



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Linear models of 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 3:**
 - **Amplifier models (equivalent circuits):**
 - voltage amplifier, current amplifier,
 - trans-conductance amplifier and trans-resistance amplifier.
 - **Cascading of multiple amplifiers.**
 - **Common emitter (CE) amplifier**
 - operating principle, biasing, analysis and design.
 - **Common source (CS) amplifier**
 - operating principle, biasing, analysis and design.



CONCEPTS COVERED

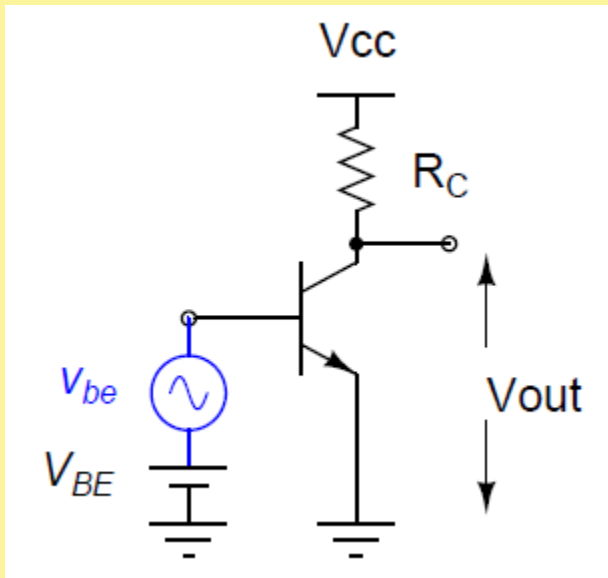
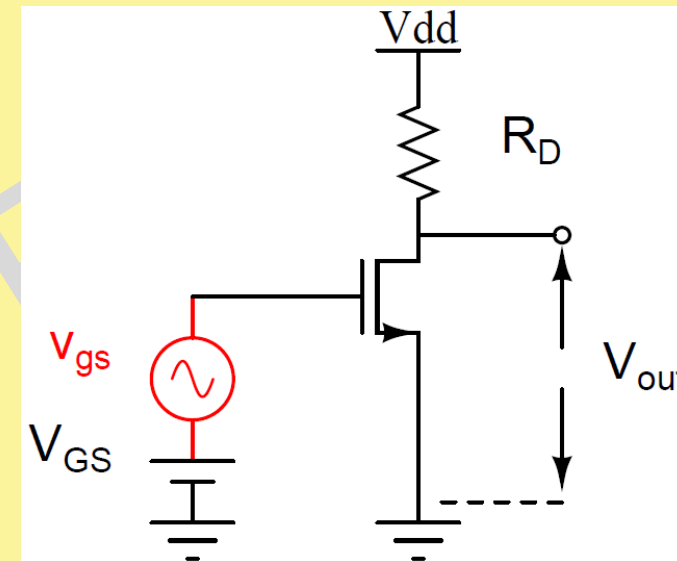
Concepts Covered:

- ☐ Model of Voltage Amplifier
- ☐ Model of Current Amplifier
- ☐ Model of Trans-conductance Amplifier
- ☐ Model of Trans-Impedance Amplifier



Two simple Voltage Amplifiers

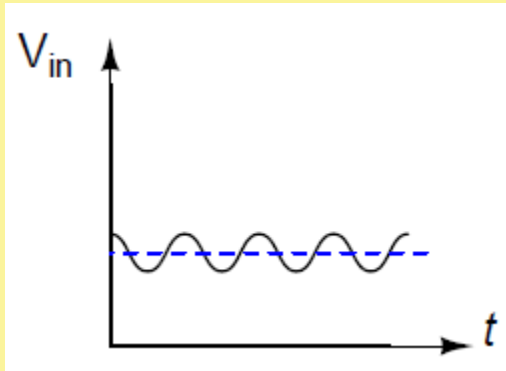
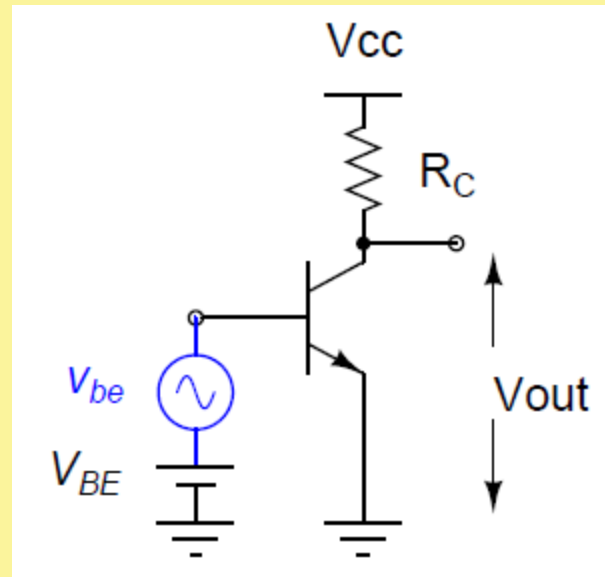
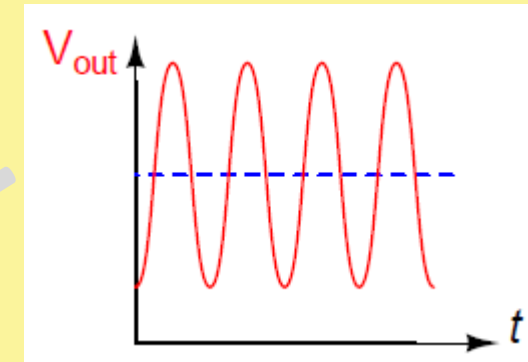
- **Example circuit (containing BJT or MOSFET)**
- Transistors are biased in proper region of operation



- Dependency of the output signal on the input signal

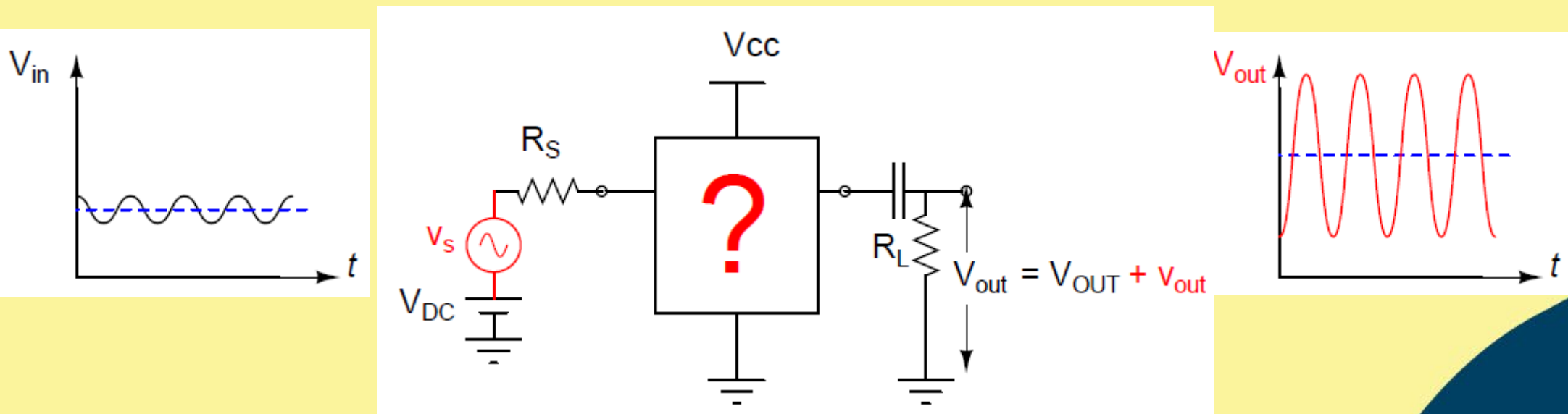
Meaning of Model of Voltage Amplifier

- **An equivalent linear circuit providing**
Dependency of the output signal on the input signal



Meaning of Model of Voltage Amplifier (contd.)

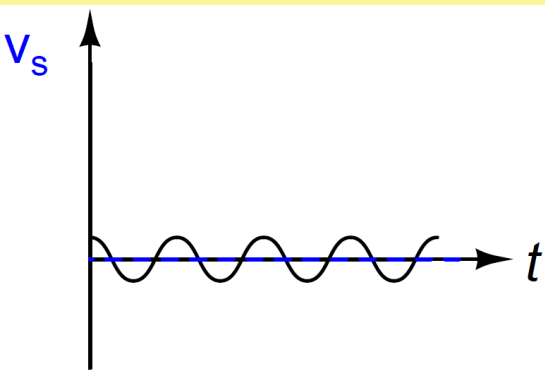
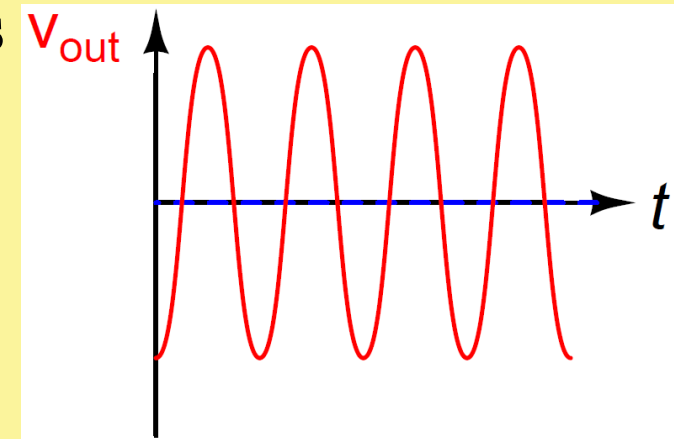
- **An equivalent linear circuit providing**
Dependency of the output signal on the input signal



- **DC parts are eliminated in the model**

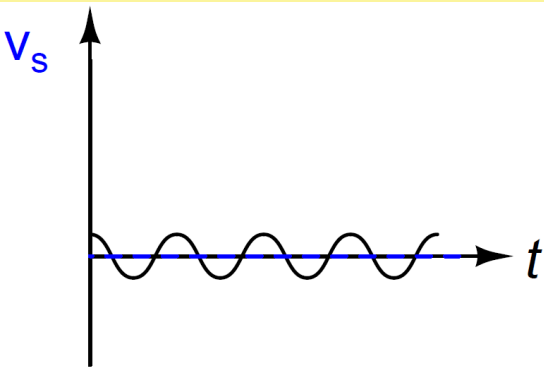
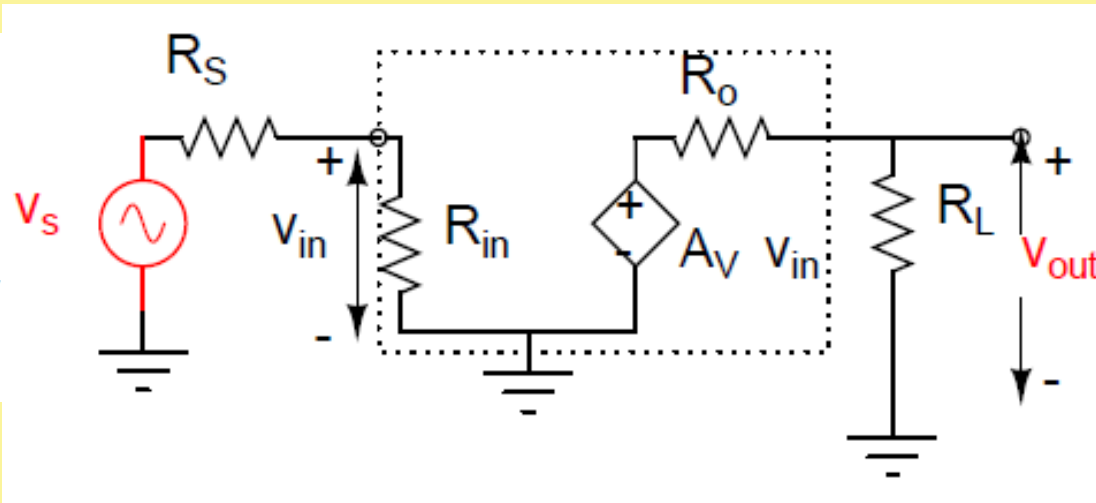
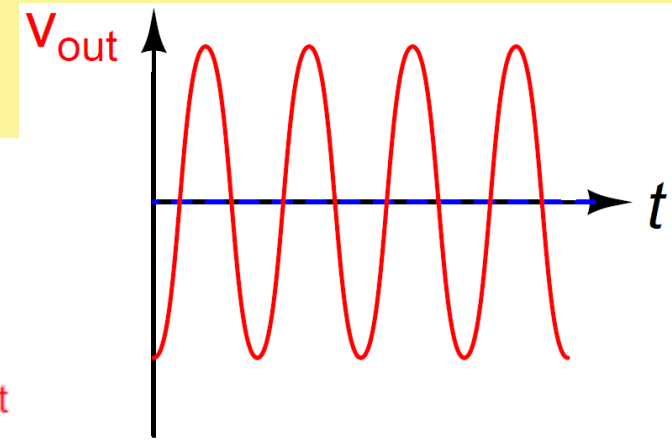
Model of a Voltage Amplifier

- **Represents**
 - **Input-to-Output Voltage gain (unloaded) and**
 - **Loading effect at the output and input ports**



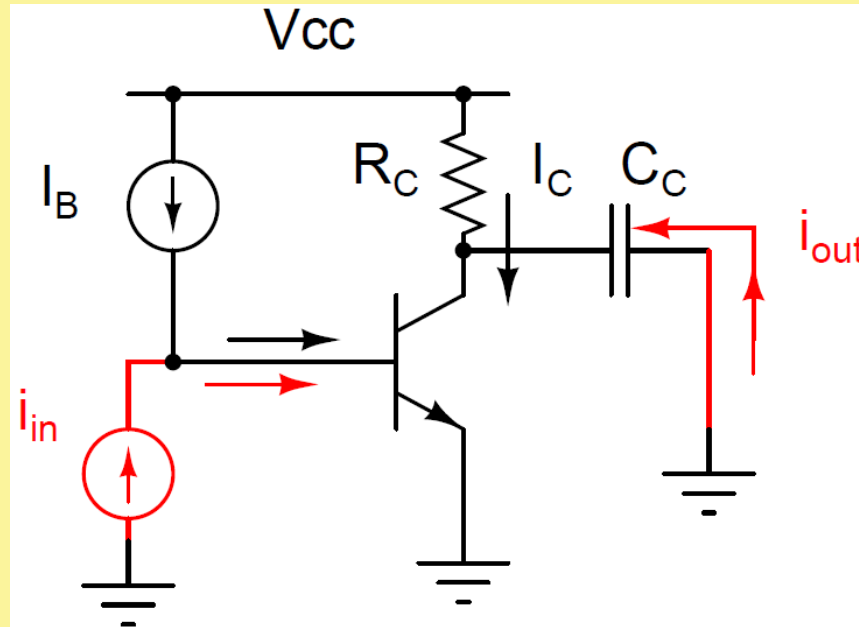
Model of Voltage Amplifier (Contd.)

- **Represents**
 - **Input-to-Output Voltage gain (unloaded) and**
 - **Loading effect at the output and input ports**



A simple Current Amplifier

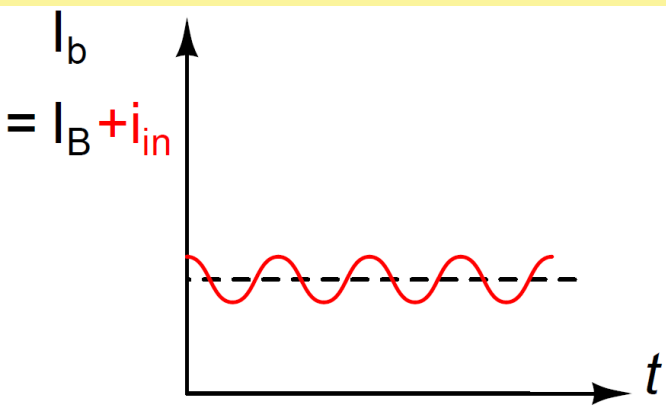
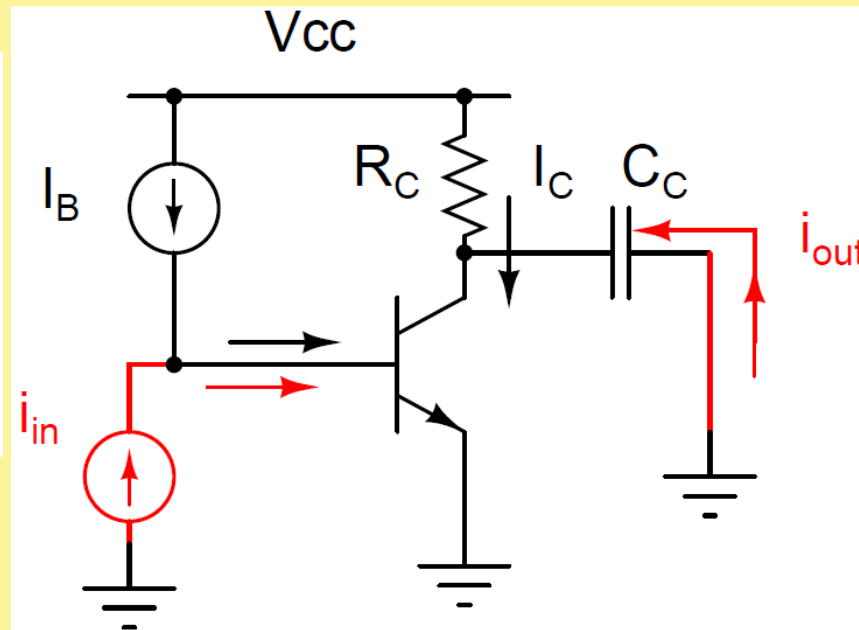
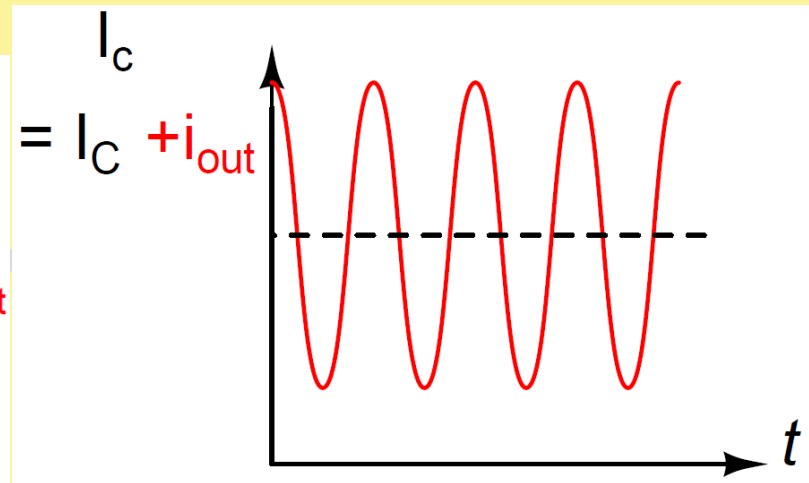
- **Example circuit (containing BJT)**
- Transistors are biased in proper region of operation



- Dependency of the output signal on the input signal

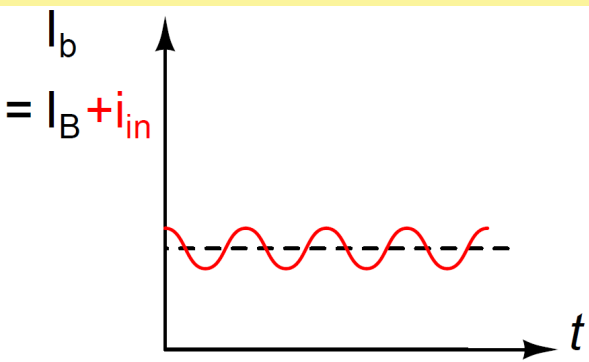
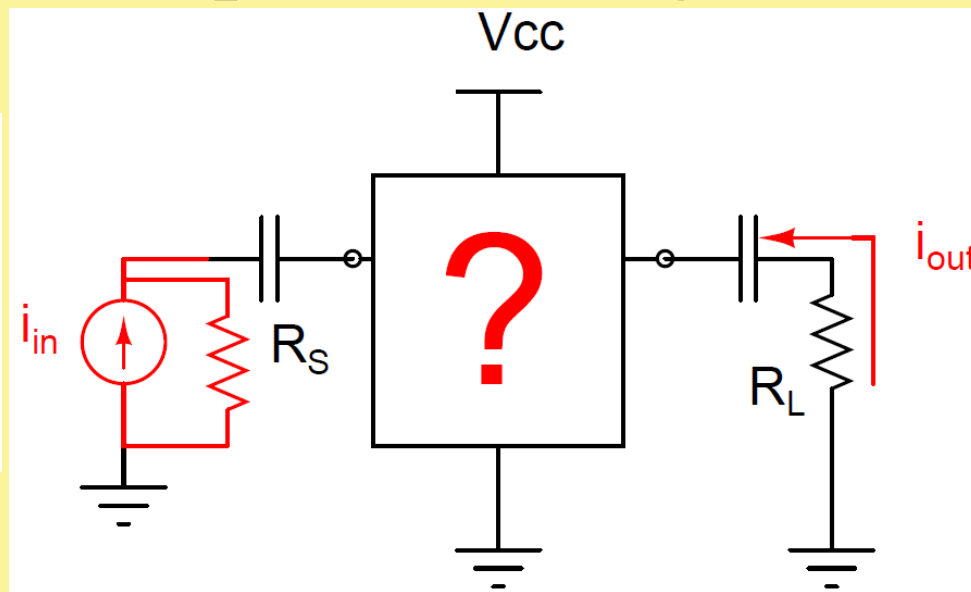
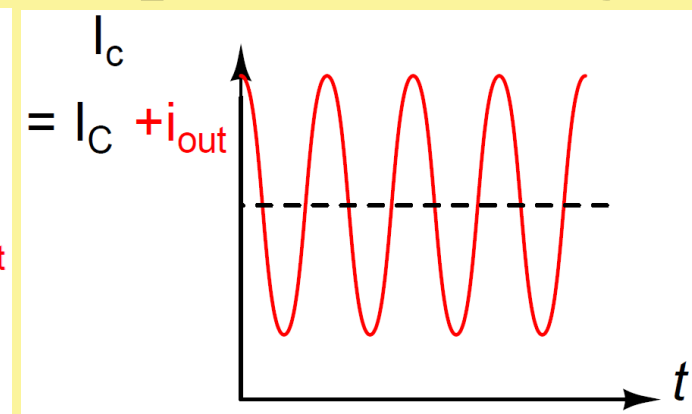
Meaning of Model of Current Amplifier

- **An equivalent linear circuit providing**
Dependency of the output current signal on the input current signal



Meaning of Model of Current Amplifier (contd.)

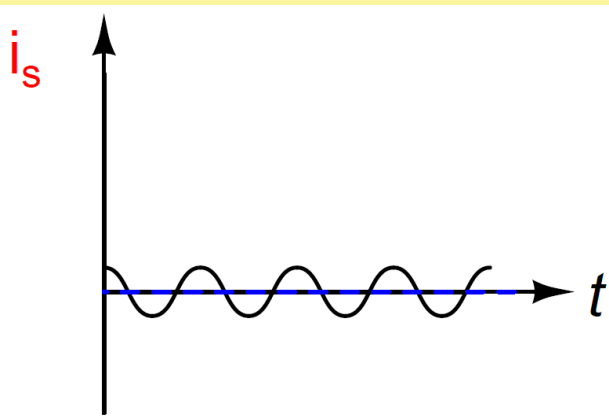
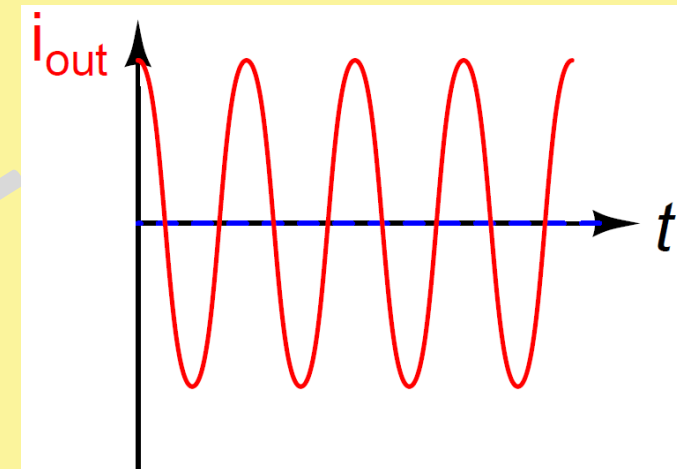
- **An equivalent linear circuit providing**
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- **DC parts are excluded in the model**

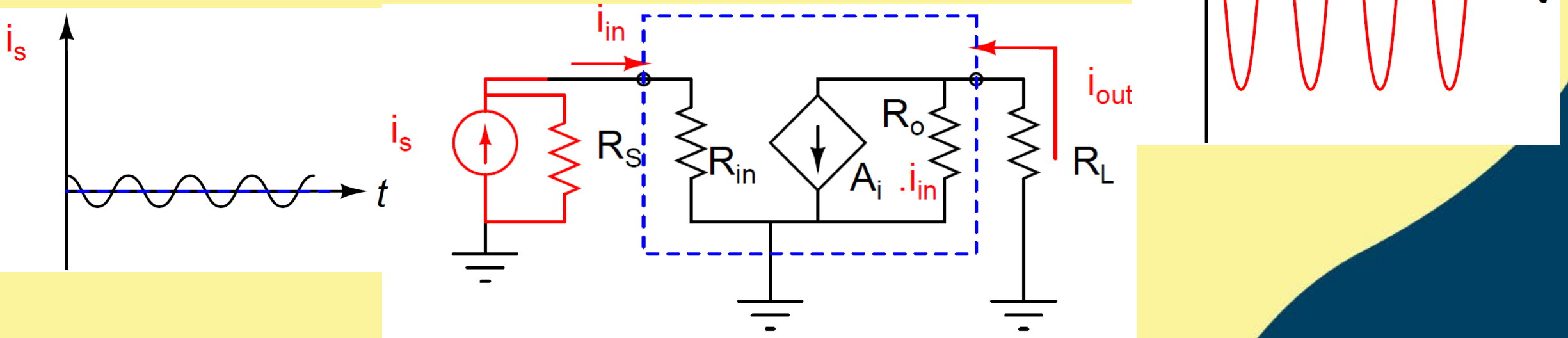
Model of a Current Amplifier

- **Represents**
 - **Input-to-Output Current gain (unloaded) and**
 - **Loading effect at the output and input ports**



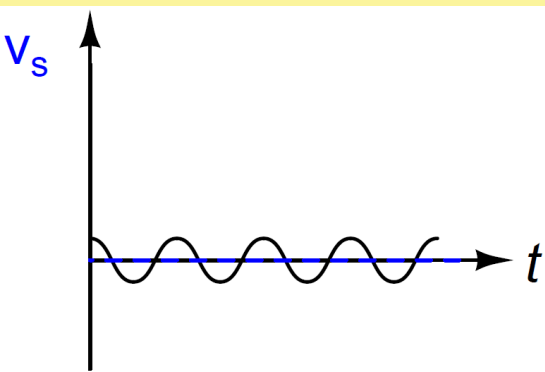
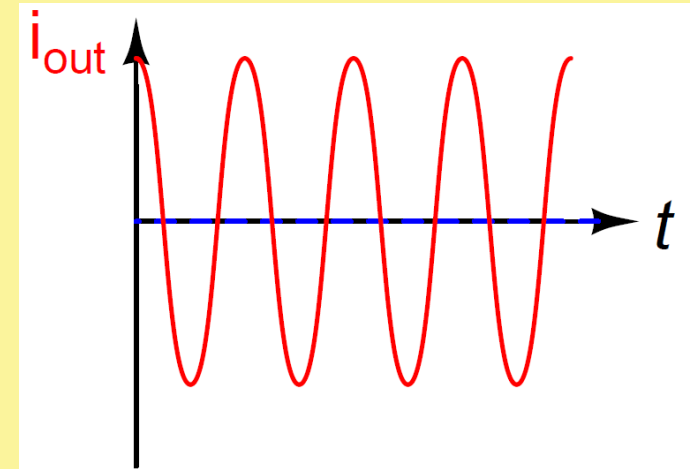
Model of Current Amplifier (Contd.)

- **Represents**
 - **Input-to-Output Current Gain (unloaded) and**
 - **Loading effect at the output and input ports**



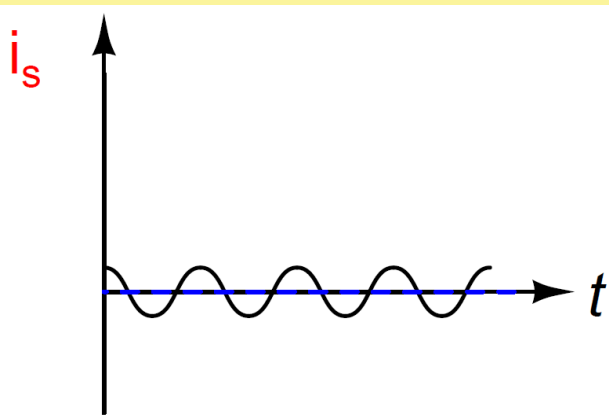
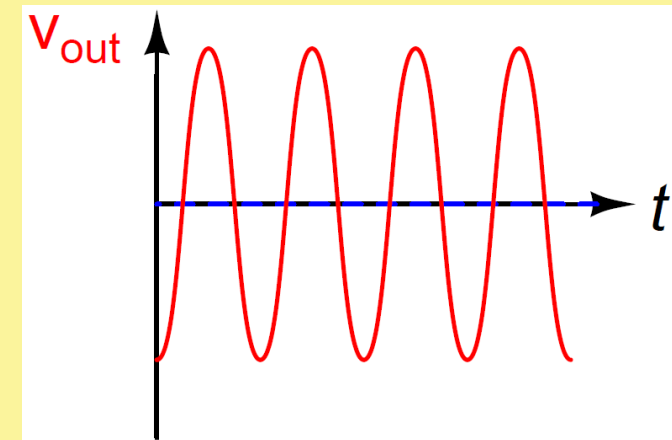
Model of Trans-Conductance Amplifier

- **Represents**
 - **Input-to-Output Signal relationship (unloaded) and**
 - **Loading effect at the output and input ports**



Model of Trans-Impedance Amplifier

- **Represents**
 - **Input-to-Output Signal relationship (unloaded) and**
 - **Loading effect at the output and input ports**



Conclusion

Conclusion:

- ❑ Linearization of Simple Amplifier results to Models of
 - ❑ Voltage Amplifier,
 - ❑ Current Amplifier,
 - ❑ Trans-conductance Amplifier and
 - ❑ Trans-Impedance Amplifier
- ❑ Each of the Models Represent
Input-to-Output Signal relationship (unloaded) and
Loading effect at the output and input ports





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Topic:

Common Emitter Amplifier

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

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CONCEPTS COVERED

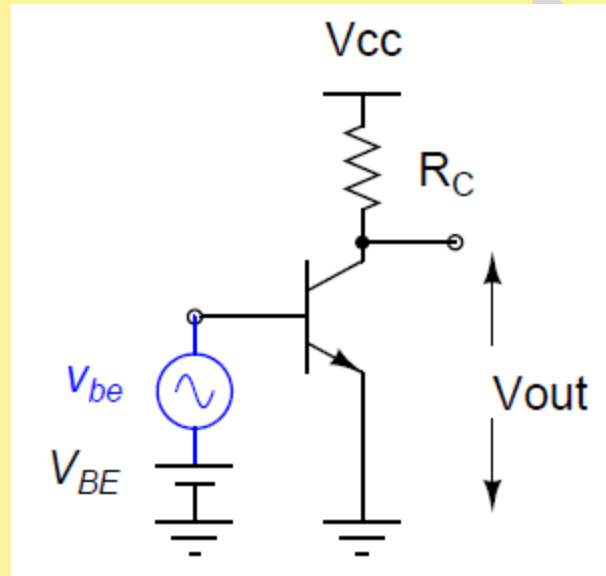
Concepts Covered:

- ☐ Operating principle
- ☐ Biasing: *Fixed bias*
- ☐ Analysis: *Operating point and Small signal*
- ☐ Issue in Fixed bias CE amplifier



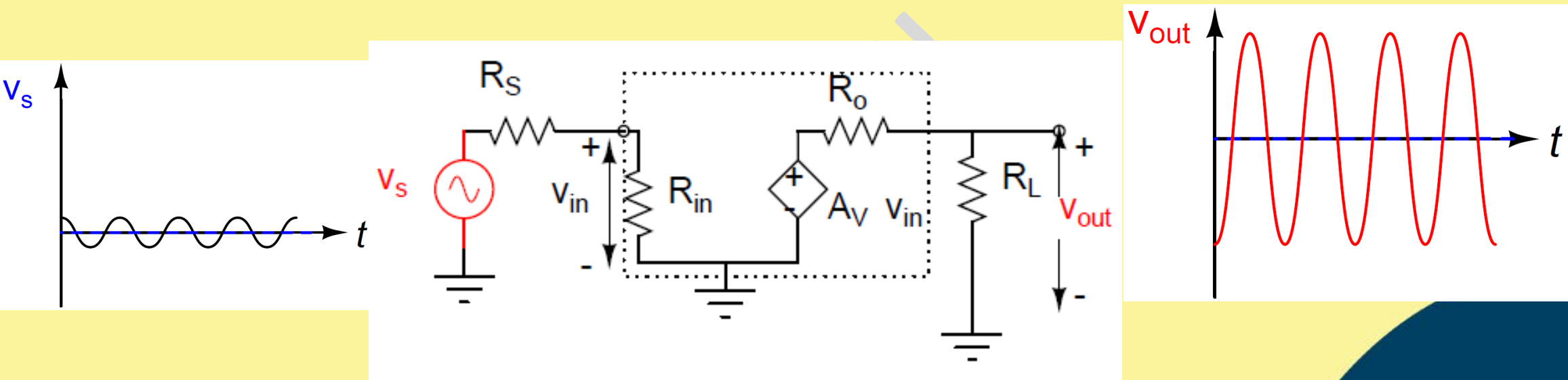
Basic operation of CE amplifier

- **Normally, it is considered as a Voltage Amplifier**
 - Input is fed at the Base node
 - Output is observed at the collector node
 - Both, input and output signals are voltage



CE amplifier as Voltage amplifier

- Both, input and output signals are voltage
- Important parameters A_v , R_o and R_{in} are dependent on Q-point



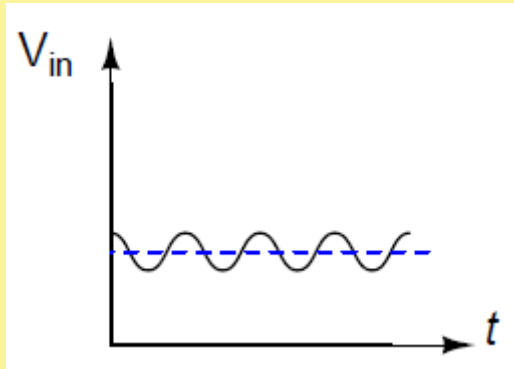
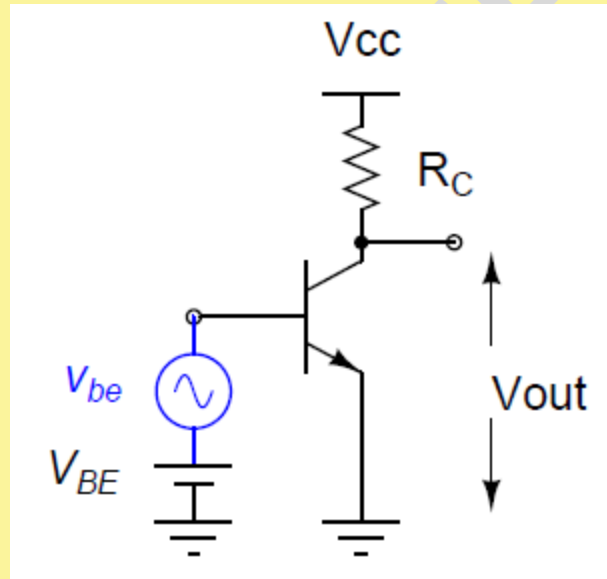
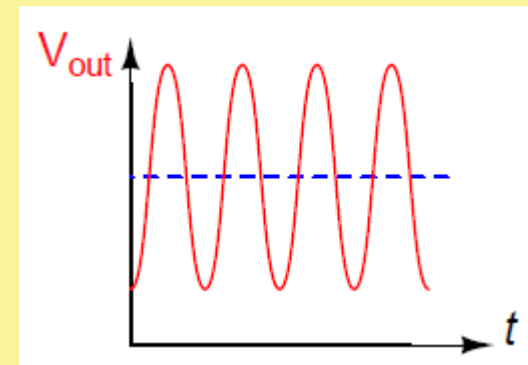
Basic operation of CE amplifier

- **Basic Operation**

Base node must have a d.c. voltage

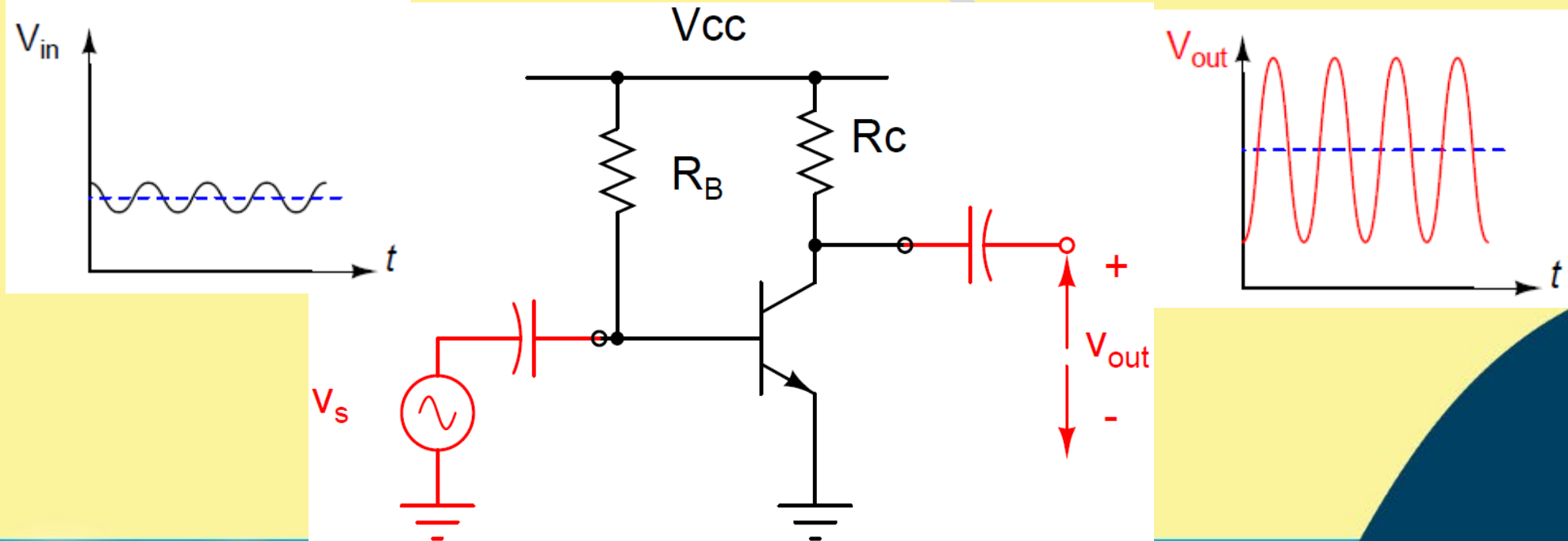
Collector node voltage must be sufficiently high

Biasing is an important aspect keeping transistor in active region



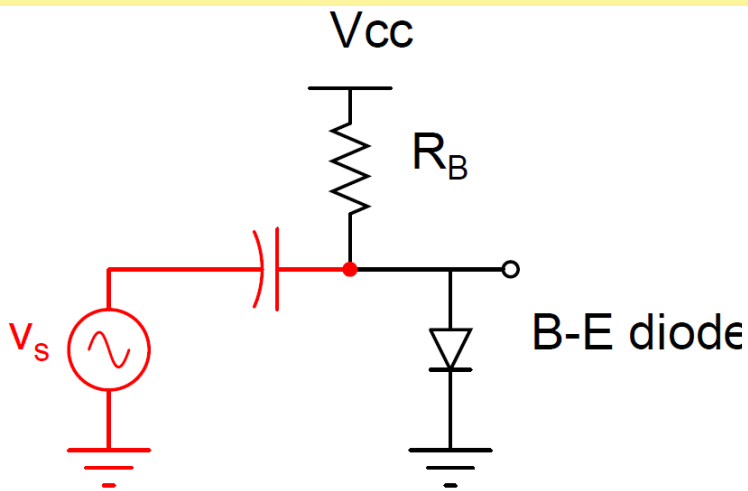
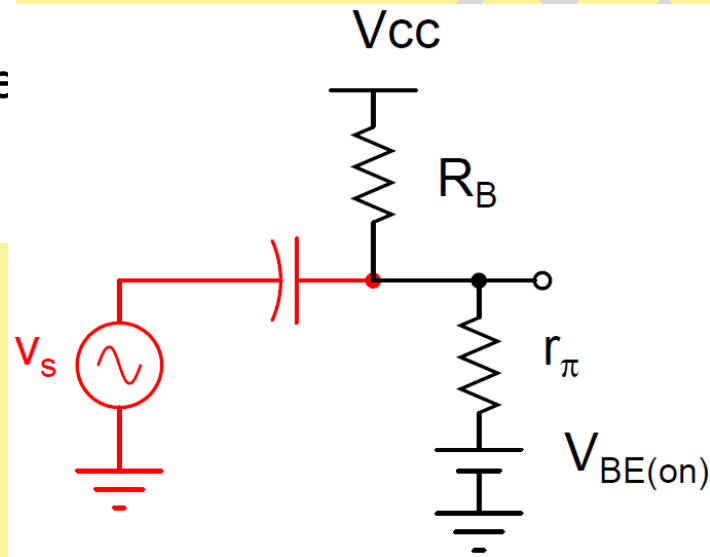
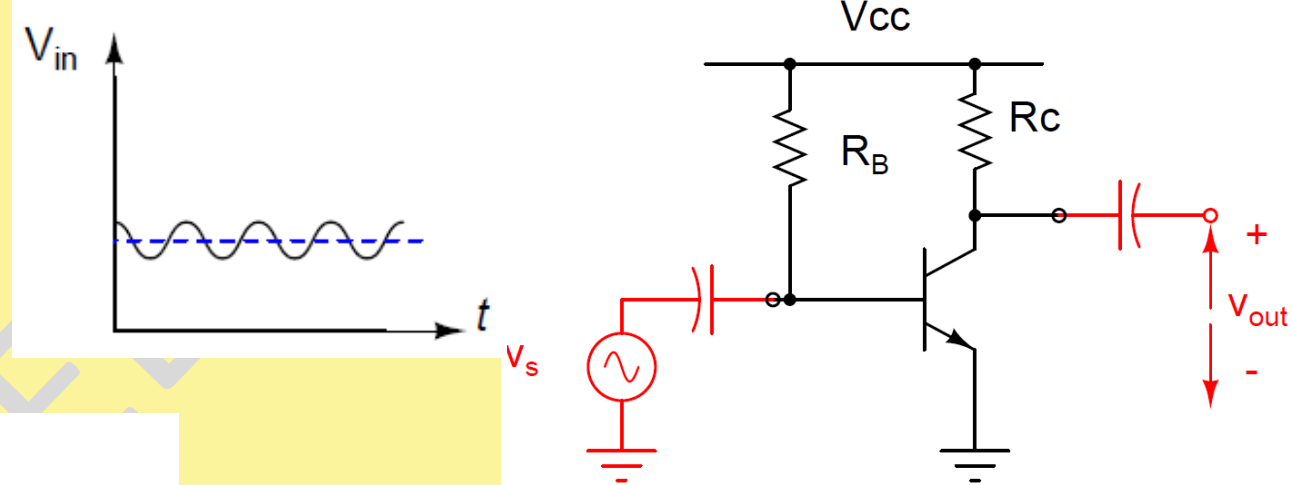
Practical circuit to bias CE amplifier – Fixed bias

- D.C. voltage at the base is defined by V_{CC} , R_B and B-E diode
- Capacitor at input port blocks d.c. voltage of the input signal source
- Capacitor at output port blocks the d.c. at collector node to extract only a.c.



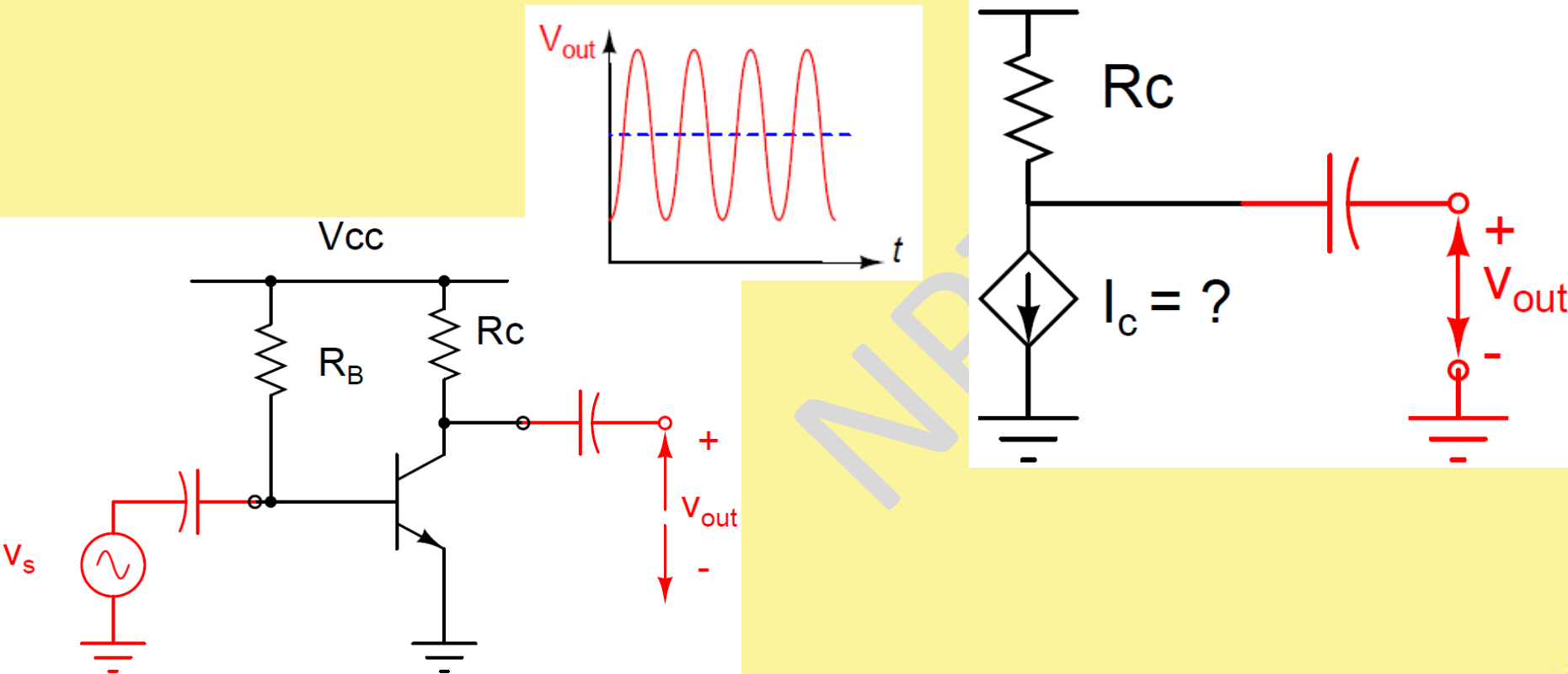
CE amplifier – Fixed bias (contd.)

• Circuit at Input port



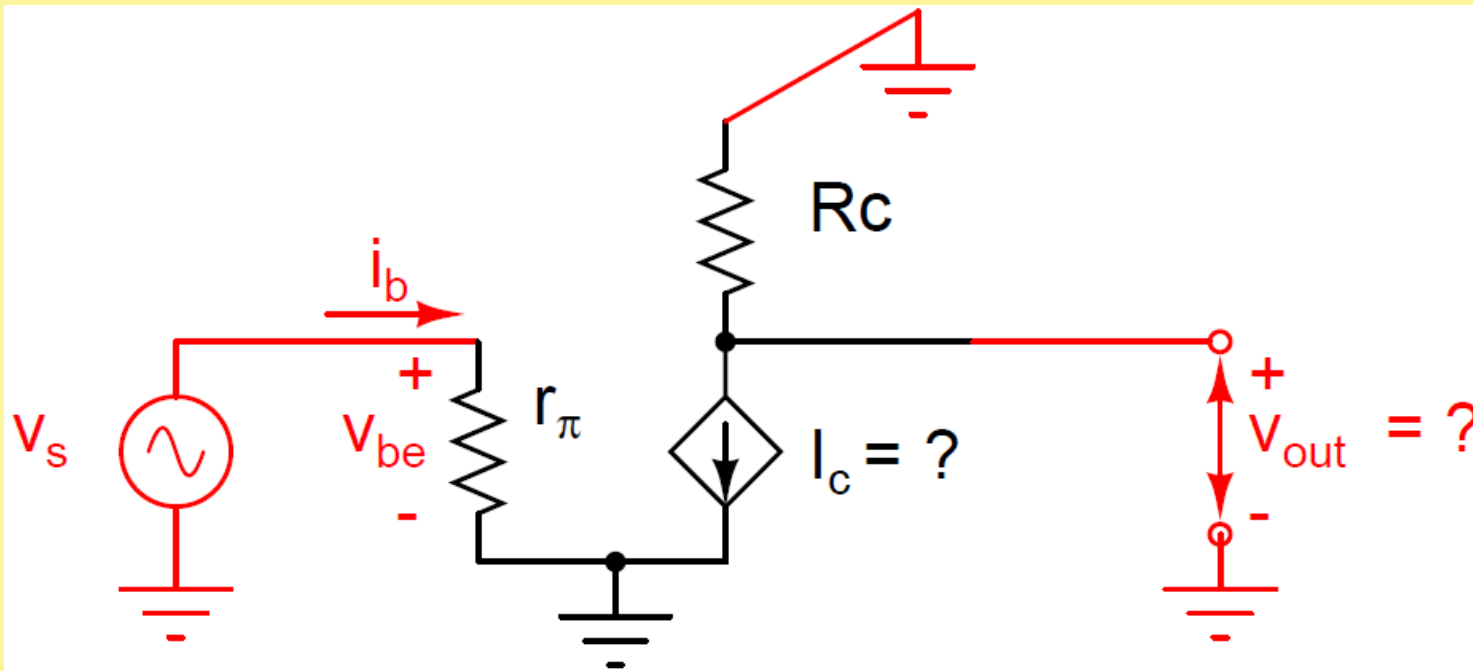
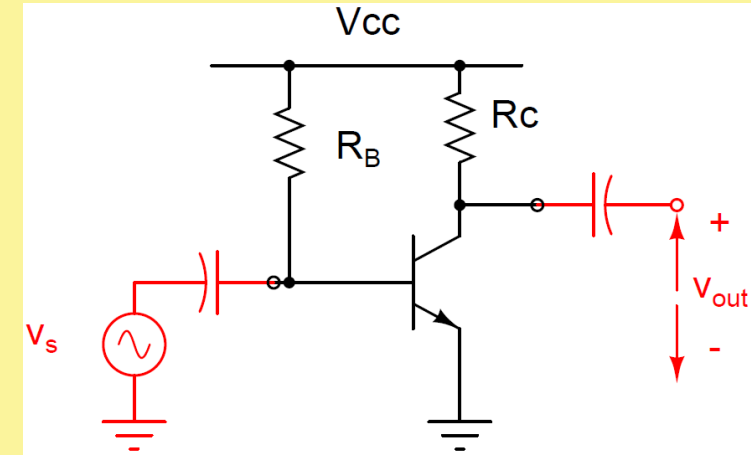
CE amplifier – Fixed bias (contd..)

- **Circuit at Output port**



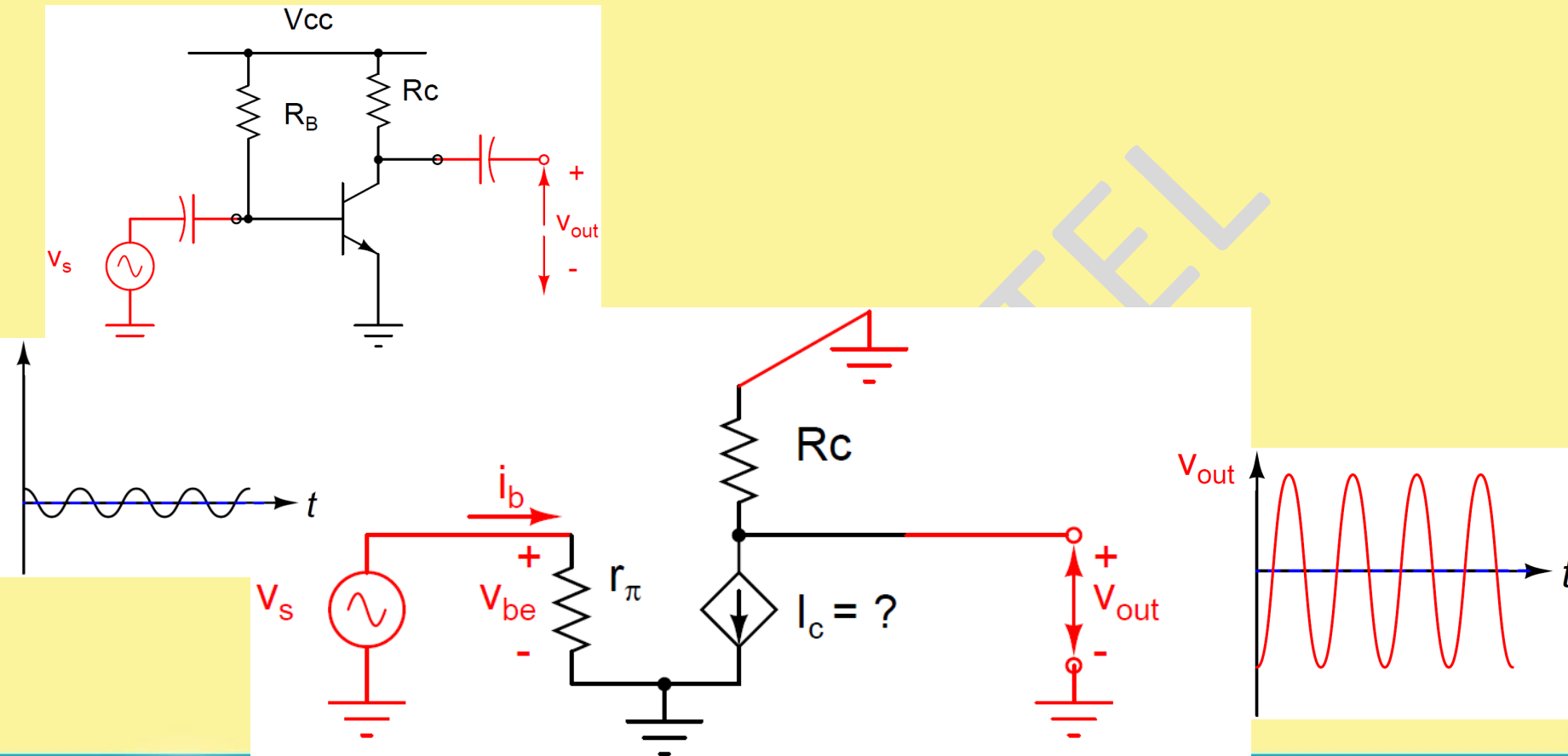
CE amplifier – Fixed bias (contd...)

- Small signal equivalent circuit(s)



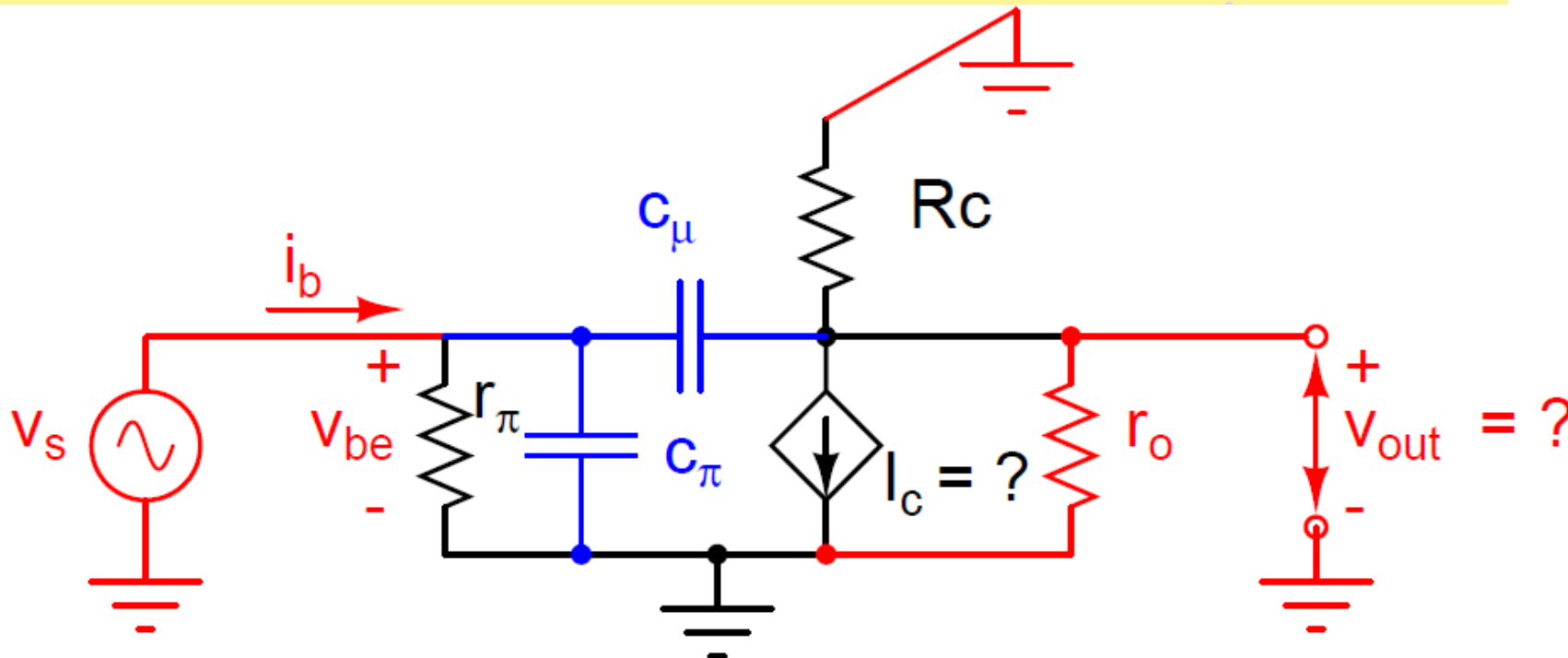
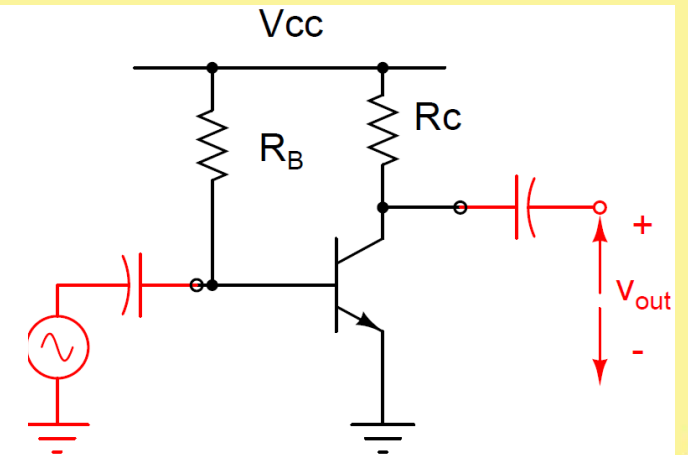
CE amplifier – Fixed bias (contd...)

- Mapping small signal equivalent circuit into Voltage Amplifier



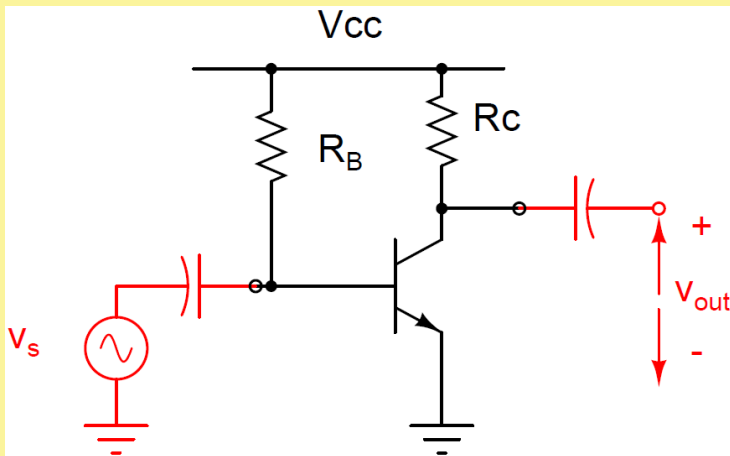
CE amplifier – Fixed bias (contd...)

- High frequency Small signal equivalent circuits



Sensitivity of Operating point of CE Amp

- Operating point of Fixed bias CE amp is sensitive on β of the BJT



- A series Resistor R_E is added at the emitter terminal to de-sensitize the operating point

Conclusion

Conclusion:

- ❑ Operation of CE Amplifier
- ❑ Biasing of CE amplifier:
 - ❑ *Fixed bias*
 - ❑ *D.C. decoupling capacitors*
- ❑ Analysis CE amplifier
 - ❑ *Operating point and*
 - ❑ *Small (a.c.) signal*
- ❑ Sensitivity problem in Fixed bias CE amplifier





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you*





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Department : *Electronics and Electrical Communication Engineering*

Topic:

Common Emitter Amplifier (contd.)

CONCEPTS COVERED

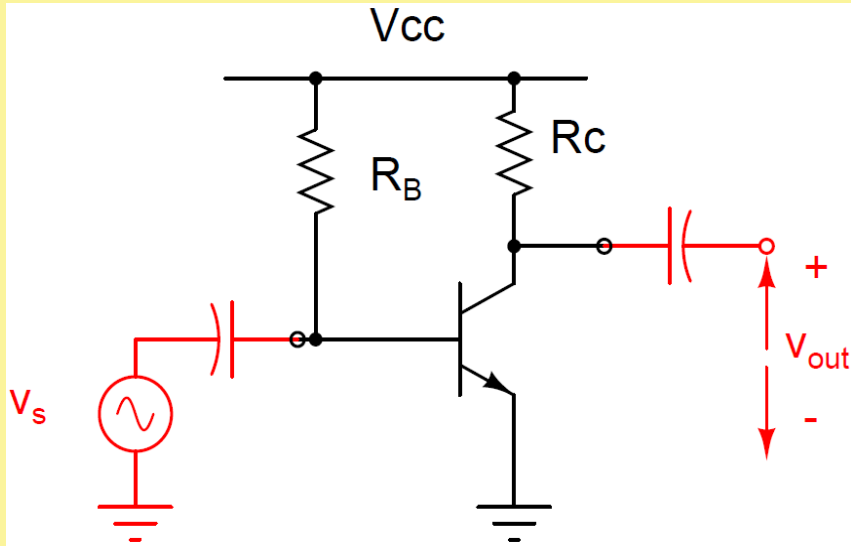
Concepts Covered:

- ☐ Fixed-biasing vs. Self biasing of CE amplifier
- ☐ **Analysis:** *Operating point and Small signal*
- ☐ Method of finding parameters in Voltage Amplifier
- ☐ **Numerical Examples:** *Analysis and Design*

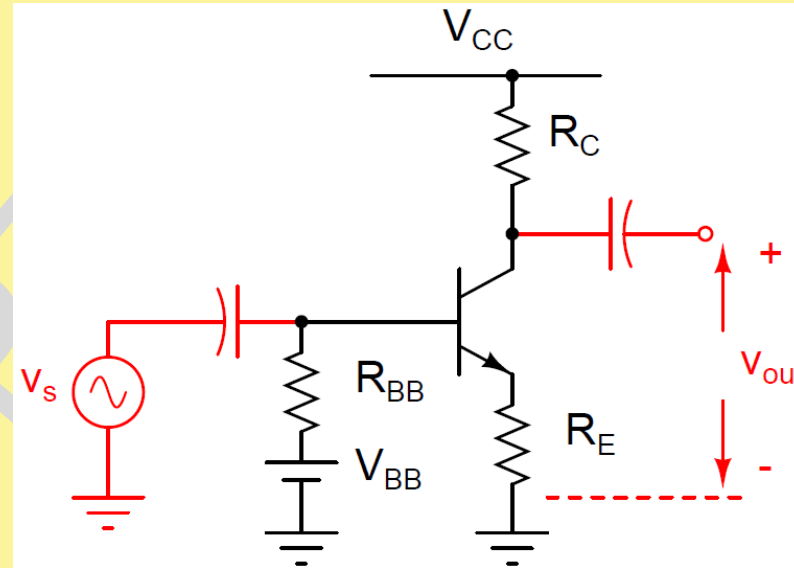


Biasing of CE amplifier: *Fixed-bias vs. Self-bias*

- In Fixed-bias, I_B is defined by R_B (and $V_{CC} - V_{BE(on)}$)
- In Self-bias, I_E and hence I_C are set by R_E (and $V_{BB} - V_{BE(on)}$)



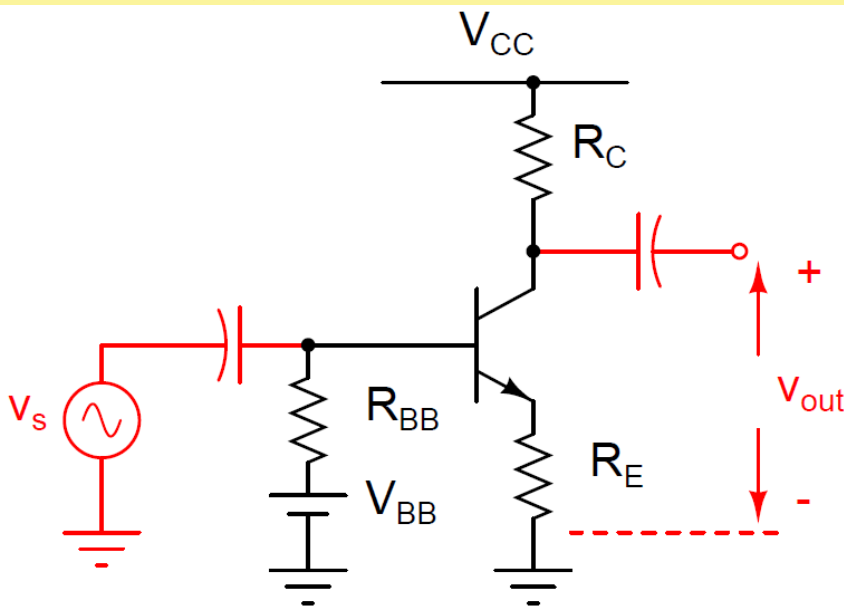
$$I_C = \beta_F I_B$$



$$I_C \approx I_E = \frac{(V_{BB} - V_{BE(on)})}{R_E}$$

Biasing of CE amplifier (cond..)

• Analysis to find I_C :



$$\frac{\Delta I_C}{I_C} \bigg/ \frac{\Delta \beta_F}{\beta_F} = \frac{(V_{BB} - V_{BE(on)})}{\{R_{BB} + (1 + \beta_F)R_E\}}$$

$$V_{BB} = V_{BE(on)} + R_{BB} \cdot I_B + R_E(1 + \beta_F)I_B$$

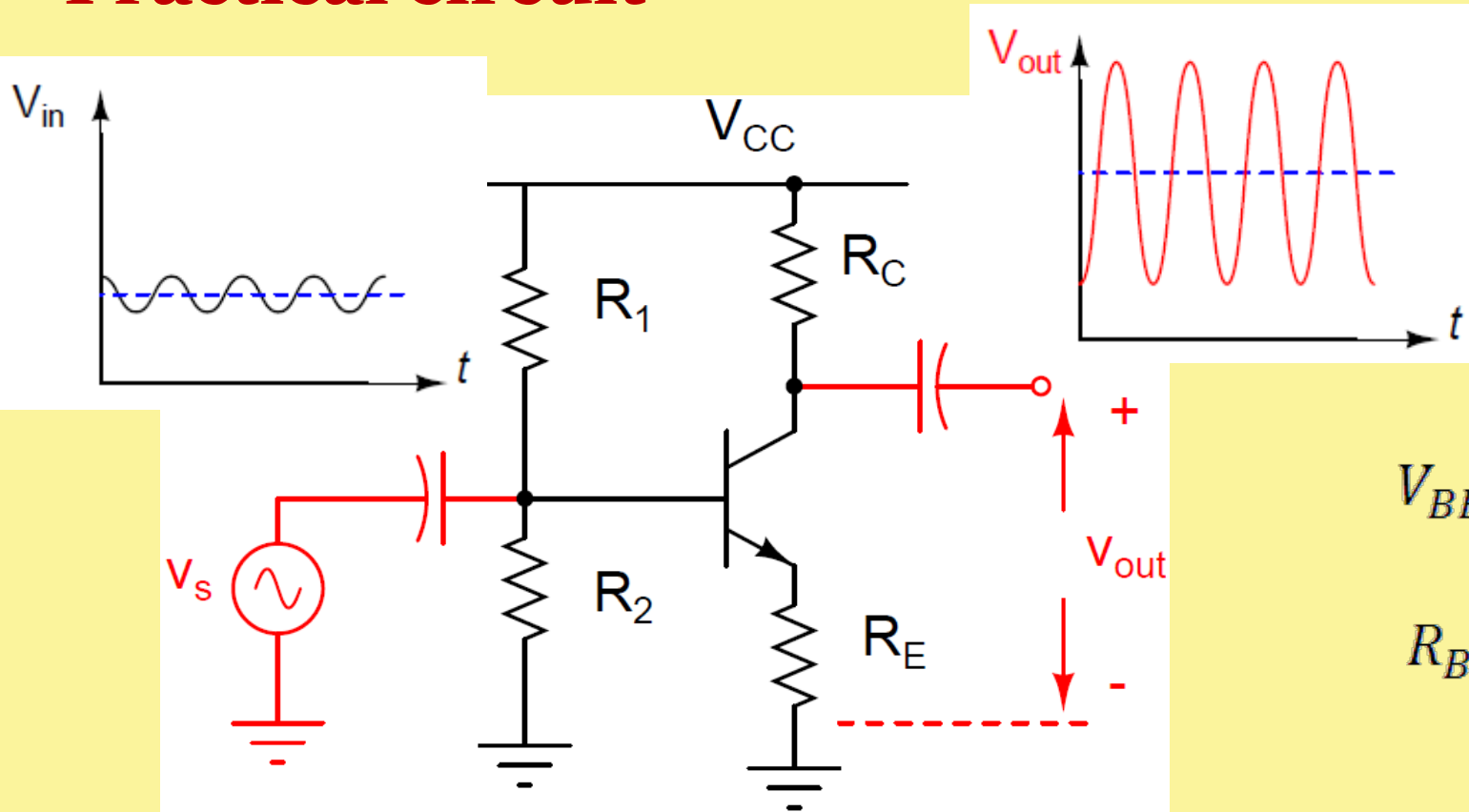
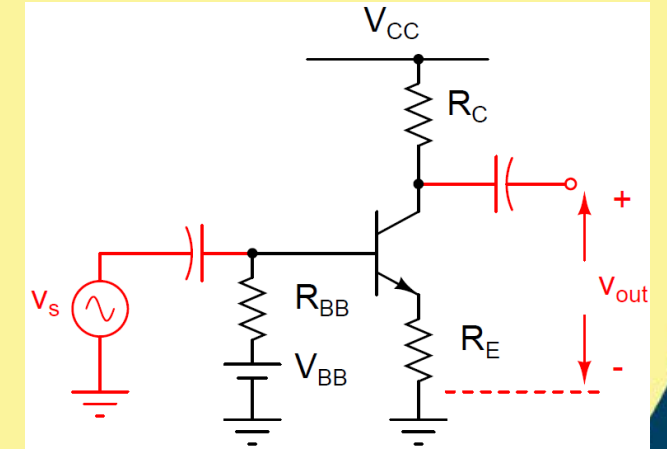
$$I_B = \frac{(V_{BB} - V_{BE(on)})}{\{R_{BB} + (1 + \beta_F)R_E\}}$$

$$I_C = \beta_F I_B = \frac{\beta_F (V_{BB} - V_{BE(on)})}{\{R_{BB} + (1 + \beta_F)R_E\}}$$

$$\frac{\partial I_C}{\partial \beta_F} = \frac{I_C}{\beta_F} \cdot \frac{(V_{BB} - V_{BE(on)})}{\{R_{BB} + (1 + \beta_F)R_E\}}$$

Self-biased CE amplifier

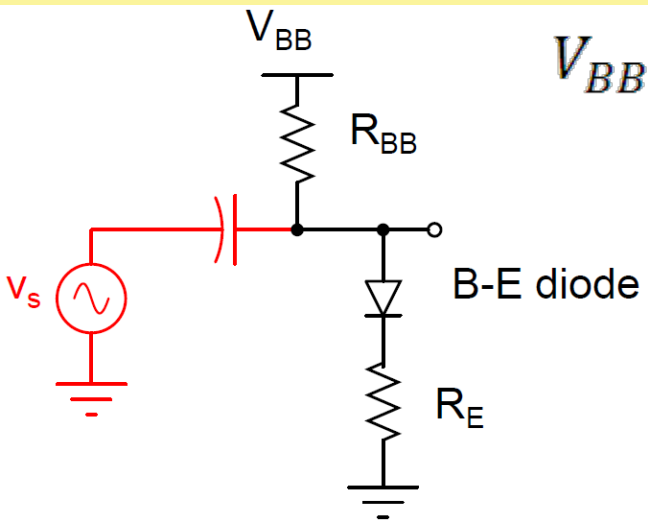
• Practical circuit



$$V_{BB} = V_{CC} \frac{R_2}{\{R_1 + R_2\}}$$
$$R_{BB} = \frac{R_1 \cdot R_2}{\{R_1 + R_2\}}$$

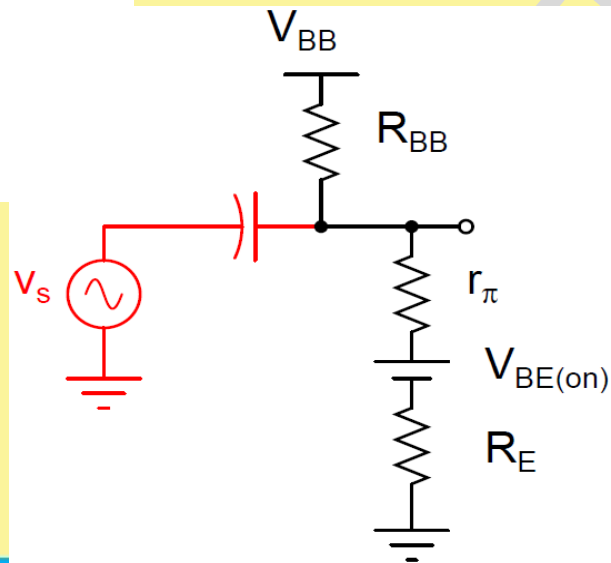
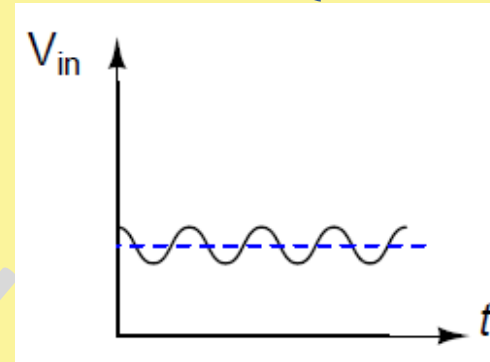
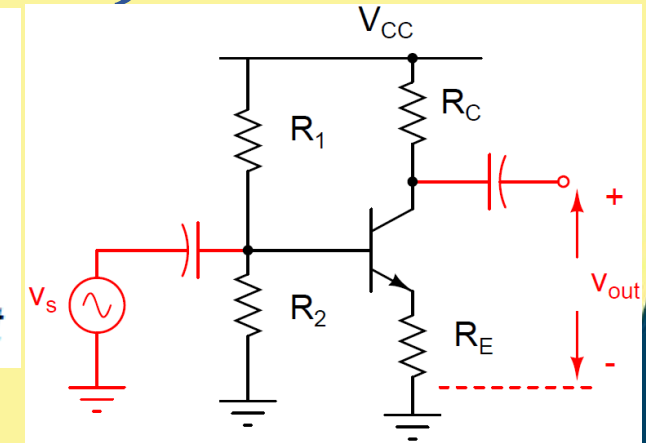
CE amplifier – Self-bias (contd.)

- **Circuit at Input port- Large signal**



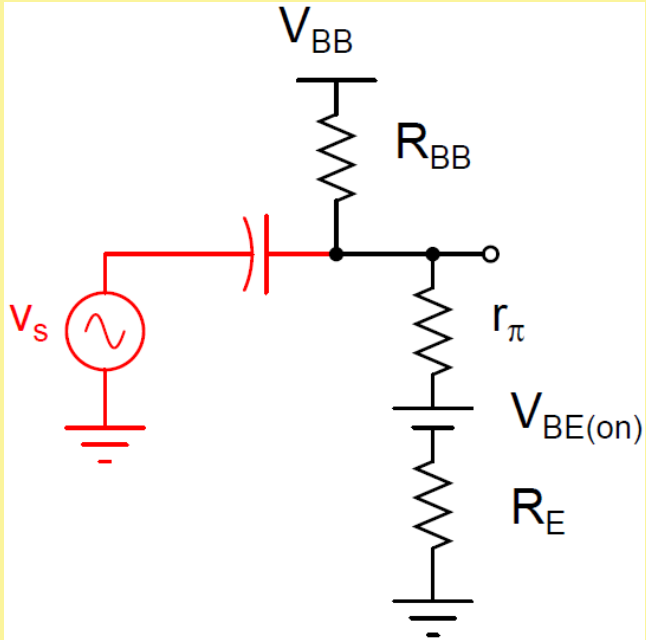
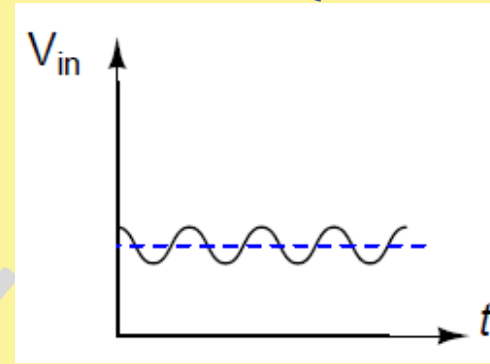
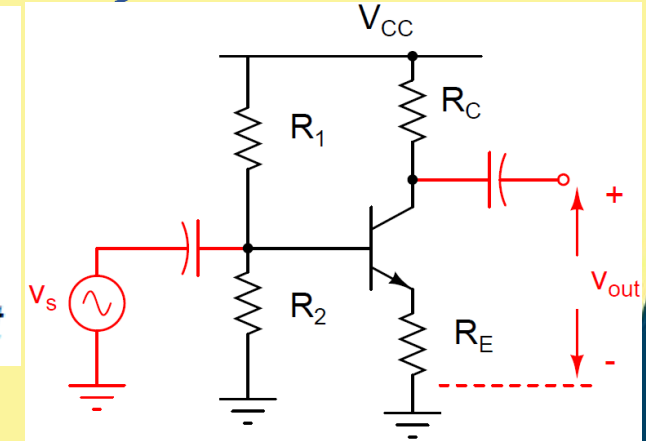
$$V_{BB} = V_{CC} \frac{R_2}{R_1 + R_2}$$

$$R_{BB} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$



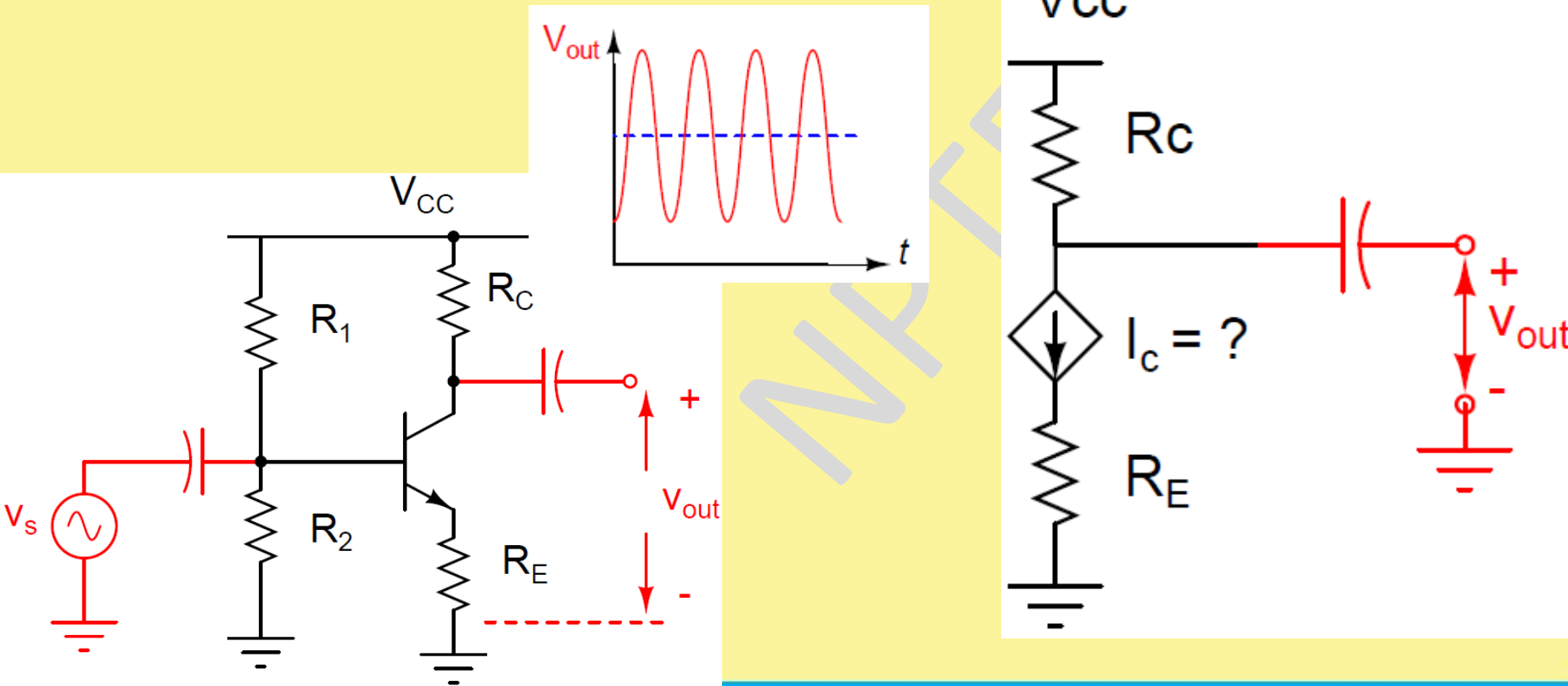
CE amplifier – Self-bias (contd.)

- **Circuit at Input port- small signal**



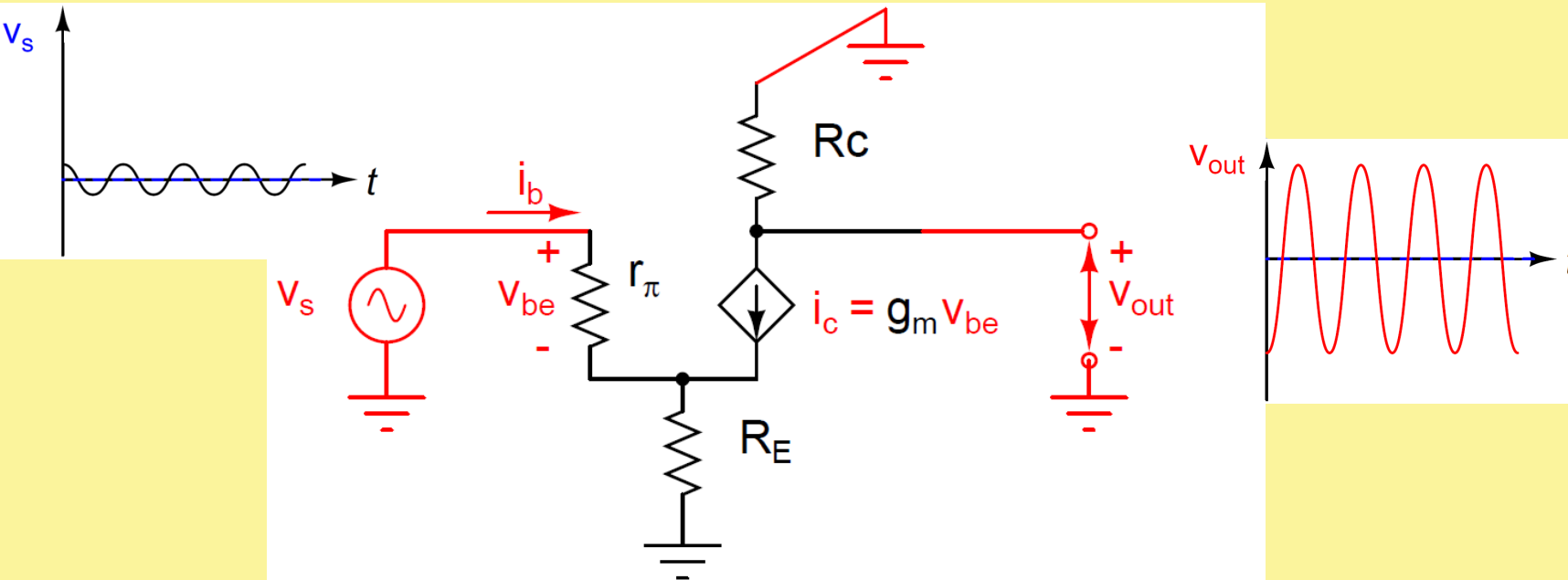
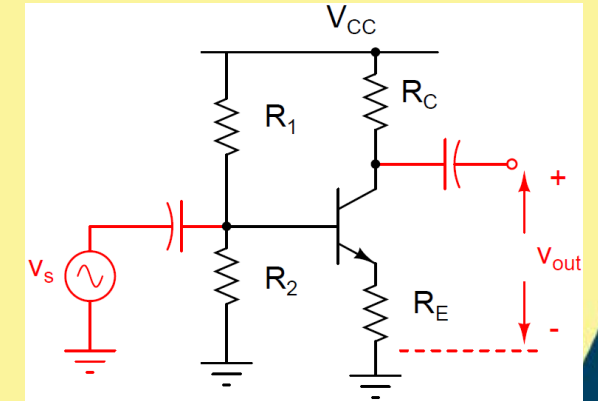
CE amplifier – Self-bias (contd..)

- **Circuit at Output port:** Large signal and small signal



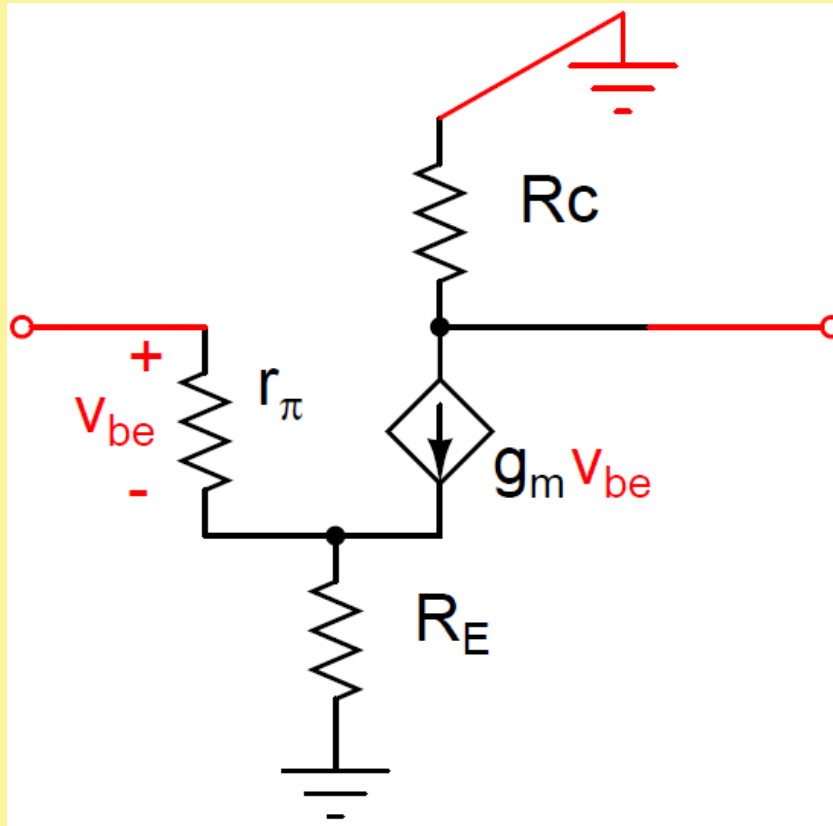
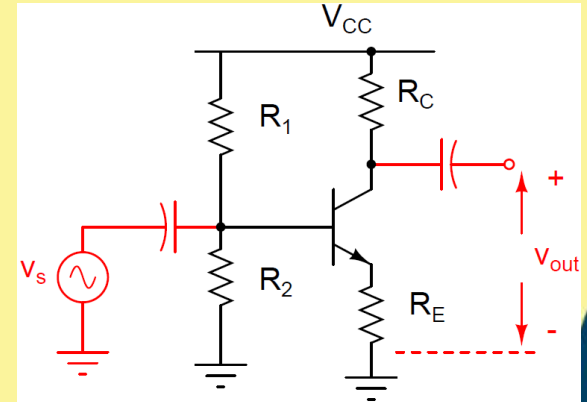
CE amplifier – Self-bias (contd...)

- **Small signal equivalent circuit and Mapping on V. Amp.**



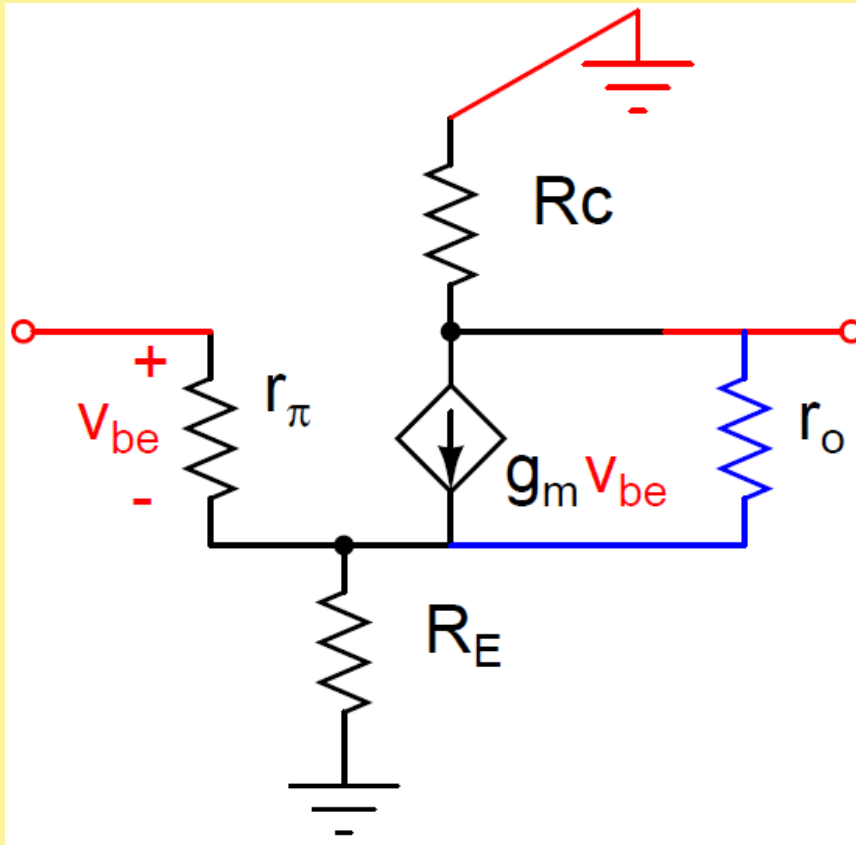
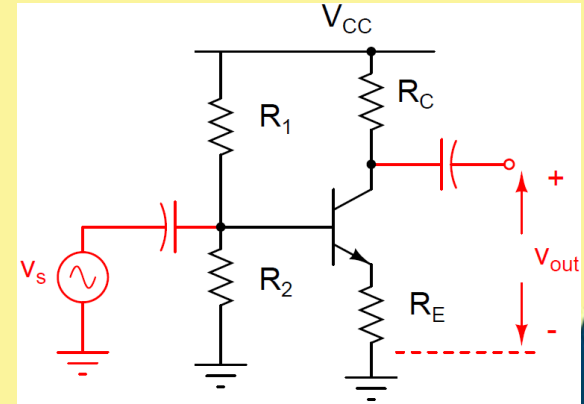
CE amplifier – Self-bias (contd...)

- Finding parameters in Voltage Amplifier



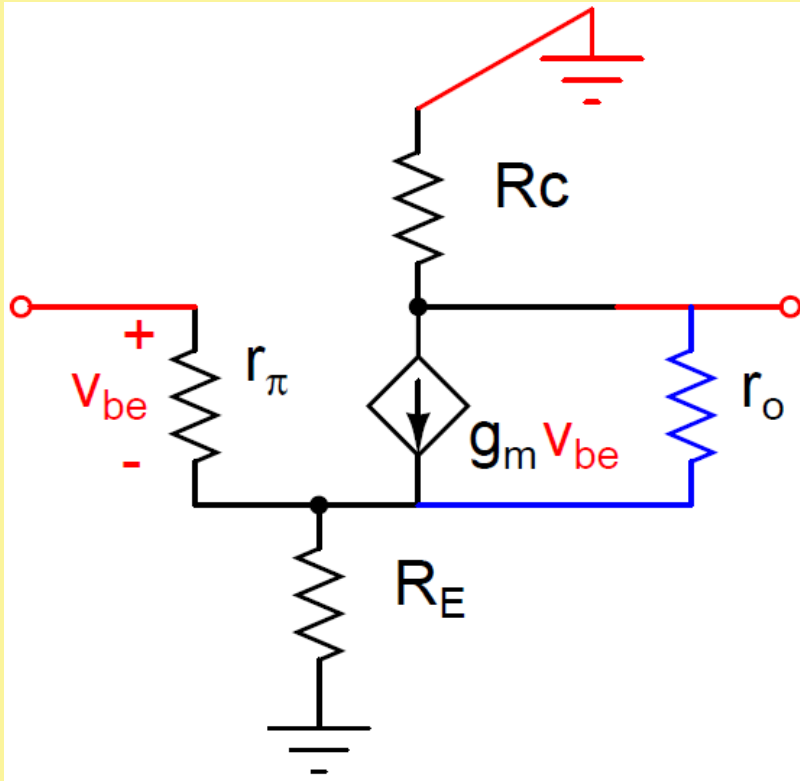
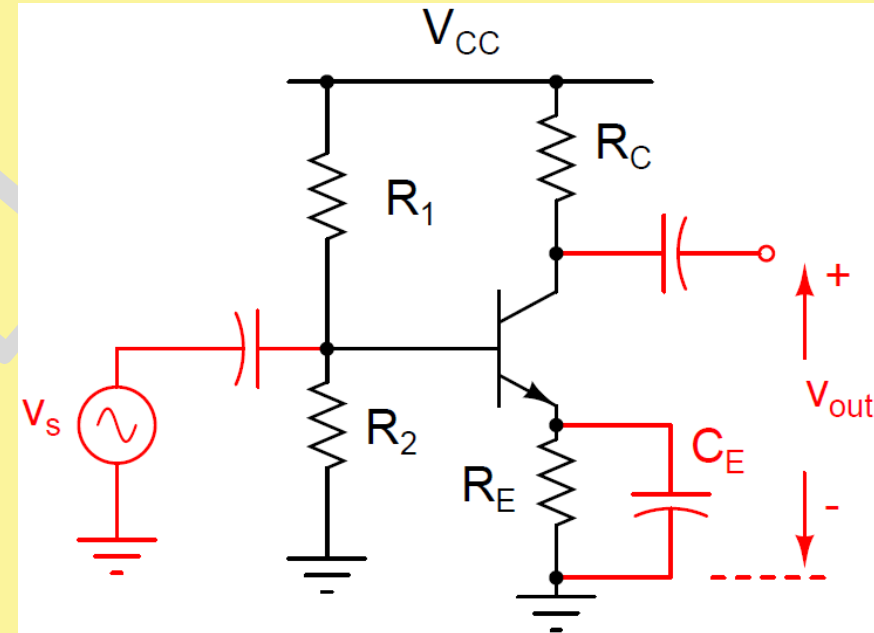
CE amplifier – Self-bias (contd...)

- Finding parameters in Voltage Amplifier considering r_o



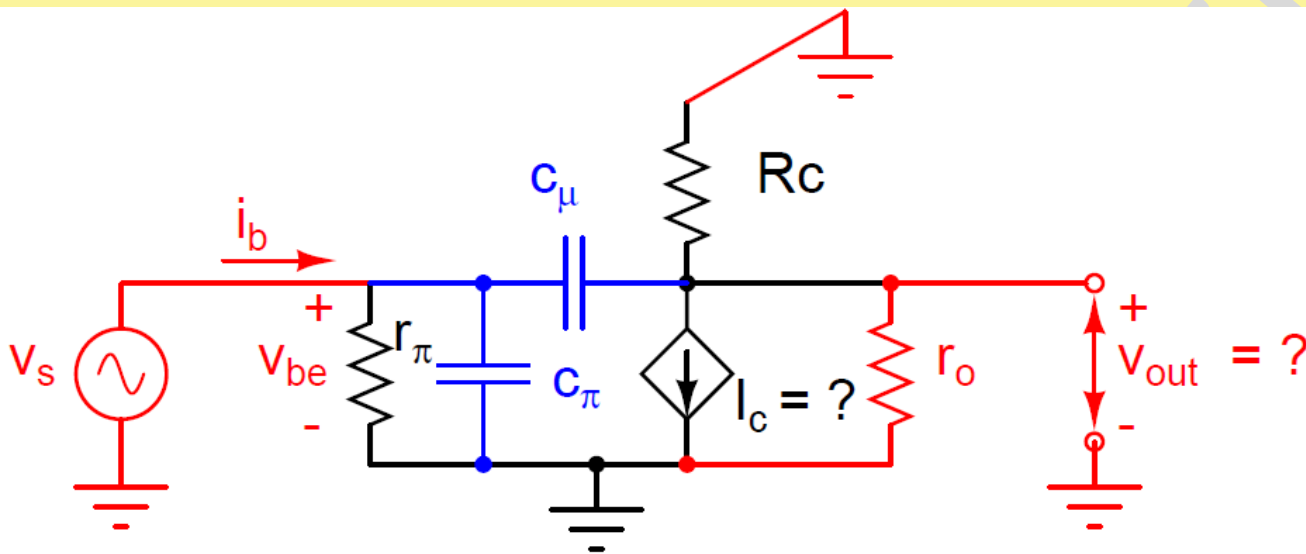
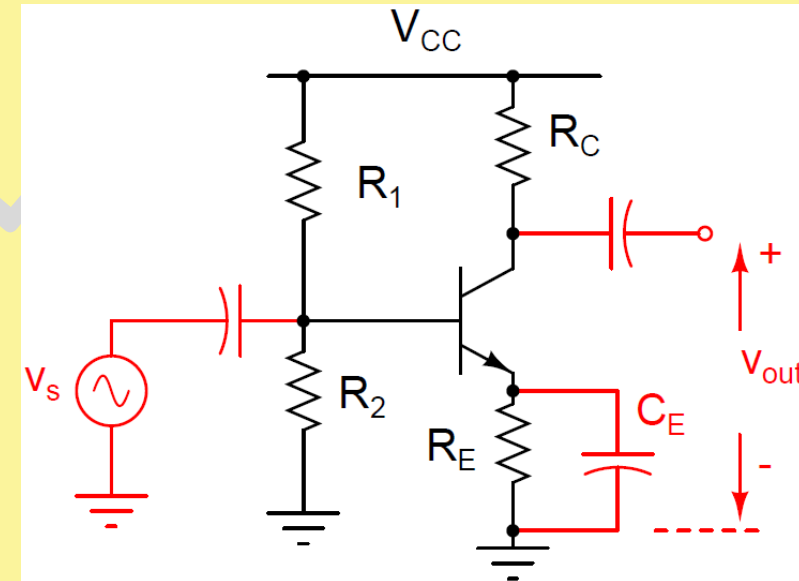
CE amplifier – Self-bias (contd...)

- Getting back high gain



CE amplifier – Fixed bias (contd...)

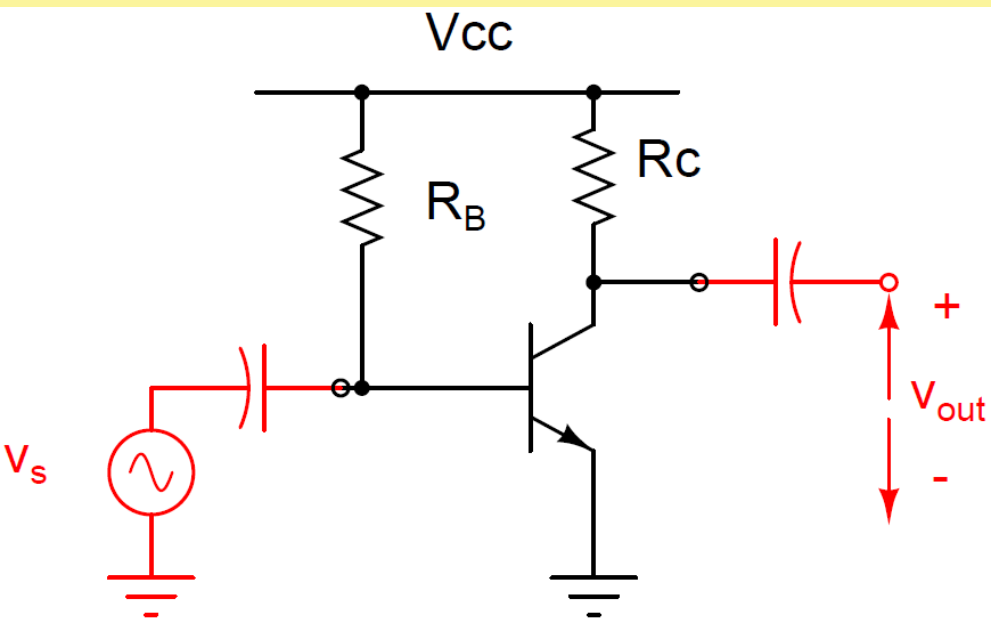
- High frequency Small signal equivalent circuits



Numerical Example: CE amplifier – Fixed-bias

• $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 3.3k\Omega$;

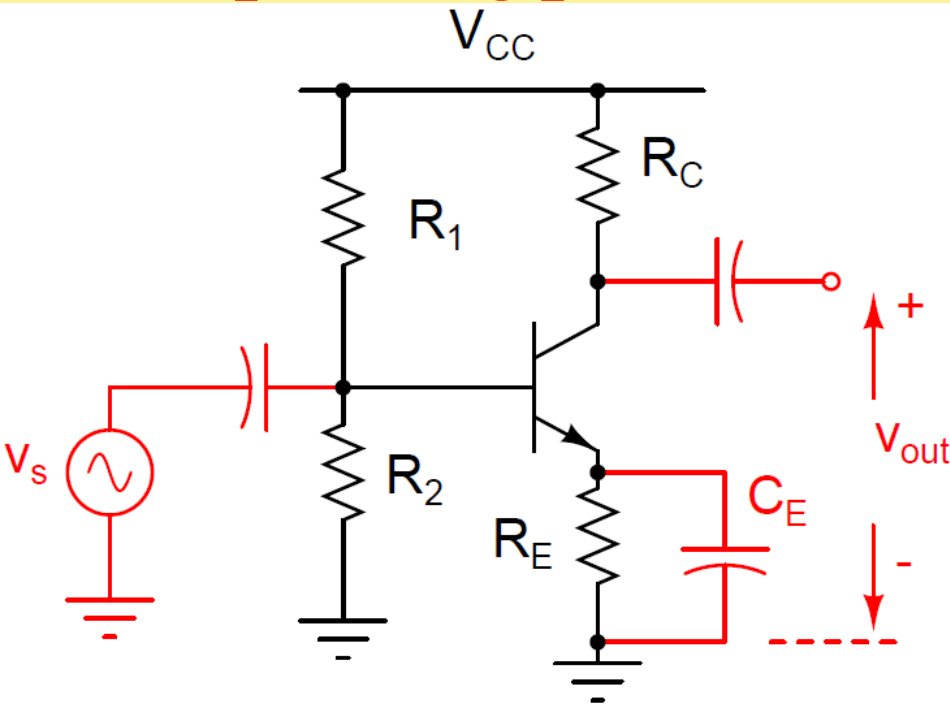
Find Operating point, small signal parameters and voltage gain



Numerical Example: CE amplifier –Self-bias

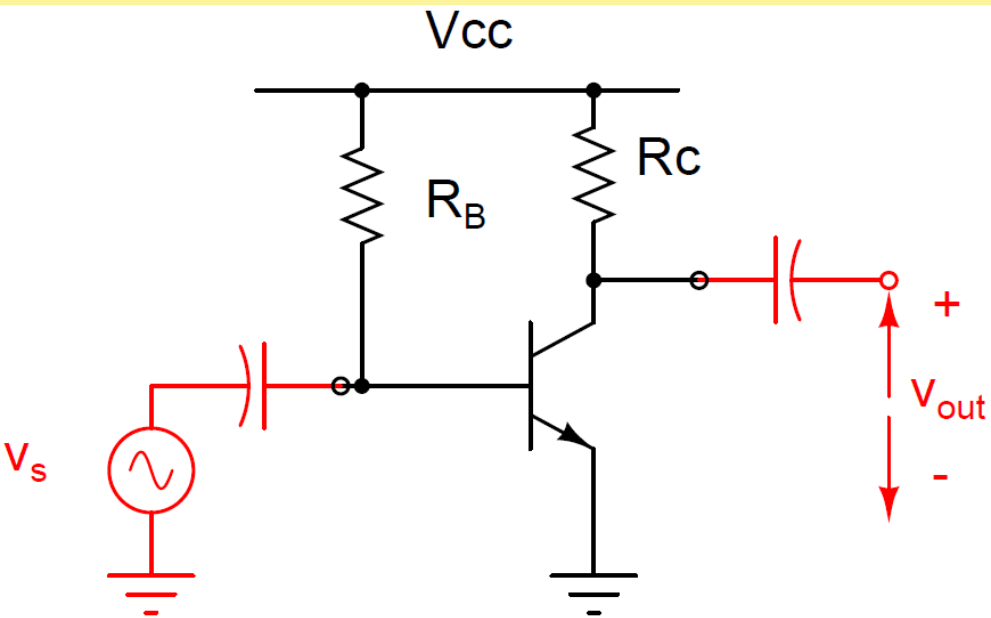
- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$; $R_1 = 9.9k\Omega$; $R_2 = 3.3k\Omega$; $R_C = 2.7k\Omega$; $R_E = 1.2k\Omega$

Find Operating point, small signal parameters and voltage gain



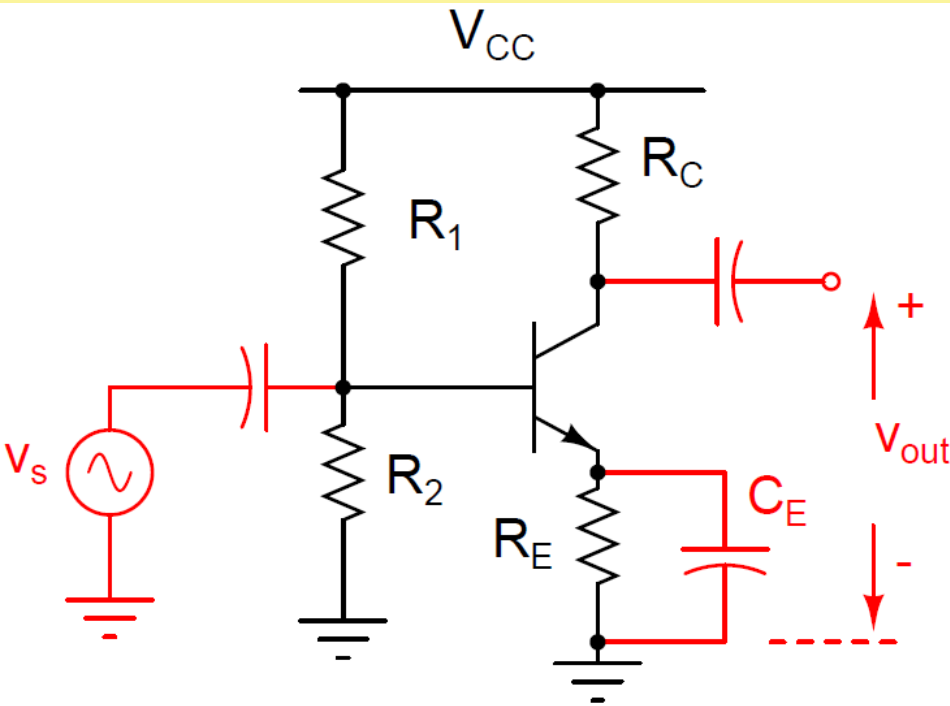
Design guidelines: CE amplifier – Fixed-bias

- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$;



Design guidelines: CE amplifier –Self-bias

- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$;



Conclusion

Conclusion:

- ❑ Self biasing stabilizes Q-pt of CE amplifier
- ❑ **Analysis:** *Operating point and Small signal*
- ❑ Methods of finding parameters in Voltage Amplifier
- ❑ Use of by-pass capacitor to get back gain
- ❑ **Numerical Examples of CE amplifier:** *Analysis and Design*





NPTEL ONLINE CERTIFICATION COURSES

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NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Common Emitter Amplifier (contd.)

– numerical examples

CONCEPTS COVERED

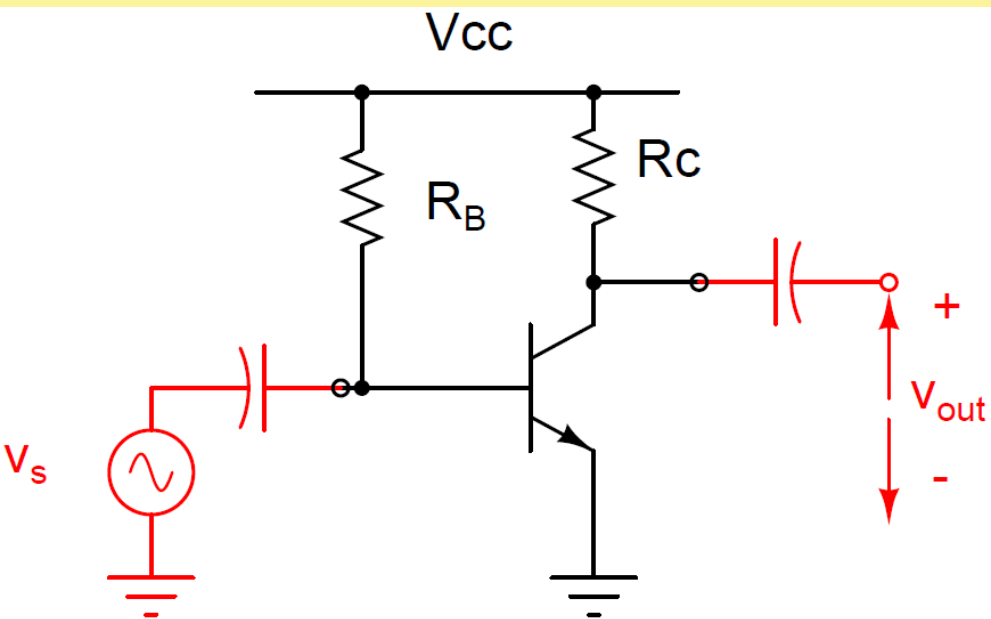
Concepts Covered:

- ❑ Fixed-biasing vs. Self biasing of CE amplifier
- ❑ **Analysis:** *Operating point and Small signal*
- ❑ Method of finding parameters in Voltage Amplifier
- ❑ **Numerical Examples:**
 - ❑ *Operating point stability*
 - ❑ *Finding performance metrics*
 - ❑ *Design guidelines*



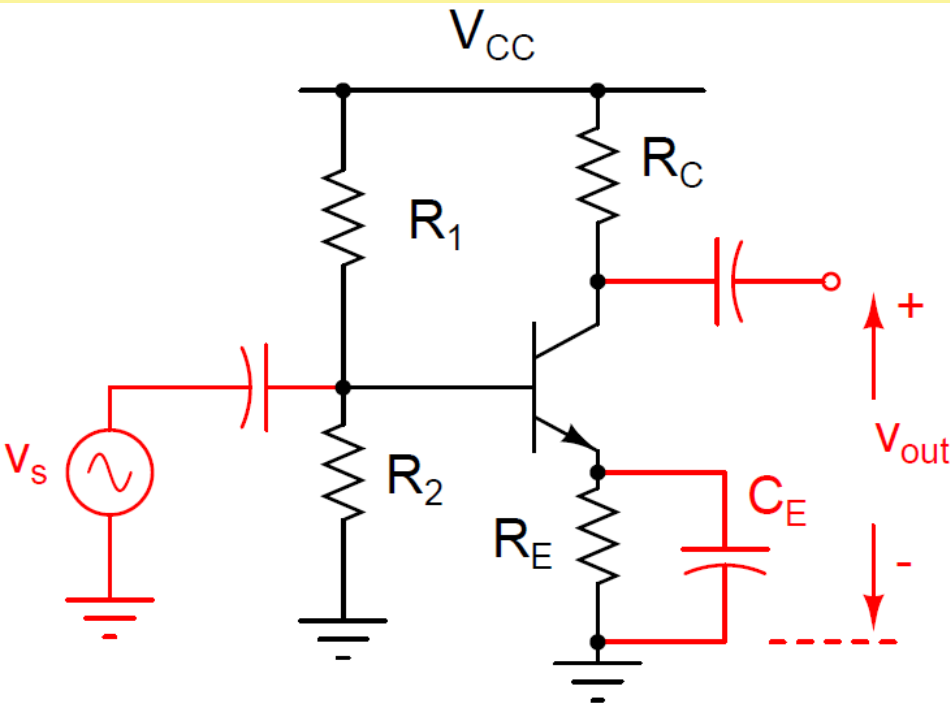
Numerical Example: CE amplifier –Fixed-bias

- $V_{CC} = 12V$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 3.3k\Omega$;
➤ Find Operating point, for $\beta = 100$ and $\beta = 200$



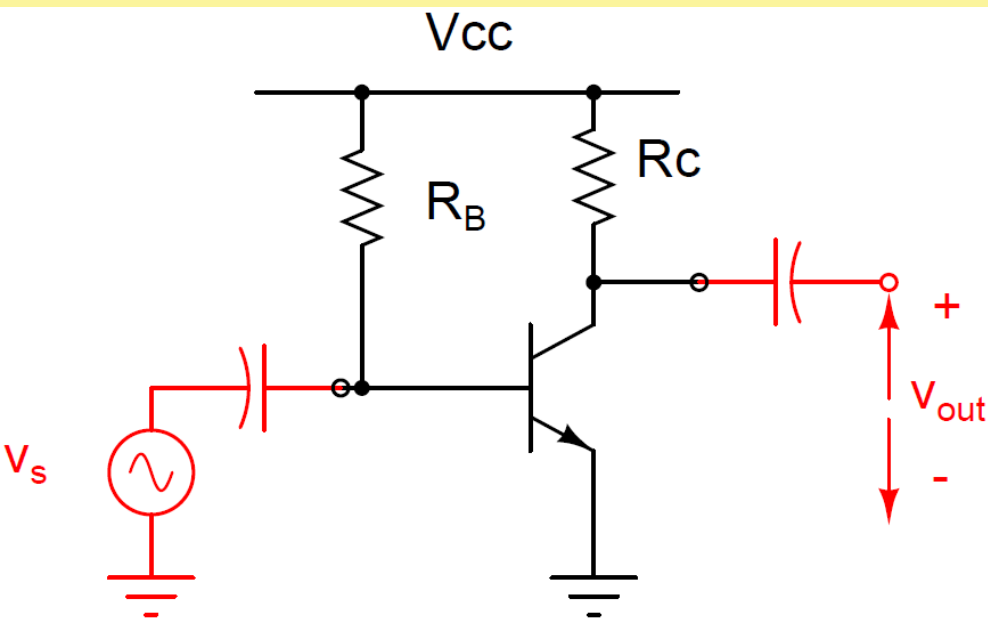
Numerical Example: CE amplifier –Self-bias

- $V_{CC} = 12V$; $V_{BE(on)} \approx 0.6V$; $R_1 = 9.9k\Omega$; $R_2 = 3.3k\Omega$; $R_C = 2.7k\Omega$; $R_E = 1.2k\Omega$
➤ Find Operating point for $\beta = 200$ and $\beta = 200$



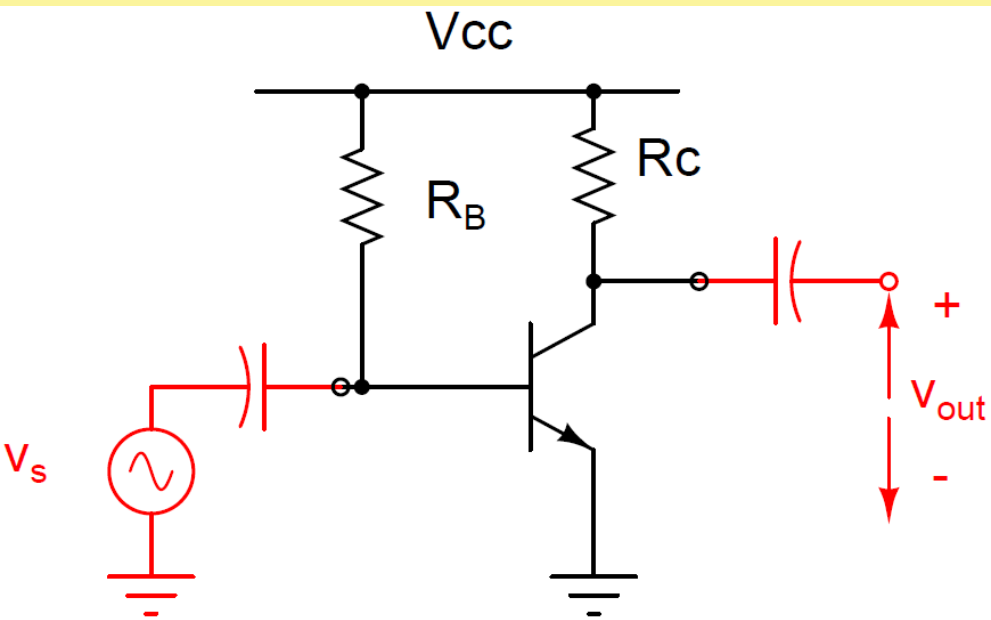
Numerical Example: CE amplifier –Fixed-bias

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



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

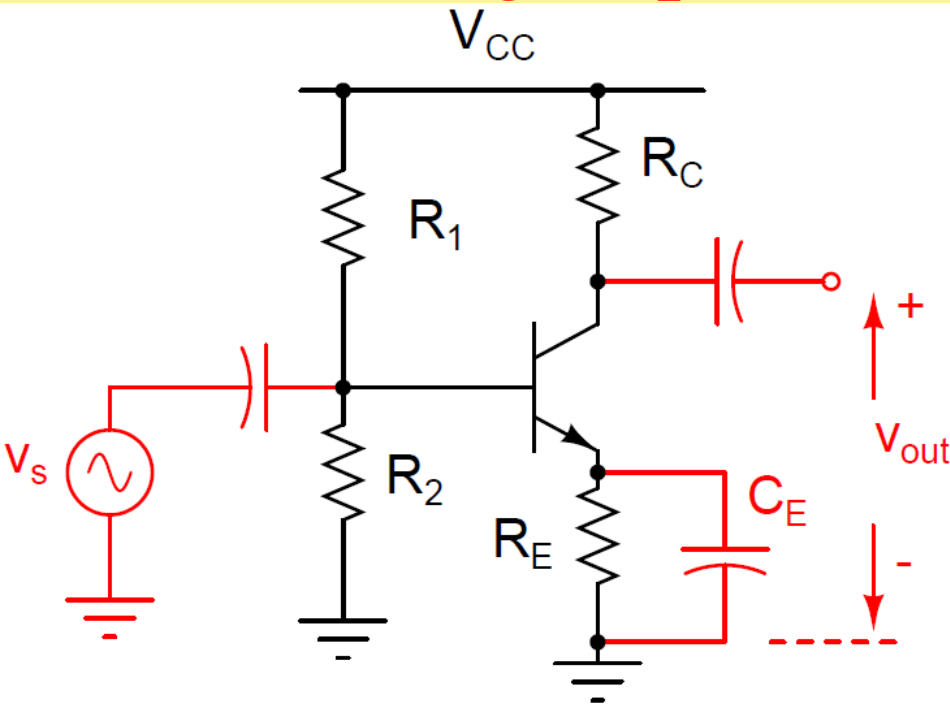
- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_B = 570k\Omega$; $R_C = 3.3k\Omega$;
 - Find Output swing (distortion free output signal) and Power dissipation
 - Comment about Cutoff frequencies



Numerical Example: CE amplifier –Self-bias

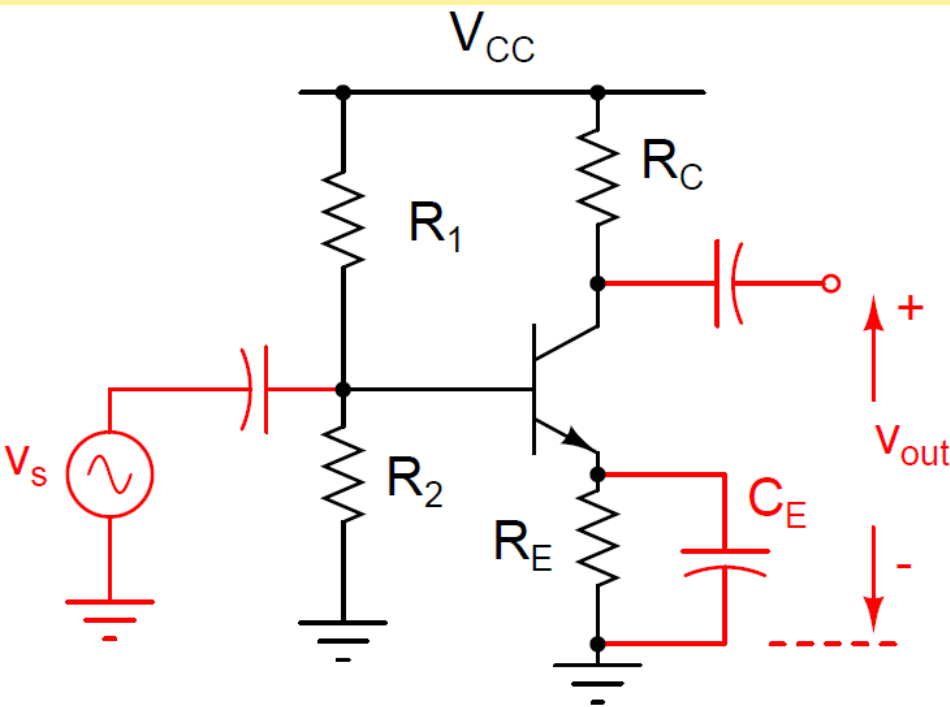
- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$; $R_1 = 9.9k\Omega$; $R_2 = 3.3k\Omega$; $R_C = 2.7k\Omega$; $R_E = 1.2k\Omega$

➤ Find small signal parameters of transistor and, voltage gain, R_{in} and R_o



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

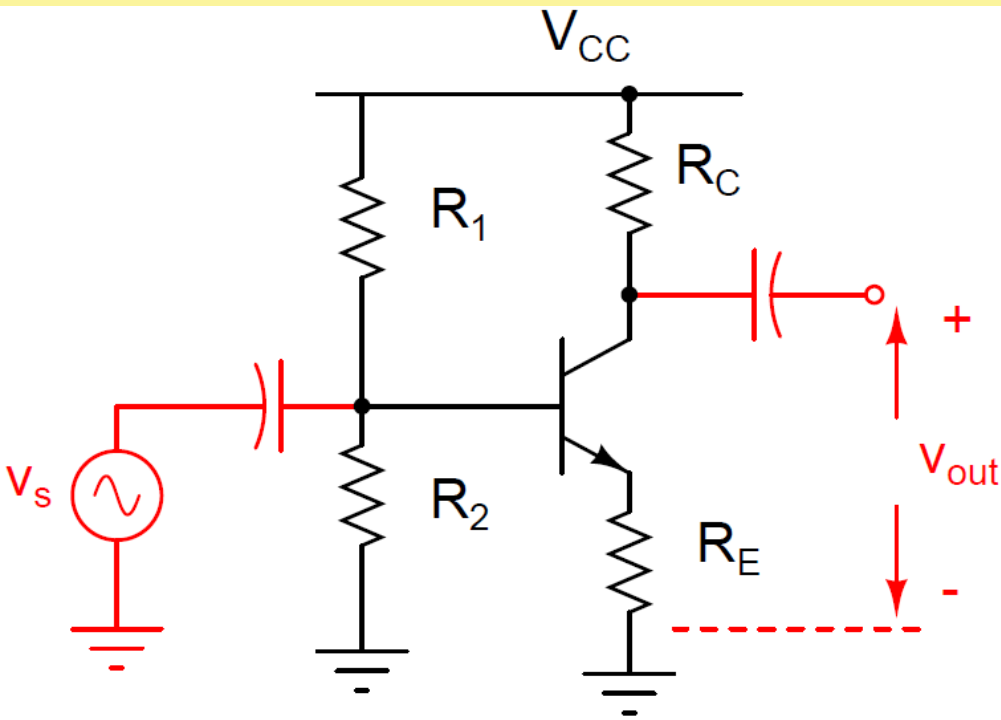
- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$; $R_1 = 9.9k\Omega$; $R_2 = 3.3k\Omega$; $R_C = 2.7k\Omega$; $R_E = 1.2k\Omega$
 - Find Output swing and Power dissipation
 - Comment about Cutoff frequencies



Numerical Example: CE amplifier –Self-bias (without CE)

- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$; $R_1 = 9.9k\Omega$; $R_2 = 3.3k\Omega$; $R_C = 2.7k\Omega$; $R_E = 1.2k\Omega$

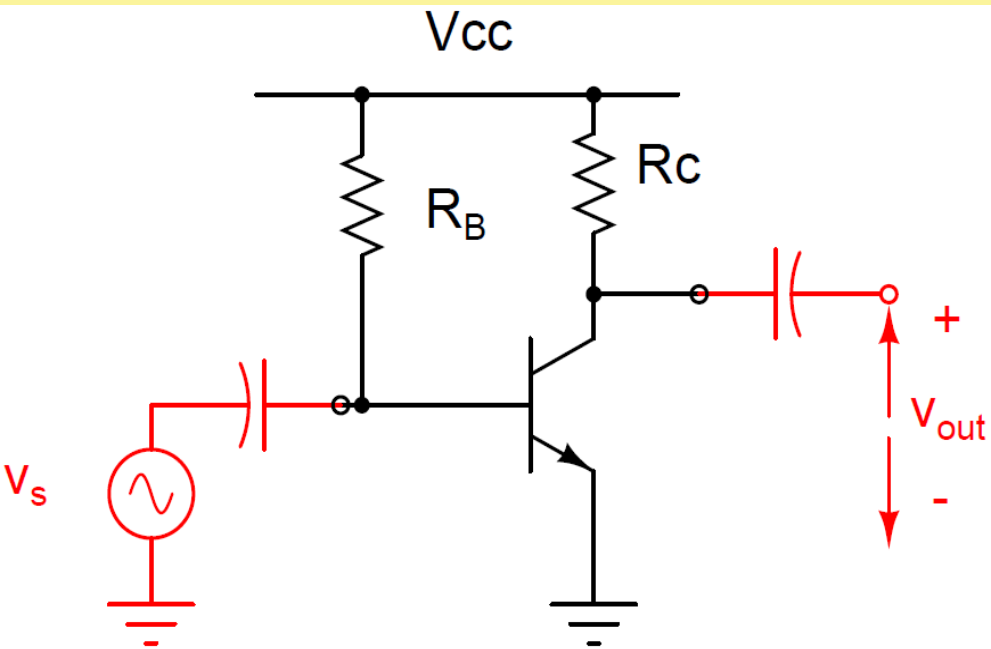
Find small signal parameters and voltage gain



Design guidelines: CE amplifier – Fixed-bias

- **Given:** $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$;
- **Find:** R_C , R_B , C_1 , C_2

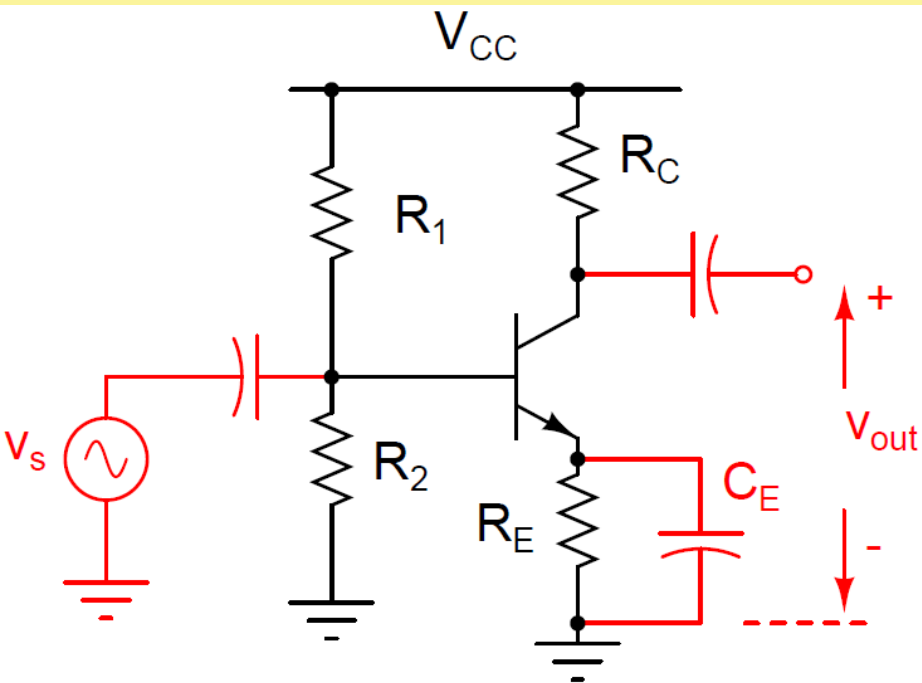
Important performance metrics: A_v , Output swing, d.c. Power, R_{in} , R_o , C_{in}



Design guidelines: CE amplifier –Self-bias

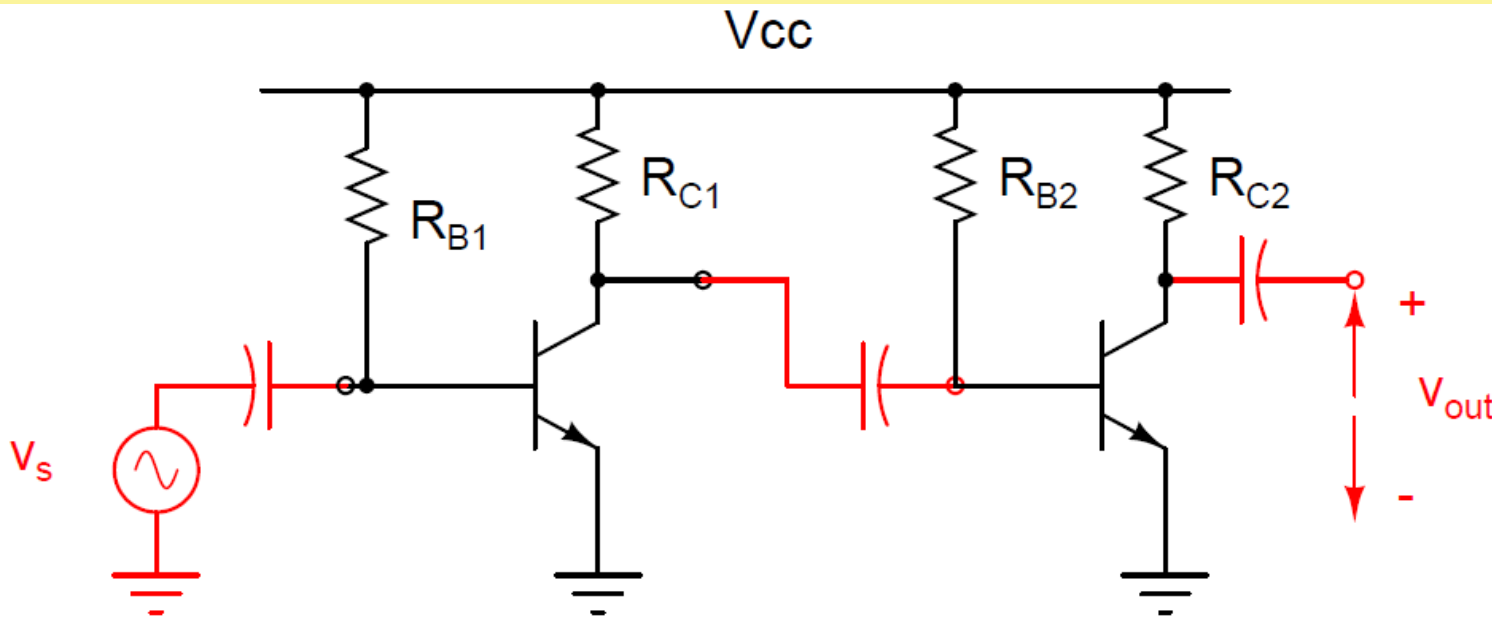
- **Given:** $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$;
- **Find:** R_C , R_1 , R_2 , R_E , C_1 , C_2 , C_E

Important performance metrics: A_v , Output swing, d.c. Power, R_{in} , R_o , C_{in}



Numerical Example: Cascaded CE amplifier

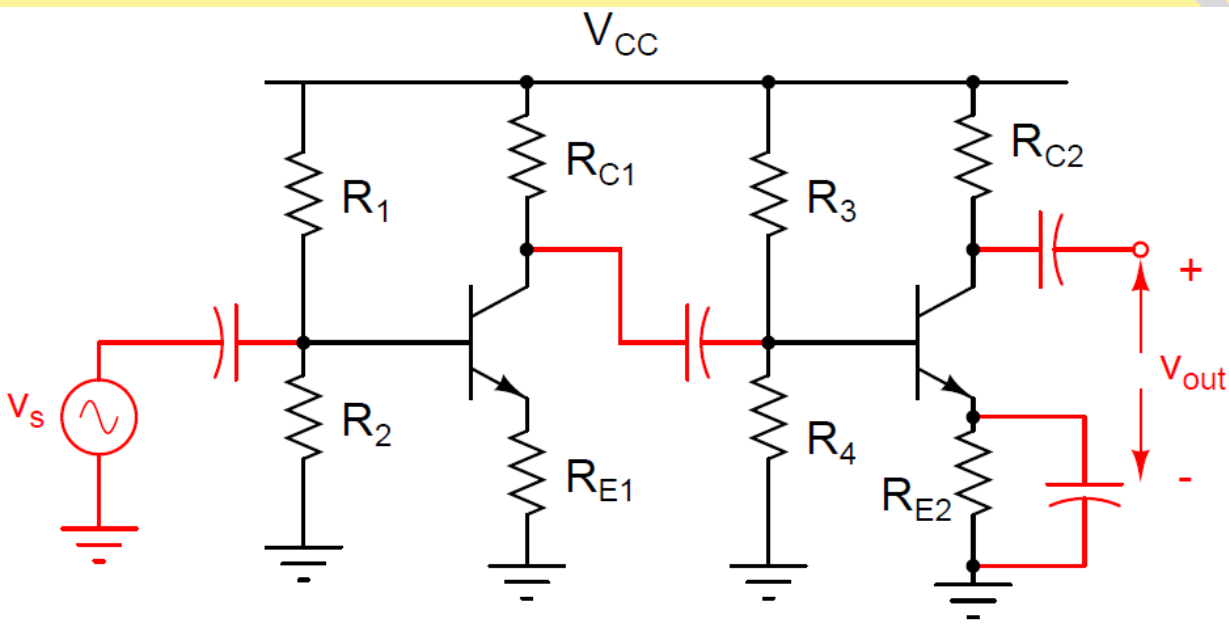
- $V_{CC} = 12V$; $\beta = 100$; $V_{BE(on)} \approx 0.6V$; $R_{B1} = R_{B2} = 570k\Omega$; $R_{C1} = R_{C2} = 3.3k\Omega$;
➤ Find over all voltage gain using A_v , R_{in} and R_o of each stages



Numerical Example: Cascaded CE amplifier (cond.)

- $V_{CC} = 12V$; $\beta = 200$; $V_{BE(on)} \approx 0.6V$; $R_1 = R_3 = 9.9k\Omega$; $R_2 = R_4 = 3.3k\Omega$; $R_{C1} = R_{C2} = 2.7k\Omega$; $R_{E1} = R_{E2} = 1.2k\Omega$

➤ Find over all voltage gain using A_v , R_{in} and R_o of each stages



Conclusion

Conclusion:

- ❑ Self biasing stabilizes Q-pt of CE amplifier
- ❑ **Analysis:** *Operating point and Small signal*
- ❑ Methods of finding parameters in Voltage Amplifier
- ❑ Use of by-pass capacitor to get back gain in self-biased CE
- ❑ **Numerical Examples of CE amplifier:** *Analysis and Design*





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NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Common Source Amplifier

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 3:**
 - **Amplifier models (equivalent circuits):**
 - voltage amplifier, current amplifier,
 - trans-conductance amplifier and trans-resistance amplifier.
 - **Cascading of multiple amplifiers.**
 - **Common emitter (CE) amplifier**
 - operating principle, biasing, analysis and design.
 - **Common source (CS) amplifier**
 - operating principle, biasing, analysis and design.



CONCEPTS COVERED

Concepts Covered:

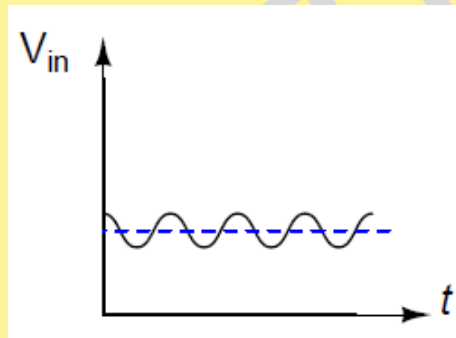
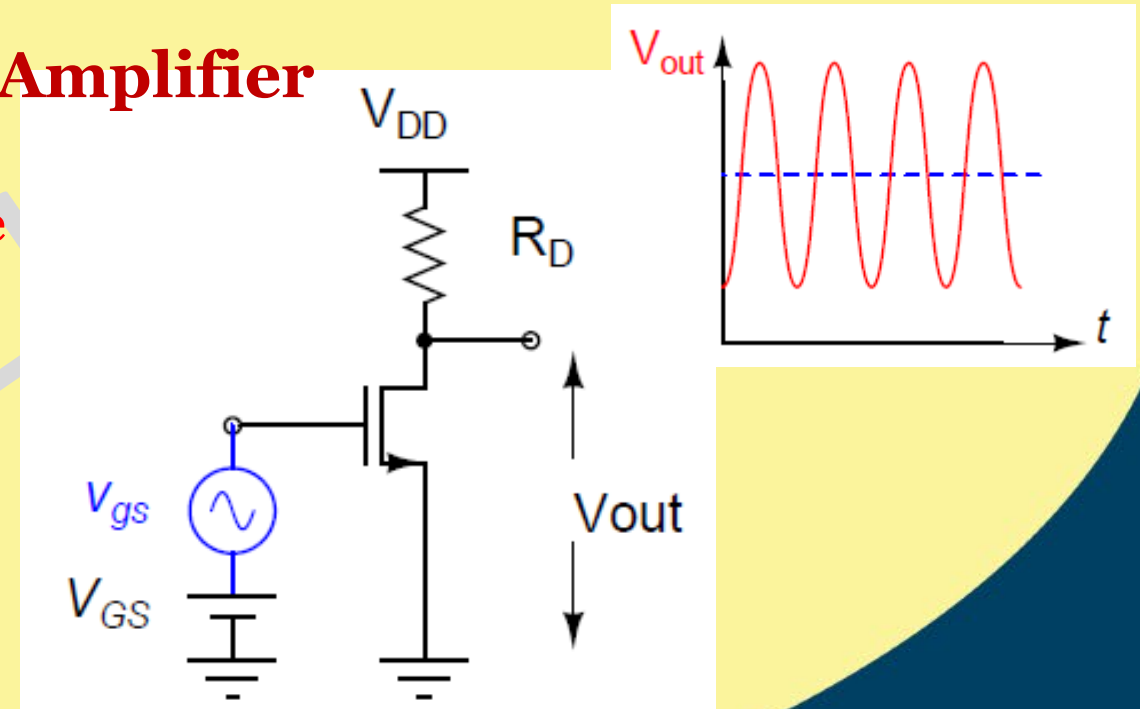
- ☐ Operating principle
- ☐ Biasing: *Voltage bias*
- ☐ Analysis: *Operating point and Small signal*
- ☐ Mapping to Voltage amplifier and Transconductance amplifier
- ☐ Numerical Exercise



Basic operation of CS amplifier

- **Normally, it is considered as a Voltage Amplifier**

- Input signal is fed at the **Gate node**
- Output signal is observed at the **Drain node**
- Both, input and output signals are voltage

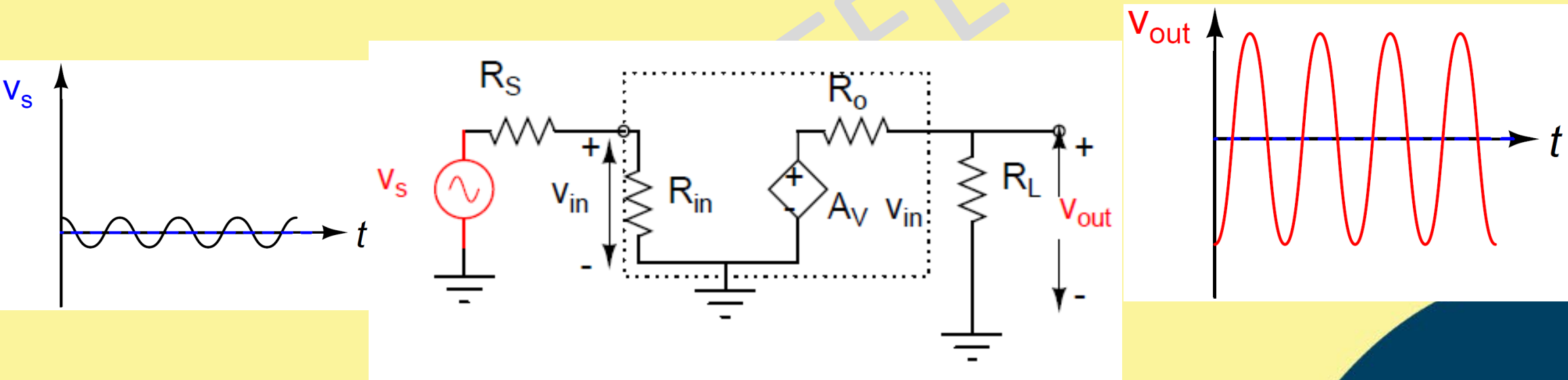


- **Voltage biasing**

- Biasing is an important aspect keeping transistor in **saturation region**
- Gate node to Source node must have a d.c. voltage
- Gate terminal has “zero” d.c. current and hence, **voltage bias**
- Drain node voltage must be sufficiently high

CS amplifier as Voltage amplifier

- Both, input and output signals are voltage
- Important parameters A_v , R_{in} and R_o are dependent on Q-point



Basic operation of CS amplifier (recollect)

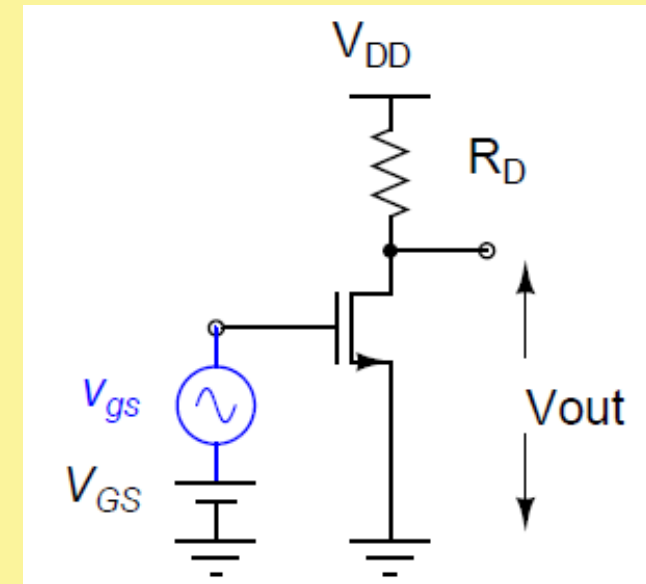
- **I_{ds}** : $I_{ds} = I_{DS} + i_{ds} = \frac{KW}{2L} (V_{GS} + v_{gs} - V_{th})^2$

- **With linear approximation :**

$$i_{ds} = \frac{K.W}{L} (V_{GS} - V_{th}) \cdot v_{gs} = \sqrt{\frac{2 \cdot I_{DS} K.W}{L}} \cdot v_{gs} = \frac{2 \cdot I_{DS}}{(V_{GS} - V_{th})} \cdot v_{gs}$$

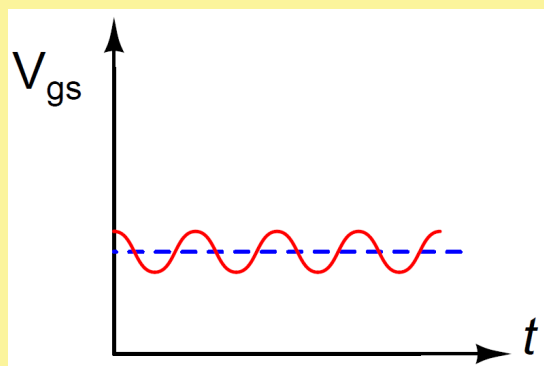
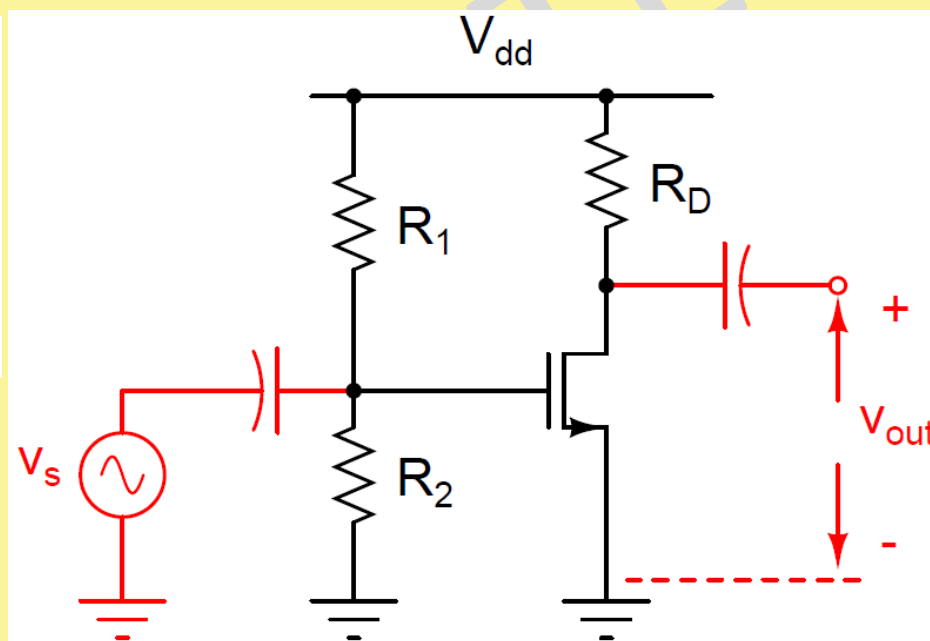
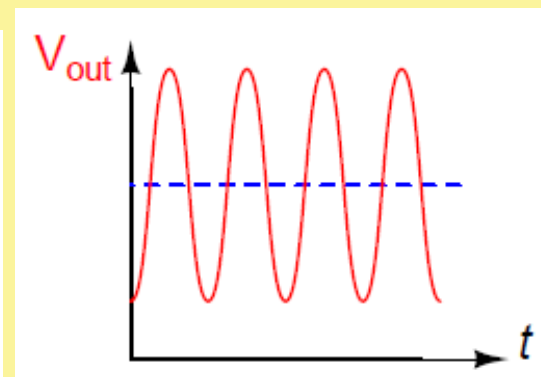
$$V_{out} = V_{DD} - R_D \cdot (I_{DS} + i_{ds})$$

$$V_{OUT} = V_{DD} - R_D \cdot I_{DS} \qquad v_{out} = -R_D \cdot \sqrt{\frac{2 \cdot I_{DS} K.W}{L}} \cdot v_{gs}$$

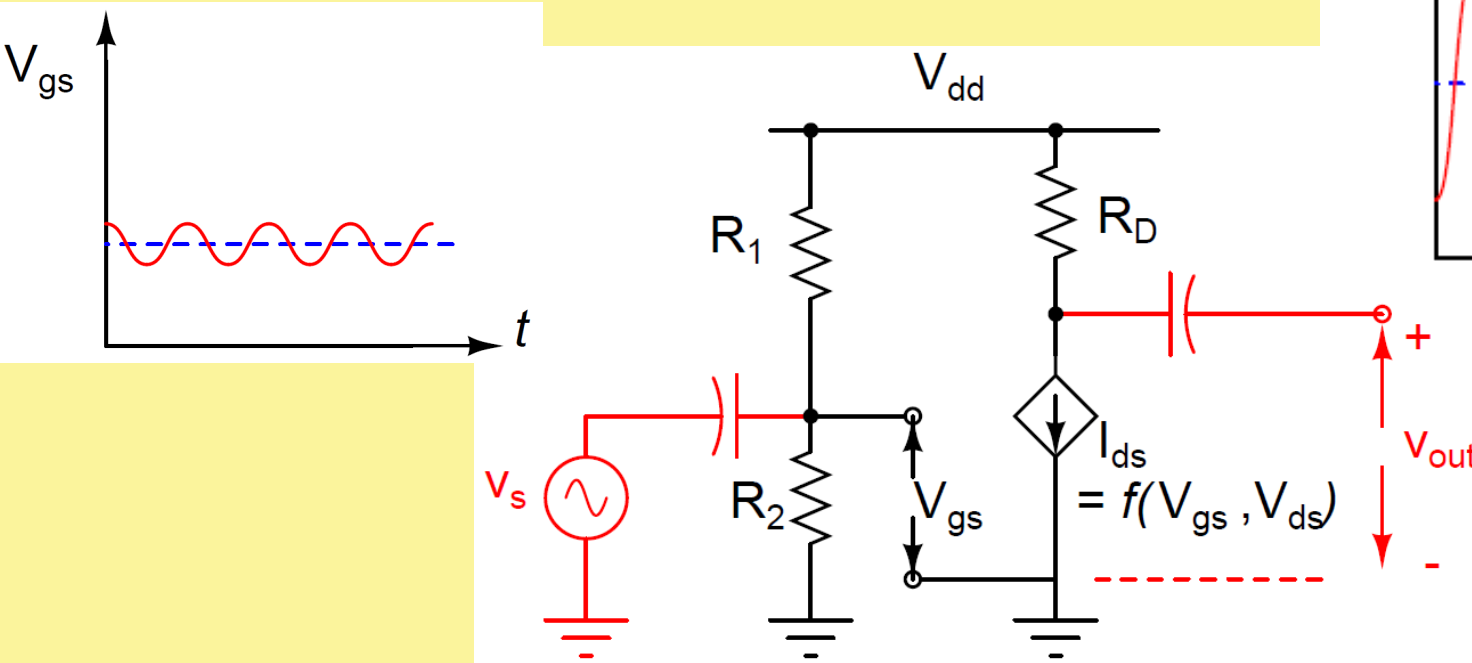
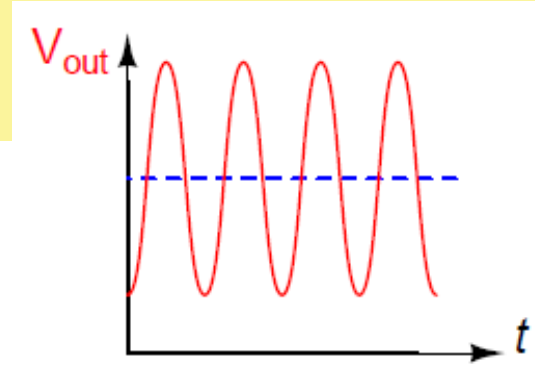
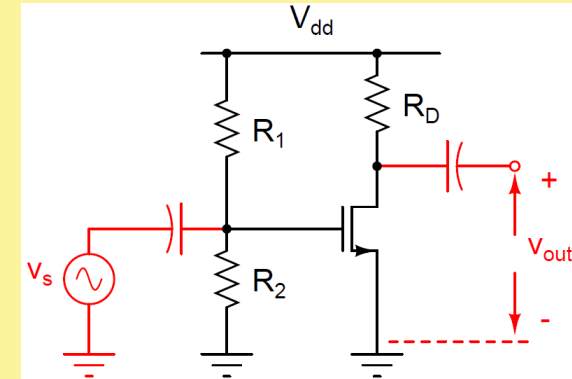


Practical circuit to bias CS amplifier

- D.C. voltage at the Gate is defined by V_{dd} , R_1 and R_2
- Capacitor at input port blocks d.c. voltage of the input signal source
- Capacitor at output port blocks the d.c. at Drain node to extract only a.c.

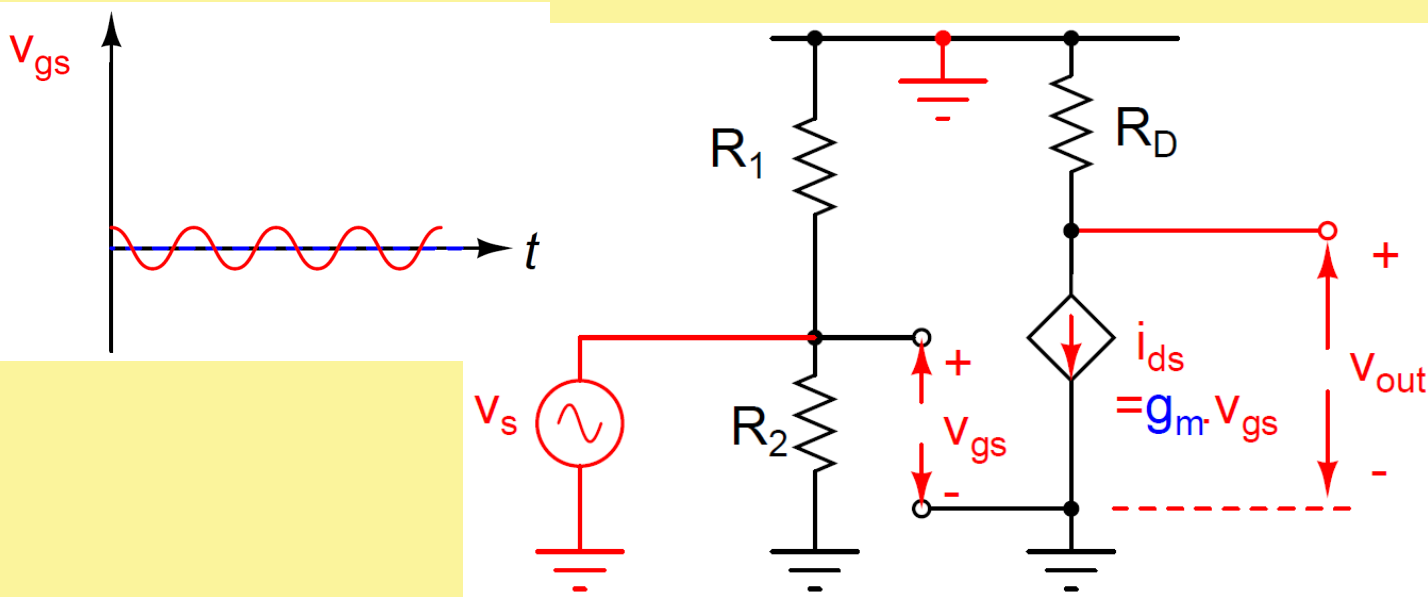
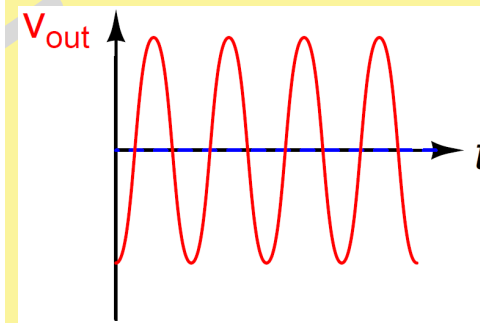
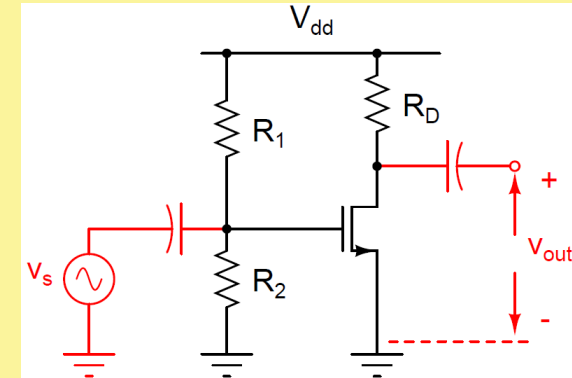


CS amplifier – Equivalent circuit for Q-pt analysis



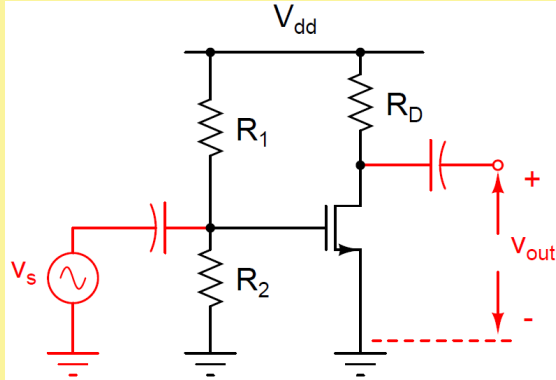
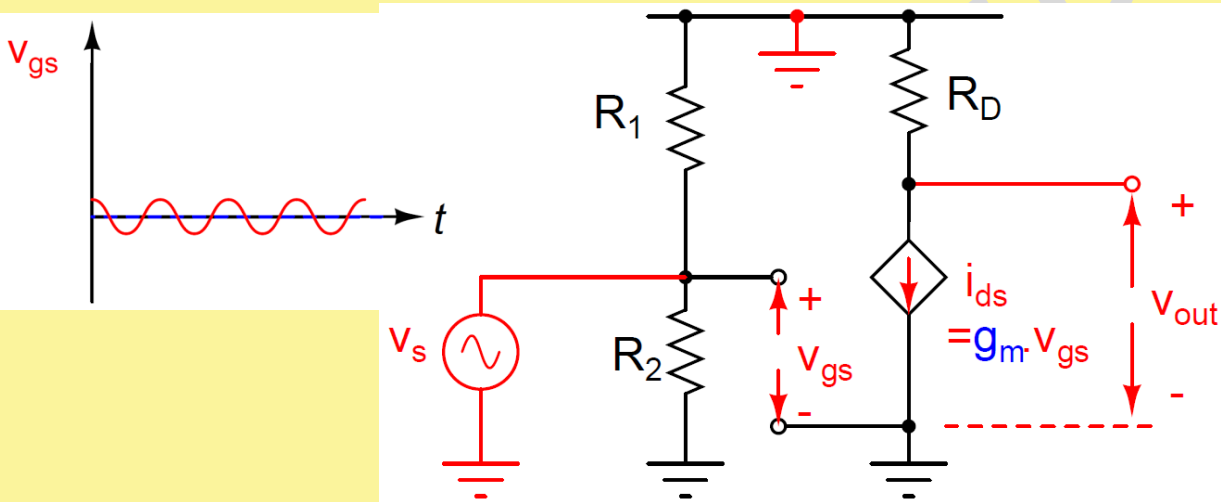
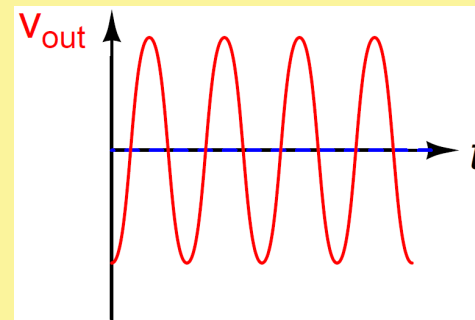
$$I_{ds} = I_{DS} + i_{ds} = \frac{KW}{2L} (V_{GS} + v_{gs} - V_{th})^2$$

CE amplifier – *Small signal equivalent circuit*



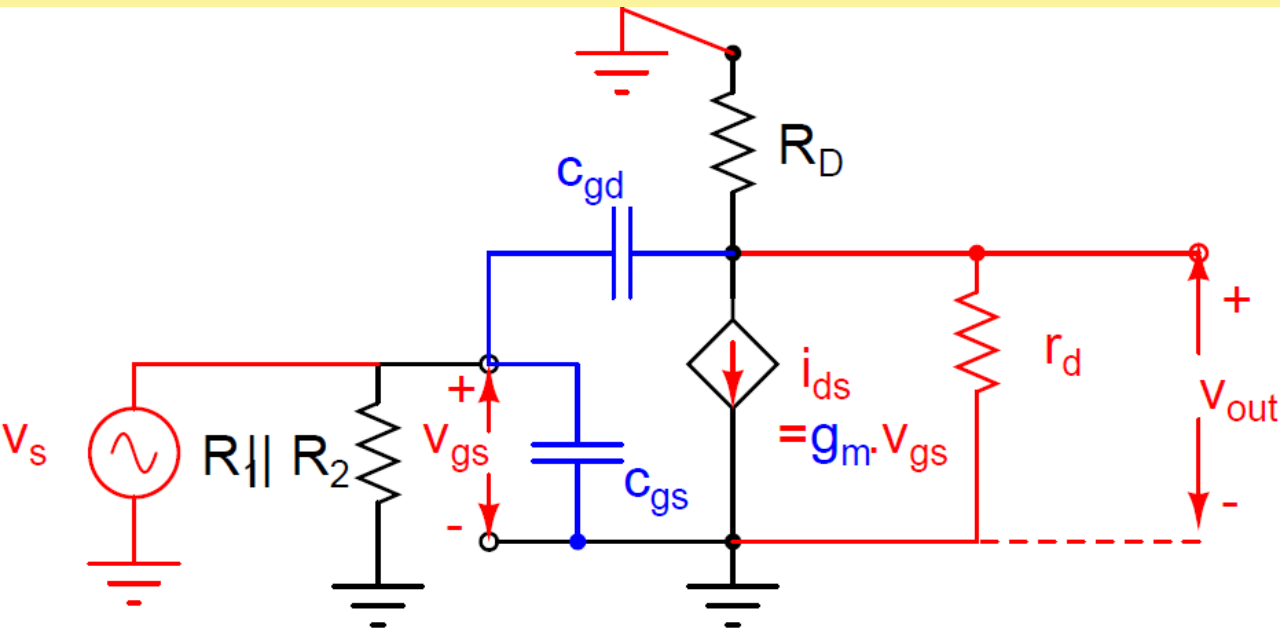
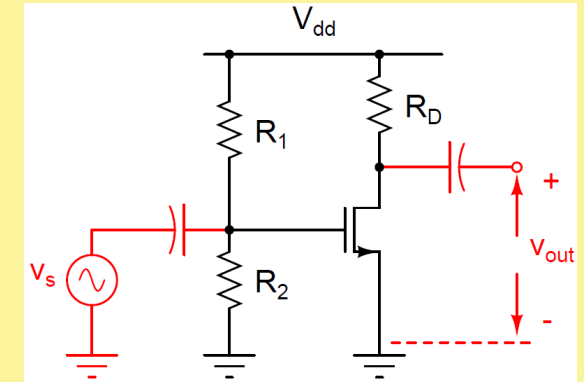
$$i_{ds} = \frac{K.W}{L} (V_{GS} - V_{th}) \cdot v_{gs} = \sqrt{\frac{2 \cdot I_{DS} K.W}{L}} \cdot v_{gs}$$

CE amplifier – Mapping to Voltage amplifier and Transconductance amplifier



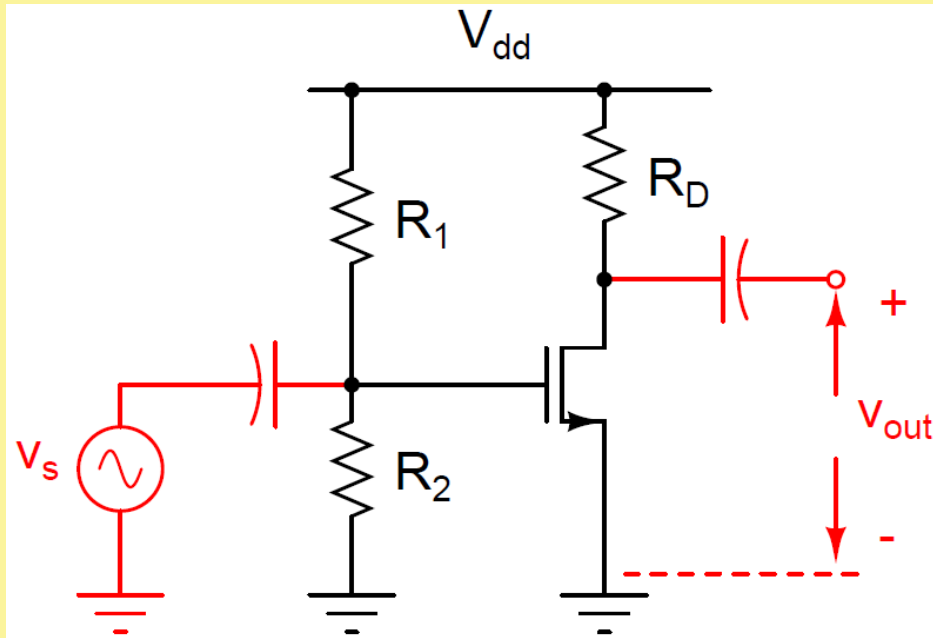
CS amplifier (Contd.)

- High frequency Small signal equivalent circuits



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



Conclusion:

- ❑ Operation of CS Amplifier
- ❑ Biasing of CS amplifier:
 - ❑ *Voltage bias*
 - ❑ *D.C. decoupling capacitors*
- ❑ Analysis CS amplifier
 - ❑ *Operating point and*
 - ❑ *Small (a.c.) signal*
- ❑ Mapping to Voltage Amp. and Transconductance Amp
- ❑ Numerical example

Conclusion





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Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Common Source Amplifier (contd.)

– numerical examples

CONCEPTS COVERED

Concepts Covered:

- ☐ Design guidelines of CS amplifier
- ☐ Numerical Exercise

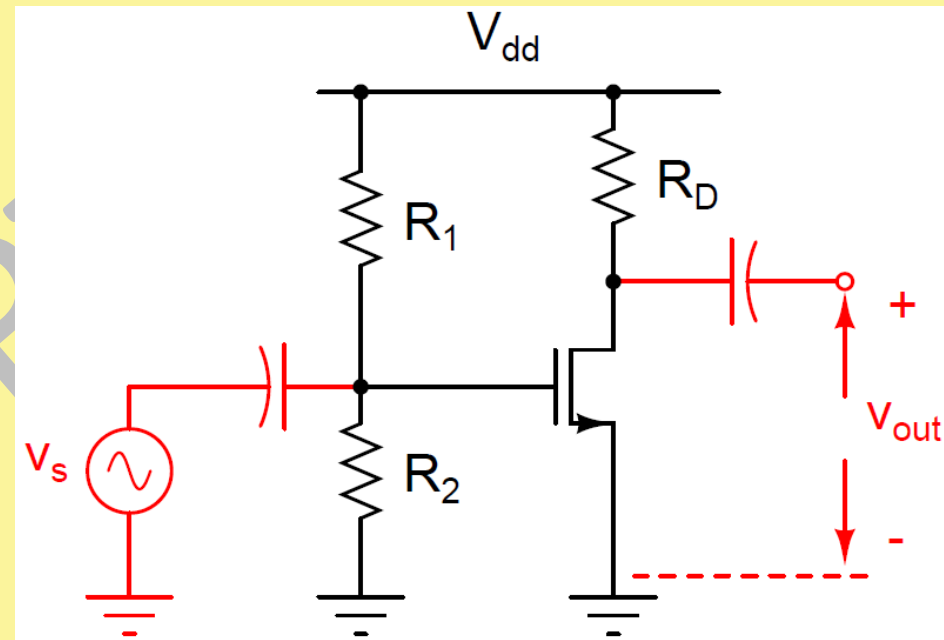


Numerical Example of CS amplifier: *Analysis*

- **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
- ✓ Input and output resistances



Design guidelines of CS amplifier

- **Given:** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$

- **Find suitable value of Resistors and Capacitors**

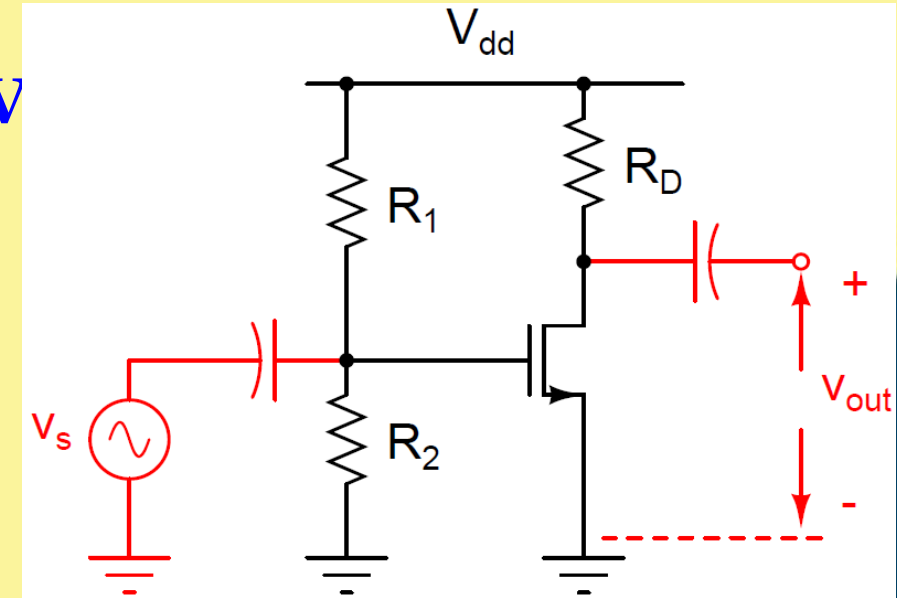
- **Output swing**

$$\leq \frac{\{V_{dd} - (V_{GS} - V_{th})\}}{2}$$

- **Voltage gain**

$$g_m \cdot R_D = \frac{2 I_{DS} \cdot R_D}{(V_{GS} - V_{th})}$$

Start with I_{DS} and then $(V_{GS} - V_{th})$



Design guidelines of CS amplifier (contd.)

- **Given:** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$,

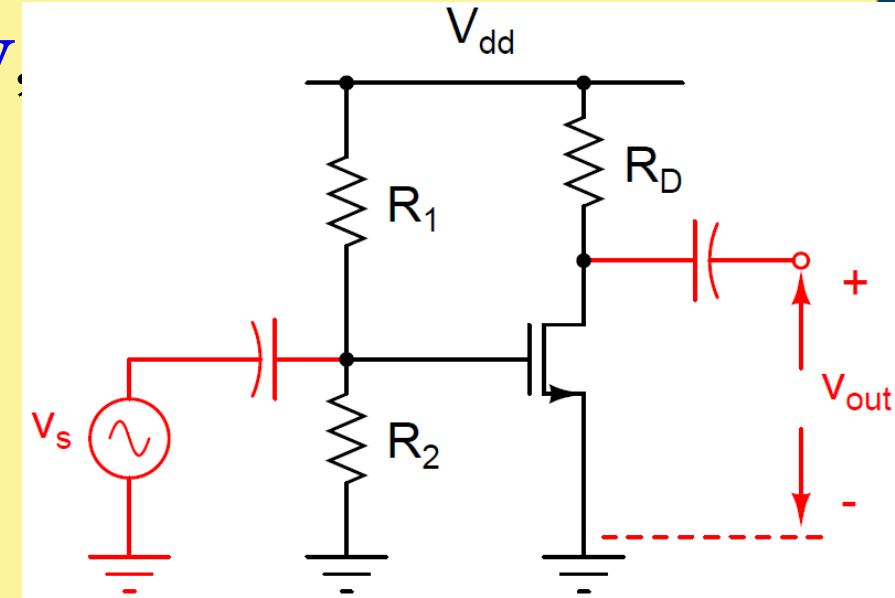
Start with **$I_{DS} = 0.5\text{ mA}$** :

$$V_{GS} = V_{th} + \Delta_{GS} =$$

$$V_{GS} = V_{dd} \frac{R_2}{\{R_1 + R_2\}}$$

$$I_{bias} = \frac{V_{dd}}{\{R_1 + R_2\}} = 0.1 \times I_{DS}$$

- **Values of R_1 and R_2 :**



Design guidelines of CS amplifier (contd.)

- **Given:** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$,

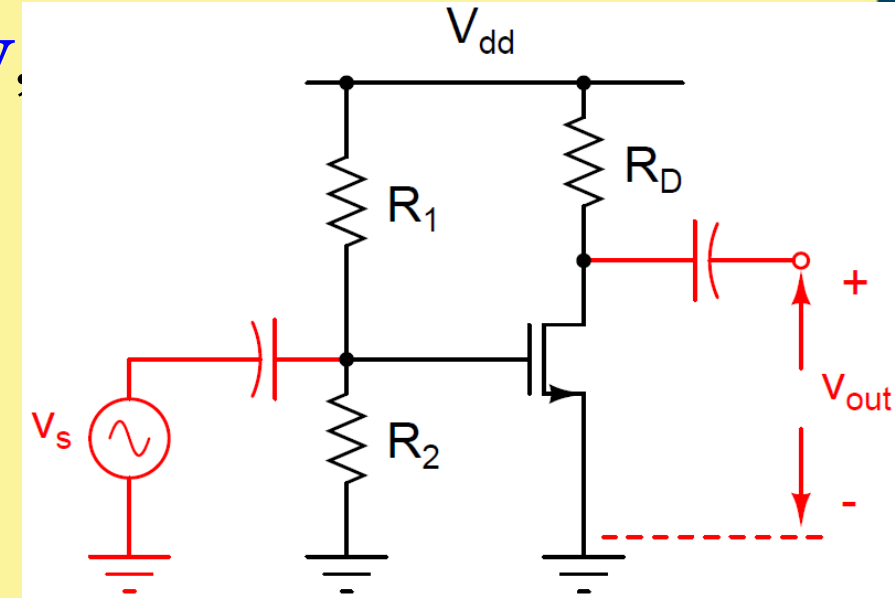
With $I_{DS} = 0.5\text{ mA}$:

$$V_{GS} = 2\text{V}$$

- **Maximum Output swing**

$$R_D = \frac{\{V_{dd} - (V_{GS} - V_{th})\}}{2 \cdot I_{DS}}$$

- **Value of R_D :**



Design guidelines of CS amplifier (contd.)

- **Given:** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$.

With $I_{DS} = 0.5\text{ mA}$:

Performance of the amplifier:

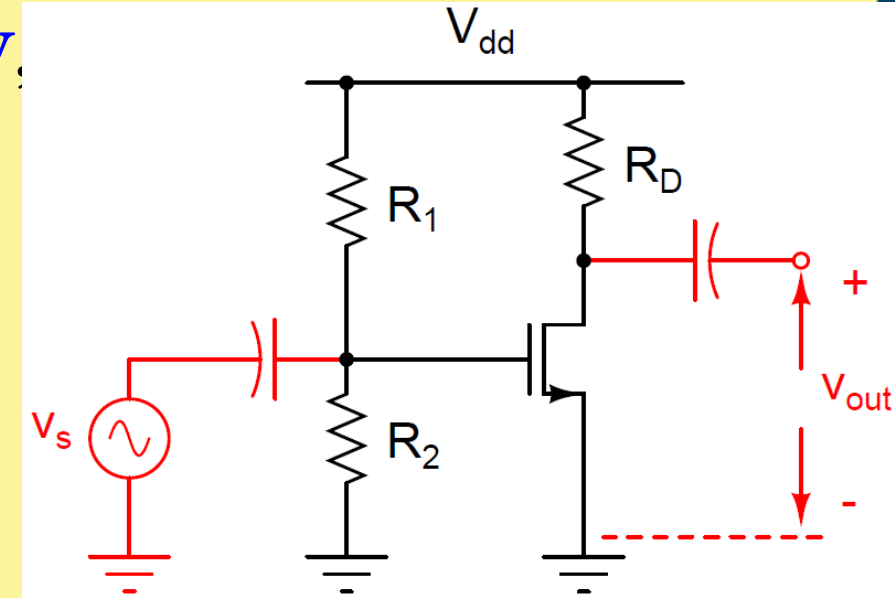
- **Output swing :**

$$\frac{\{V_{dd} - (V_{GS} - V_{th})\}}{2}$$

- **Voltage gain:**

$$g_m \cdot R_D = \frac{2 I_{DS} \cdot R_D}{(V_{GS} - V_{th})}$$

- **Input and Output resistances:**



Design guidelines of CS amplifier (contd.)

- **Given:** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$,

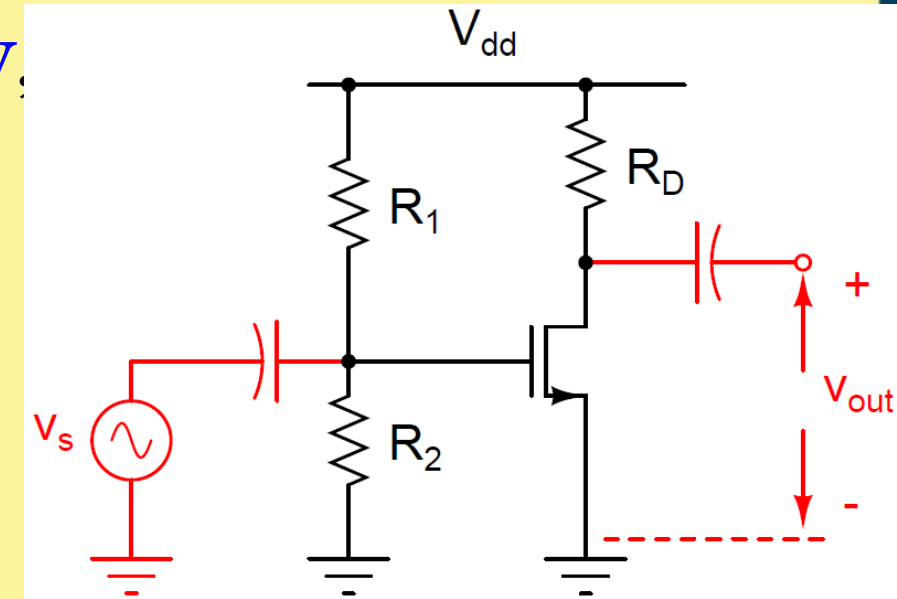
Start with **$I_{DS} = 2\text{mA}$** :

$$V_{GS} = V_{th} + \Delta_{GS} =$$

$$V_{GS} = V_{dd} \frac{R_2}{\{R_1 + R_2\}}$$

$$I_{bias} = \frac{V_{dd}}{\{R_1 + R_2\}} = 0.1 \times I_{DS}$$

- **Values of R_1 and R_2 :**



Design guidelines of CS amplifier (contd.)

- **Given:** $(K.W/L) = 1\text{mA/V}^2$; $V_{th} = 1\text{V}$, $V_{dd} = 12\text{V}$,

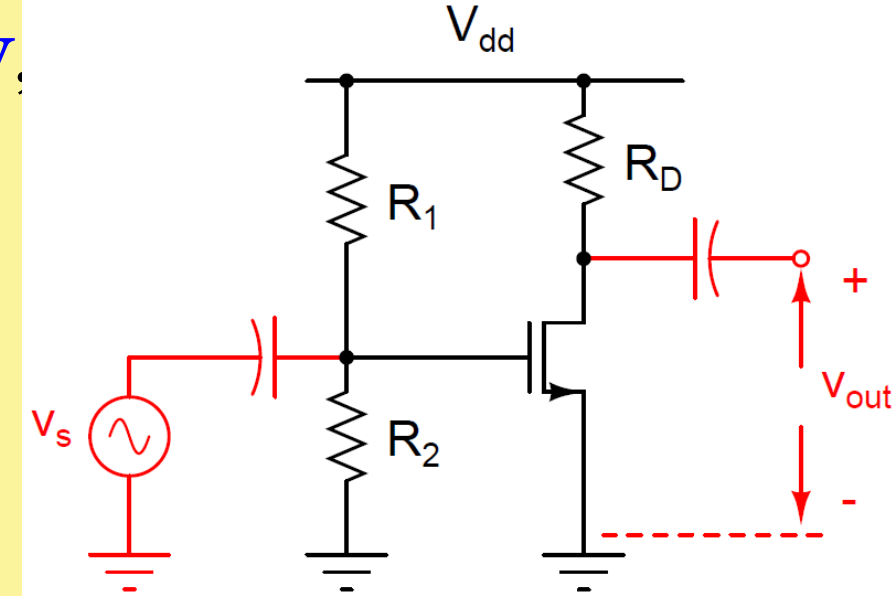
With $I_{DS} = 2\text{ mA}$:

$$V_{GS} = 3\text{V}$$

- **Maximum Output swing**

$$R_D = \frac{\{V_{dd} - (V_{GS} - V_{th})\}}{2 \cdot I_{DS}}$$

- **Value of R_D :**



Conclusion:

❑ From Device parameters and supply voltage we obtain values of different resistors in CS amplifier

❑ Discussed through Numerical Exercise

Conclusion





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