



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Multi transistor 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 6:**

- **Multi transistor Amplifiers (operation and analysis):**

- CE-CC; CS-CD; CC-CC; Darlington pair etc.

- **Cascode amplifiers**

- CS-CB and CS-CG

- **Amplifier with active load.**



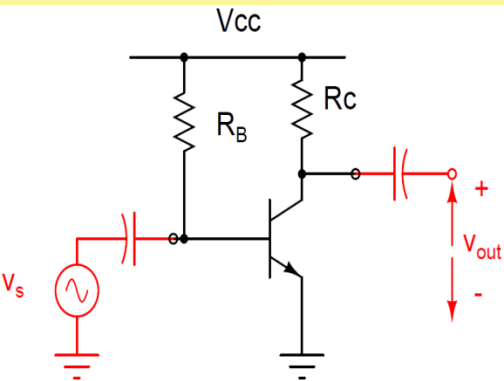
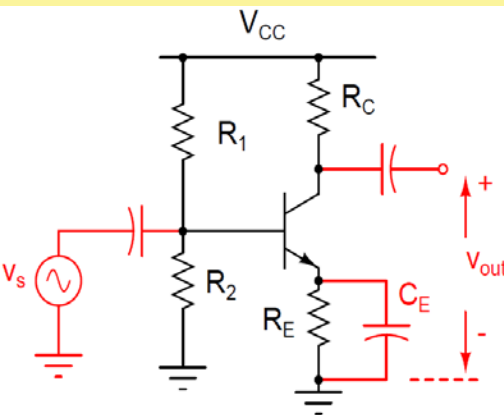
CONCEPTS COVERED

Concepts Covered:

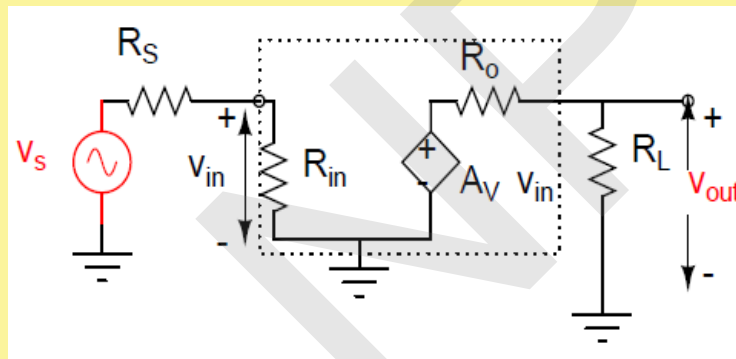
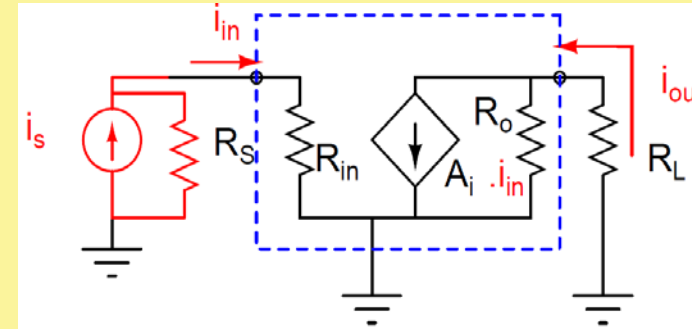
- ☐ Motivation of mixing different configurations
- ☐ Decreasing output impedance by cascading CC:
 - CE-CC
 - CC-CC
- ☐ Increasing input impedance by preceding CC stage:
 - CC-CC
 - CC-CE
 - Darlington pair
- ☐ Decreasing output impedance by cascading CD :
 - CS-CD



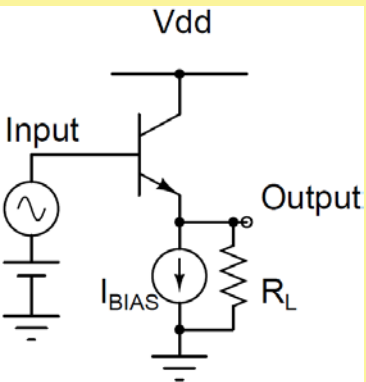
Performance metrics of CE /CC/CB configurations



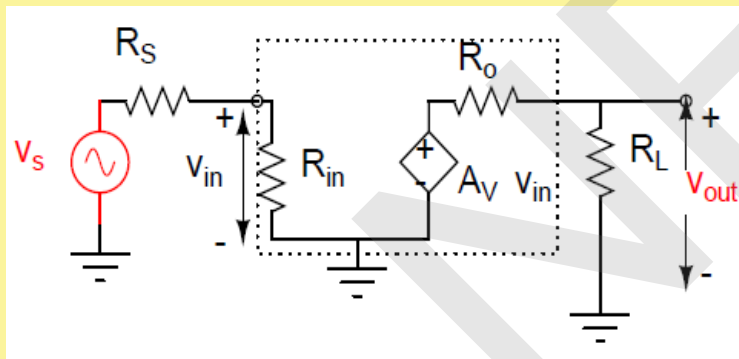
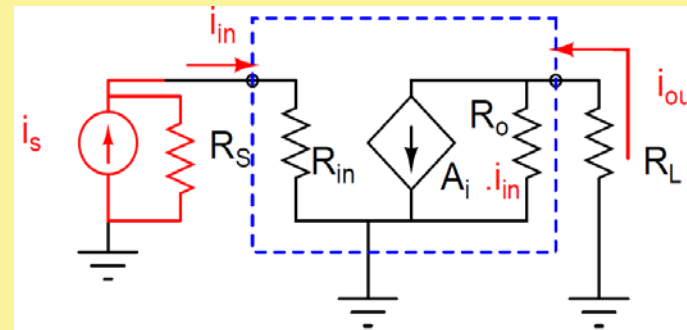
Config.	A_v	R_{in}	R_o	C_{in}	A_i
CE	$-g_m(R_C r_o)$	$(R_B r_{\pi})$	$(R_C r_o)$	$(c_{\pi} + c_{\mu} \cdot g_m(R_C r_o))$	β
	High	High	High	High	High



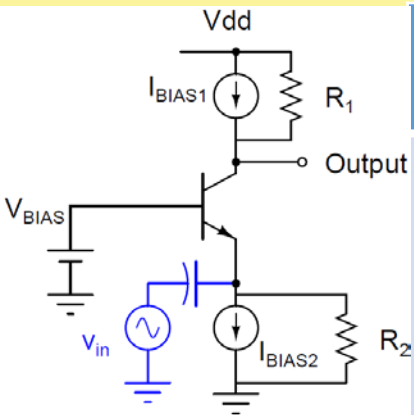
Performance metrics of CE /CC/CB configurations



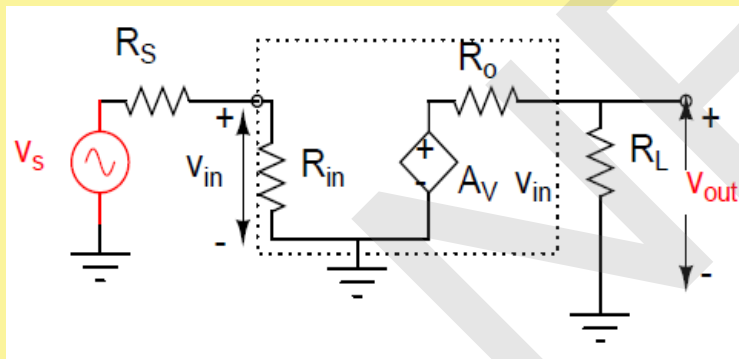
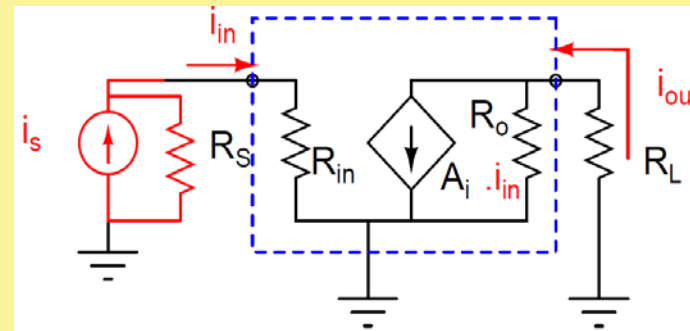
Config.	A_v	R_{in}	R_o	C_{in}	A_i
CC	$\frac{(\beta + 1)(R_L r_o)}{(\beta + 1)(R_L r_o) + r_\pi}$	$(\beta + 1)(R_L r_o) + r_\pi$	$\frac{1}{g_m} R_L r_\pi r_o$	C_μ	$-(\beta + 1)$
	V. Low	V. High	V. Low	V. Low	High



Performance metrics of CE /CC/CB configurations

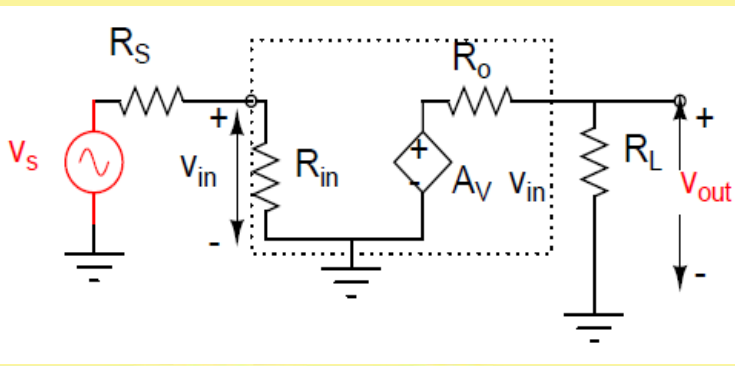
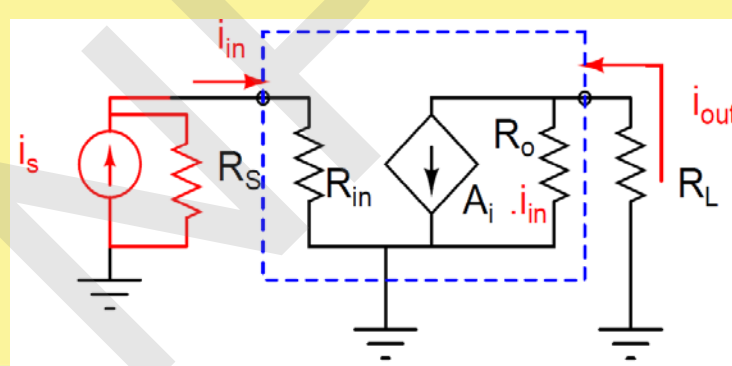


Config.	A_v	R_{in}	R_o	C_{in}	A_i
CB	$g_m(R_1 r_o)$	$r_\pi \frac{(R_1 + r_o)}{(g_m r_o + 1)}$	$R_1 (r_o + g_m r_o (R_s r_\pi R_2))$	C_π	α
	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low



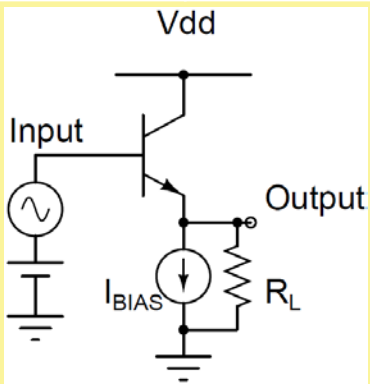
Summary of Performance metrics of CE /CC/CB configs.

Config.	A_v	R_{in}	R_o	C_{in}	A_i	Remarks
CE	High	High	High	High	High	Good Voltage amp & Current amp but needs suitable buffers (for cascading)
CC	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer and Power amplifier
CB	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster



Multi-configuration amplifiers: CC-CC

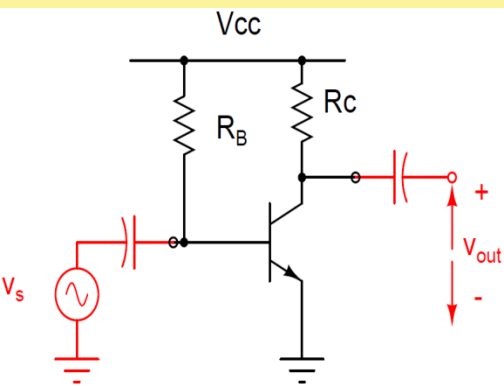
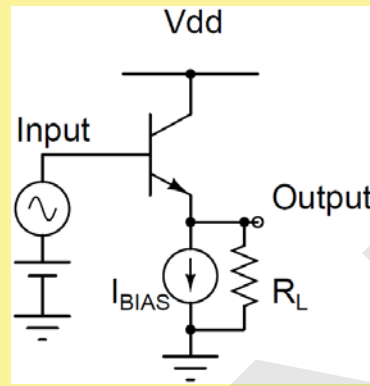
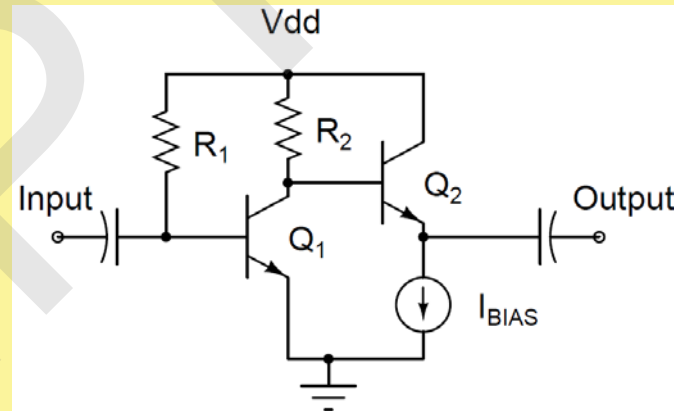
Config.	A_v	R_{in}	R_o	C_{in}	A_i	Remarks
CE	High	High	High	High	High	Good Voltage amp & Current amp but needs suitable buffers (for cascading)
CC	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer and Power amplifier
CB	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster



Advantage ?

Multi-configuration amplifiers: CE-CC

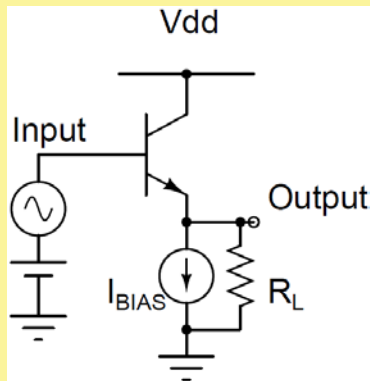
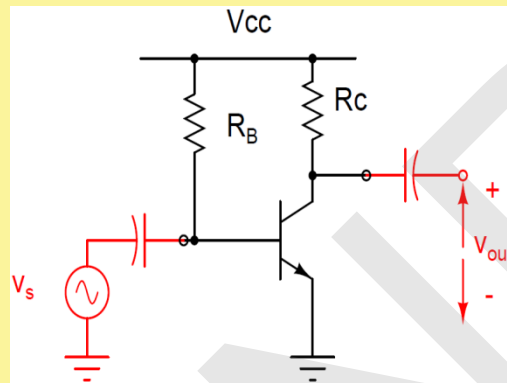
Config.	A_v	R_{in}	R_o	C_{in}	A_i	Remarks
CE	High	High	High	High	High	Good Voltage amp & Current amp but needs suitable buffers (for cascading)
CC	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer and Power amplifier
CB	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster



Advantage ?

Multi-configuration amplifiers: CC-CE

Config.	A_v	R_{in}	R_o	C_{in}	A_I	Remarks
CE	High	High	High	High	High	Good Voltage amp & Current amp but needs suitable buffers (for cascading)
CC	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer and Power amplifier
CB	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster

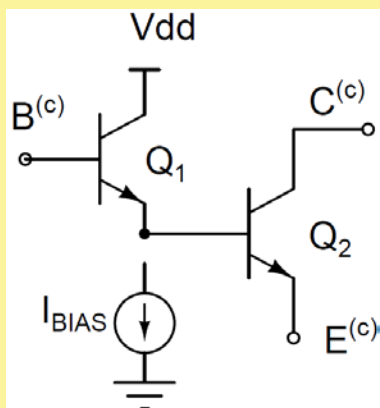


Advantage ?



Multi-configuration amplifiers: *Composite transistor*

Config.	A_v	R_{in}	R_o	C_{in}	A_I	Remarks
CE	High	High	High	High	High	Good Voltage amp & Current amp but needs suitable buffers (for cascading)
CC	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer and Power amplifier
CB	“High” with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster



Analysis of CC-CE and CC-CC amplifiers: *Composite transistor (contd.)*

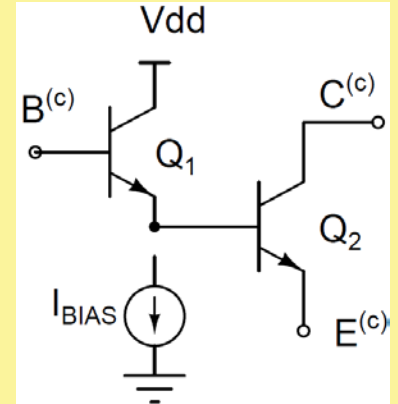
Small signal Parameters:

$$\beta^{(c)} = (1 + \beta_1)\beta_2$$

$$r_{\pi}^{(c)} = r_{\pi 1} + (1 + \beta_1)r_{\pi 2}$$

$$g_m^{(c)} = \frac{(1 + \beta_1)\beta_2}{r_{\pi 1} + (1 + \beta_1)r_{\pi 2}}$$

$$r_o^{(c)} = r_o$$



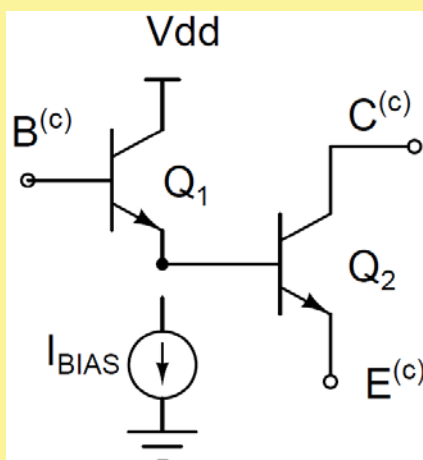
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$$\beta^{(c)} = (1 + \beta_1)\beta_2 \quad r_o^{(c)} = r_o$$

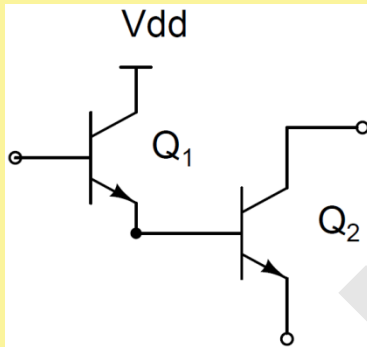
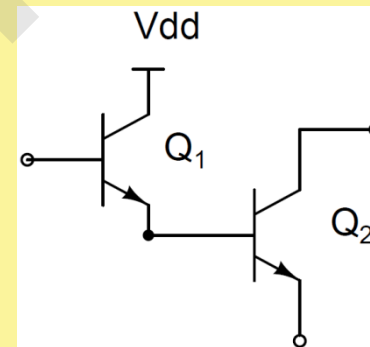
$$r_{\pi}^{(c)} = r_{\pi 1} + (1 + \beta_1)r_{\pi 2}$$

$$g_m^{(c)} = \frac{(1 + \beta_1)\beta_2}{r_{\pi 1} + (1 + \beta_1)r_{\pi 2}}$$



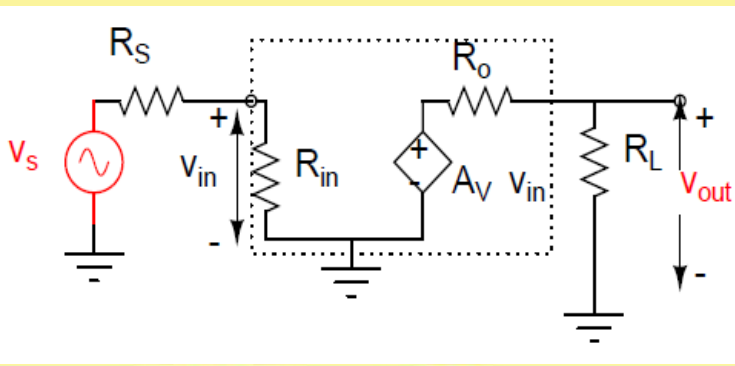
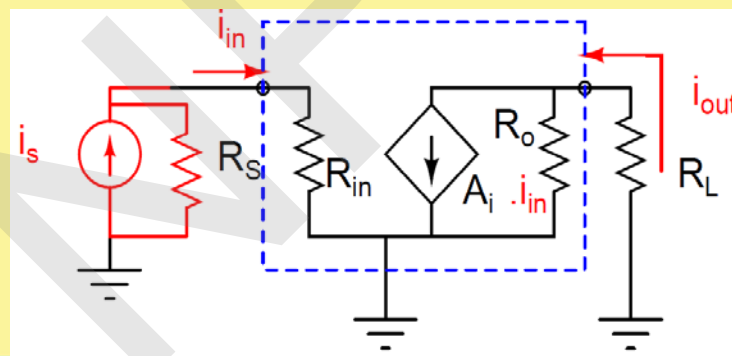
Multi-figuration amplifiers: *Darlington pair and CC-CE*

Config.	A_v	R_{in}	R_o	C_{in}	A_i	Remarks
CE	High	High	High	High	High	Good Voltage amp & Current amp but needs suitable buffers (for cascading)
CC	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer and Power amplifier
CB	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster



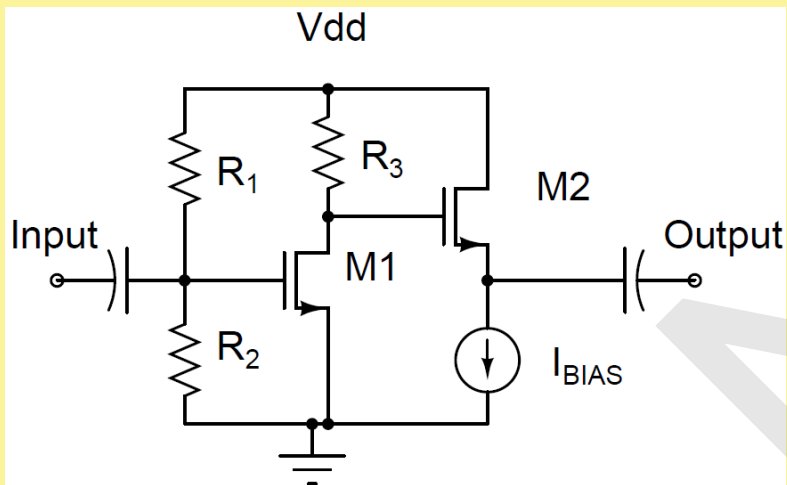
Summary of Performance metrics of CS /CD/CG configs.

Config.	A_v	R_{in}	R_o	C_{in}	A_i	Remarks
CS	High	V. High	High	High	High	Good Voltage amp but needs suitable buffer (for cascading)
CD	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer
CG	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster



CS-CD configuration

Config.	A_v	R_{in}	R_o	C_{in}	A_I	Remarks
CS	High	V. High	High	High	High	Good Voltage amp but needs suitable buffer (for cascading)
CD	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer
CG	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster



Conclusion:

- ❑ Motivation of mixing different configurations
- ❑ Decreasing output impedance by cascading CC:
 - CE-CC
 - CC-CC
- ❑ Increasing input impedance by preceding CC stage:
 - CC-CC
 - CC-CE
 - Darlington pair
- ❑ Decreasing output impedance by cascading CD :
- CS-CD
- ❑ Yet to cover Numerical example

Conclusion





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*Thank
you*





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- **Week 6:**

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- **Cascode amplifiers**

- CS-CB and CS-CG

- **Amplifier with active load.**



CONCEPTS COVERED

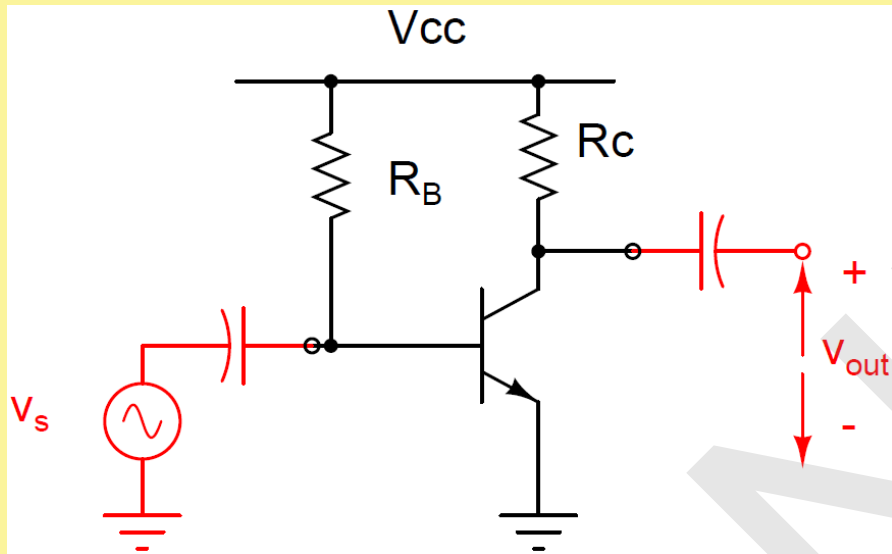
Concepts Covered:

- ❑ Motivation of mixing different configurations
- ❑ Decreasing output impedance by cascading CC:
 - CE-CC
 - CC-CC
- ❑ Increasing input impedance by preceding CC stage:
 - CC-CC
 - CC-CE
 - Darlington pair
- ❑ Decreasing output impedance by cascading CD :
 - CS-CD
- ❑ Numerical examples on
 - CE-CC
 - CS-CD
 - CC-CE



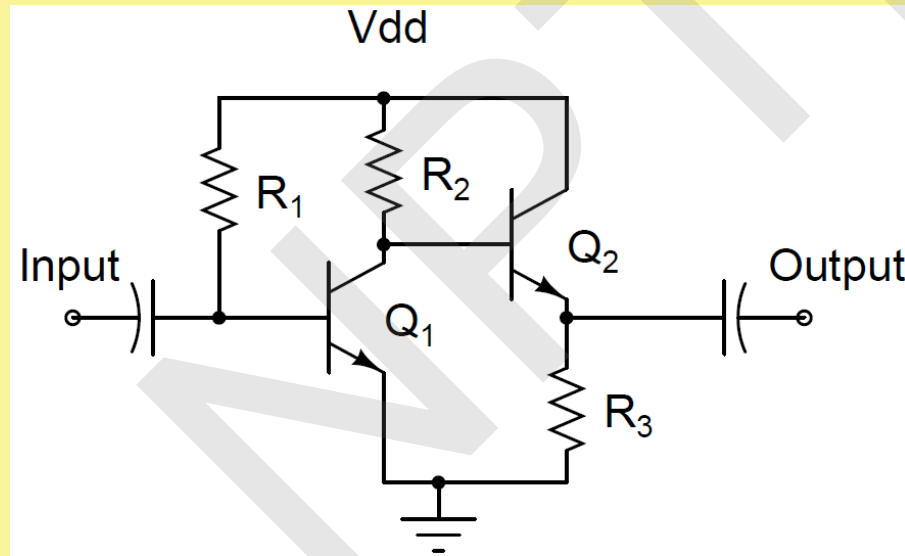
Recall: Numerical Example: CE amplifier –Fixed-bias

- $V_{CC} = 12V$; $V_A = 100V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 3.3k\Omega$.
- $C_1 = C_2 = 10\ \mu F$; $C_L = 100\ pF$; $C_\pi = 10\ pF$ and $C_\mu = 5\ pF$
- *Find Operating point, small signal parameters and voltage gain*
- *Find the upper cutoff frequency*



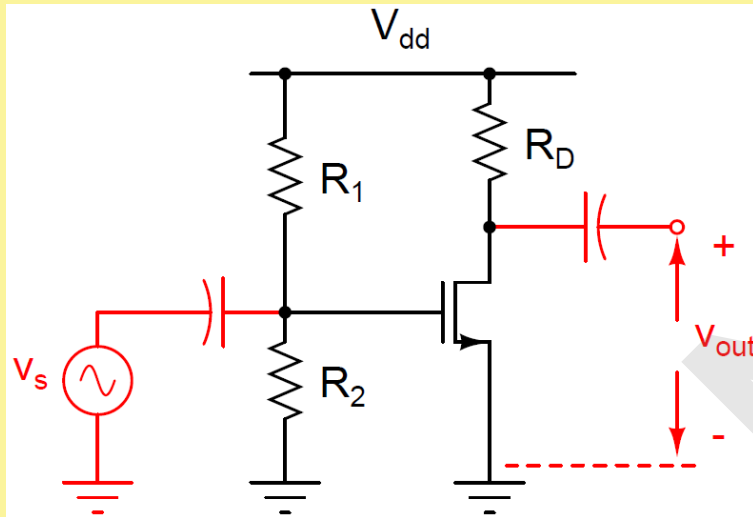
Numerical Example: CE–CC amplifier

- $V_{DD} = 12V$; $V_A = 100V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $C_\pi = 10 \text{ pF}$ and $C_\mu = 5 \text{ pF}$;
- $R_1 = 570k\Omega$; $R_2 = 3.3k\Omega$; $R_3 = 1.2 \text{ k}\Omega$; $C_1 = C_2 = 10 \text{ }\mu\text{F}$; $C_L = 100 \text{ pF}$.
- Find Operating point, small signal parameters and voltage gain
- Find the upper cutoff frequency



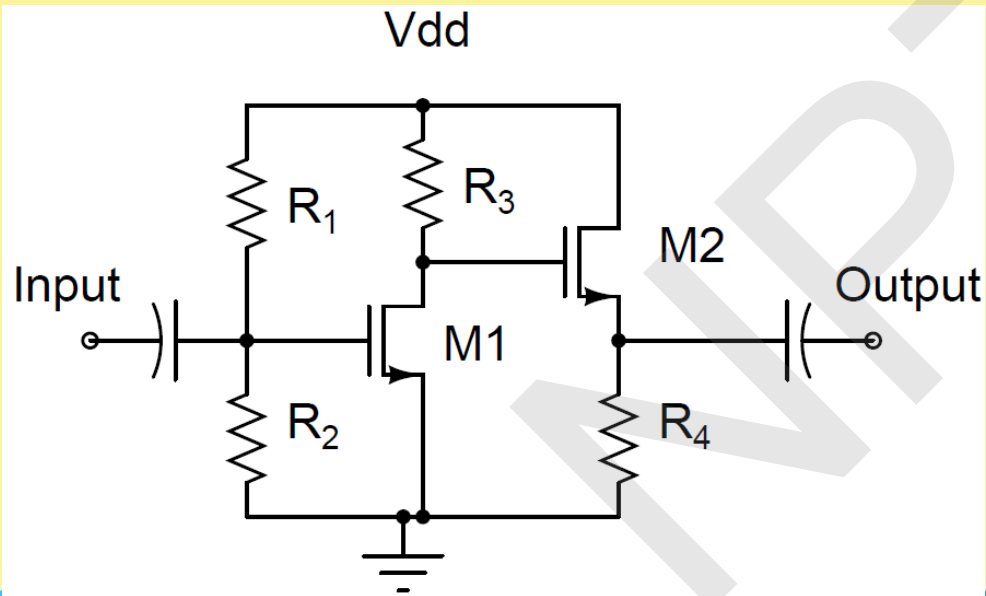
Recall: Numerical Exercise (CS amplifier)

- **Given: for both transistors,** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$,
- $V_{dd} = 12\text{V}$, $R_1 = 9\text{k}\Omega$, $R_2 = 3\text{k}\Omega$, $R_D = 3\text{k}\Omega$;
- $C_1 = C_2 = 10\text{ }\mu\text{F}$; $C_L = 100\text{ pF}$; $C_{gs} = 10\text{ pF}$ and $C_{gd} = 5\text{ pF}$
- *Find small signal parameters, A_v , R_{in} and R_o*
- *Find Lower and upper cutoff frequencies*



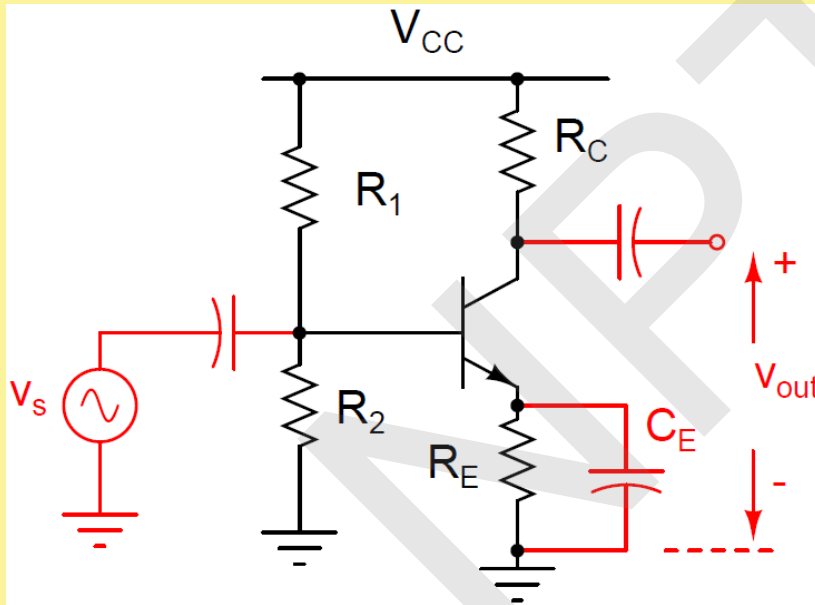
Numerical Exercise: CS-CD amplifier

- **Given: for both transistors,** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$,
- $V_{dd} = 12\text{V}$, $R_1 = 9\text{k}\Omega$, $R_2 = 3\text{k}\Omega$, $R_3 = 3\text{k}\Omega$, $R_4 = 1.5\text{k}\Omega$;
- $C_1 = C_2 = 10\text{ }\mu\text{F}$; $C_L = 100\text{ pF}$; $C_{gs} = 10\text{ pF}$ and $C_{gd} = 5\text{ pF}$
- **Find small signal parameters, A_v , R_{in} and R_o**
- **Find Lower and upper cutoff frequencies**



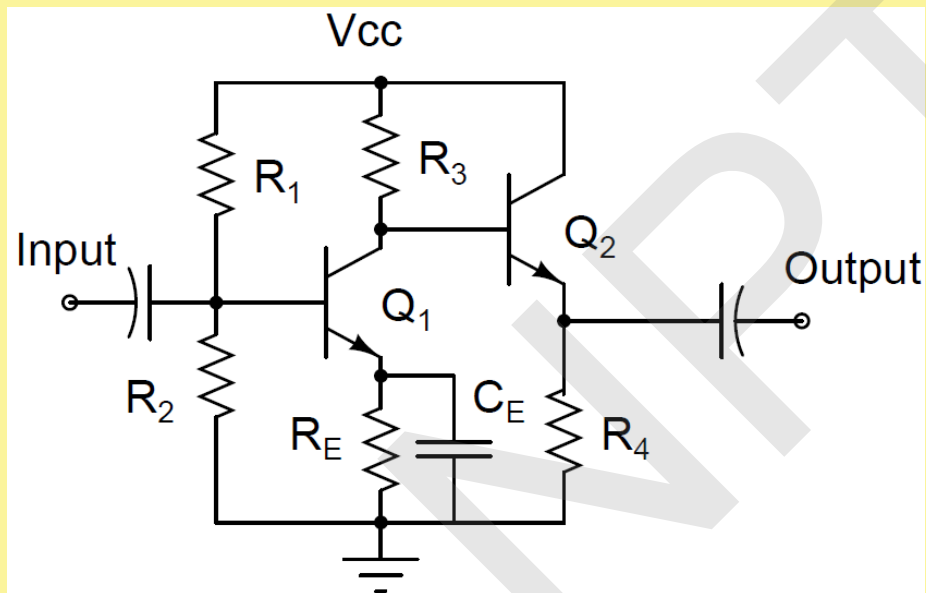
Recall: Numerical Exercise: CE amplifier – Self-bias

- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$; $R_1 = 9.9k\Omega$; $R_2 = 3.3k\Omega$; $R_C = 2.7k\Omega$; $R_E = 1.2k\Omega$
- $C_1 = C_2 = 10\mu F$; $C_E = 100\mu F$; $C_L = 100pF$; $C_\pi = 10pF$ and $C_\mu = 5pF$
- *Find Operating point, small signal parameters, voltage gain, lower and upper cutoff frequencies*



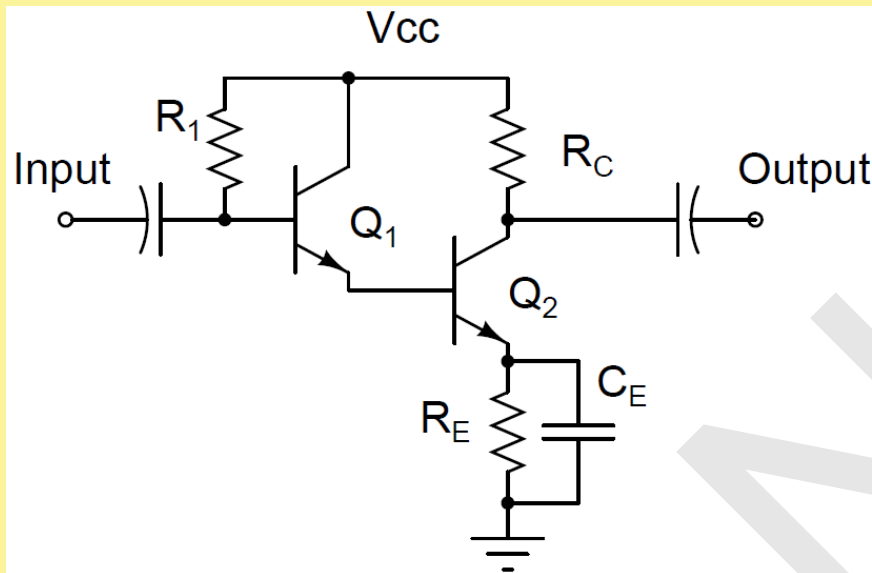
Numerical Exercise: CE(self bias)-CC amplifier

- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$; $R_1 = 9.9k\Omega$; $R_2 = 3.3k\Omega$; $R_3 = 2.7k\Omega$; $R_E = 1.2k\Omega$; $R_4 = 1.2k\Omega$
- $C_1 = C_2 = 10\mu F$; $C_E = 100\mu F$; $C_L = 100pF$; $C_\pi = 10pF$ and $C_\mu = 5pF$
- *Find Operating point, small signal parameters, voltage gain, lower and upper cutoff frequencies*



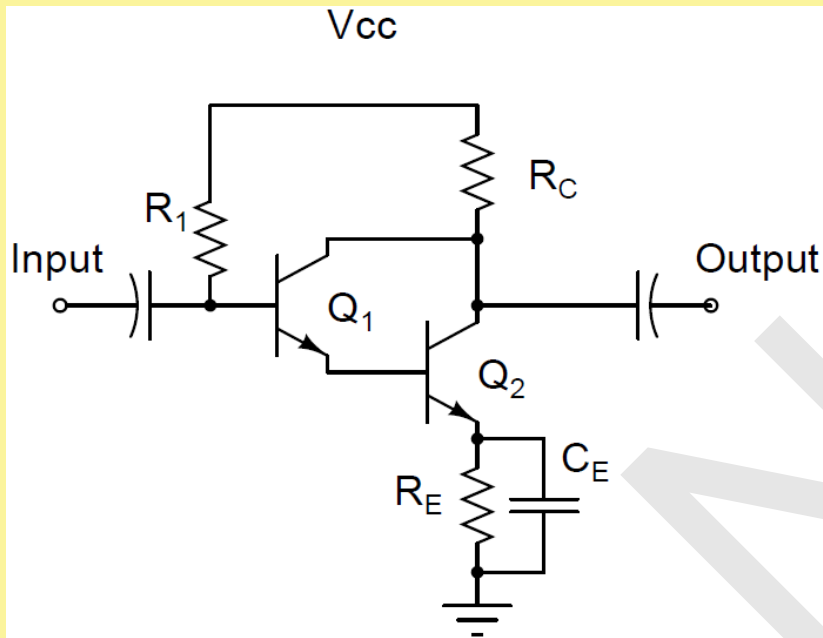
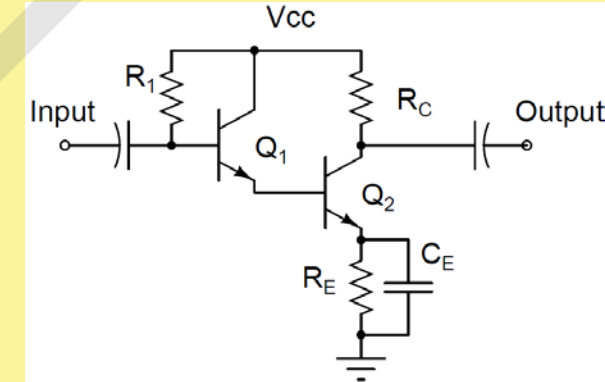
Numerical Exercise: CC-CE amplifier

- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_1 = 98M\Omega$; $R_C = 2.7 k\Omega$; $R_E = 1.2 k\Omega$
- $C_1 = C_2 = 10 \mu F$; $C_E = 100 \mu F$; $C_L = 100 pF$; $C_\pi = 10 pF$ and $C_\mu = 5 pF$
- *Find Operating point and small signal parameters,*
- *Find the values of input resistance, input capacitance and voltage gain*



Numerical Exercise: Amplifier using Darlington pair

- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_1 = 98M\Omega$; $R_C = 2.7 k\Omega$; $R_E = 1.2 k\Omega$
- $C_1 = C_2 = 10 \mu F$; $C_E = 100 \mu F$; $C_L = 100 pF$; $C_\pi = 10 pF$ and $C_\mu = 5 pF$
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Conclusion

Conclusion:

- ❑ Motivation of mixing different configurations
- ❑ Decreasing output impedance by cascading CC:
 - CE-CC
 - CC-CC
- ❑ Increasing input impedance by preceding CC stage:
 - CC-CC
 - CC-CE
 - Darlington pair
- ❑ Decreasing output impedance by cascading CD :
 - CS-CD
- ❑ Usefulness of CC and CD through numerical example
- ❑ Examples on
 - CE-CC
 - CS-CD
 - CC-CE and amp. Darlington pair





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*Thank
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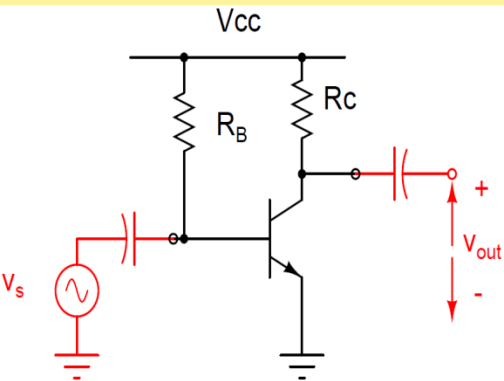
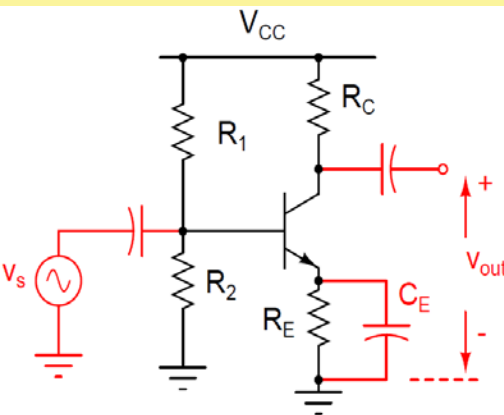
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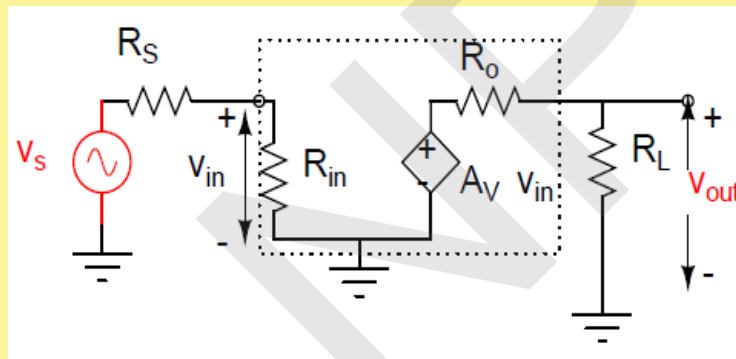
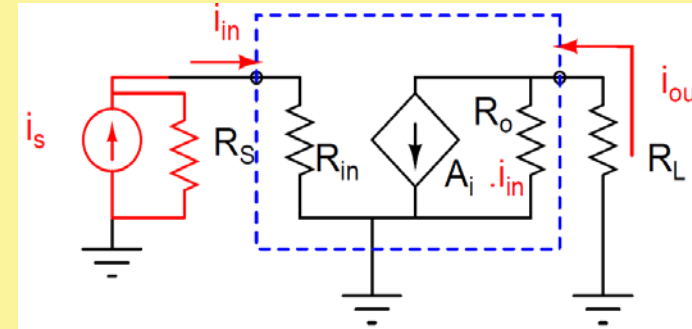
- ❑ Continuing multi-configuration amplifiers:
 - CE-CB
 - Cascode amplifier using BJTs
 - CS-CG
 - Cascode amplifier using MOSFETs



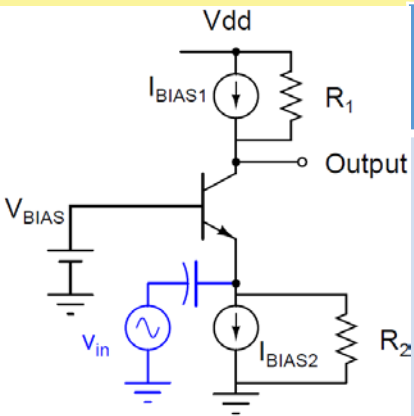
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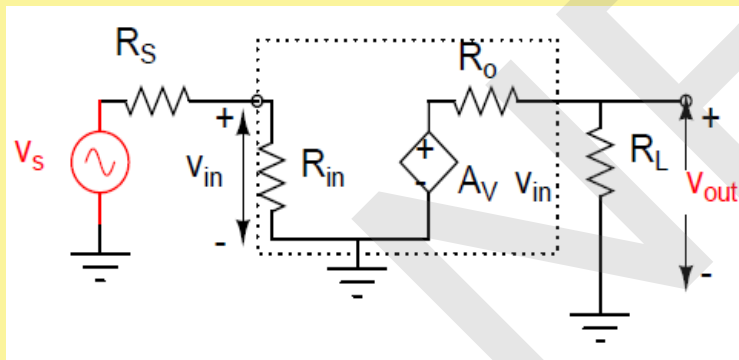
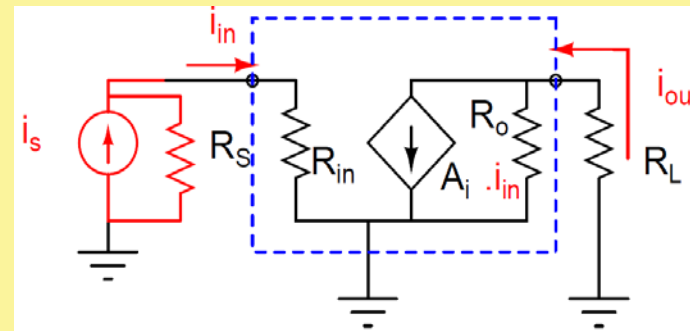
Config.	A_v	R_{in}	R_o	C_{in}	A_i
CE	$-g_m(R_C r_o)$	$(R_B r_{\pi})$	$(R_C r_o)$	$(c_{\pi} + c_{\mu} \cdot g_m(R_C r_o))$	β
	High	High	High	High	High



Performance metrics of CE /CC/CB configurations

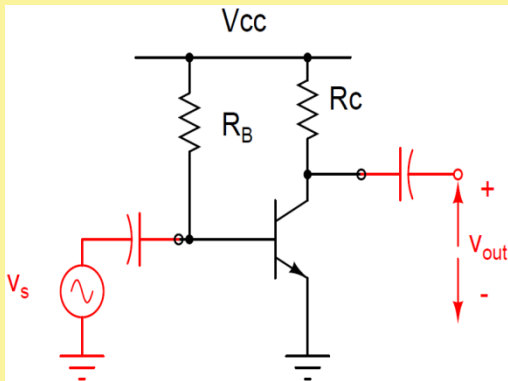
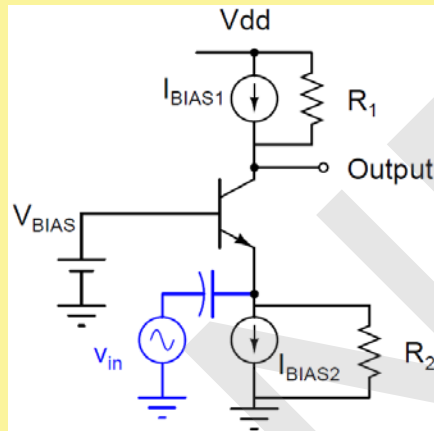
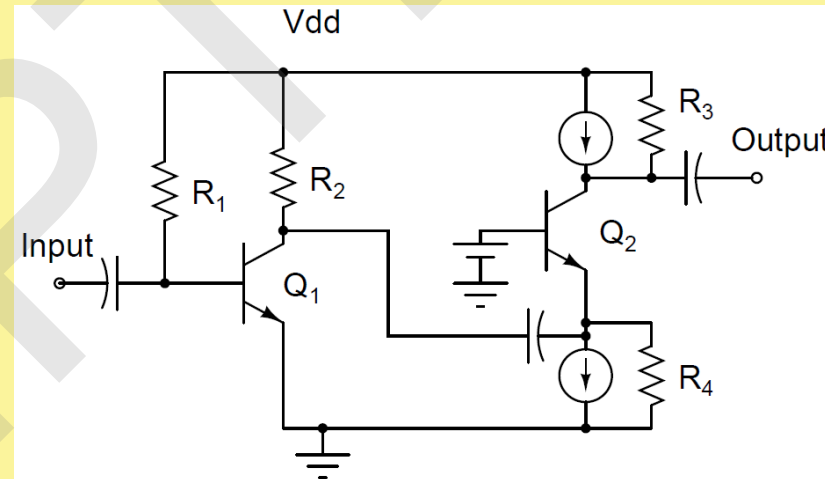


Config.	A_v	R_{in}	R_o	C_{in}	A_i
CB	$g_m(R_1 r_o)$	$r_\pi \frac{(R_1 + r_o)}{(g_m r_o + 1)}$	$R_1 (r_o + g_m r_o (R_s r_\pi R_2))$	C_π	α
	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low

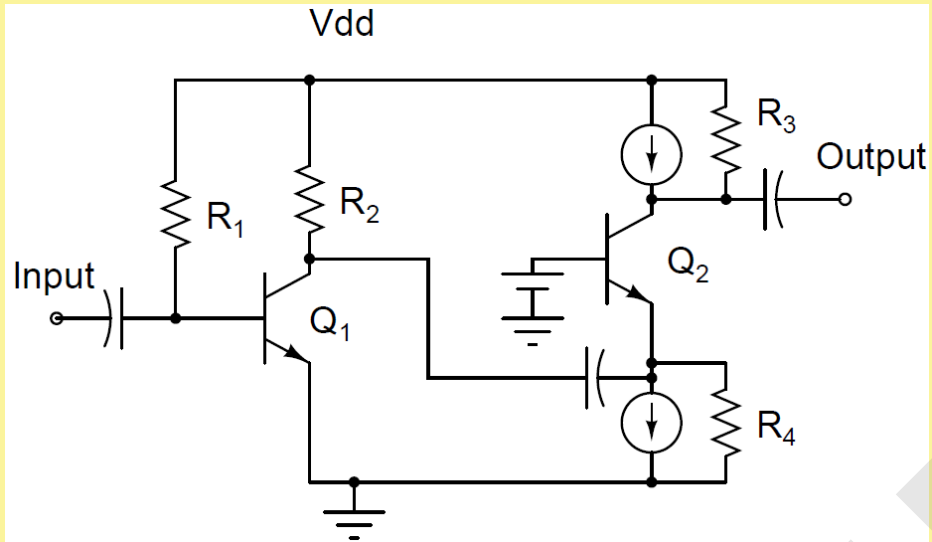
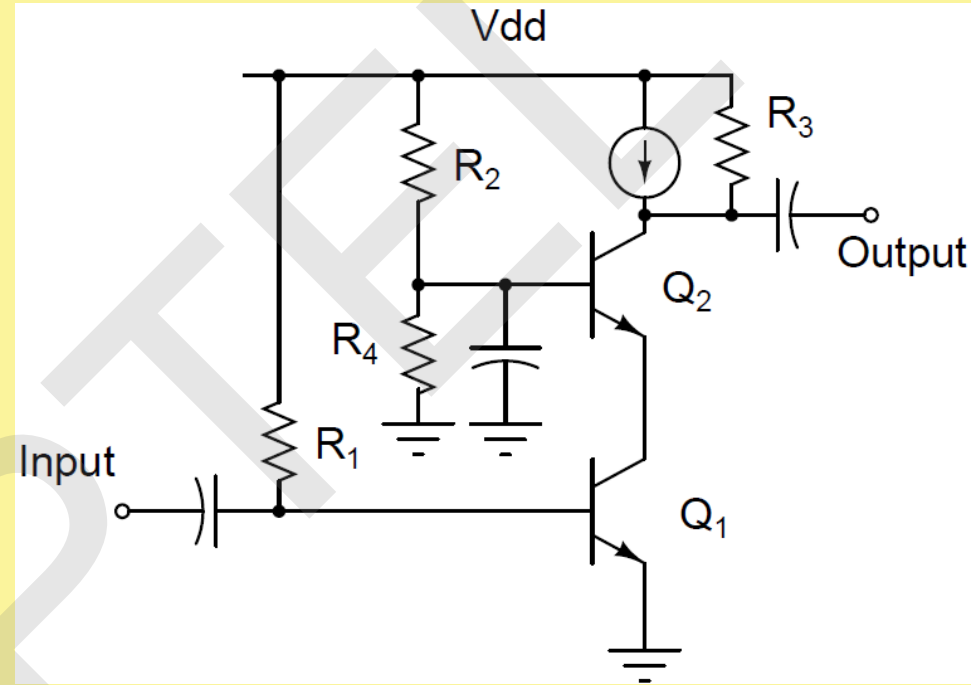


Multi-configuration amplifiers: CE-CB

Config.	A_v	R_{in}	R_o	C_{in}	A_I	Remarks
CE	High	High	High	High	High	Good Voltage amp & Current amp but needs suitable buffers (for cascading)
CC	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer and Power amplifier
CB	"High" with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster

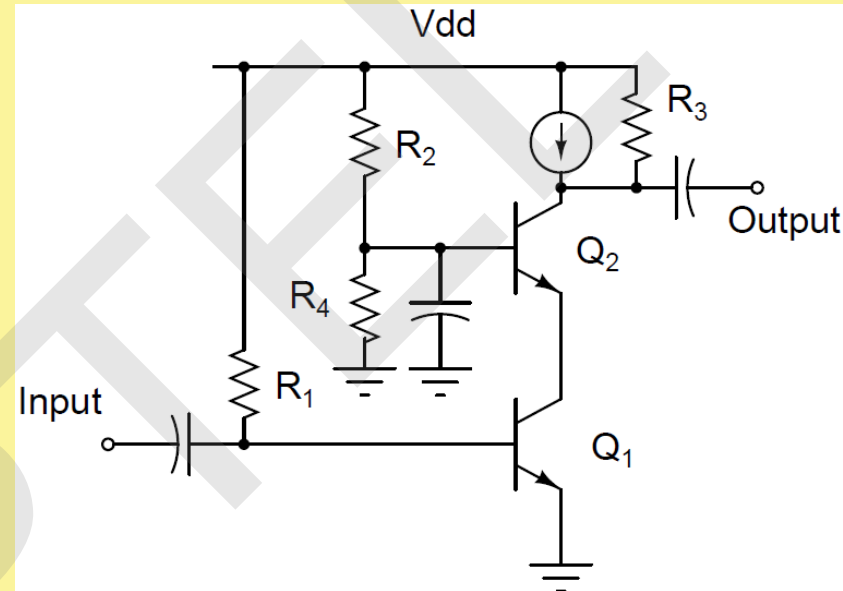


Multi-configuration amplifiers: CE-CB and Cascode amplifier



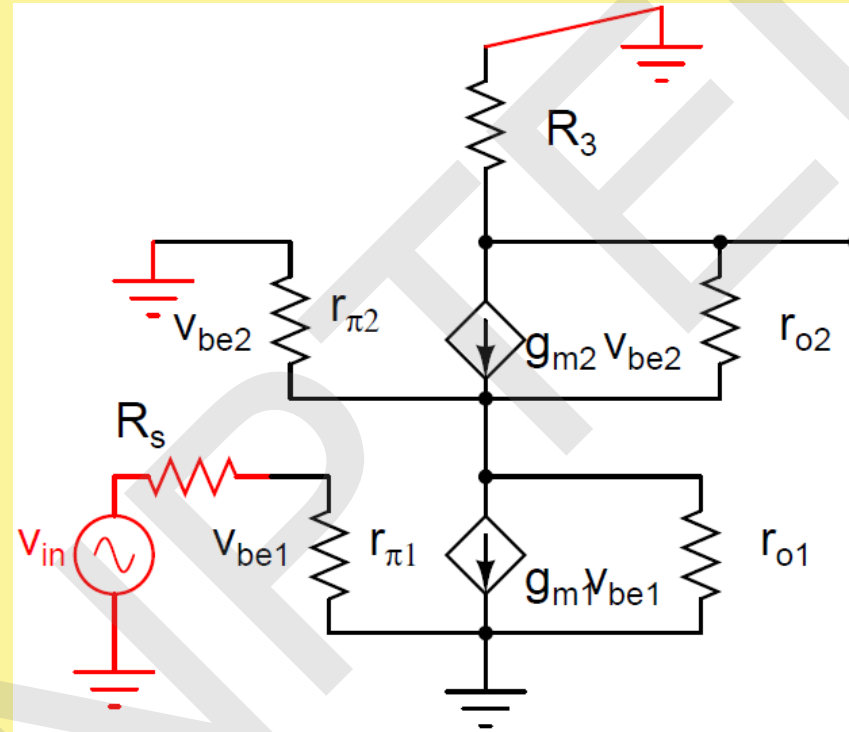
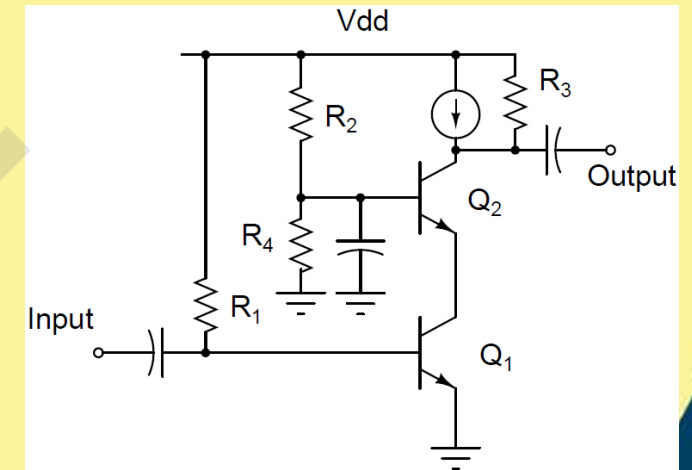
Analysis of Cascode amplifier and comparison with CE amp.

- Biasing and operating point of BJTs
- Small signal analysis
 - Voltage gain
 - Output impedance
 - Input impedance and
 - Input capacitance



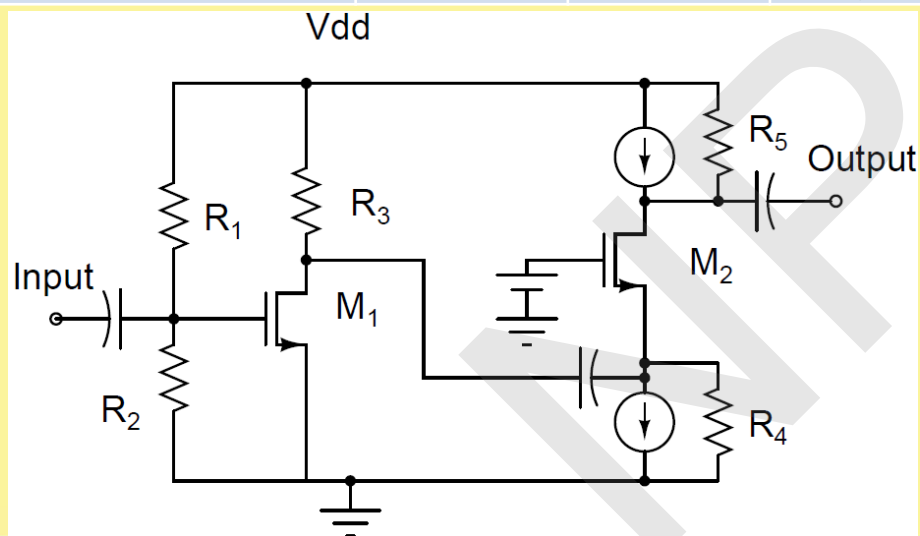
Analysis of Cascode amplifier and comparison with CE amp.

- Biasing and operating point of BJTs
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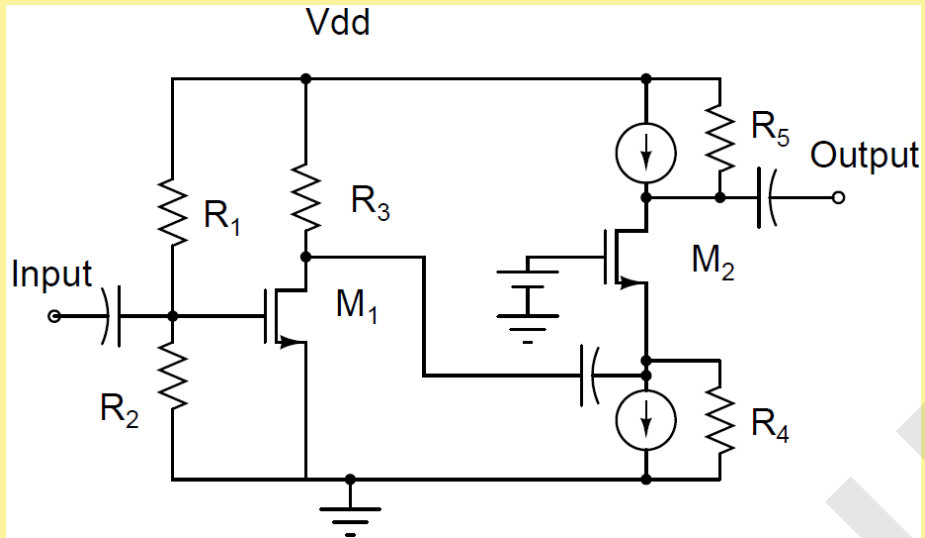
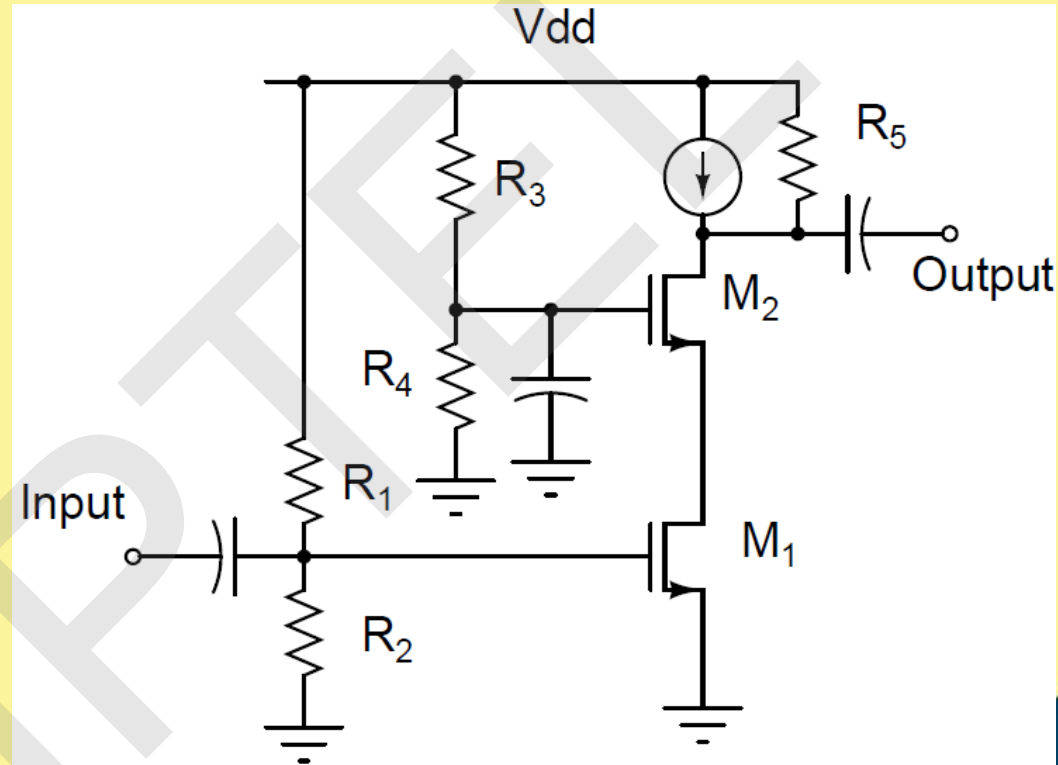


CS-CG configuration

Config.	A_v	R_{in}	R_o	C_{in}	A_I	Remarks
CS	High	V. High	High	High	High	Good Voltage amp but needs suitable buffer (for cascading)
CD	V. Low	V. High	V. Low	V. Low	High	Voltage mode buffer
CG	“High” with $R_s \approx 0$	V. Low	V. High	V. Low	V. Low	Current mode buffer and voltage gain booster

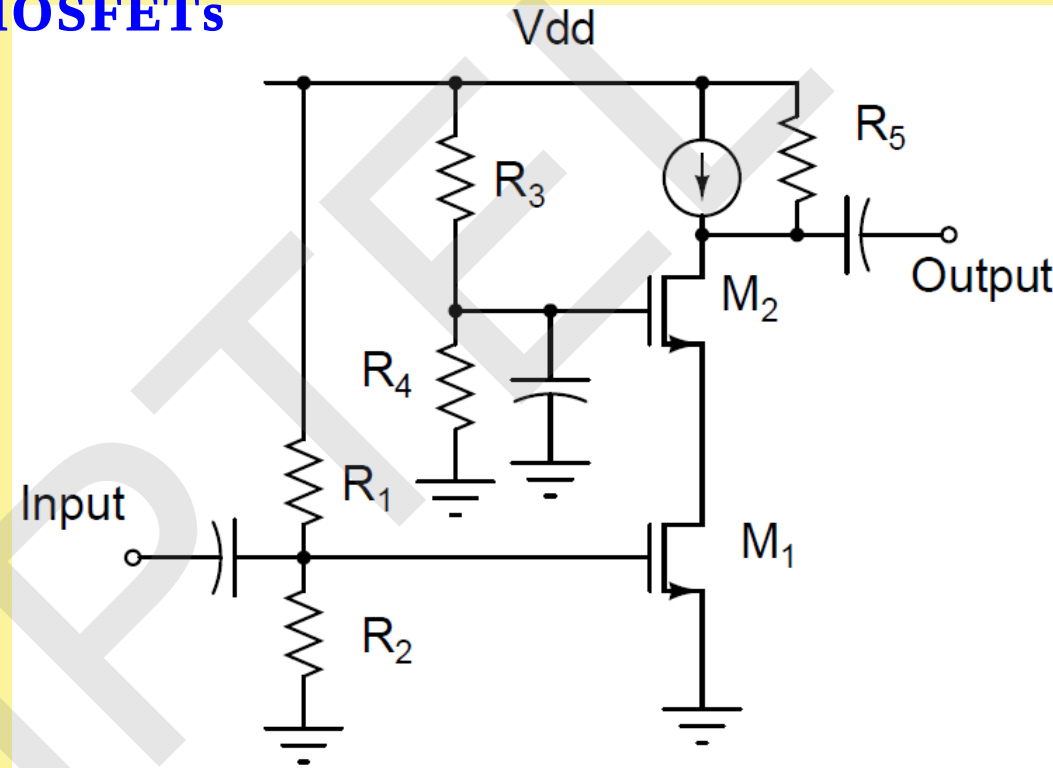


Multi-configuration amplifiers: CS-CG and Cascode amplifier



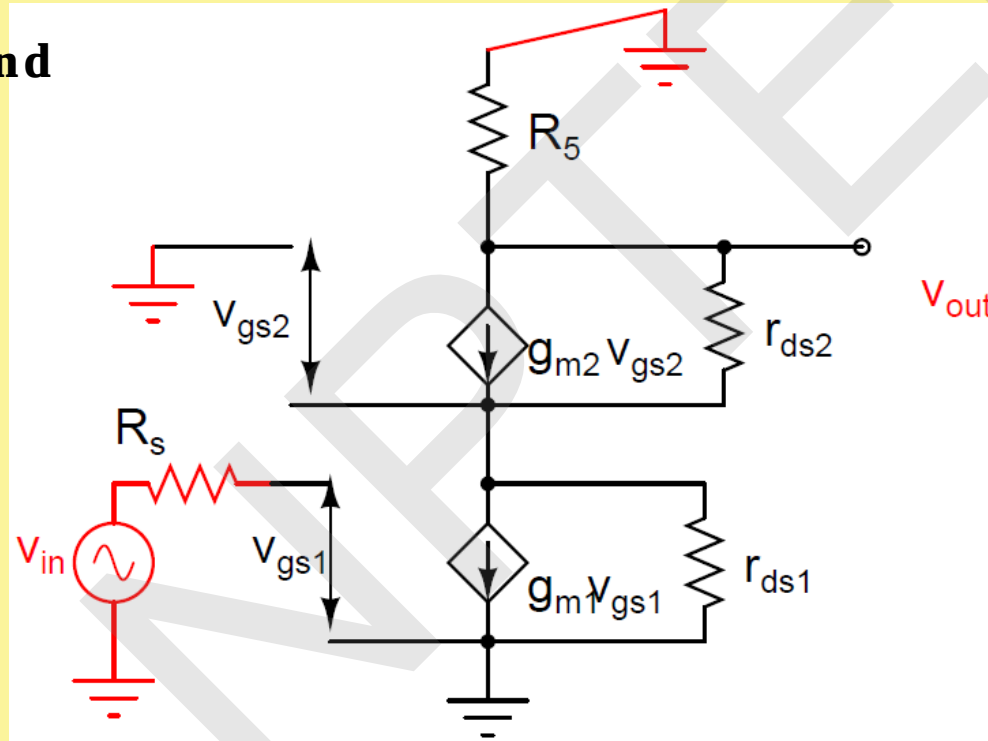
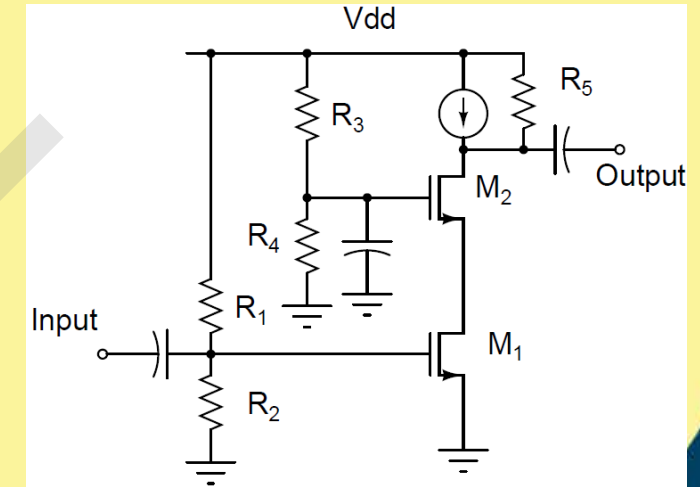
Multi-configuration amplifiers: Cascode amplifier using MOSFET

- Biasing and operating point of MOSFETs
- Small signal analysis
 - Voltage gain
 - Output impedance
 - Input impedance and
 - Input capacitance



Multi-configuration amplifiers: Cascode amplifier using MOSFET

- Biasing and operating point of MOSFETs
- Small signal analysis
 - Voltage gain
 - Output impedance
 - Input impedance and
 - Input capacitance



Conclusion:

- ❑ **Continuing multi-configuration amplifiers:**
 - CE-CB
 - Cascode amplifier using BJTs and its analysis
 - CS-CG
 - Cascode amplifier using MOSFETs and its analysis
- ❑ **Yet to cover Numerical examples**

Conclusion





NPTEL ONLINE CERTIFICATION COURSES

*Thank
you*

