



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Multi transistor Amplifiers (contd...)

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:

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



Numerical example: Cascode amplifier

$R_3 = 2.8\text{k}\Omega$ and $I_{\text{BIAS}} = 0\text{ A}$

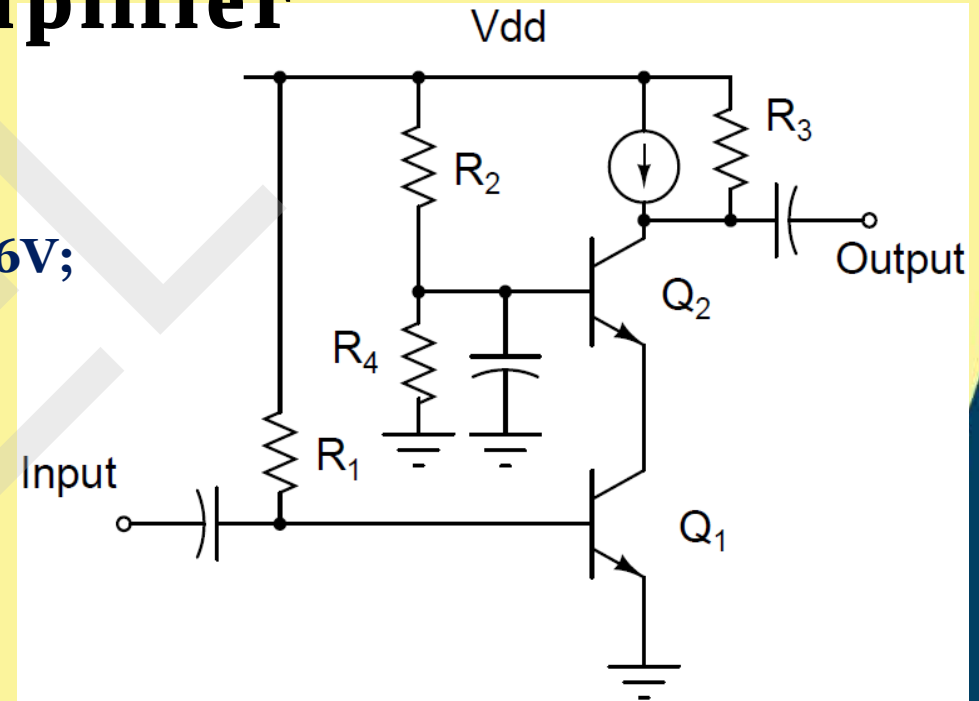
$V_{\text{CC}} = 12\text{V}$; $R_1 = 570\text{k}\Omega$; $R_2 = 90\text{k}\Omega$; $R_4 = 10\text{k}\Omega$;

$V_{\text{A1}} = V_{\text{A2}} = 100\text{V}$; $\beta_1 = 100$; $\beta_2 = 200$; $V_{\text{BE1(on)}} \approx V_{\text{BE2(on)}} \approx 0.6\text{V}$;

$C_1 = C_2 = C_3 = 10\text{ }\mu\text{F}$; $C_{\text{L}} = 100\text{ pF}$; $C_{\pi} = 10\text{ pF}$ and $C_{\mu} = 5\text{ pF}$

Find Operating point, small signal parameters

***Find voltage gain, input capacitance and
the upper cutoff frequency***



Numerical example: Cascode amplifier

$R_3 = 2.8\text{k}\Omega$ and $I_{\text{BIAS}} = 0\text{ A}$; $R_s = 1.3\text{ k}\Omega$

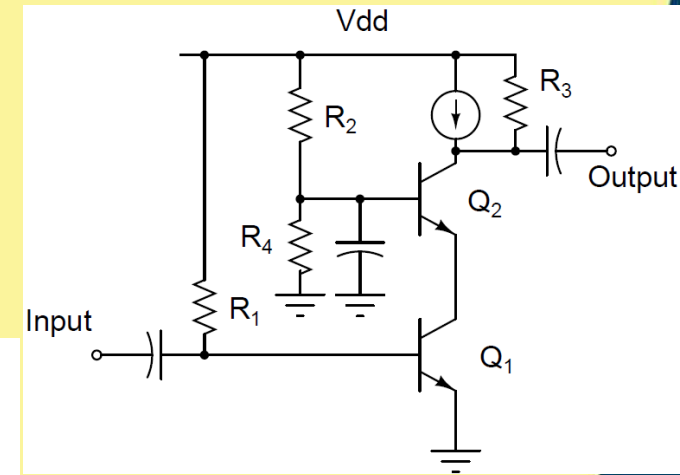
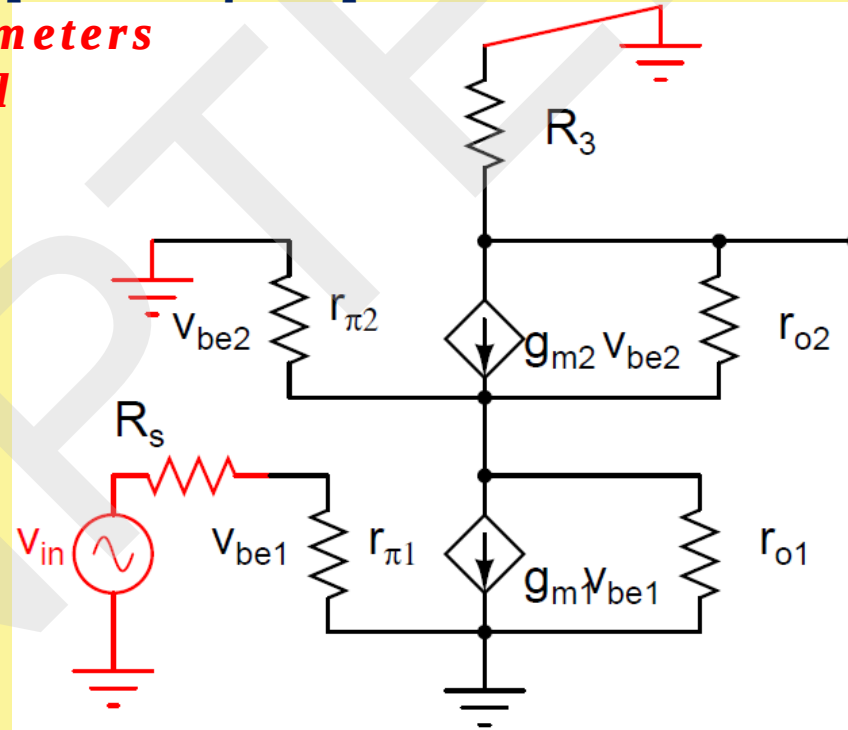
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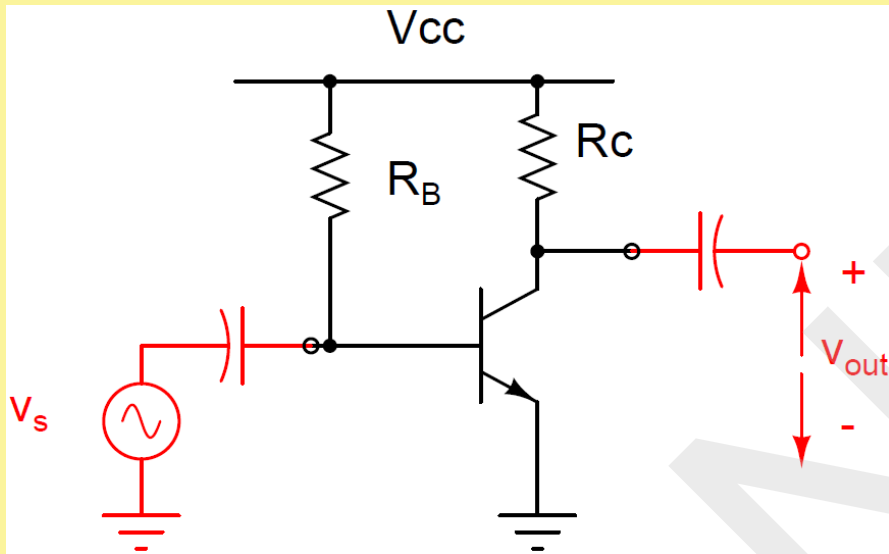
Find Operating point, small signal parameters

Find voltage gain, input capacitance and the upper cutoff frequency



Recall: Numerical Example: CE amplifier

- $V_{CC} = 12V$; $V_A = 100V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 2.8k\Omega$.
- $C_1 = C_2 = 10\ \mu F$; $C_L = 100\ pF$; $C_\pi = 10\ pF$ and $C_\mu = 5\ pF$
- *Find Operating point, small signal parameters*
- *Find voltage gain, input capacitance and the upper cutoff frequency*



Numerical example: Cascode amplifier

$R_3 = 10\text{ M}\Omega$ and $I_{BIAS} = 2\text{ mA}$; $R_s = 1.3\text{ k}\Omega$

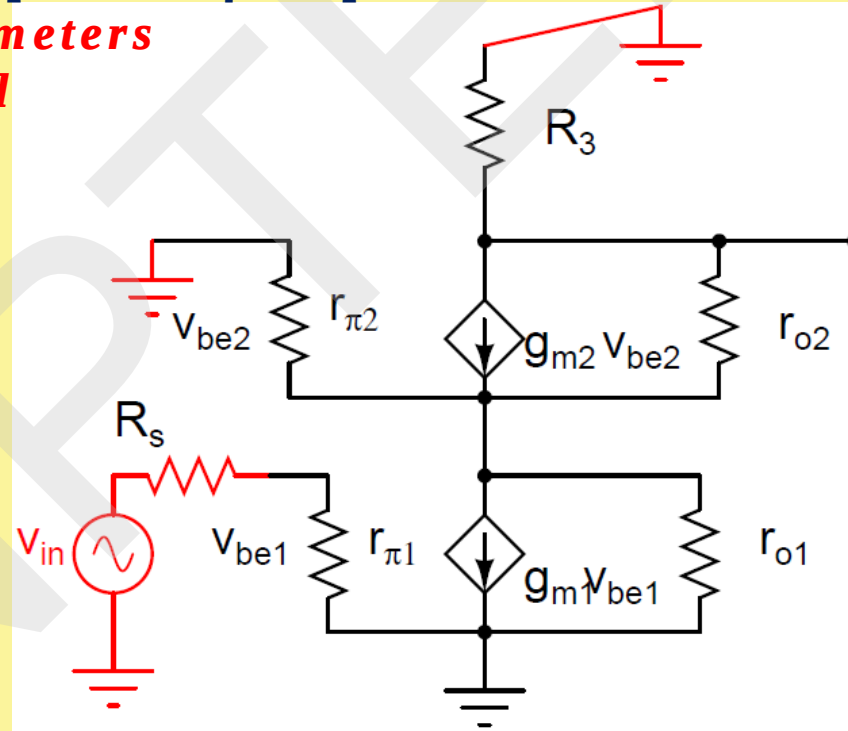
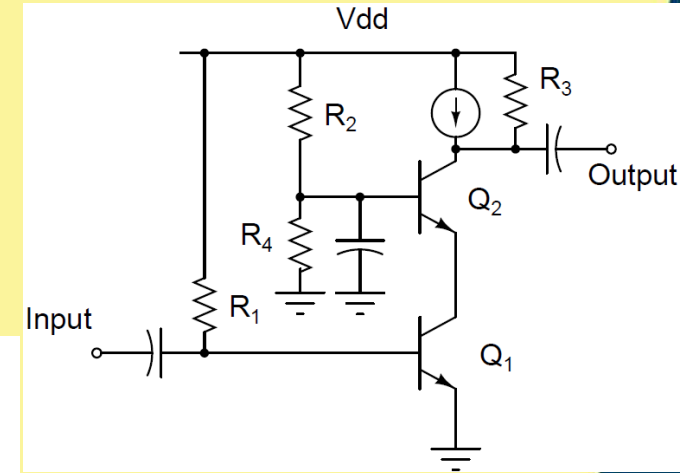
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Find voltage gain, input capacitance and the upper cutoff frequency



Numerical example: Cascode amplifier

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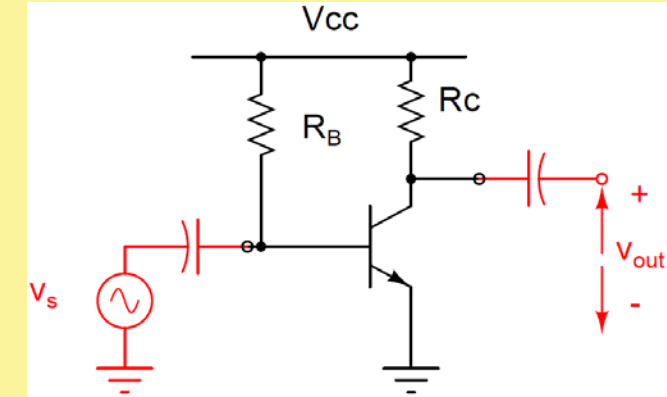
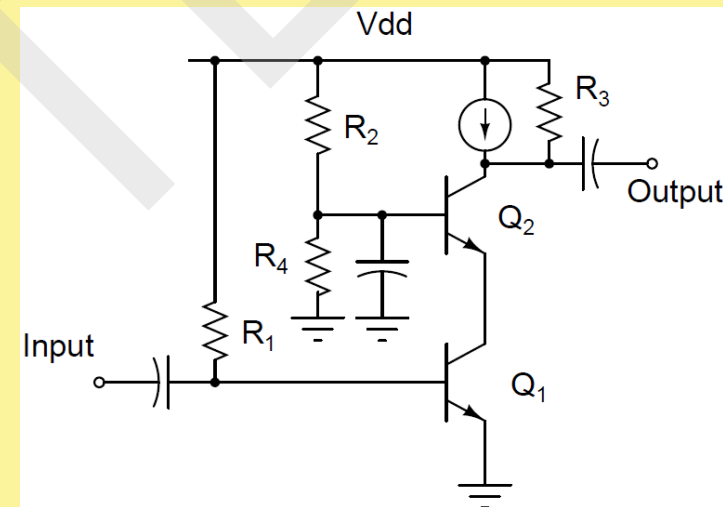
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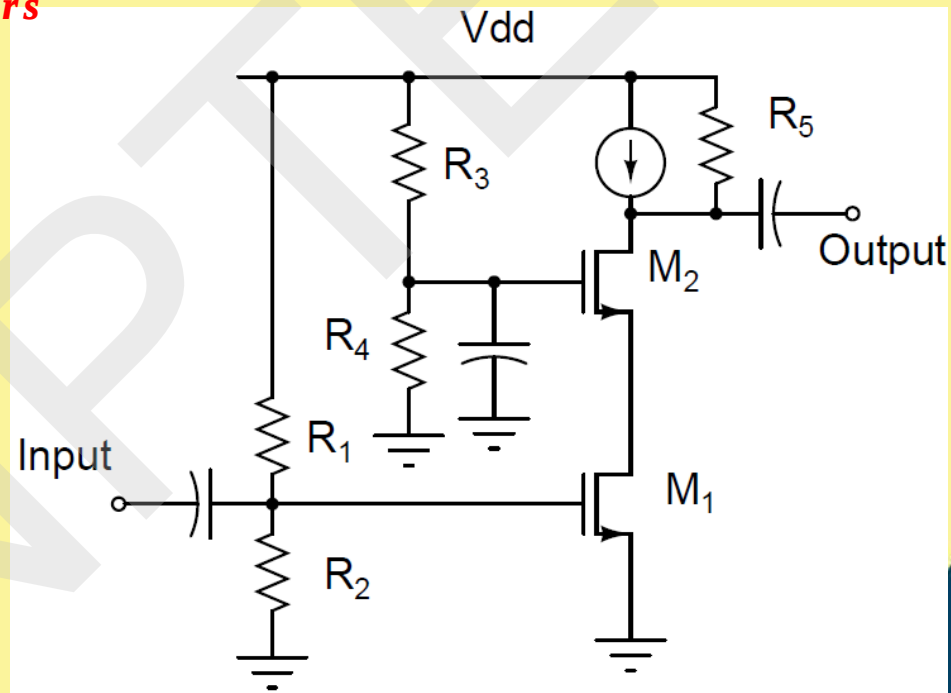
Find Operating point, small signal parameters

*Find voltage gain, input capacitance and
the upper cutoff frequency*



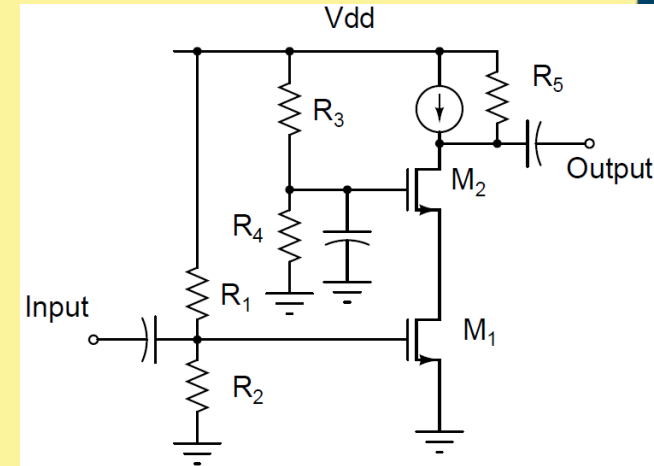
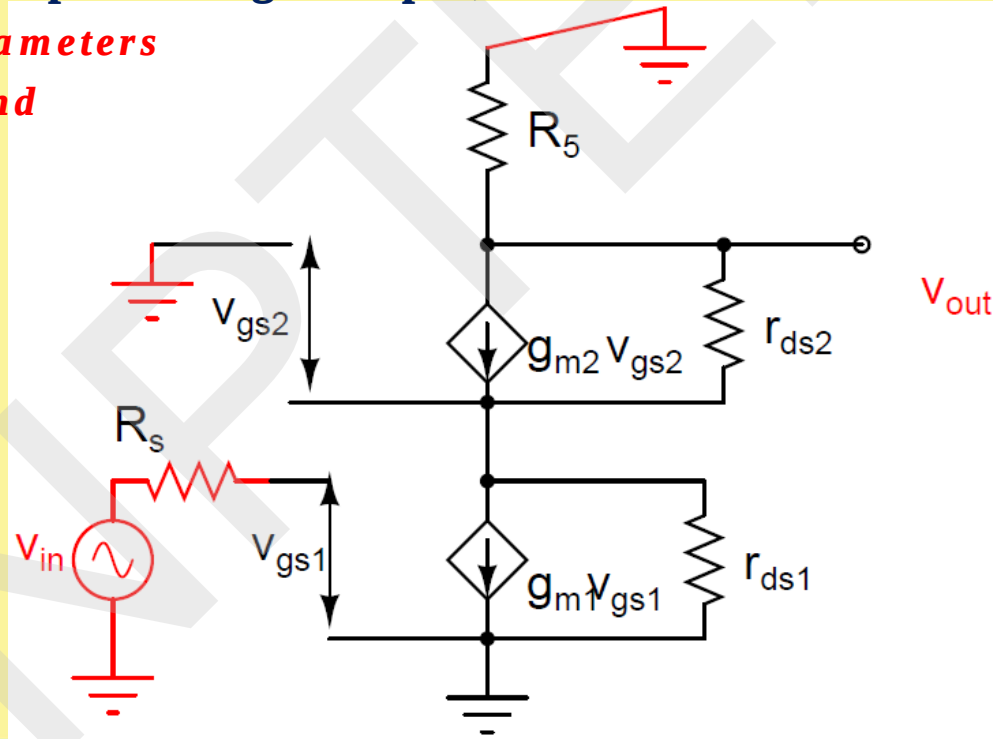
Numerical Exercise: Cascode amplifier

- $R_5 = 2 \text{ k}\Omega$ and $I_{BIAS} = 0 \text{ mA}$; $R_s = 2.25 \text{ k}\Omega$
- **Given: for both transistors,** $(K.W/L) = 1 \text{ mA/V}^2$; $\lambda = 0.01 / \text{V}$; $V_{th} = 1 \text{ V}$;
- $V_{dd} = 12 \text{ V}$, $R_1 = 9 \text{ k}\Omega$, $R_2 = 3 \text{ k}\Omega$, $R_3 = 5 \text{ k}\Omega$, $R_4 = 5 \text{ k}\Omega$;
- $C_1 = C_2 = 10 \text{ }\mu\text{F}$; $C_L = 100 \text{ pF}$; $C_{gs} = 10 \text{ pF}$ and $C_{gd} = 5 \text{ pF}$;
- **Find Operating point, small signal parameters**
- **Find voltage gain, input capacitance and**
- **the upper cutoff frequency**



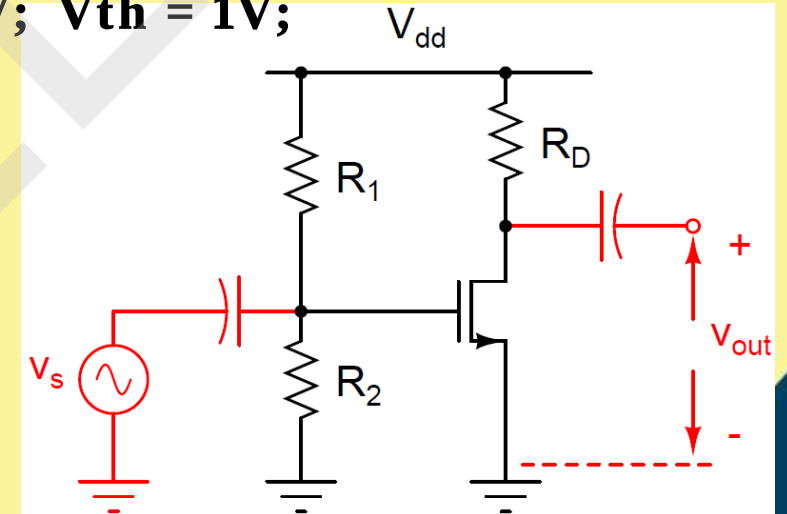
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- $C_1 = C_2 = 10 \text{ }\mu\text{F}$; $C_L = 100 \text{ pF}$; $C_{gs} = 10 \text{ pF}$ and $C_{gd} = 5 \text{ pF}$;
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- **Find voltage gain, input capacitance and**
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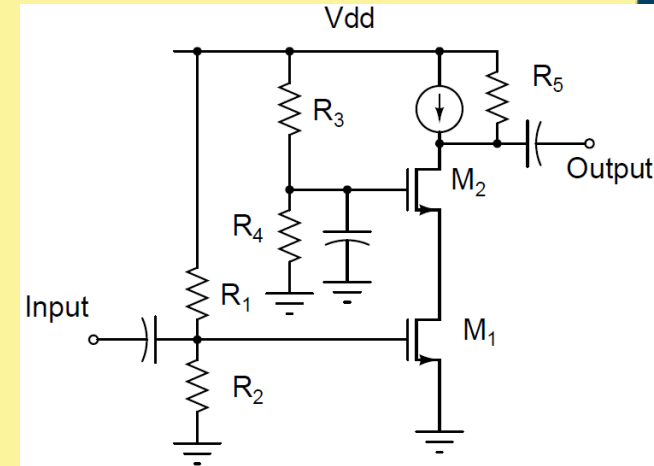
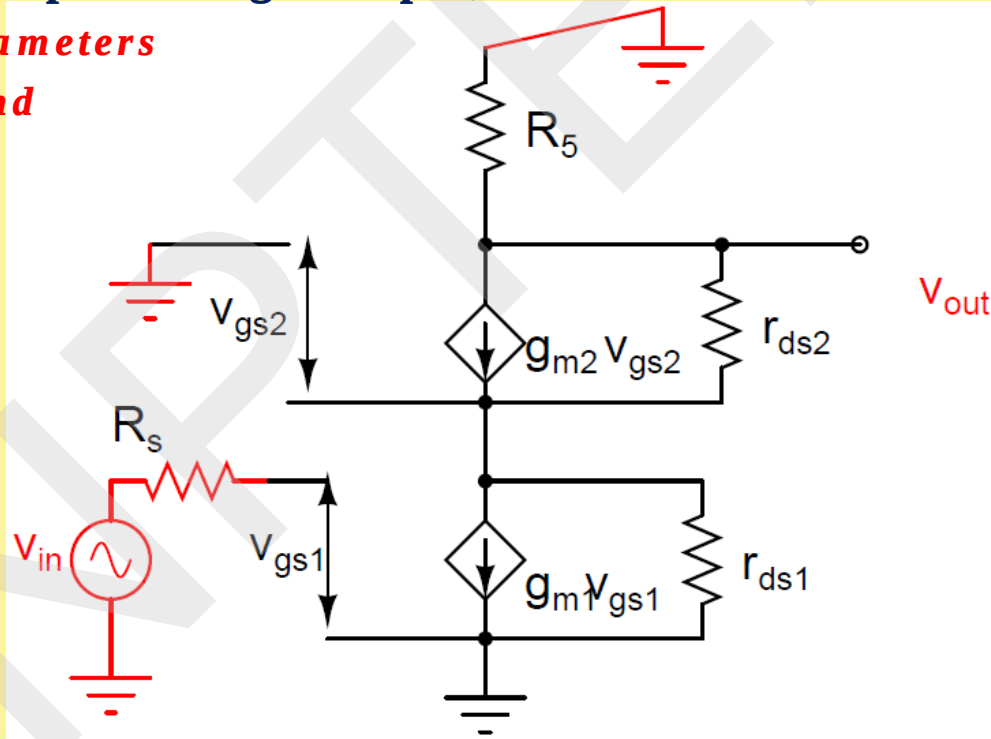
Numerical Exercise: Cascode amplifier

- $R_D = 2 \text{ k}\Omega$ and $R_S = 2.25 \text{ k}\Omega$
- **Given: for the transistor,** $(K.W/L) = 1 \text{ mA/V}^2$; $\lambda = 0.01 / \text{V}$; $V_{th} = 1 \text{ V}$;
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- $C_1 = C_2 = 10 \text{ }\mu\text{F}$; $C_L = 100 \text{ pF}$; $C_{gs} = 10 \text{ pF}$ and $C_{gd} = 5 \text{ pF}$;
- **Find Operating point, small signal parameters**
- **Find voltage gain, input capacitance and**
- **the upper cutoff frequency**



Numerical Exercise: Cascode amplifier

- $R_5 = 5\text{ k}\Omega$ and $I_{BIAS} = 2\text{ mA}$; $R_s = 2.25\text{ k}\Omega$
- **Given: for both transistors,** $(K.W/L) = 1\text{ mA/V}^2$; $\lambda = 0.01/\text{V}$; $V_{th} = 1\text{ V}$;
- $V_{dd} = 12\text{ V}$, $R_1 = 9\text{ k}\Omega$, $R_2 = 3\text{ k}\Omega$, $R_3 = 5\text{ k}\Omega$, $R_4 = 5\text{ k}\Omega$;
- $C_1 = C_2 = 10\text{ }\mu\text{F}$; $C_L = 100\text{ pF}$; $C_{gs} = 10\text{ pF}$ and $C_{gd} = 5\text{ pF}$;
- Find Operating point, small signal parameters
- Find voltage gain, input capacitance and
- the upper cutoff frequency



Conclusion

Conclusion:

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





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*Thank
you*





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Course Name: *Analog Electronic Circuits*

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Topic:

Amplifiers with active load

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

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- **Cascode amplifiers**

- CS-CB and CS-CG

- **Amplifier with active load.**



CONCEPTS COVERED

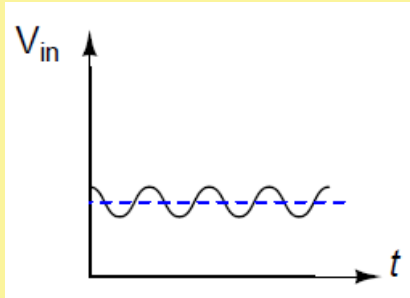
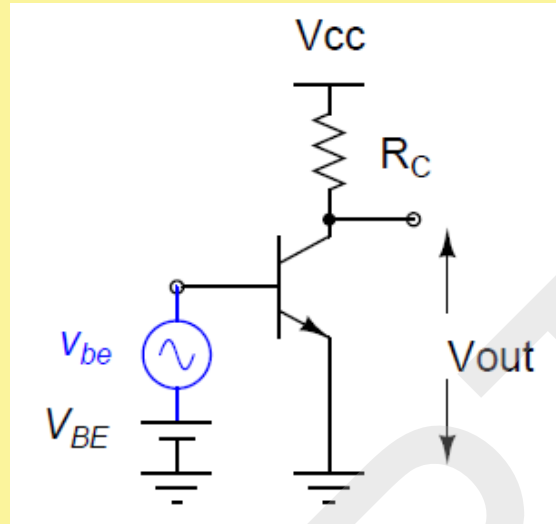
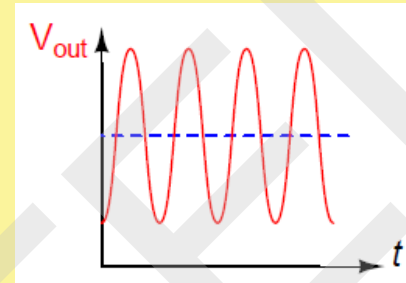
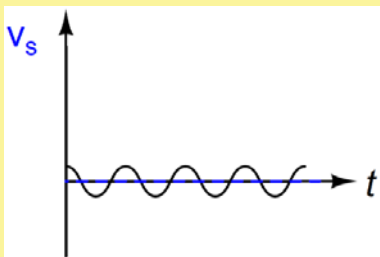
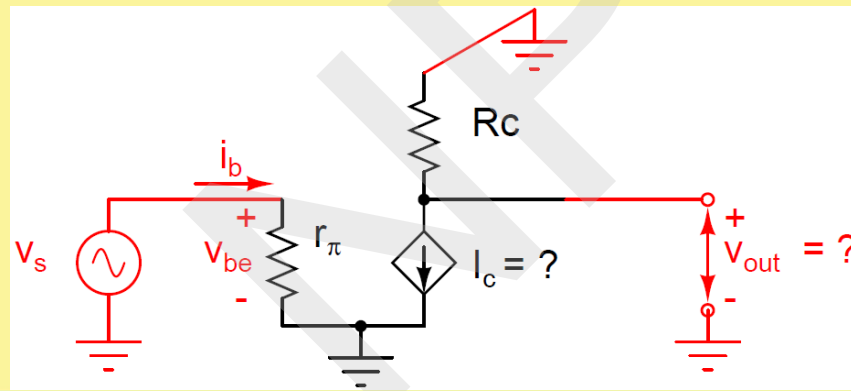
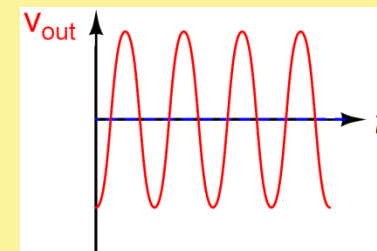
Concepts Covered:

- ❑ Motivation of using active load
- ❑ Basic operation and analysis of
 - CS amplifier with active load
 - CE amplifier with active load
- ❑ Practical amplifier circuits with active load:
 - CS
 - CE



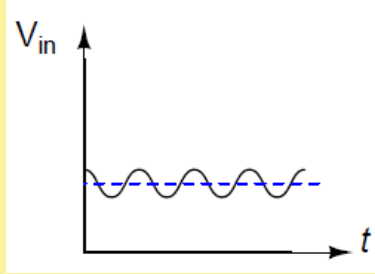
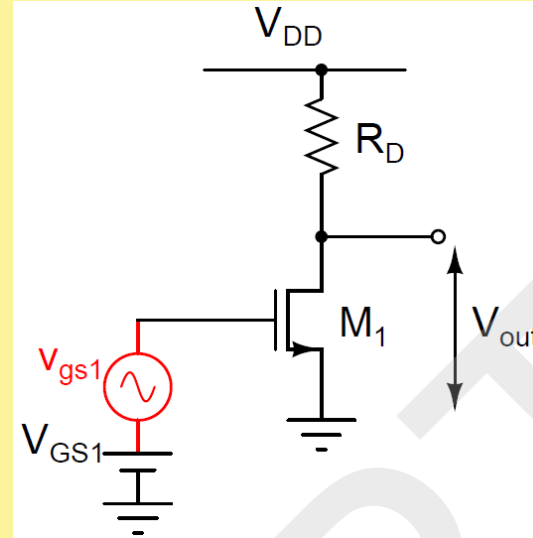
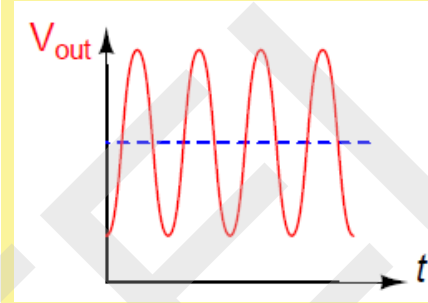
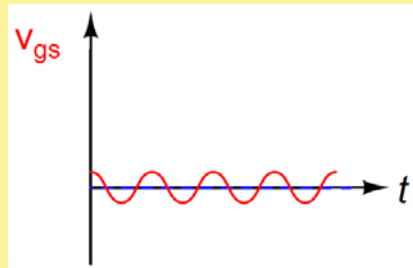
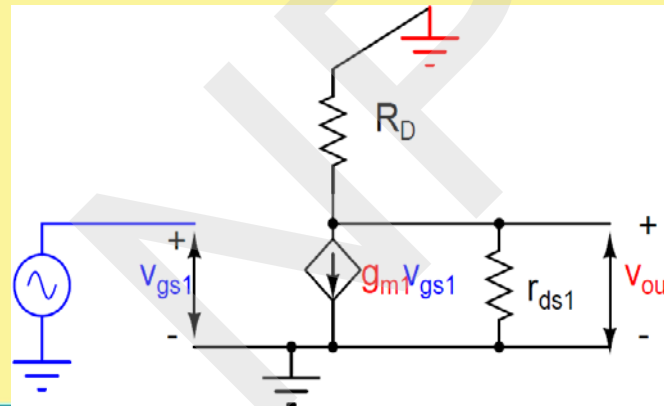
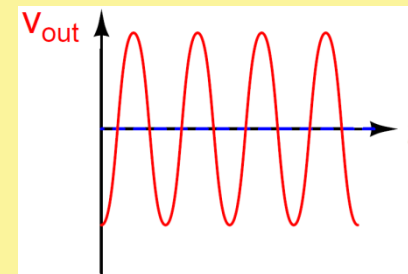
Recall: Basic operation of CE amplifier with passive load

Limitation on voltage gain

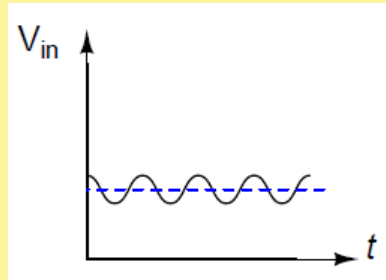
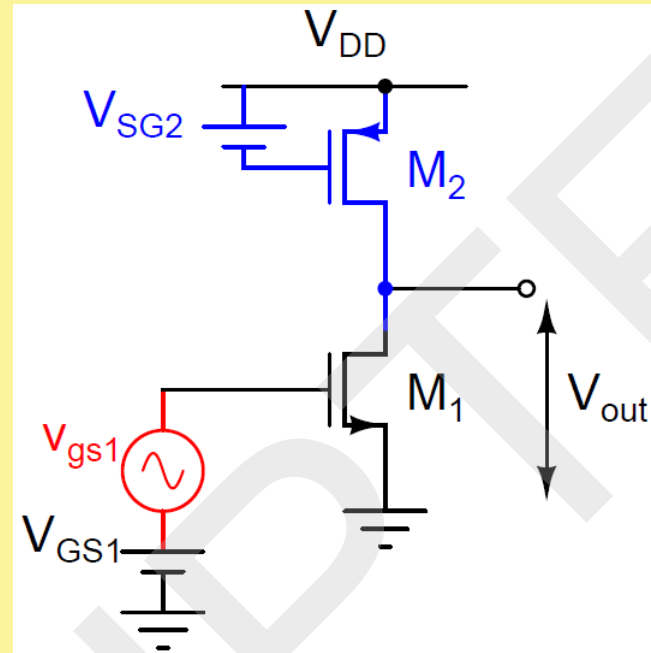
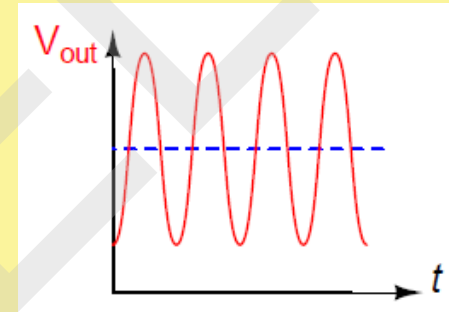


Recall: Basic operation of CS amplifier with passive load

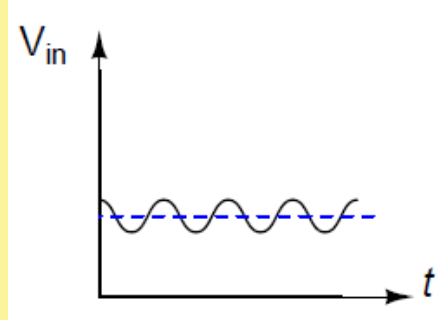
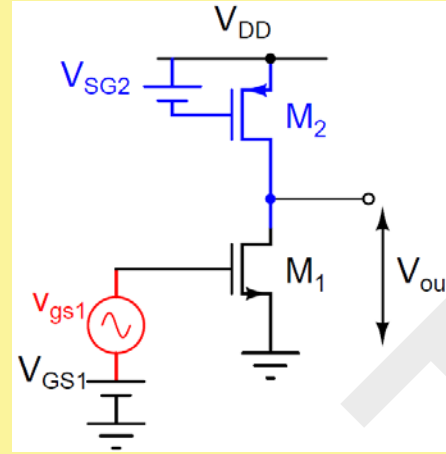
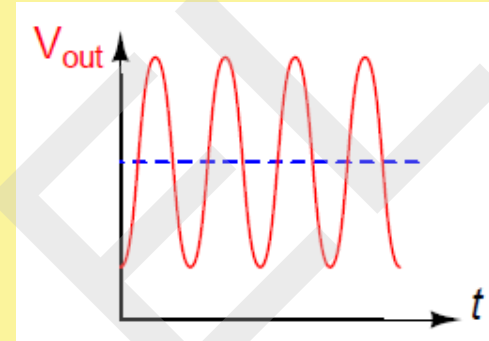
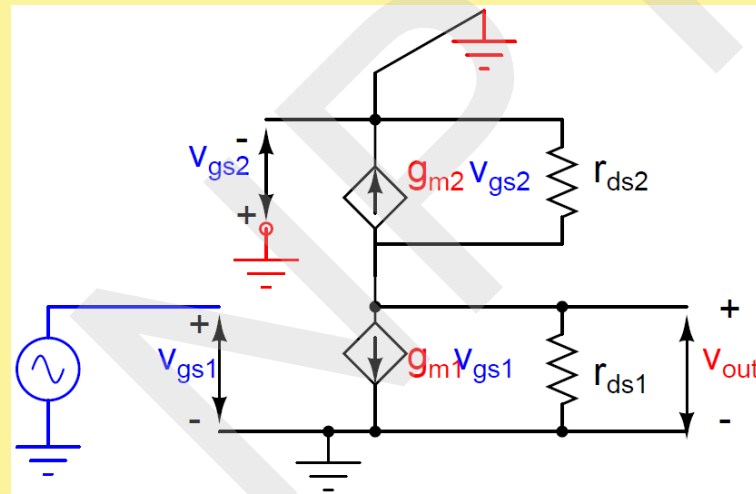
Limitation on voltage gain



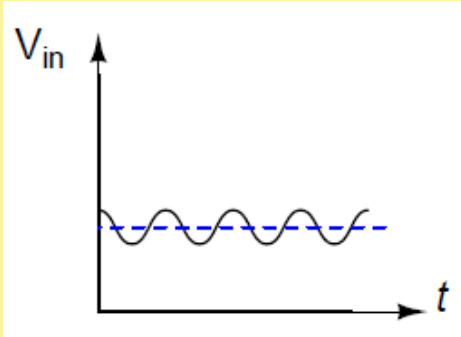
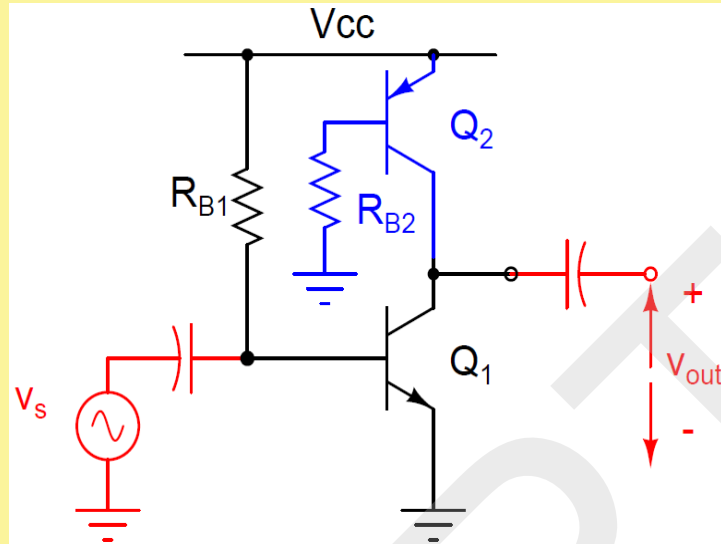
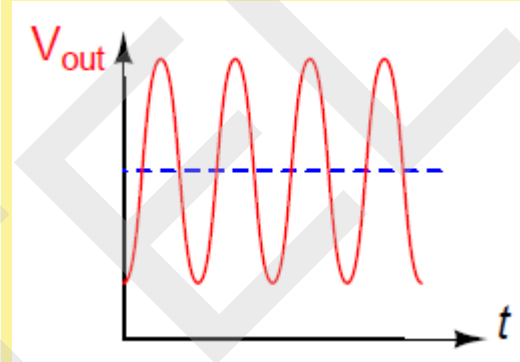
Basic operation of CS amplifier with **active load** *voltage gain enhancement*



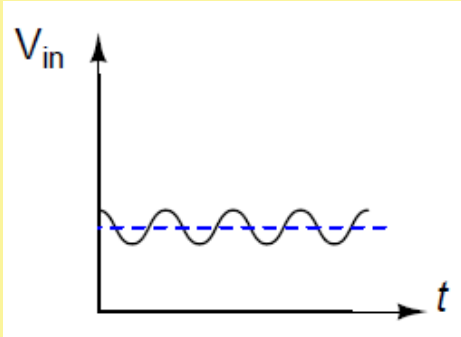
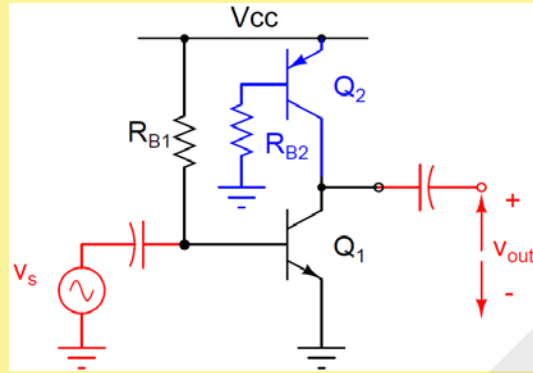
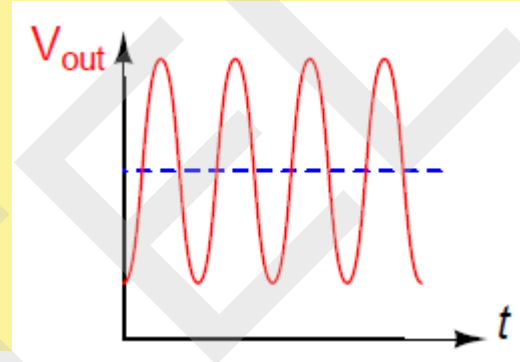
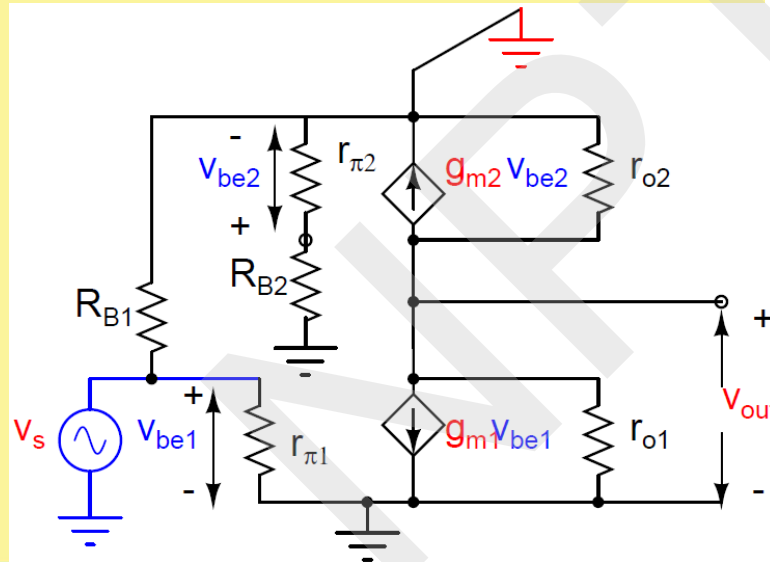
Small signal analysis of CS amplifier with **active load** *voltage gain enhancement*



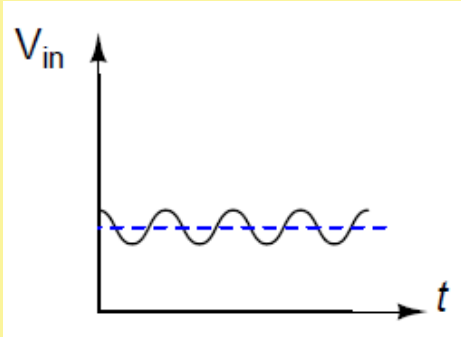
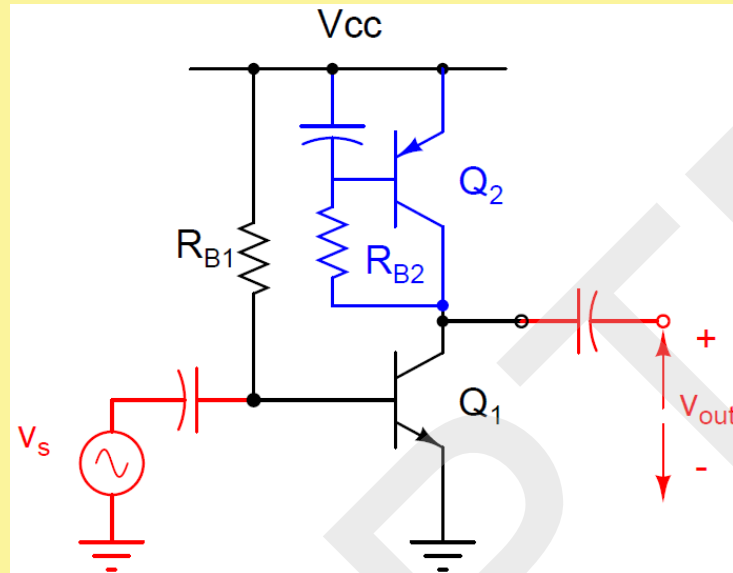
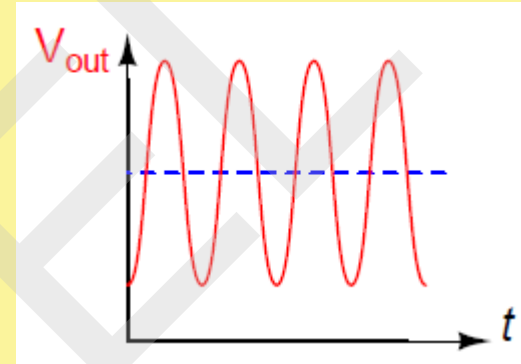
Basic operation of CE amplifier with **active** load *voltage gain enhancement*



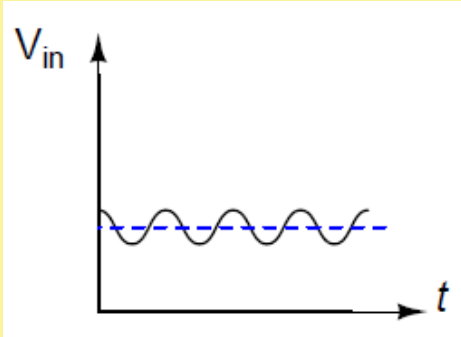
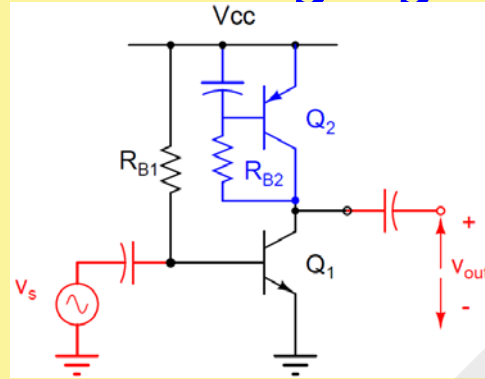
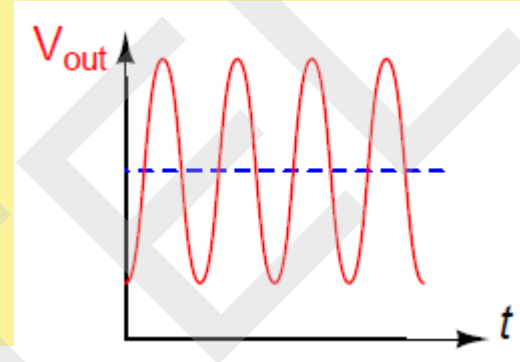
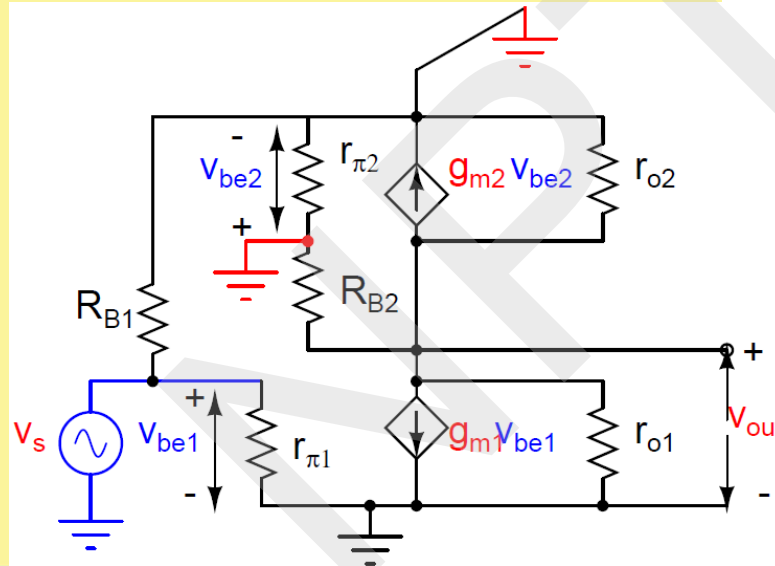
Small signal analysis of CE amplifier with **active** load *voltage gain enhancement*



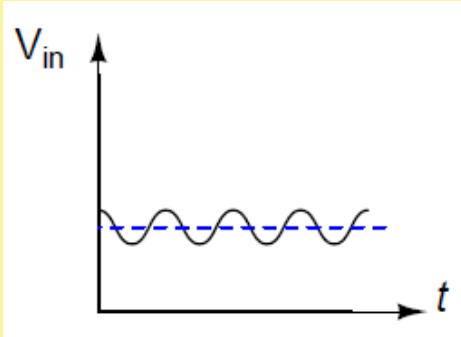
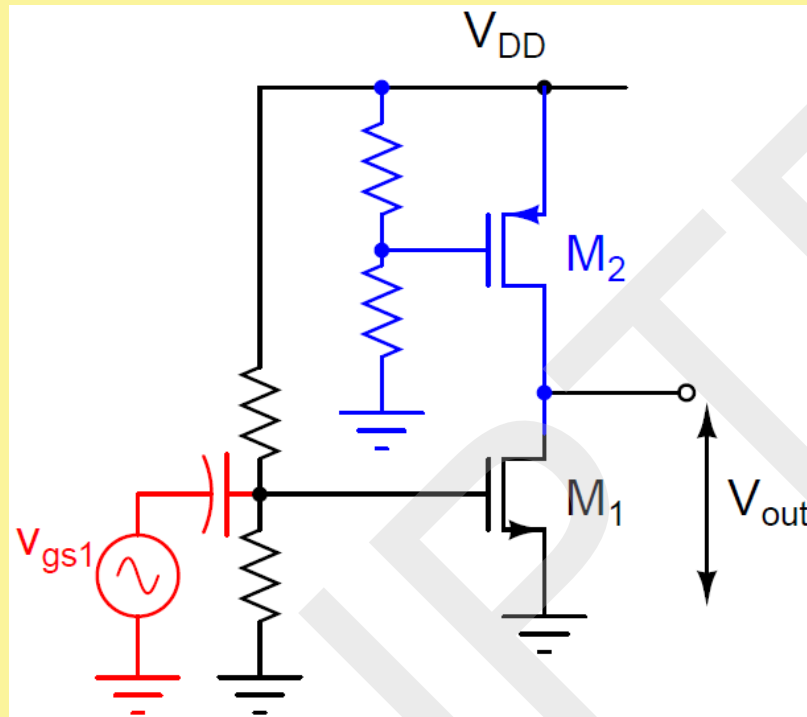
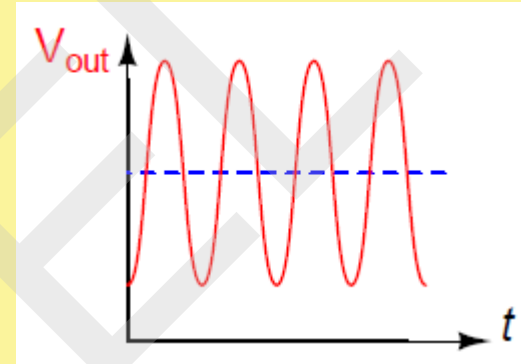
Practical circuit of CE amplifier with **active** load *voltage gain enhancement*



Analysis of Practical CE amplifier with **active** load *voltage gain enhancement*



Practical circuit of CS amplifier with **active** load *voltage gain enhancement*



Conclusion:

- ☐ Motivation of using active load
- ☐ Basic operation and analysis of
 - CS amplifier with active load
 - CE amplifier with active load
- ☐ Practical amplifier circuits with active load:
 - CS
 - CE
- ☐ Yet to cover Numerical examples
- ☐ Yet to cover Design guidelines

Conclusion





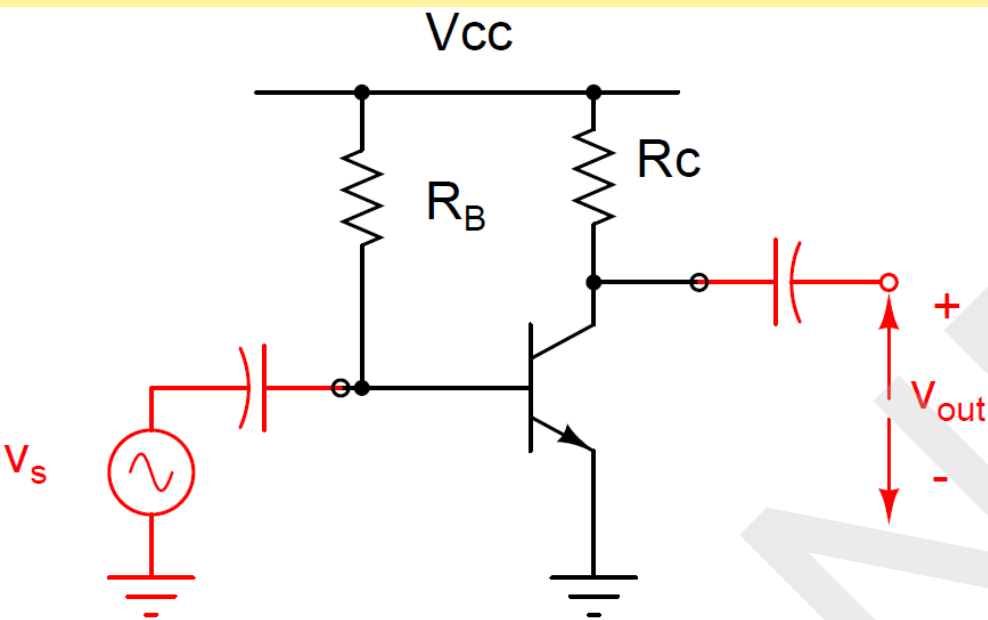
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*Thank
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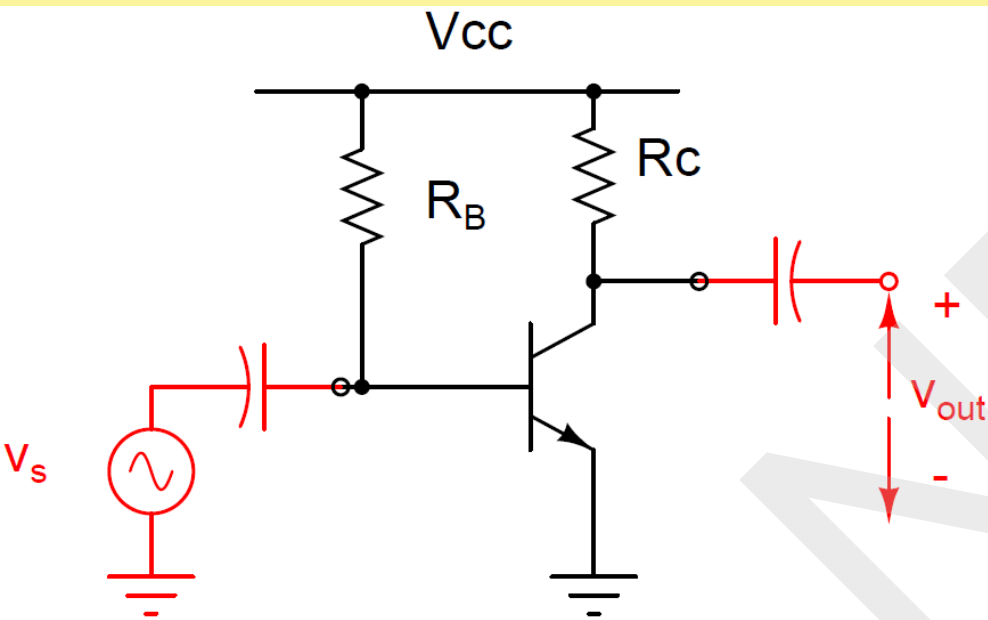
Numerical Example: CE amplifier –Fixed-bias

- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 3.3k\Omega$;
- Find small signal parameters of transistor and, voltage gain, R_{in} and R_o



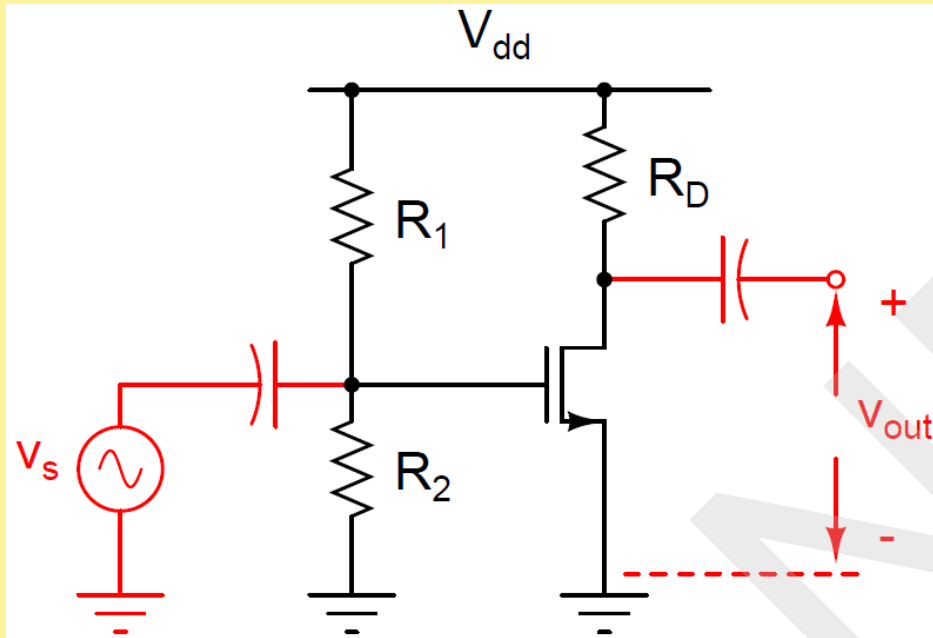
Numerical Example: CE amplifier –Fixed-bias (contd.)

- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 3.3k\Omega$;
 - Find Output swing (distortion free output signal) and Power dissipation
 - Comment about Cutoff frequencies



Numerical Example of CS amplifier

- **Given:** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$, $R_1 = 9\text{k}\Omega$, $R_2 = 3\text{k}\Omega$, $R_D = 3\text{k}\Omega$
- **Sequence of calculation:** D.C. voltage at the Gate; I_{DS} ; g_m ; A_v





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Topic:

Amplifiers with active load (contd.)

CONCEPTS COVERED

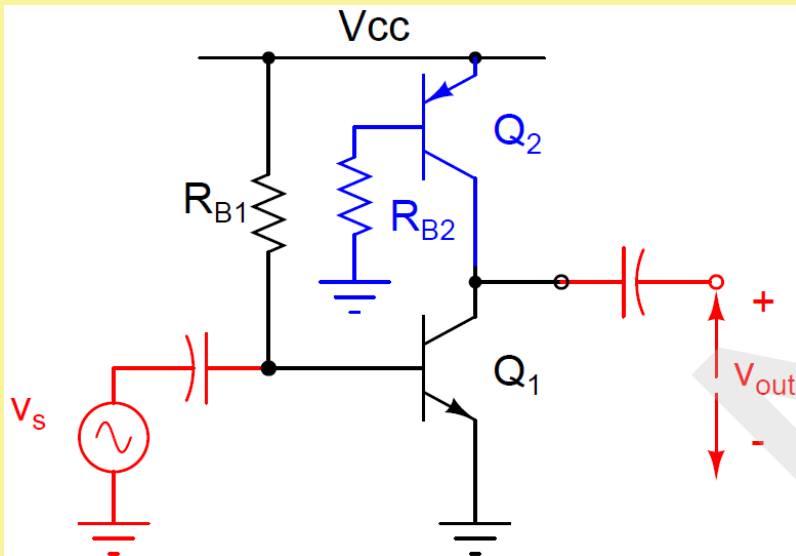
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- ☐ Practical amplifier circuits with active load:
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- ☐ **Numerical examples and Design guidelines**
 - CE amplifier with active load
 - CS amplifier with active load



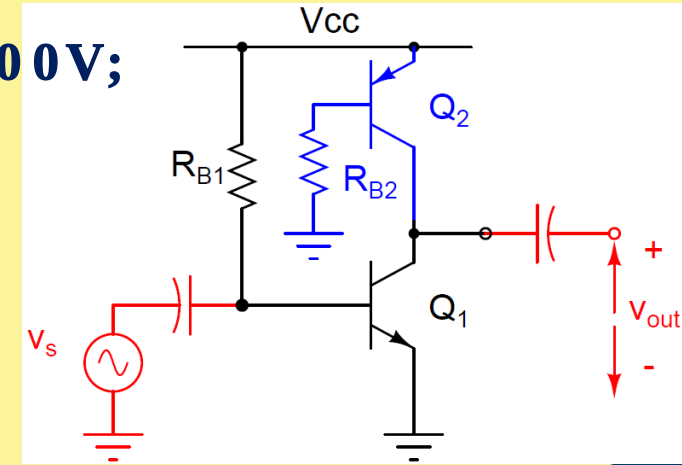
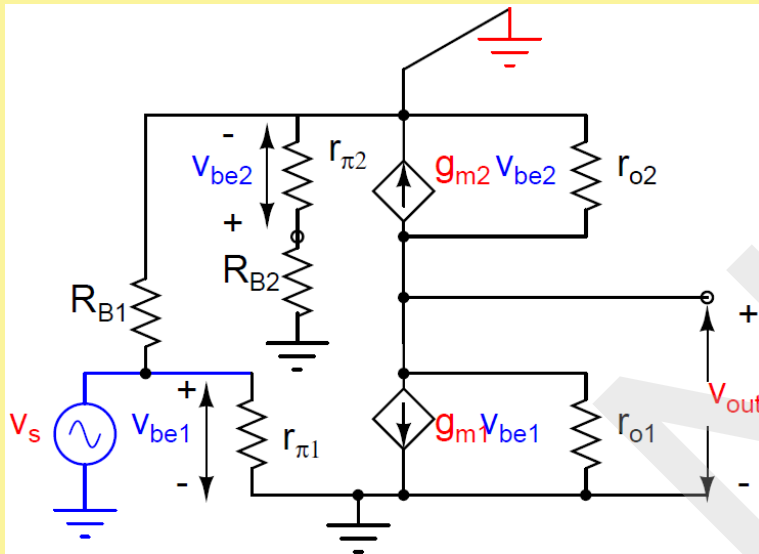
Numerical example: CE amplifier with **active load** (*voltage gain enhancement*)

- $\beta_1 = 100$; $\beta_2 = 200$; $V_{BE(on)1} \approx V_{BE(on)2} \approx 0.6V$; $V_{A1} = 100V$; $V_{A2} = 100V$;
- $C_{\pi 1} = C_{\pi 2} = 10 \text{ pF}$; $C_{\mu 1} = C_{\mu 2} = 5 \text{ pF}$
- $V_{CC} = 12V$; $R_{B1} = 570k\Omega$; $R_{B2} = 1.14M\Omega$; $C_L = 100pF$
 - Find operating points and values of small signal parameters of transistors
 - Find Output swing (distortion free output signal)



Numerical example: CE amplifier with **active load** (contd.)

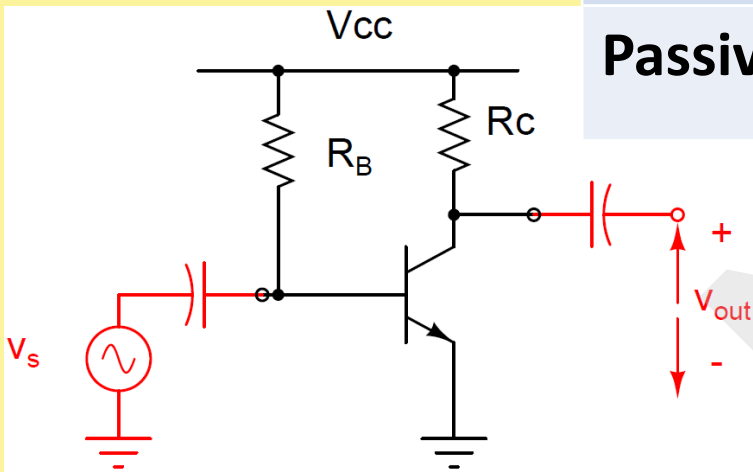
- $\beta_1 = 100$; $\beta_2 = 200$; $V_{BE(on)1} \approx V_{BE(on)2} \approx 0.6V$; $V_{A1} = 100V$; $V_{A2} = 100V$;
- $C_{\pi 1} = C_{\pi 2} = 10 \text{ pF}$; $C_{\mu 1} = C_{\mu 2} = 5 \text{ pF}$
- $V_{CC} = 12V$; $R_{B1} = 570k\Omega$; $R_{B2} = 1.14M\Omega$; $C_L = 100 \text{ pF}$
 - Find voltage gain, R_{in} , R_o and C_{in}
 - Find the Upper Cutoff frequency



Performance comparison with CE amplifier with Passive load

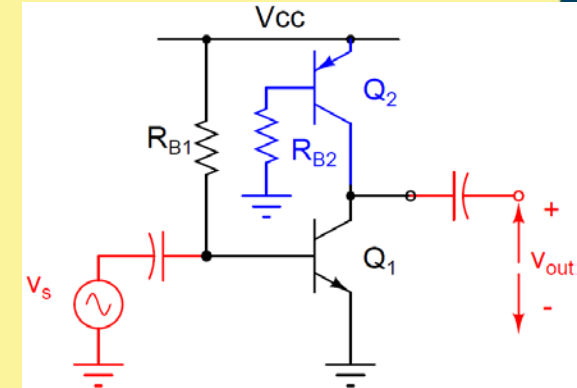
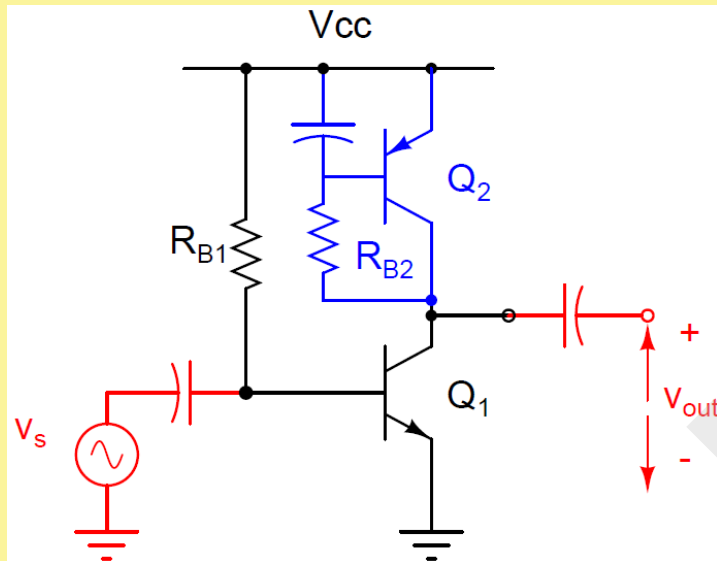
- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 3k\Omega$; $C_\pi = 10 \text{ pF}$; $C_\mu = 5 \text{ pF}$

Ckt load	A_v	R_{in}	R_o	C_{in}	B.W.
Active					
Passive					



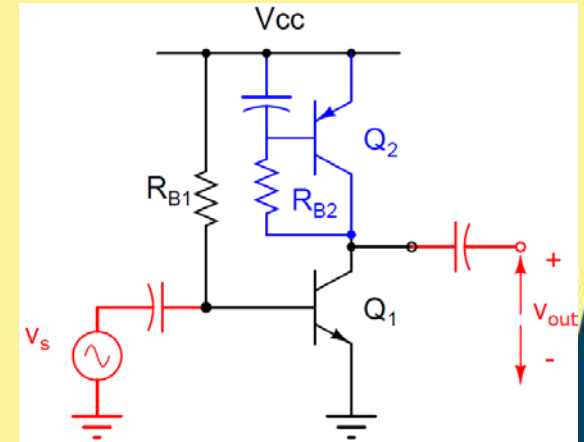
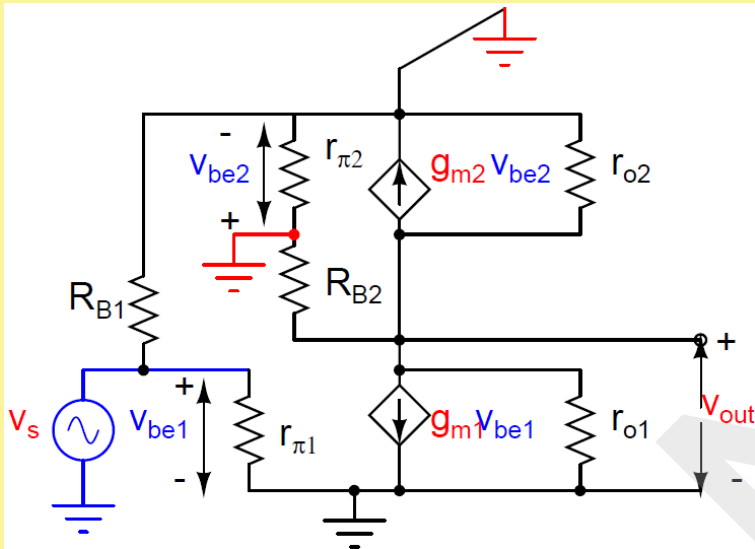
CE amplifier with active load having **stable bias**

- $\beta_1 = 100$; $\beta_2 = 200$; $V_{BE(on)1} \approx V_{BE(on)2} \approx 0.6V$;
- $V_{A1} = 100V$; $V_{A2} = 100V$; $C_{\pi 1} = C_{\pi 2} = 10 \text{ pF}$; $C_{\mu 1} = C_{\mu 2} = 5 \text{ pF}$
- $V_{CC} = 12V$; $R_{B1} = 570k\Omega$; $R_{B2} = 1.14M\Omega$; $C_L = 100 \text{ pF}$
 - Find voltage gain, R_{in} , R_o and C_{in}
 - Find the Upper Cutoff frequency



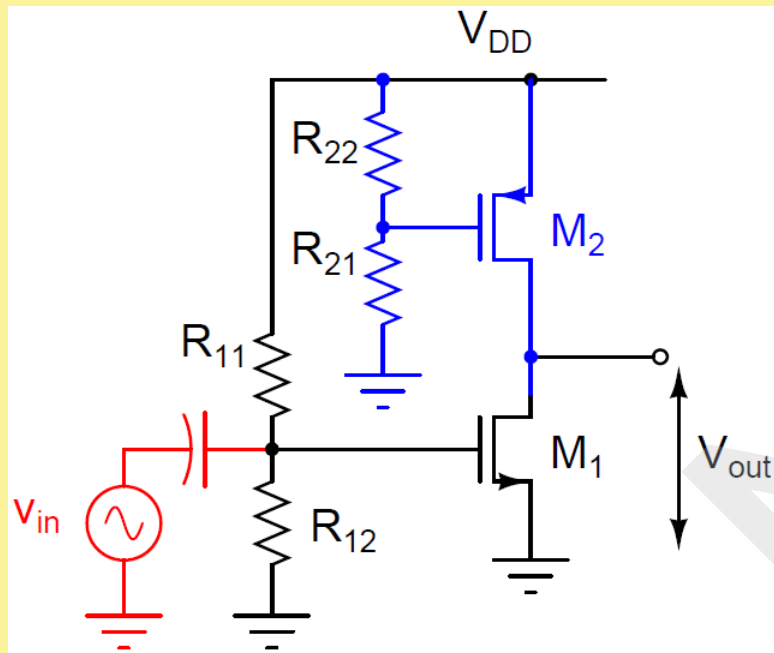
CE amplifier with active load having **stable bias**

- $\beta_1 = 100$; $\beta_2 = 200$; $V_{BE(on)1} \approx V_{BE(on)2} \approx 0.6V$;
- $V_{A1} = 100V$; $V_{A2} = 100V$; $C_{\pi 1} = C_{\pi 2} = 10 \text{ pF}$; $C_{\mu 1} = C_{\mu 2} = 5 \text{ pF}$
- $V_{CC} = 12V$; $R_{B1} = 570k\Omega$; $R_{B2} = 1.14M\Omega$; $C_L = 100pF$
 - Find voltage gain, R_{in} , R_o and C_{in}
 - Find the Upper Cutoff frequency



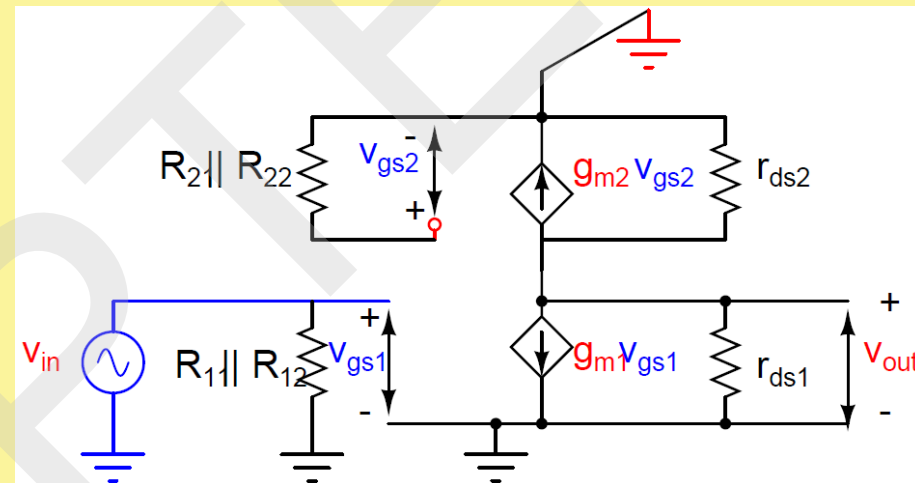
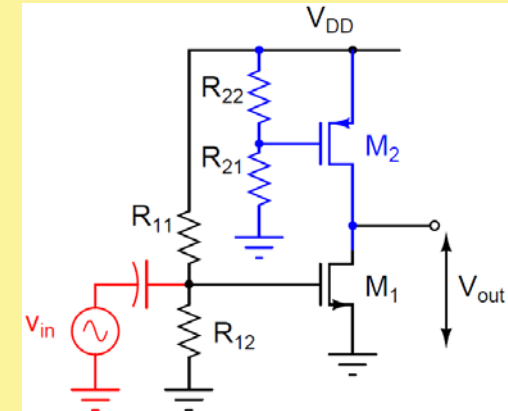
Numerical example: CS amplifier with **active load**

- $(K_n.W1/L1) = 1\text{mA/V}^2$, $(K_p.W2/L2) = 4\text{mA/V}^2$; $V_{th1} = 1\text{V}$, $V_{th2} = -1.5\text{V}$, $\lambda_1 = \lambda_2 = 0.01/\text{V}$,
- $C_{gs1} = C_{gs2} = 10\text{ pF}$; $C_{gd1} = C_{gd2} = 5\text{ pF}$
- $V_{DD} = 12\text{V}$, $R_{11} = 9\text{k}\Omega$, $R_{12} = 3\text{k}\Omega$, $R_{21} = 95\text{k}\Omega$, $R_{22} = 25\text{k}\Omega$, $C_L = 100\text{ pF}$
 - Find operating points and values of small signal parameters of transistors
 - Find Output swing (distortion free output signal)



Numerical example: CS amplifier with **active load** (contd.)

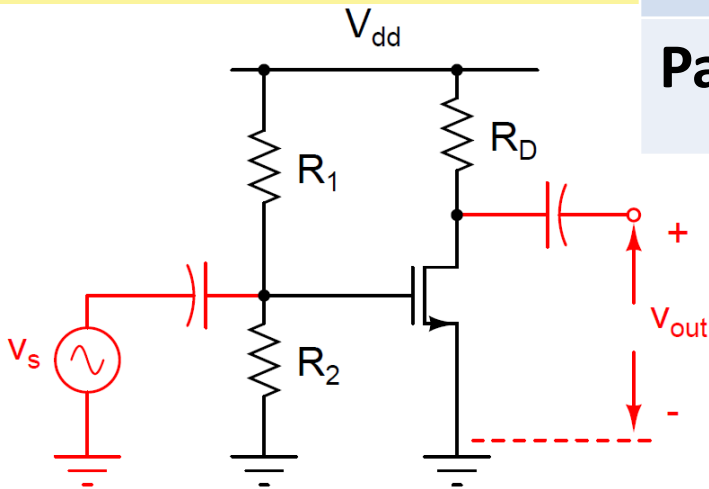
- $(K_n.W1/L1) = 1\text{mA/V}^2$, $(K_p.W2/L2) = 4\text{mA/V}^2$; $V_{th1} = 1\text{V}$, $V_{th2} = -1.5\text{V}$, $\lambda_1 = \lambda_2 = 0.01/\text{V}$,
- $C_{gs1} = C_{gs2} = 10\text{ pF}$; $C_{gd1} = C_{gd2} = 5\text{ pF}$
- $V_{DD} = 12\text{V}$, $R_{11} = 9\text{k}\Omega$, $R_{12} = 3\text{k}\Omega$, $R_{21} = 95\text{k}\Omega$, $R_{22} = 25\text{k}\Omega$, $C_L = 100\text{ pF}$
 - Find voltage gain, R_{in} , R_o and C_{in}
 - Find the Upper Cutoff frequency



Comparison with CS amplifier having passive load

- $(K_n.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$, $R_1 = 9\text{k}\Omega$, $R_2 = 3\text{k}\Omega$, $R_D = 3\text{k}\Omega$; $C_L = 100\text{pF}$

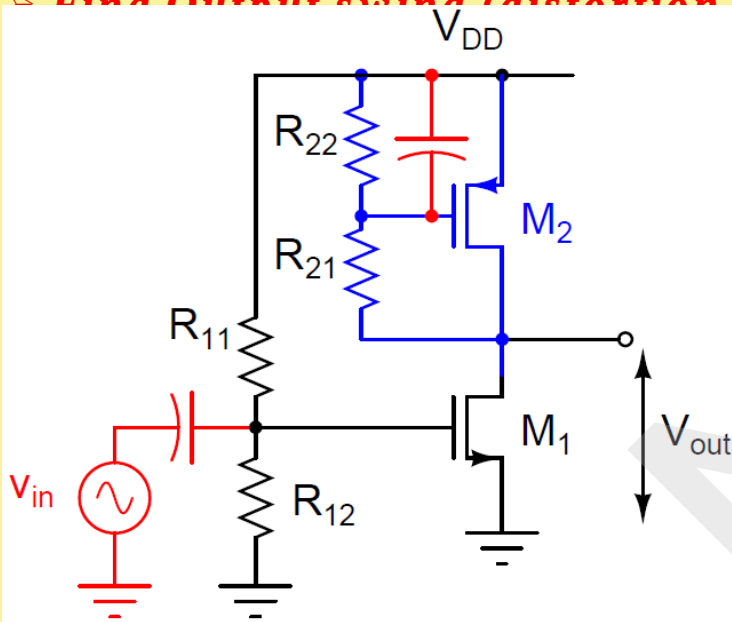
Ckt load	A_v	R_{in}	R_o	C_{in}	B.W.
Active					
Passive					



Numerical example:

CS amplifier with active load having **stable bias**

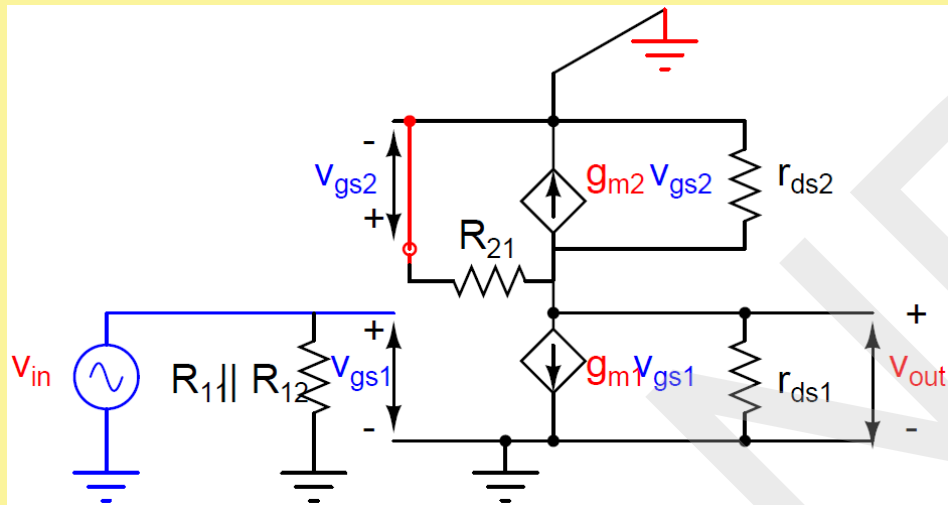
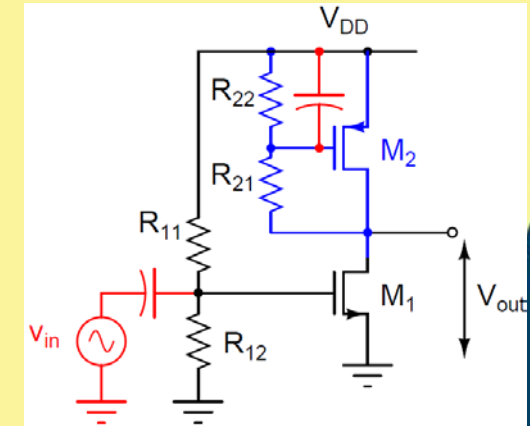
- $(K_n.W1/L1) = 1\text{mA/V}^2$, $(K_p.W2/L2) = 4\text{mA/V}^2$; $V_{th1} = 1\text{V}$, $V_{th2} = -1.5\text{V}$, $\lambda_1 = \lambda_2 = 0.01/\text{V}$,
 - $C_{gs1} = C_{gs2} = 10\text{ pF}$; $C_{gd1} = C_{gd2} = 5\text{ pF}$
 - $V_{DD} = 12\text{V}$, $R_{11} = 9\text{k}\Omega$, $R_{12} = 3\text{k}\Omega$, **$R_{21} = 35\text{k}\Omega$** , $R_{22} = 25\text{k}\Omega$, $C_L = 100\text{pF}$
- Find operating points and values of small signal parameters of transistors
- Find Output swing (distortion free output signal)



Numerical example:

CS amplifier with active load having **stable bias (contd.)**

- $(K_n.W1/L1) = 1\text{mA/V}^2$, $(K_p.W2/L2) = 4\text{mA/V}^2$; $V_{th1} = 1\text{V}$, $V_{th2} = -1.5\text{V}$, $\lambda_1 = \lambda_2 = 0.01/\text{V}$,
- $C_{gs1} = C_{gs2} = 10\text{ pF}$; $C_{gd1} = C_{gd2} = 5\text{ pF}$
- $V_{DD} = 12\text{V}$, $R_{11} = 9\text{ k}\Omega$, $R_{12} = 3\text{ k}\Omega$, $R_{21} = 35\text{ k}\Omega$, $R_{22} = 25\text{ k}\Omega$, $C_L = 100\text{ pF}$
 - Find voltage gain, R_{in} , R_o and C_{in}
 - Find the Upper Cutoff frequency



Conclusion:

- ❑ Motivation of using active load
- ❑ Basic operation and analysis of
 - CS amplifier with active load
 - CE amplifier with active load
- ❑ Practical amplifier circuits with active load:
 - CS
 - CE
- ❑ **Numerical examples and Design guidelines**
 - CE amplifier with active load and comparison with passive load
 - CE amplifier with active load having stable bias
 - CS amplifier with active load and comparison with passive load
 - CE amplifier with active load having stable bias

Conclusion





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*Thank
you*

