. point
- Values of small signal pars.
- Voltage gain,
- Input Imp.
- Output Imp.
- Input Cap.
- Upper cutoff freq.

Conclusion:

- ☐ CC and CD amplifiers works as voltage mode buffer
- ☐ Basic operation and biasing has been discussed
- ☐ Analysis for gain, impedance and input capacitance has been discussed
- ☐ Analysis for voltage gain, impedance and input capacitance considering realistic components
- ☐ Numerical examples and
- ☐ Design guidelines of CC and CD to be covered

Conclusion





NPTEL ONLINE CERTIFICATION COURSES

*Thank
you*





NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Common Base and Common Gate Amplifiers

Flow of Discussion (Bottom-up) – *Building blocks*

- **System/ Sub-systems** (*for specific application*)
 - **Modules** (*performing specific tasks*)
 - **Building blocks** (*having specific characteristics*)
 - **Components** (*devices/circuit elements*)
- **Week 5:**
 - **Common Collector (CC) and Common Drain (CD) amplifiers**
 - **biasing, operation, analysis and design.**
 - **Common Base (CB) and Common Gate (CG) amplifier**
 - **biasing, operation, analysis and design.**



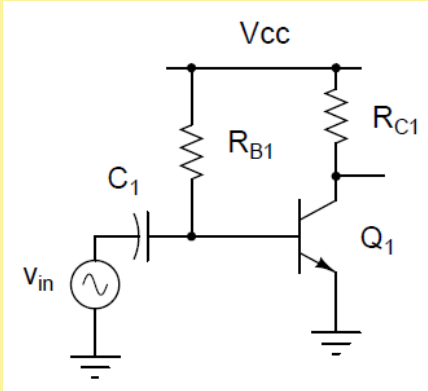
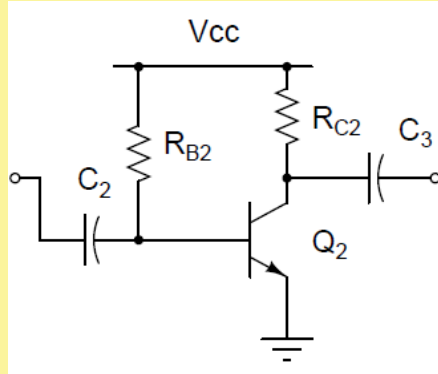
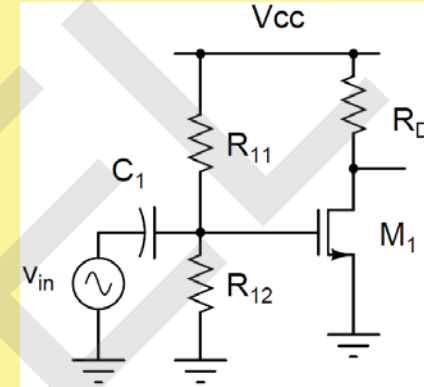
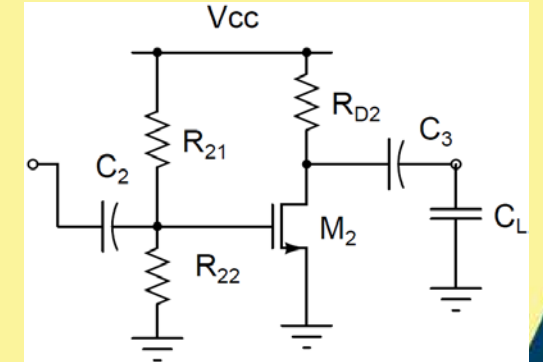
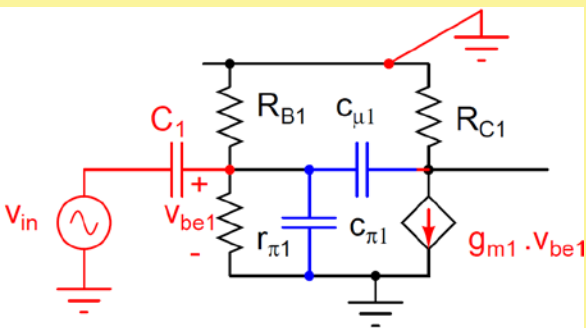
CONCEPTS COVERED

Concepts Covered:

- ❑ Motivation of using CB and CG amplifiers
- ❑ Basic operation and Biasing of CB and CG amplifiers
- ❑ Small signal Analysis for,
 - Voltage gain,
 - Input impedance
 - Output impedance and
 - Current gain

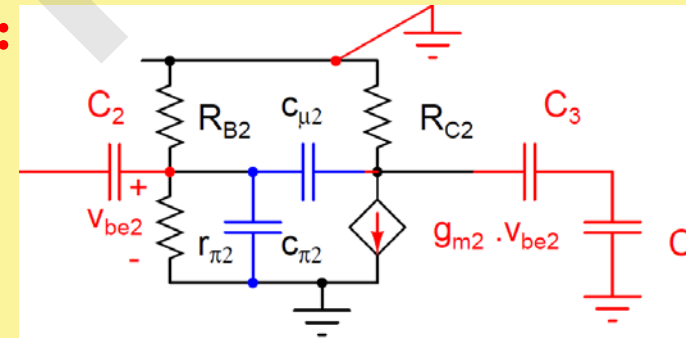


Recapitulation of cascading CE-CE (and CS-CS) amplifier

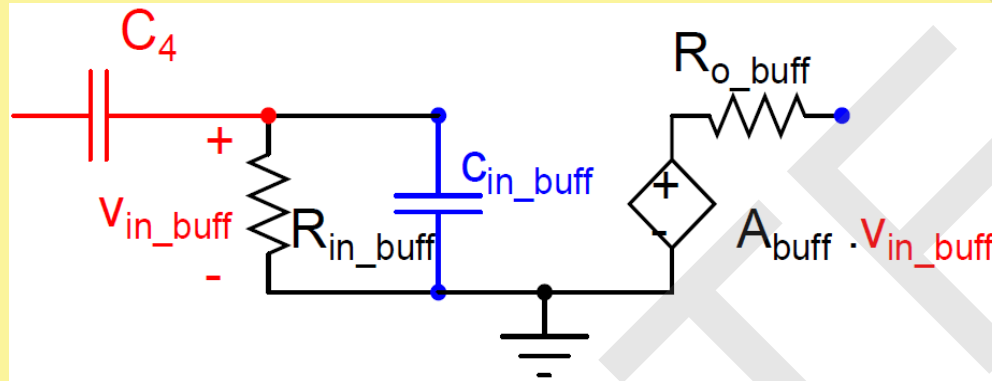


Loading effect degrades:

- Overall voltage gain
- Upper cutoff frequency
- Solution: Use BUFFER

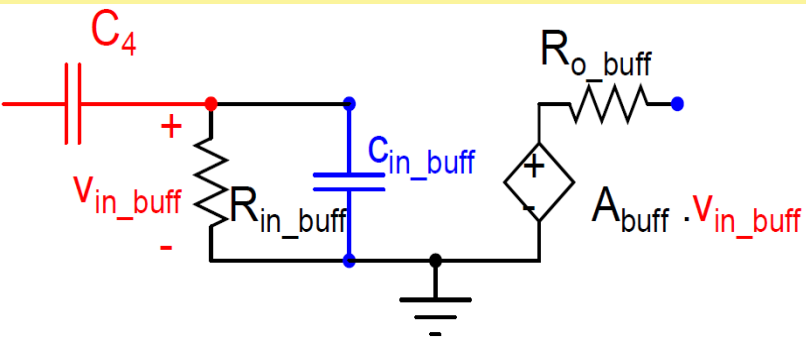
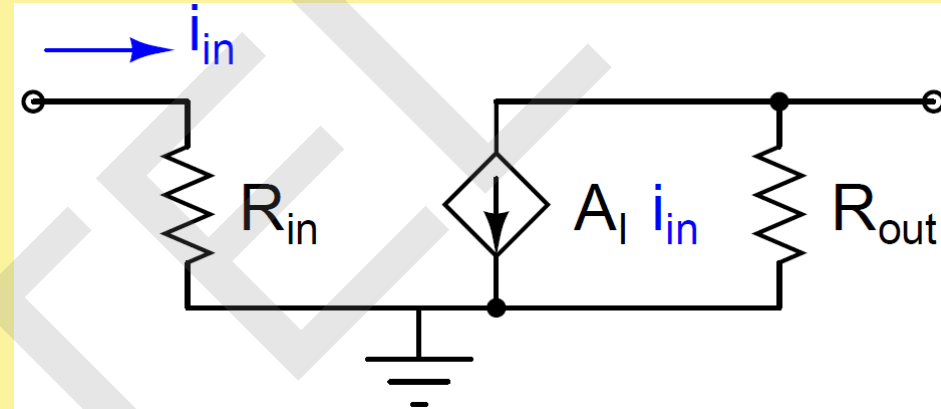


Recapitulation Necessary features of a Buffer (Voltage mode)



- Low Output resistance
- High Input resistance
- Low Voltage attenuation
- *Leading to CC and CD*

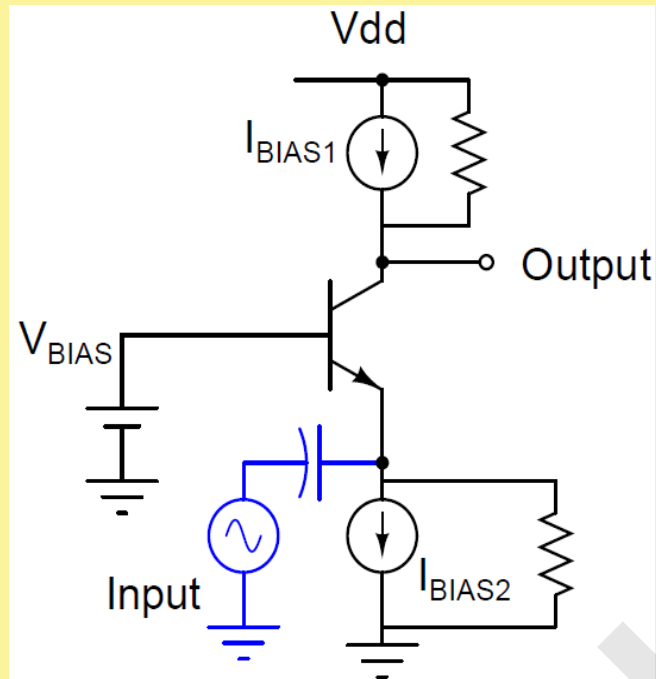
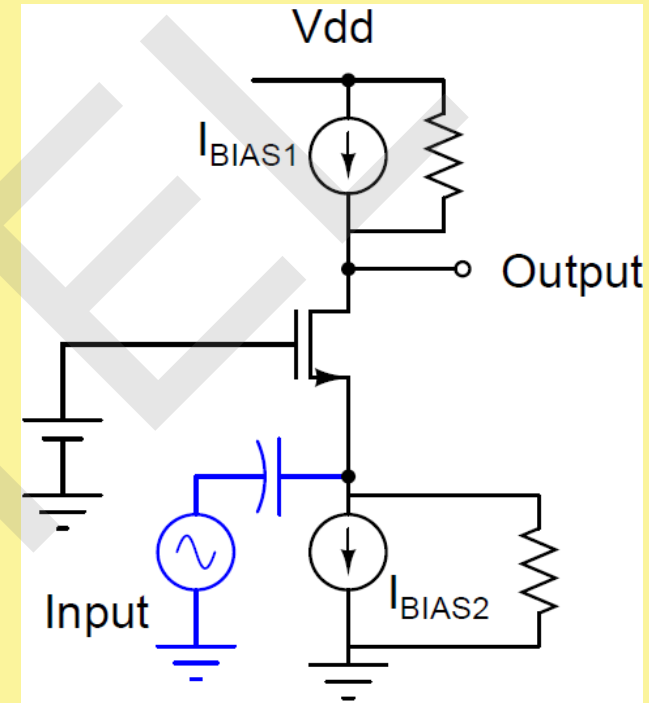
Necessary features of a *Current mode* Buffer



- **Low Output resistance**
- **High Input resistance**
- **Low Voltage attenuation**
- *Leading to CC and CD*

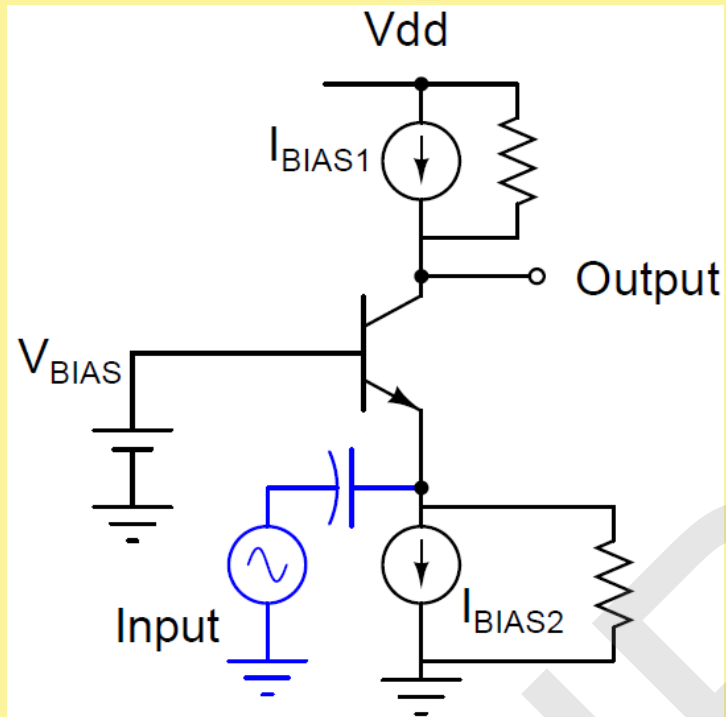
- **High Output resistance**
- **Low Input resistance**
- **Low Current attenuation**
- *Leading to CB and CG*

Basic operation of CB and CG amplifiers



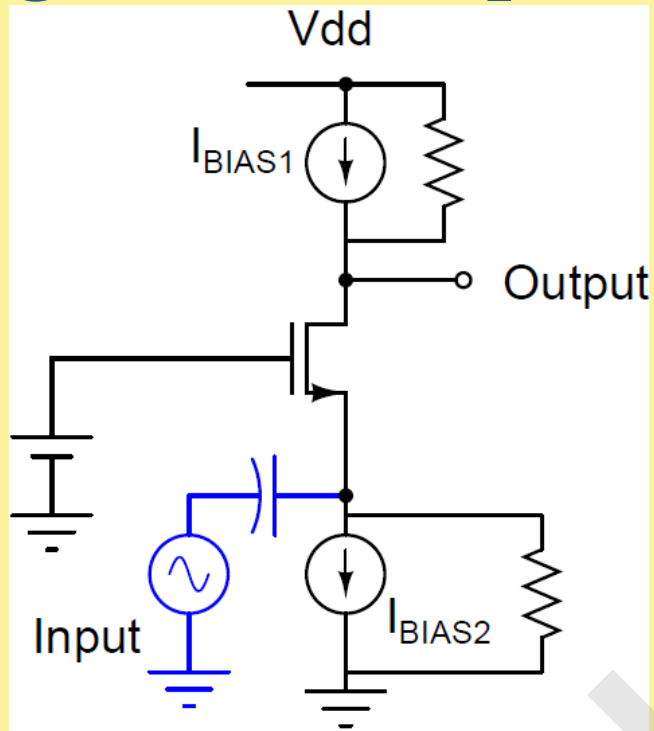
- *With Ideal biasing*

Biassing of CB amplifier



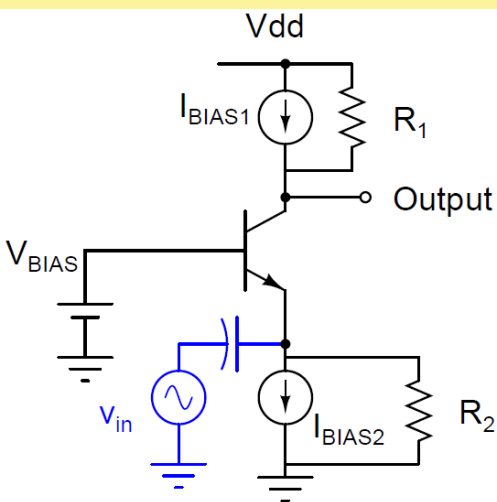
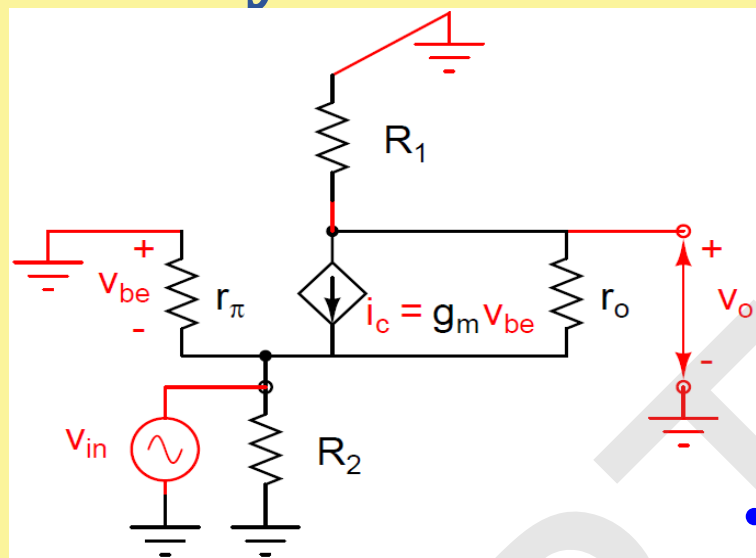
- **Biassing at the emitter / source terminal**
- **Collector / Drain connection**
- **Biassing at the Base / Gate terminal**

Biasing of CG amplifier



- **Biasing at the emitter / source terminal**
- **Collector / Drain connection**
- **Biasing at the Base / Gate terminal**

Small signal analysis of **CB** amplifier



• **Voltage gain:**

$$v_{be} = -v_{in}$$

$$\frac{(v_{in} - v_o)}{r_o} + g_m(v_{in}) = \frac{v_o}{R_1}$$

$$v_o = v_{in} \cdot \frac{(g_m \cdot r_o + 1) \cdot R_1}{R_1 + r_o}$$

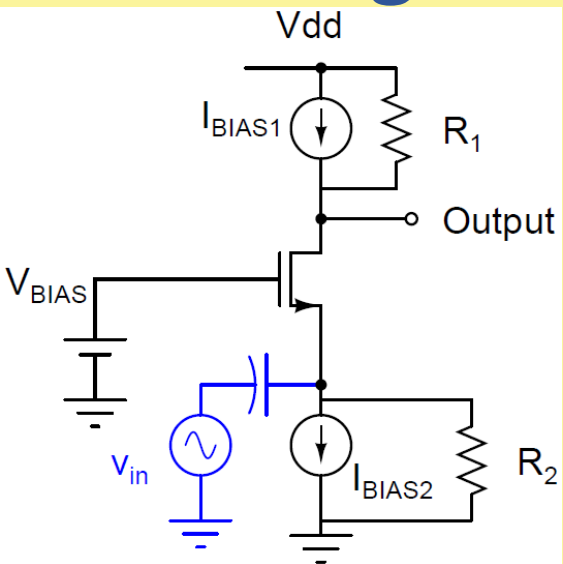
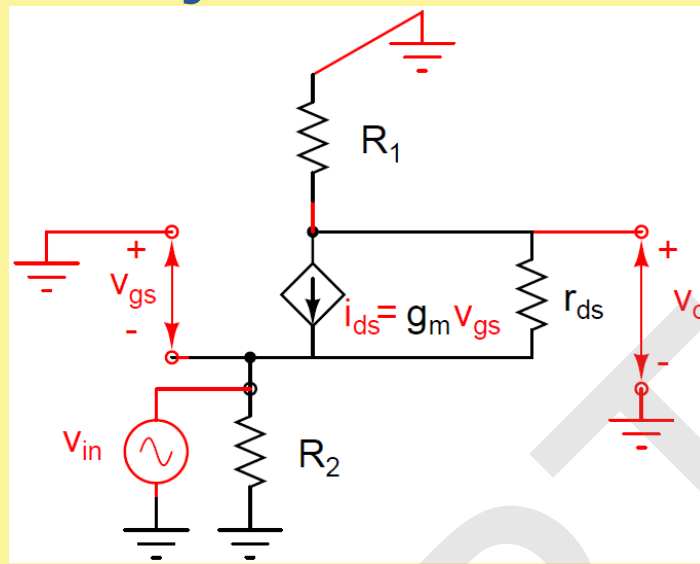
• **Input Impedance:**

$$i_{in} = \frac{v_{in}}{r_{\pi}} + \frac{v_o}{R_1} = v_{in} \cdot \left\{ \frac{1}{r_{\pi}} + \frac{(g_m \cdot r_o + 1)}{R_1 + r_o} \right\}$$

$$\frac{v_{in}}{i_{in}} = r_{\pi} \parallel \left\{ \frac{R_1 + r_o}{(g_m \cdot r_o + 1)} \right\}$$

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_o + 1) \cdot R_1}{R_1 + r_o}$$

Small signal analysis of **CG** amplifier



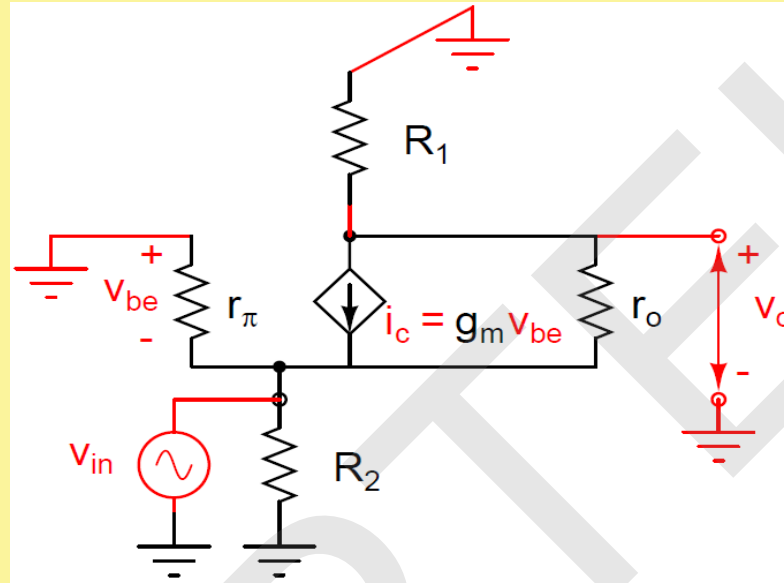
• Voltage gain:

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_o + 1) \cdot R_1}{R_1 + r_o}$$

• Input Impedance:

$$\frac{v_{in}}{i_{in}} = r_{\pi} \parallel \left\{ \frac{R_1 + r_o}{(g_m \cdot r_o + 1)} \right\}$$

Small signal analysis of **CB/CG** amplifier (with signal source resistance)

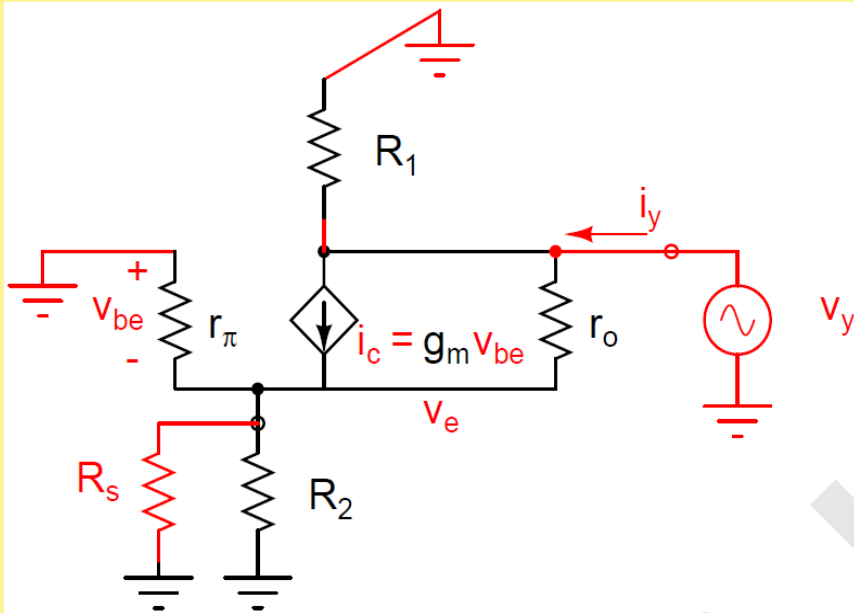
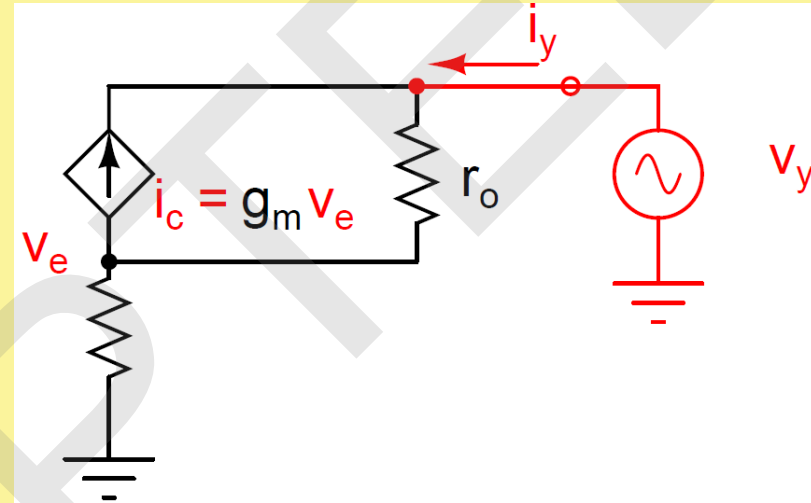


- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_o + 1) \cdot R_1}{R_1 + r_o} \cdot \frac{r_{\pi} || R_1 || \left\{ \frac{R_1 + r_o}{(g_m \cdot r_o + 1)} \right\}}{R_s + r_{\pi} || R_1 || \left\{ \frac{R_1 + r_o}{(g_m \cdot r_o + 1)} \right\}}$$

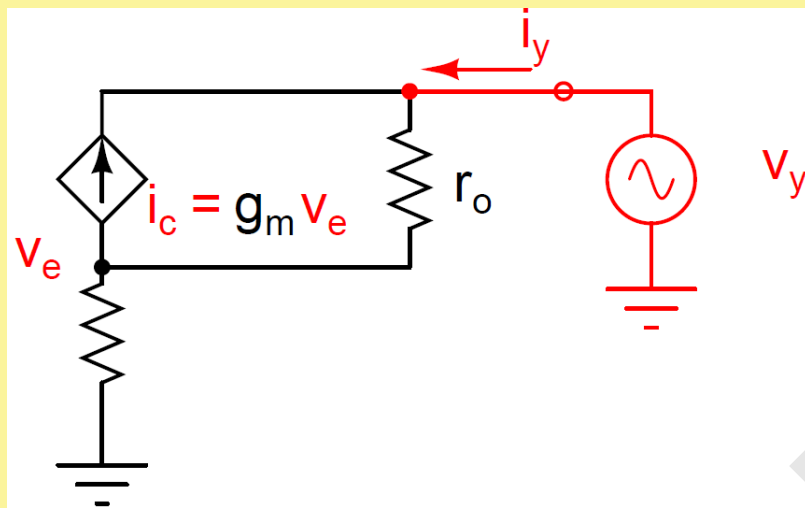
Small signal analysis of **CB** amplifier (with R_s)

- **Output Impedance:**



Small signal analysis of **CB** amplifier (with R_s)

- Output Impedance:**

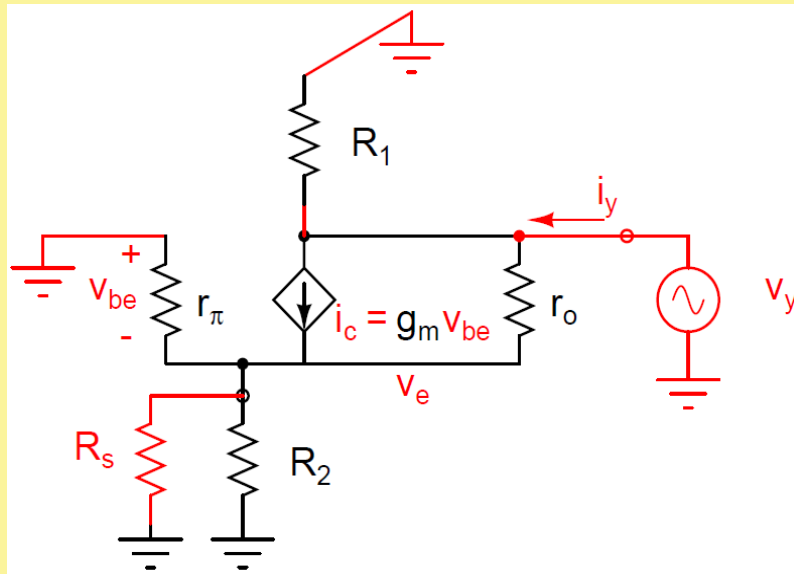


$$v_e = i_y (r_\pi || R_s || R_2) \quad i_y = \frac{v_y}{r_o} - \frac{v_e}{r_o} - g_m v_e$$

$$v_y = i_y r_o + i_y (r_\pi || R_s || R_2) + i_y (r_\pi || R_s || R_2) \cdot g_m r_o$$

$$\frac{v_y}{i_y} = r_o + (r_\pi || R_s || R_2) + (r_\pi || R_s || R_2) \cdot g_m r_o$$

Small signal analysis of **CB** amplifier (with R_s)



$$v_e = i_y(r_\pi || R_s || R_2) \quad i_y = \frac{v_y}{r_o} - \frac{v_e}{r_o} - g_m v_e$$

$$v_y = i_y r_o + i_y(r_\pi || R_s || R_2) + i_y(r_\pi || R_s || R_2) \cdot g_m r_o$$

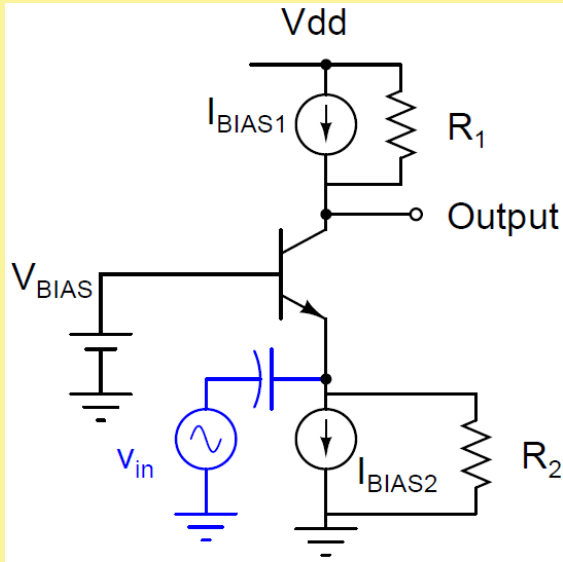
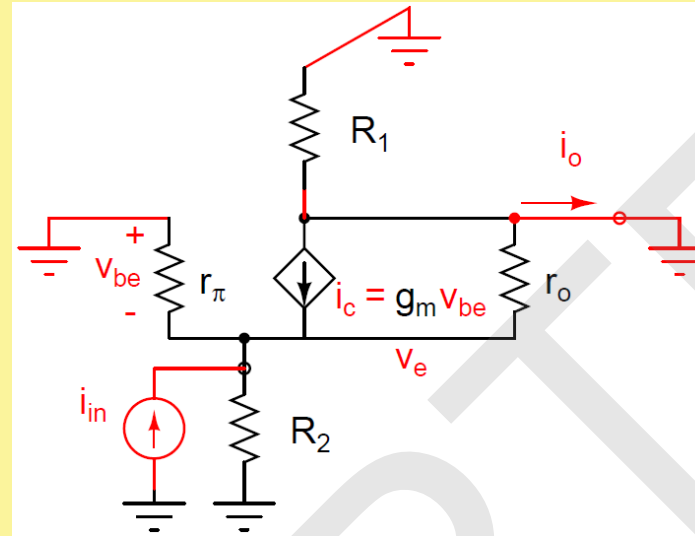
$$\frac{v_y}{i_y} = r_o + (r_\pi || R_s || R_2) + (r_\pi || R_s || R_2) \cdot g_m r_o$$

- Output Impedance:**

$$R_1 || \{r_o + (r_\pi || R_s || R_2) + (r_\pi || R_s || R_2) \cdot g_m r_o\}$$

- Output Impedance of CG ?:**

Small signal analysis of **CB** amplifier



$$i_{in} = v_e \left(g_m + \frac{1}{r_\pi} + \frac{1}{r_o} + \frac{1}{R_2} \right)$$

$$i_o = v_e \left(g_m + \frac{1}{r_o} \right)$$

- **Current gain:**

Conclusion

Conclusion:

- ☐ CB and CG amplifiers works as buffer in current mode amplification
- ☐ Basic operation and biasing has been discussed
- ☐ Analysis for gain and impedance has been discussed
- ☐ *Numerical examples and Design of CB and CG to be covered*





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*Thank
you*





NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

***Common Base and Common Gate Amplifiers
(contd.)***

CONCEPTS COVERED

Concepts Covered:

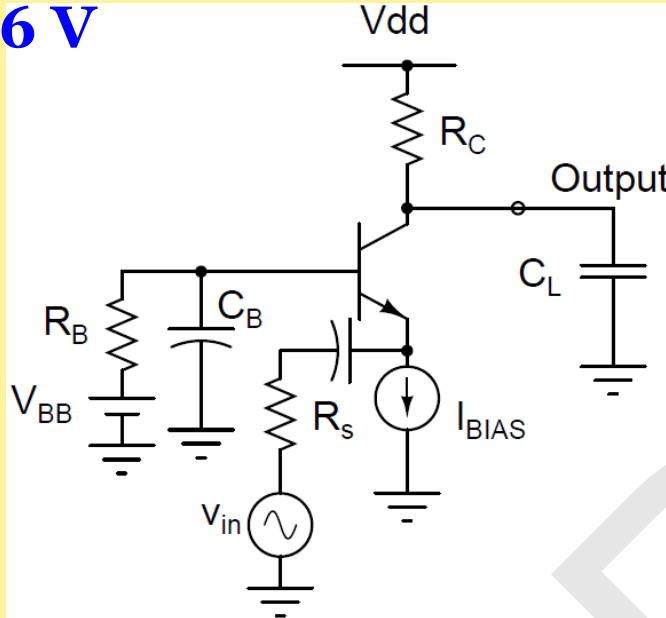
- ☐ Motivation of using CB and CG amplifiers
- ☐ Basic operation and Biasing of CB and CG amplifiers
- ☐ Small signal Analysis for,
 - Voltage gain,
 - Input impedance
 - Output impedance and
 - Current gain
- ☐ Numerical examples
- ☐ Design guidelines



Numerical example: *CB* amplifier

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$

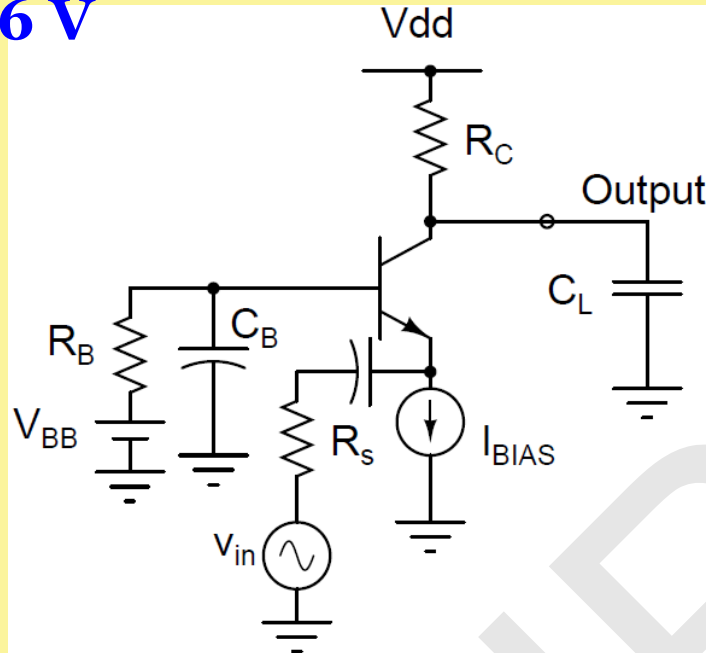
- $V_{dd} = 10 \text{ V}$
- $V_{BB} = 6 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $I_{BIAS} = 1 \text{ mA}$
- $R_S = R_B \approx 0 \Omega$
- $R_C = 3 \text{ k}\Omega$



- **Find:**
 - Opt. point
 - Values of small signal pars.
 - Voltage gain,
 - Input Imp.
 - Output Imp.
 - Input Cap.
 - Upper cutoff freq.

Numerical exercise: *CB amplifier*

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$
- $V_{dd} = 10 \text{ V}$
- $V_{BB} = 6 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $I_{BIAS} = 1 \text{ mA}$
- $R_B \approx 0 \Omega$
- $R_C = 3 \text{ k}\Omega$
- $R_s \approx 10 \text{ k}\Omega$

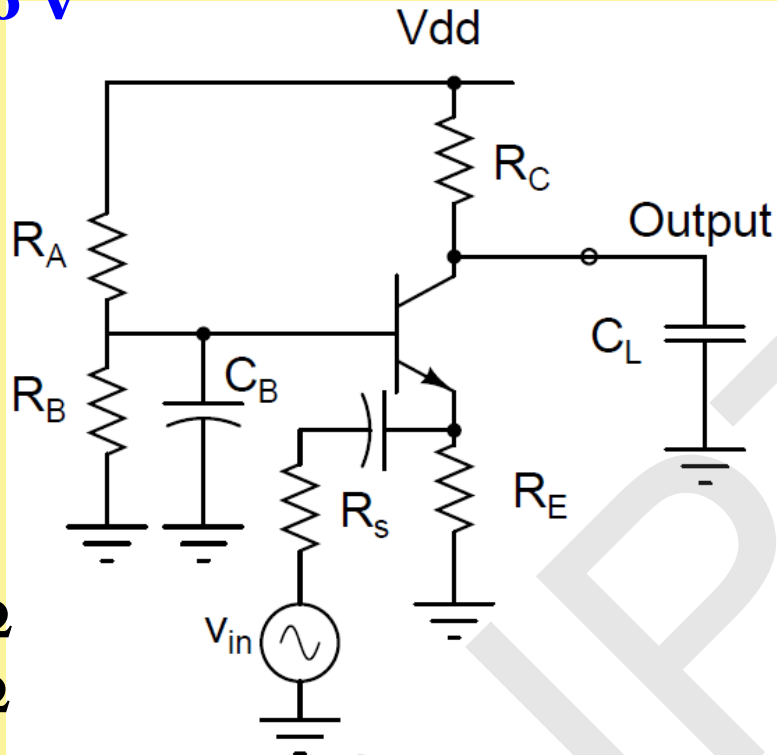


Find:

- Opt. point
- Values of small signal pars.
- Input Imp.
- Voltage gain
- Output Imp.
- Input Cap.
- Upper cutoff freq.

Numerical example: *CB* amplifier

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$
- $V_{dd} = 12 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $R_A = 100 \text{ k}\Omega$
- $R_B = 100 \text{ k}\Omega$
- $R_C = 6 \text{ k}\Omega$
- $R_S \approx 10 \text{ k}\Omega$
- $R_E = 10.306 \text{ k}\Omega$

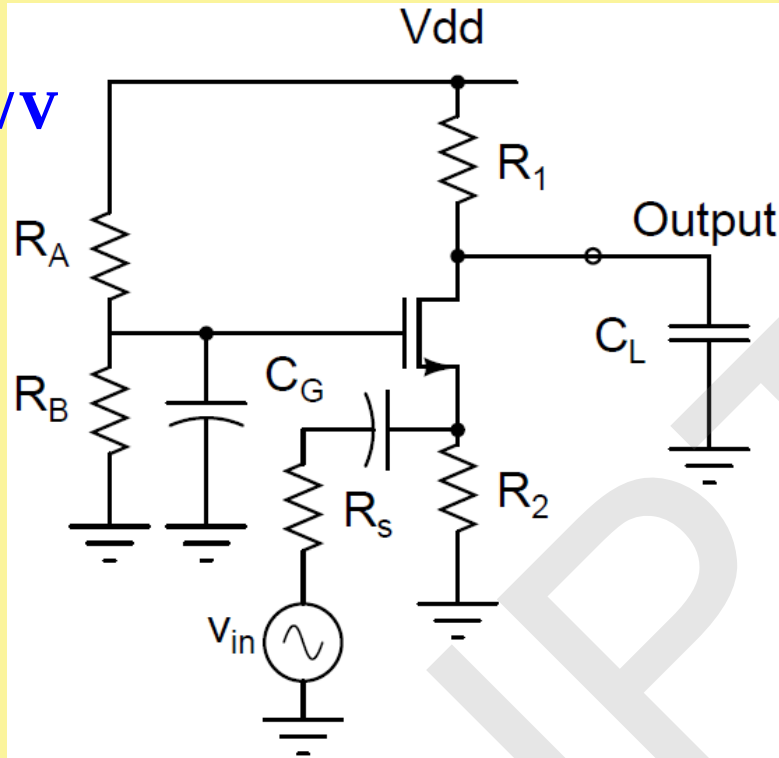


• Find:

- Opt. point
- Values of small signal pars.
- Input Imp.
- Voltage gain,
- Output Imp.
- Input Cap.
- Upper cutoff freq.
- Output swing
- **Current gain**

Numerical example: *CG amplifier*

- $V_{th} \approx 1\text{ V}$
- $KW/L = 2\text{ mA/V}$
- $\lambda = 0.01\text{ /V}$
- $C_{gs} = 10\text{ pF}$
- $C_{gd} = 2\text{ pF}$
- $V_{dd} = 12\text{ V}$
- $C_L = 100\text{ pF}$
- $R_A = 100\text{ k}\Omega$
- $R_B = 100\text{ k}\Omega$
- $R_1 = 3\text{ k}\Omega$
- $R_s \approx 10\text{ k}\Omega$
- $R_2 = 4\text{ k}\Omega$



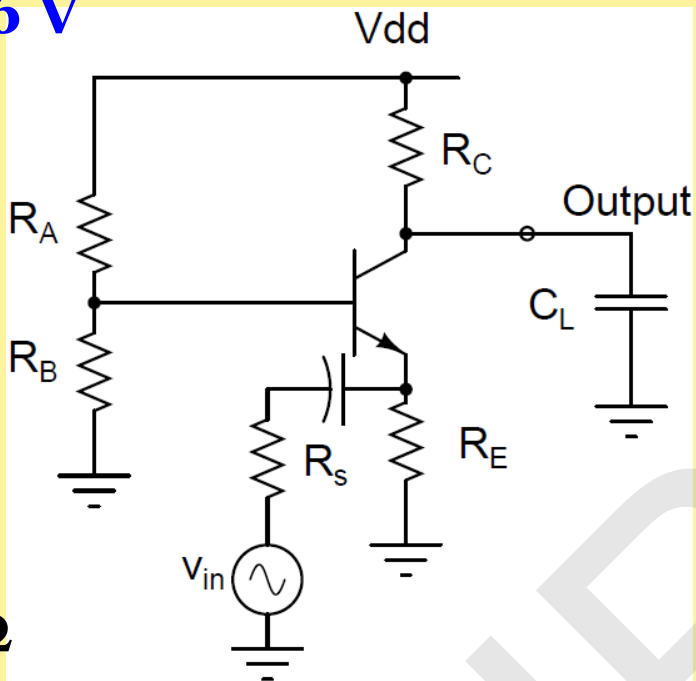
• Find:

- Opt. point
- Values of small signal pars.
- Voltage gain
- Output Imp.
- Input Cap.
- Upper cutoff freq.
- Output swing
- **Current gain**



Numerical example: **CB** amplifier *without* C_B

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$
- $V_{dd} = 12 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $R_A = 100 \text{ k}\Omega$
- $R_B = 100 \text{ k}\Omega$
- $R_C = 6 \text{ k}\Omega$
- $R_S \approx 10 \text{ k}\Omega$
- $R_E = 10.306 \text{ k}\Omega$



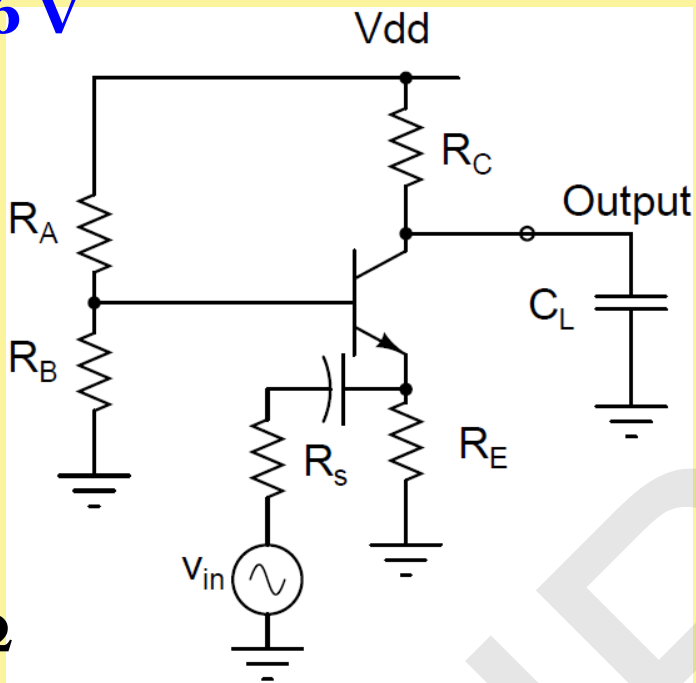
• Find:

- Input Imp.
- Voltage gain,
- Output Imp.

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_o + 1) \cdot R_1}{R_1 + r_o}$$
$$\frac{v_{in}}{i_{in}} = r_\pi \parallel \left\{ \frac{R_1 + r_o}{(g_m \cdot r_o + 1)} \right\}$$

Numerical example: **CB** amplifier *without* C_B

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
- $V_A = 50 \text{ V}$
- $C_\pi = 10 \text{ pF}$
- $C_\mu = 5 \text{ pF}$
- $V_{dd} = 12 \text{ V}$
- $V_T = 26 \text{ mV}$
- $C_L = 100 \text{ pF}$
- $R_A = 100 \text{ k}\Omega$
- $R_B = 100 \text{ k}\Omega$
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• Find:

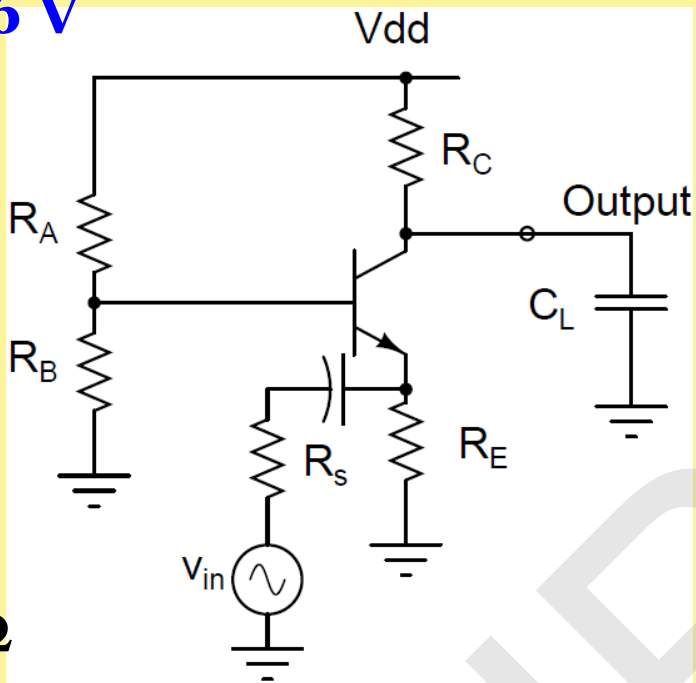
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$$R_1 || \{r_o + (r_\pi || R_S || R_2) + (r_\pi || R_S || R_2) \cdot g_m r_o\}$$

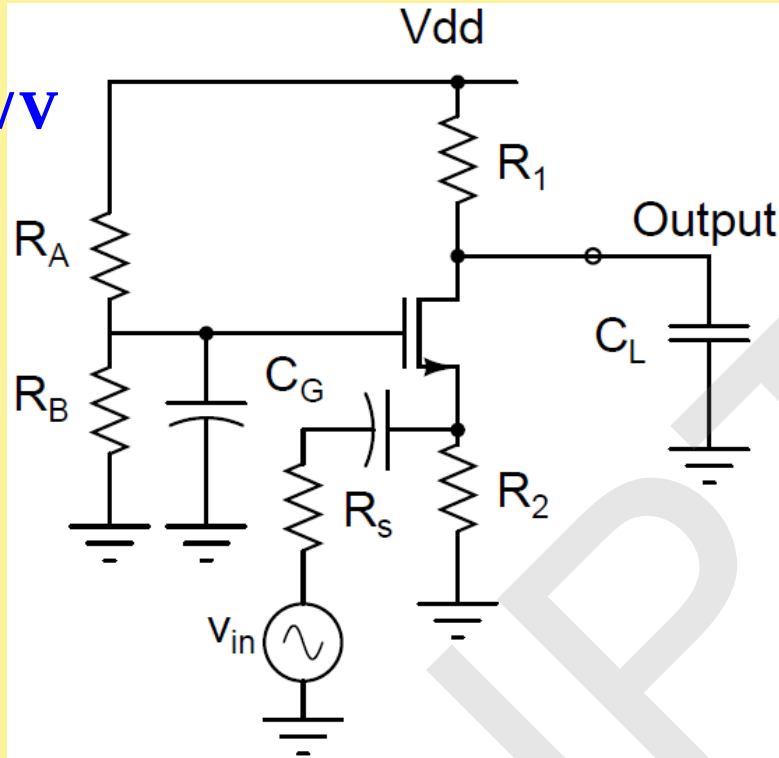
• Find:

- Input Imp.
- Voltage gain,
- Output Imp.



Design guidelines : *CG amplifier*

- $V_{th} \approx 1\text{ V}$
- $KW/L = 2\text{ mA/V}$
- $\lambda = 0.01\text{ /V}$
- $C_{gs} = 10\text{ pF}$
- $C_{gd} = 2\text{ pF}$
- $V_{dd} = 12\text{ V}$
- **$C_L = 100\text{ pF}$**
- $R_A = ?$
- $R_B = ?$
- $R_1 = ?$
- $R_2 = ?$

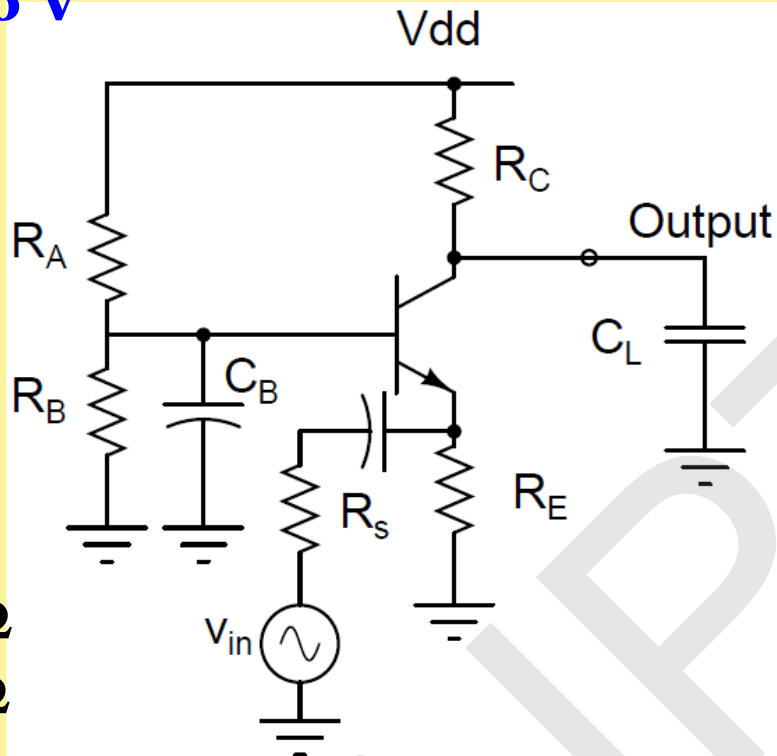


• Find:

- Opt. point
- Values of small signal pars.
- Voltage gain
- Output swing
- Input Imp.
- Output Imp.
- Current gain

Design guidelines: *CB amplifier*

- $V_{BE(on)} \approx 0.6 \text{ V}$
- $\beta = 100$
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• Find:

- Opt. point
- Values of small signal pars.
- Input Imp.
- Voltage gain,
- Output swing
- Output Imp.
- Current gain

Conclusion

Conclusion:

- ❑ Motivation of using CB and CG amplifiers
- ❑ Basic operation and Biasing of CB and CG amplifiers
- ❑ Small signal Analysis for,
 - Voltage gain,
 - Input impedance
 - Output impedance and
 - Current gain
- ❑ Numerical examples and
- ❑ Design guidelines of CB and CG





NPTEL ONLINE CERTIFICATION COURSES

*Thank
you*

