



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

***Single-ended vs. Differential signaling and
Basic model of a differential amplifier***

Flow of Discussion (Bottom-up) - Modules

- **System/Sub-systems** (*for specific application*)

- **Modules** (*performing specific tasks*)

- **Building blocks** (*having specific characteristics*)

- **Components** (*devices/circuit elements*)

- **Week 7:**

- **Single-ended signaling vs. differential signaling**

- **Basic model of Differential amplifier**

- **Differential amplifier:**

- Basic structure and principle of operation,
- analysis for differential mode gain, common mode gain,
- ICMR and output swing



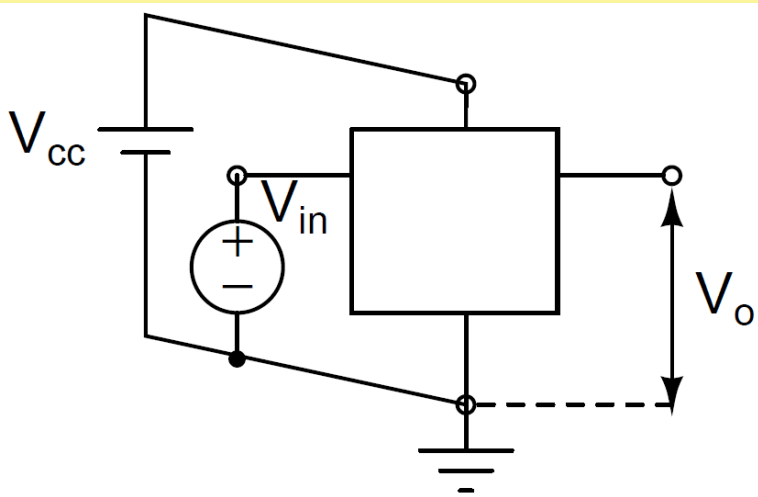
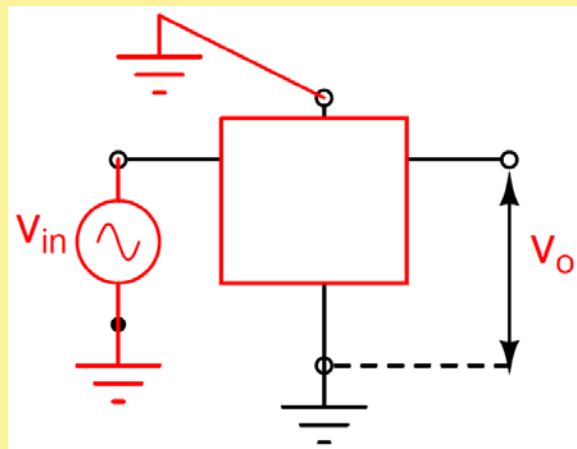
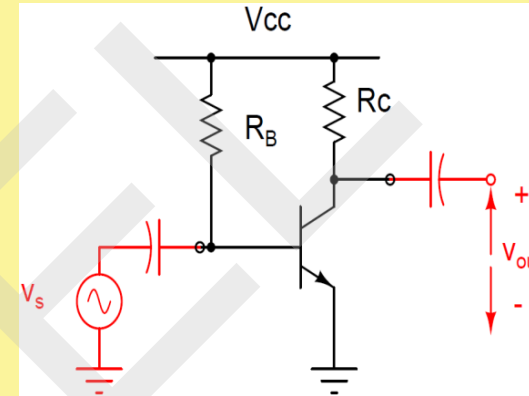
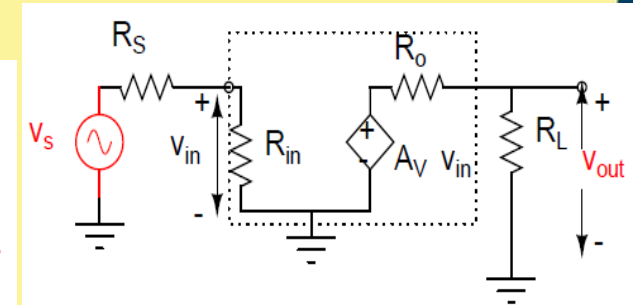
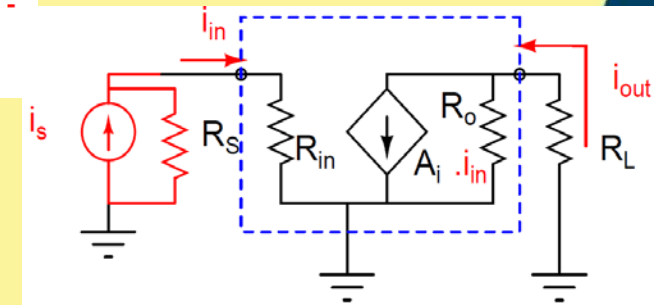
CONCEPTS COVERED

Concepts Covered:

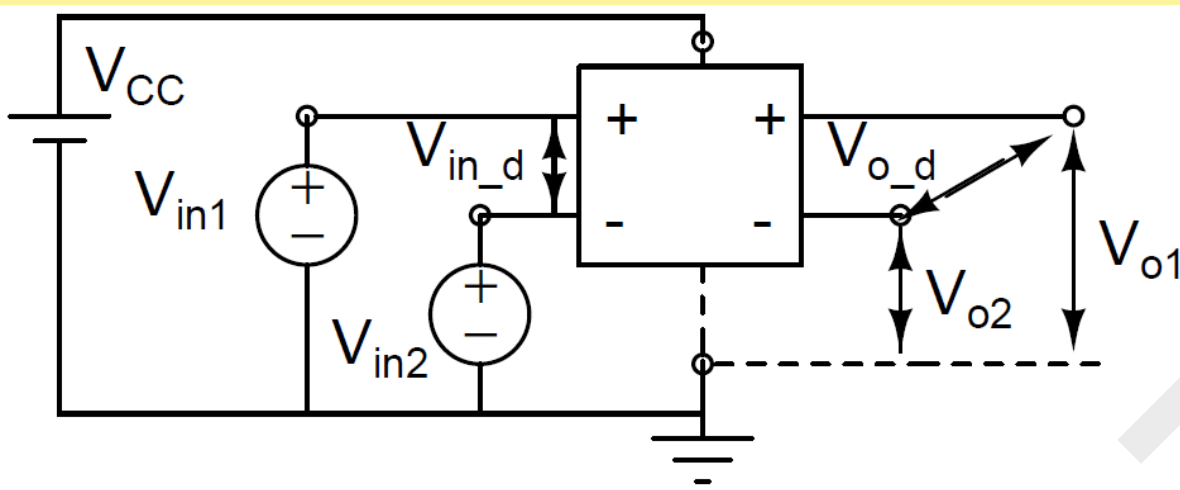
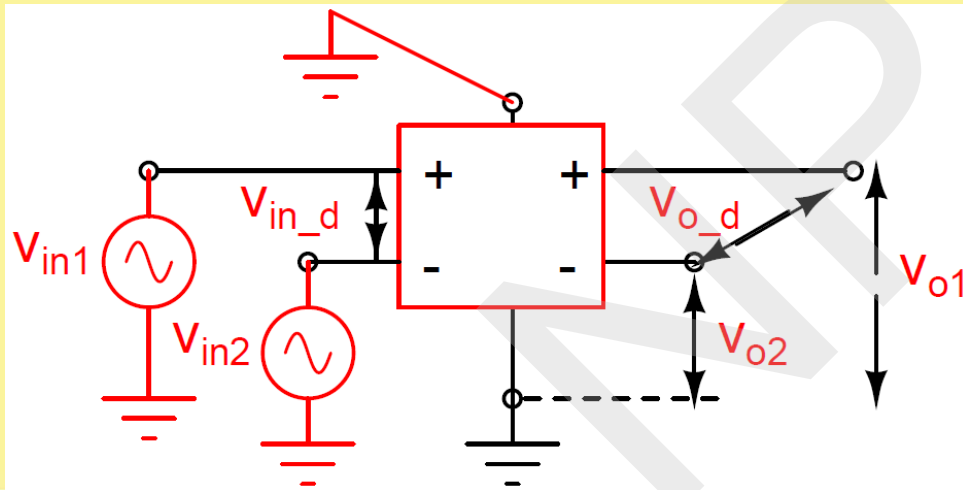
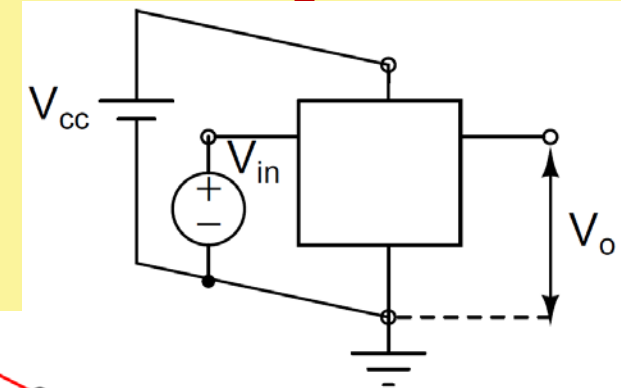
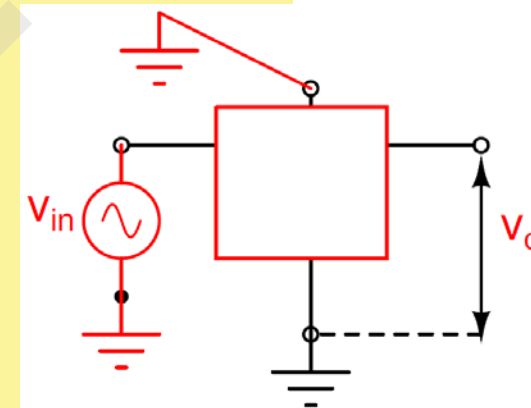
- ☐ **Basic difference between**
 - a single-ended amplifier and
 - a differential amplifier
- ☐ **A differential signal-pair and its two parts:**
 - differential-mode
 - common-mode
- ☐ **Equivalence of**
 - two single-ended signals and
 - a differential signal-pair
- ☐ **Basic models and parameters of diff. amp.**
- ☐ **Numerical examples**



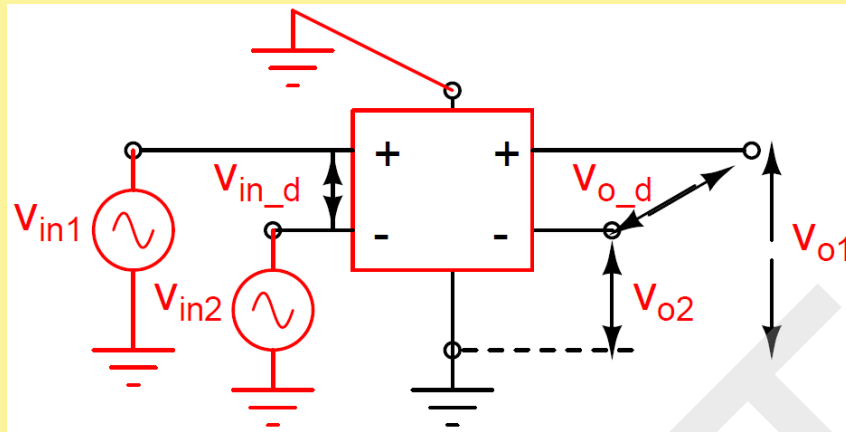
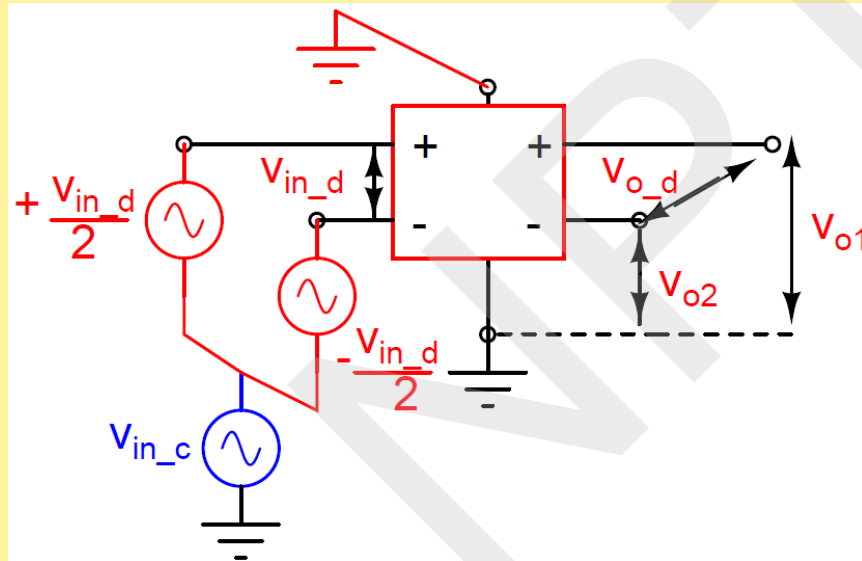
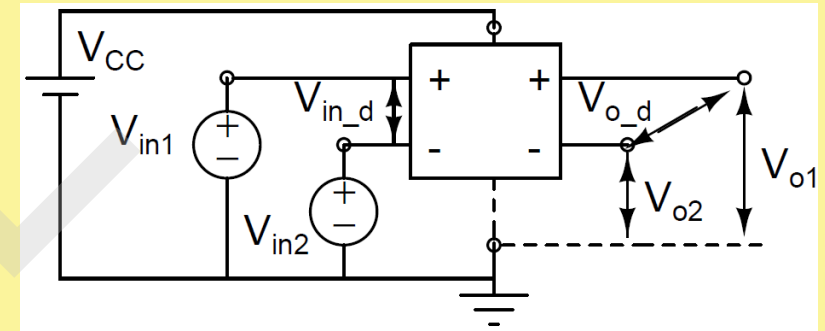
Basic operation of a single-ended amplifier



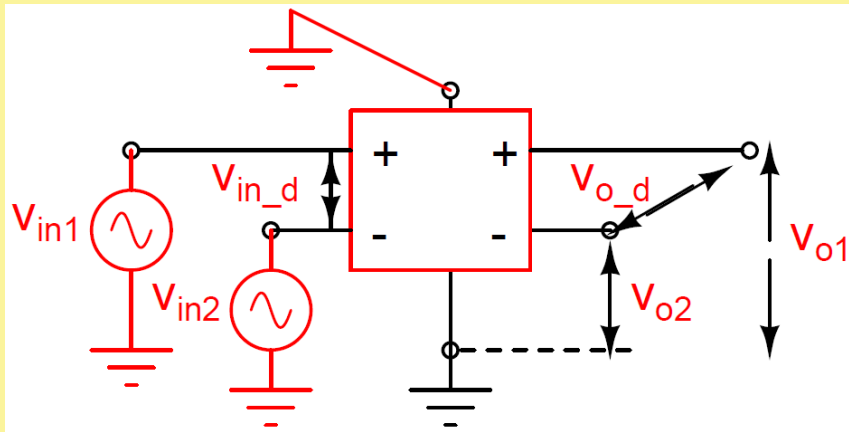
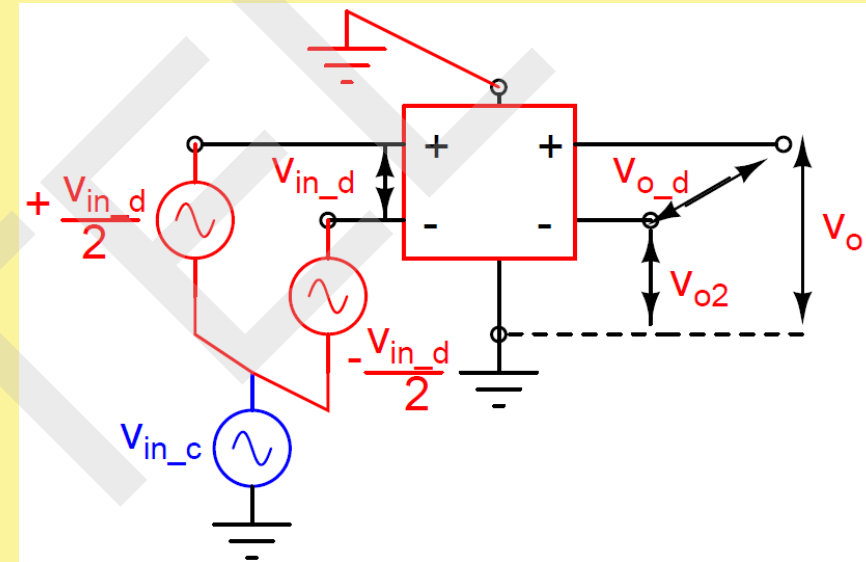
Basic difference between single-ended and differential amplifiers



Differential signal-pair and its two parts



Equivalence of two single-ended signals and a differential signal-pair



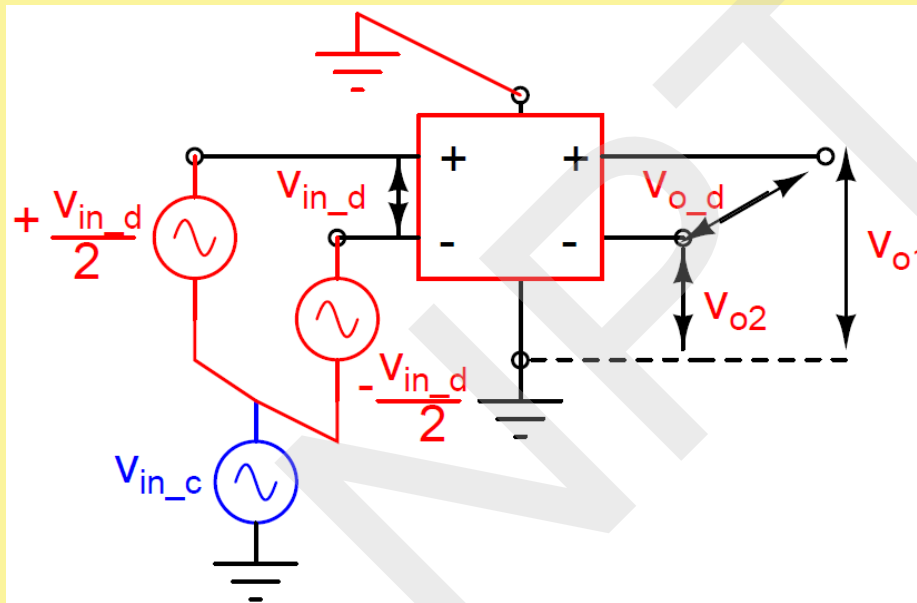
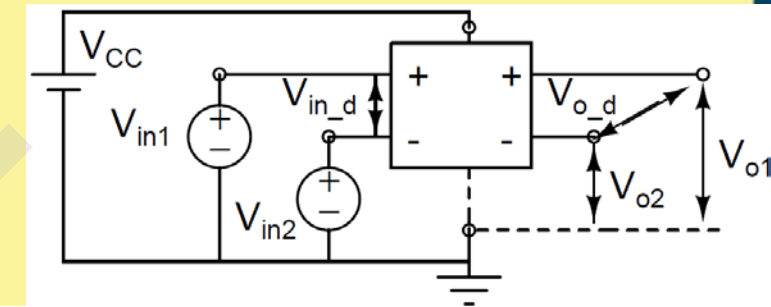
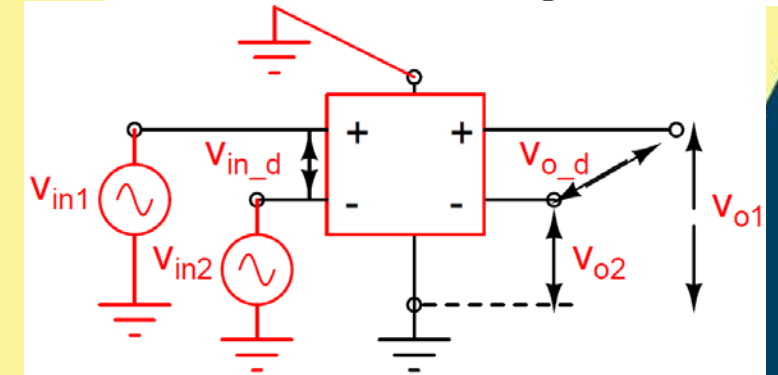
Basic Model of a differential amplifier and its parameters

Differential mode gain, A_d :

Common mode gain, A_c :

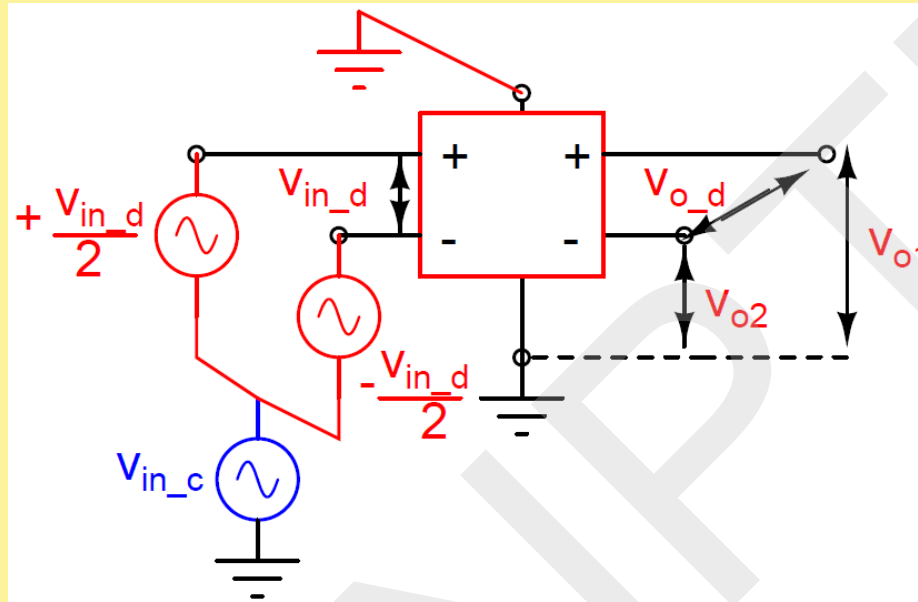
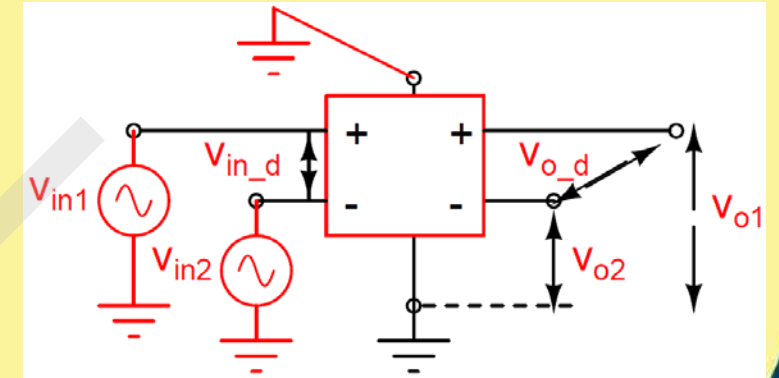
Differential to common mode gain, A_{d_c} :

Common mode to differential mode gain, A_{c_d} :



Numerical example on Basic Model of differential amplifier

$A_d = 20$, $A_c = 1$, $A_{d_c} = 0$ and $A_{c_d} = 0$



Conclusion:

- ☐ **Basic difference between**
 - a single-ended amplifier and
 - a differential amplifier
- ☐ **A differential signal-pair and its two parts:**
 - common-mode
 - differential-mode
- ☐ **Equivalence of**
 - a differential signal-pair and
 - two single-ended signals
- ☐ **Basic models and parameters of diff. amp.**
- ☐ **Numerical examples**

Conclusion





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*Thank
you*





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Basic model of a differential amplifier (contd.)***

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- **Basic model of Differential amplifier**

- **Differential amplifier:**

- Basic structure and principle of operation,
- analysis for differential mode gain, common mode gain,
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CONCEPTS COVERED

Concepts Covered:

- ☐ Numerical examples on Basic model of diff. amp.
- ☐ Motivation of using diff. amp
- ☐ Variants of diff. amp
- ☐ When to use what variants of amplifiers



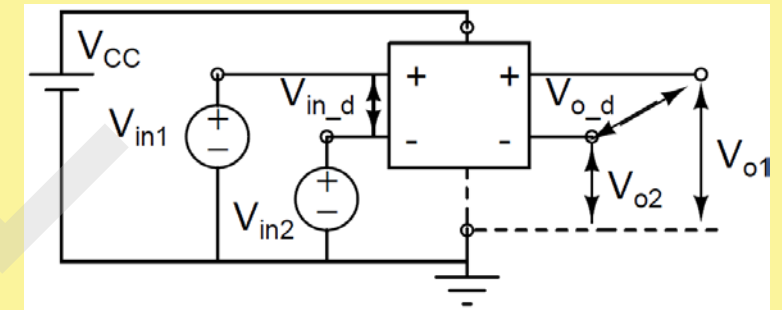
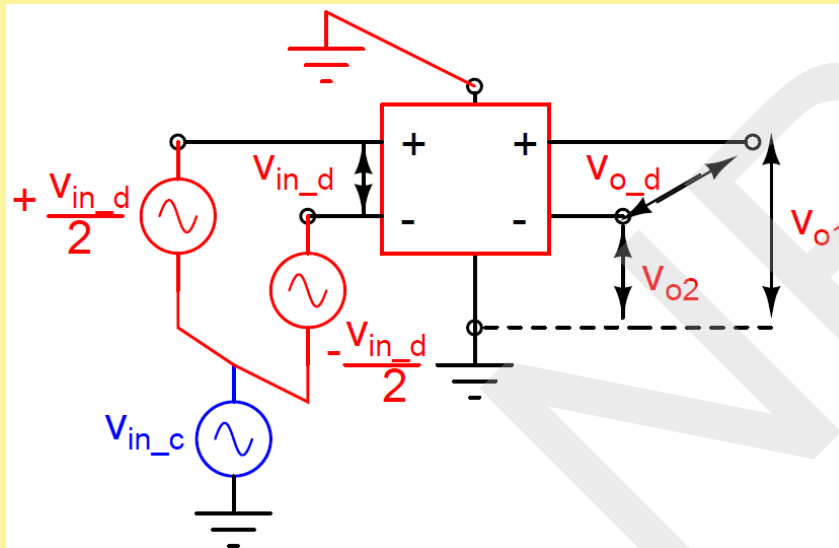
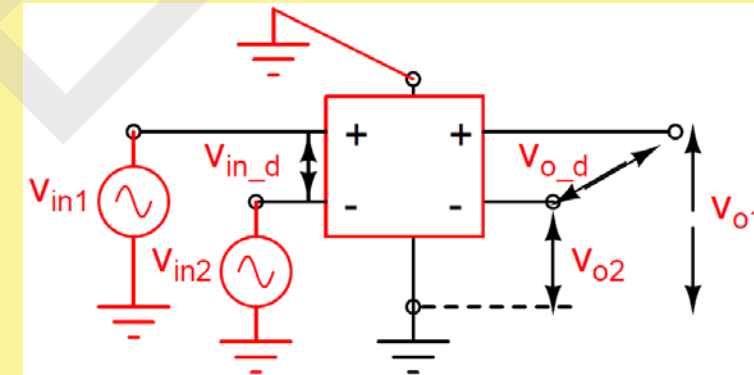
Recapitulation: Basic Model of a differential amplifier

Differential mode gain, A_d :

Common mode gain, A_c :

Differential to common mode gain, A_{d_c} :

Common mode to differential mode gain, A_{c_d} :

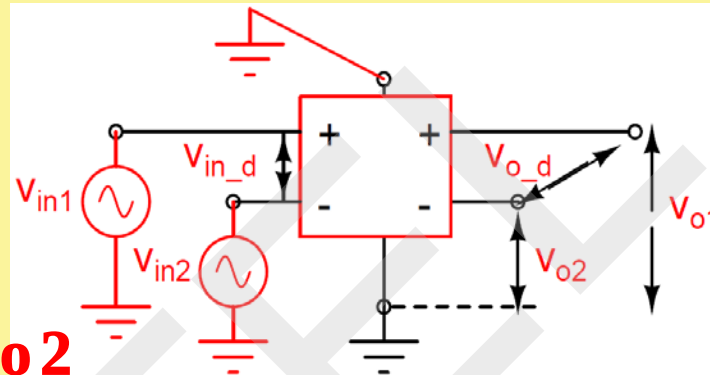
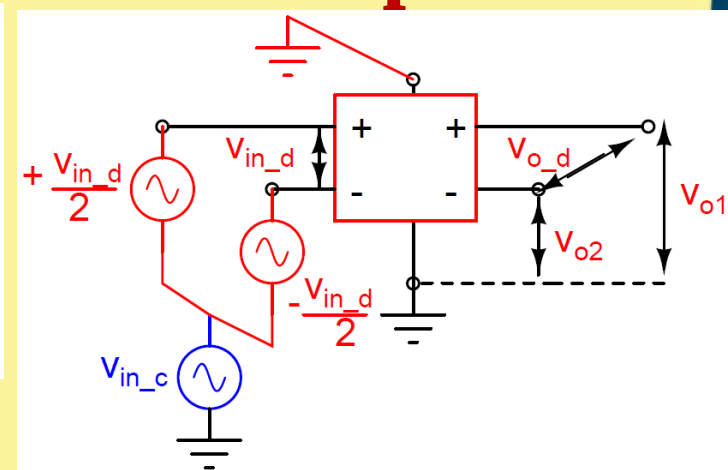
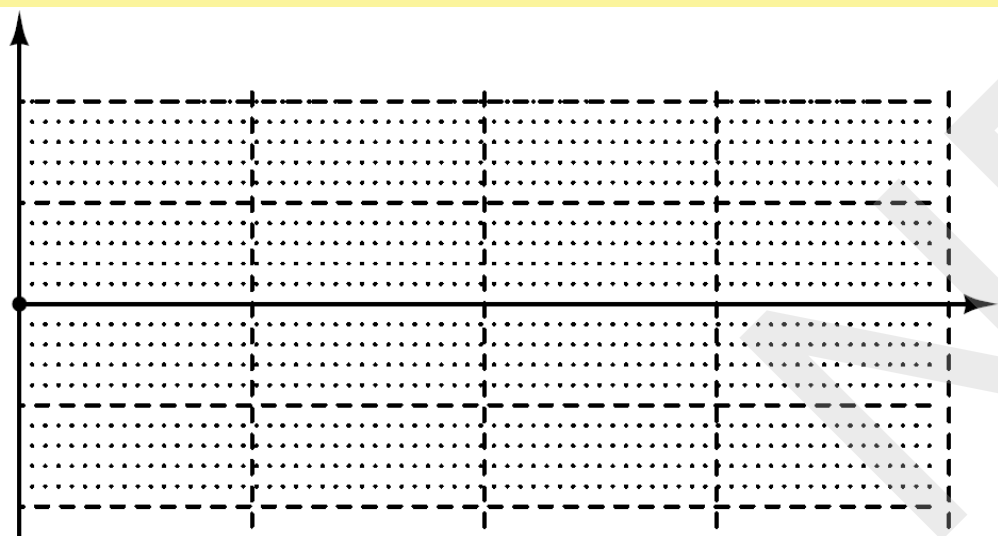


Numerical example on Basic Model of differential amplifier

$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

$$v_{in2} = -0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

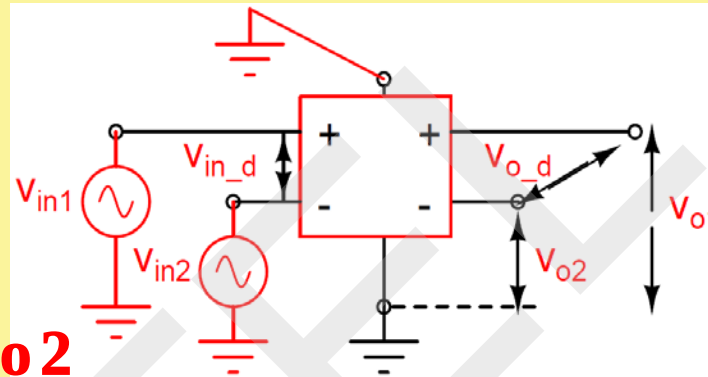
Case 0: $A_d = 40$. Find V_{o1} and V_{o2}



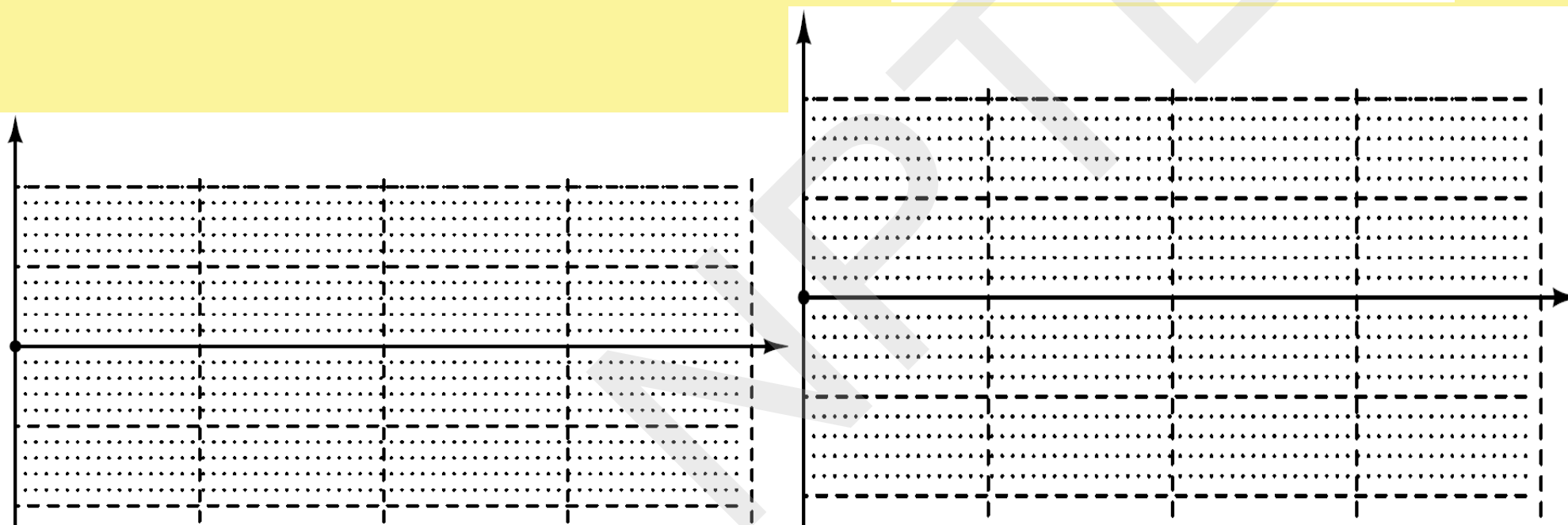
Numerical example on Basic Model of differential amplifier

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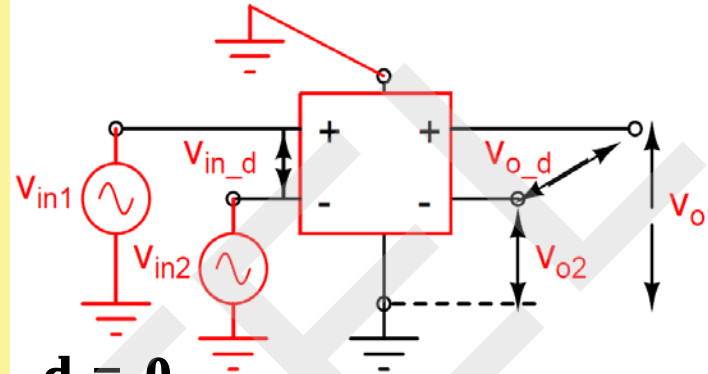
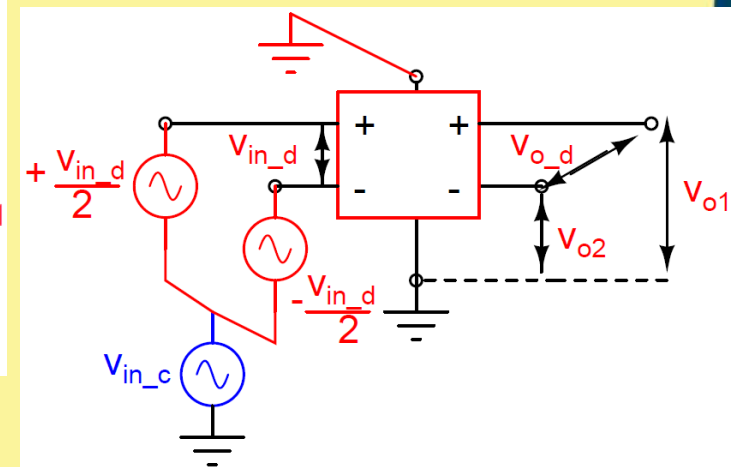
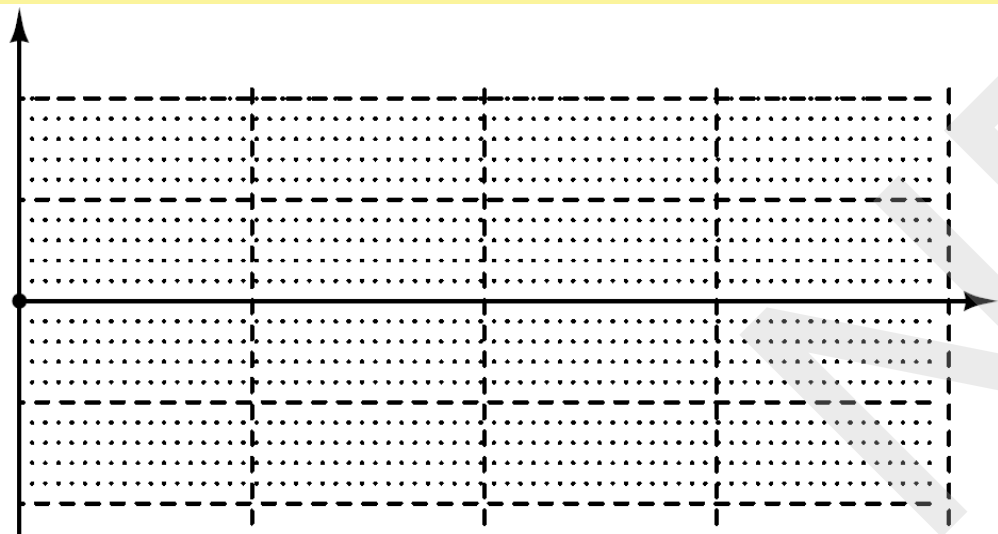
Case 0: $A_d = 40$. Find V_{o1} and V_{o2}



Numerical example on Basic Model of differential amplifier (contd.)

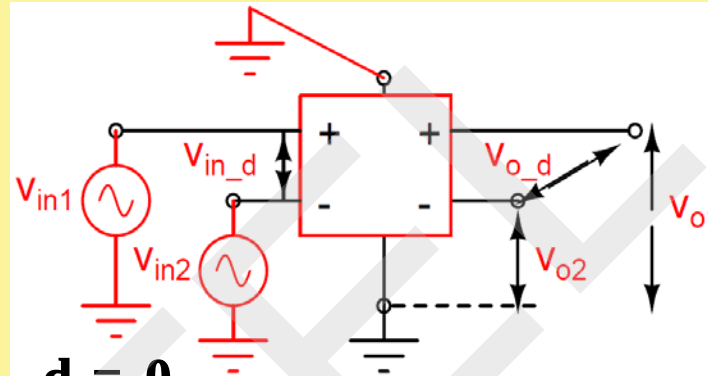
$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

Case I: $A_d = 40$, $A_c = -1$, $A_{d_c} = 0$ and $A_{c_d} = 0$
Find V_{o1} and V_{o2}

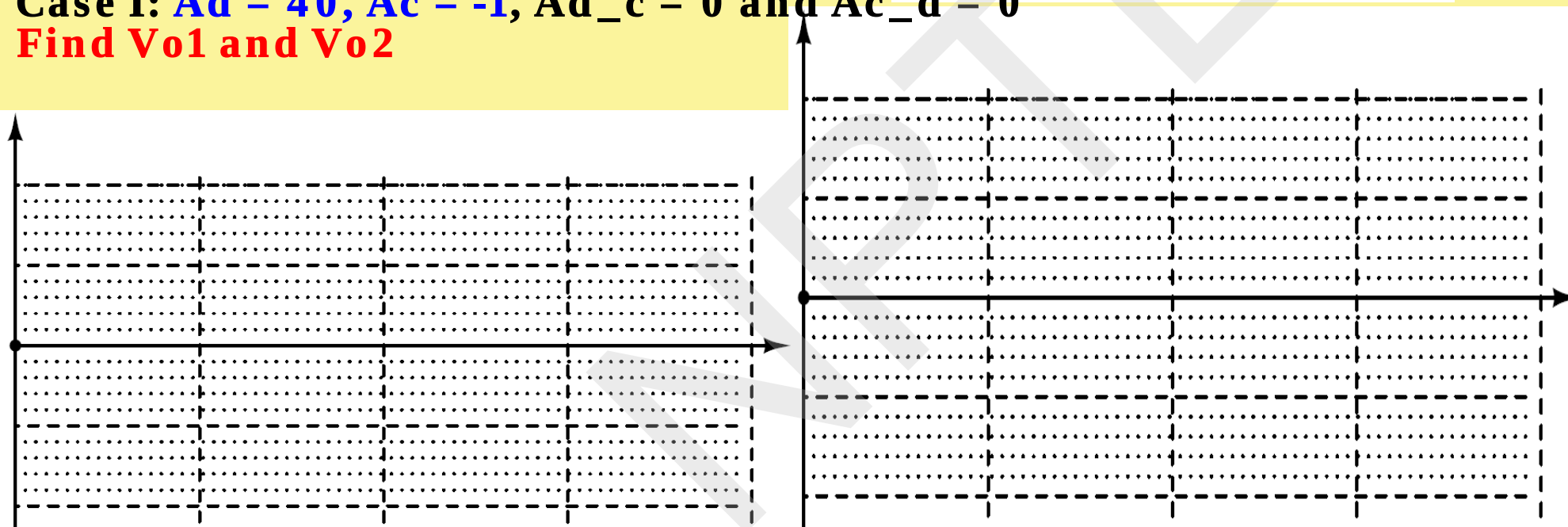


Numerical example on Basic Model of differential amplifier (contd.)

$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$



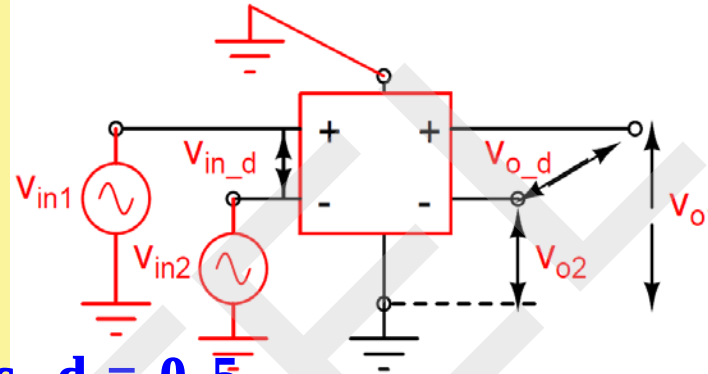
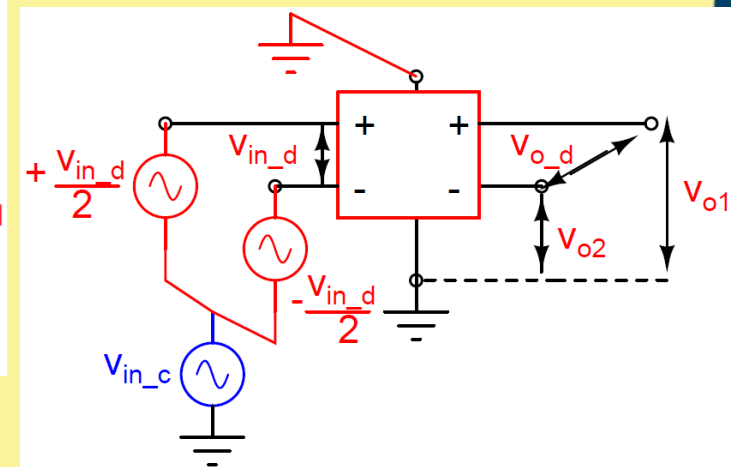
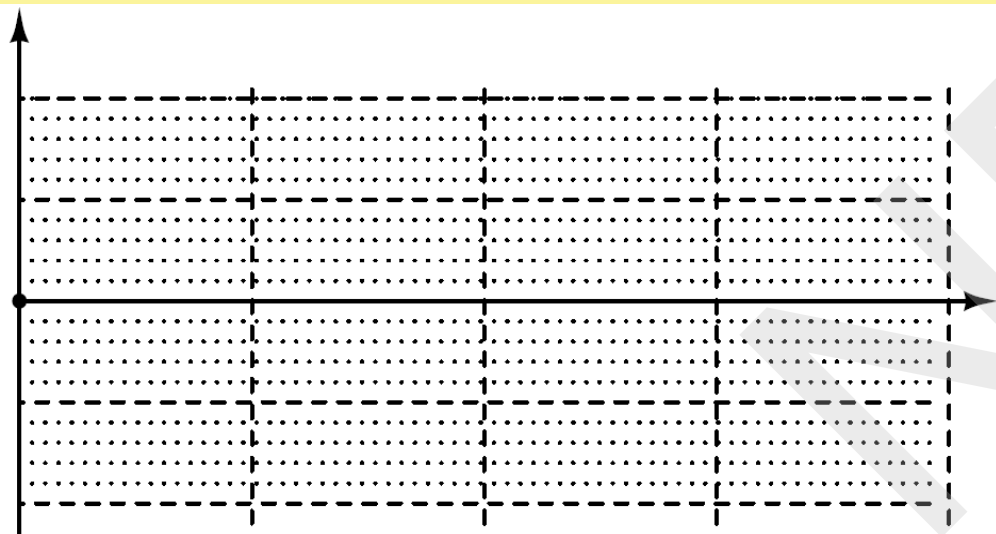
Case I: $A_d = 40$, $A_c = -1$, $A_{d_c} = 0$ and $A_{c_d} = 0$
Find V_{o1} and V_{o2}



Numerical example on Basic Model of differential amplifier (contd.)

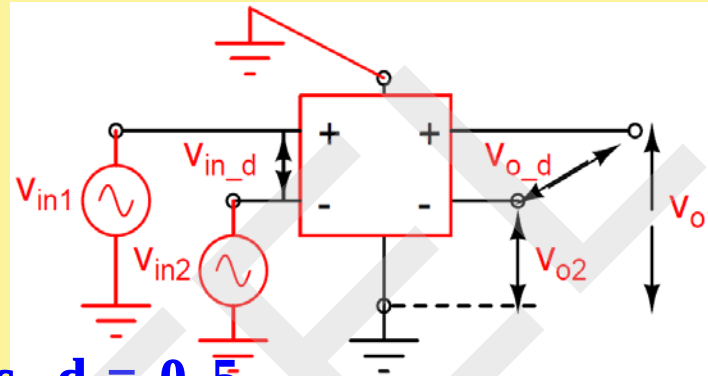
$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

Case II: $A_d = 40$, $A_c = 0$, $A_{d_c} = 0$ and $A_{c_d} = 0.5$
Find V_{o1} and V_{o2}

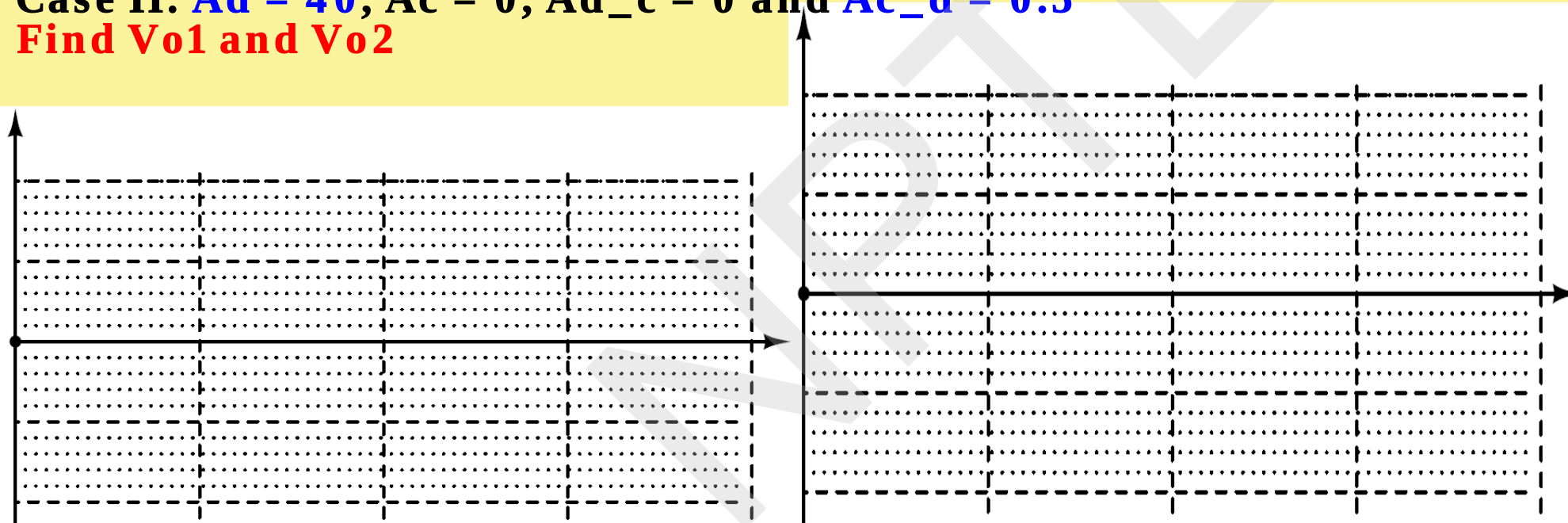


Numerical example on Basic Model of differential amplifier (contd.)

$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
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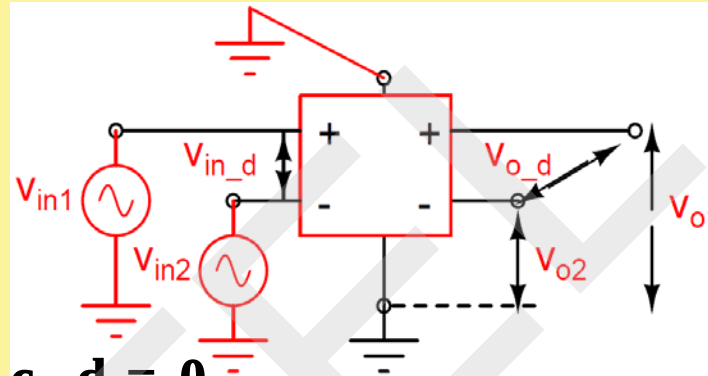
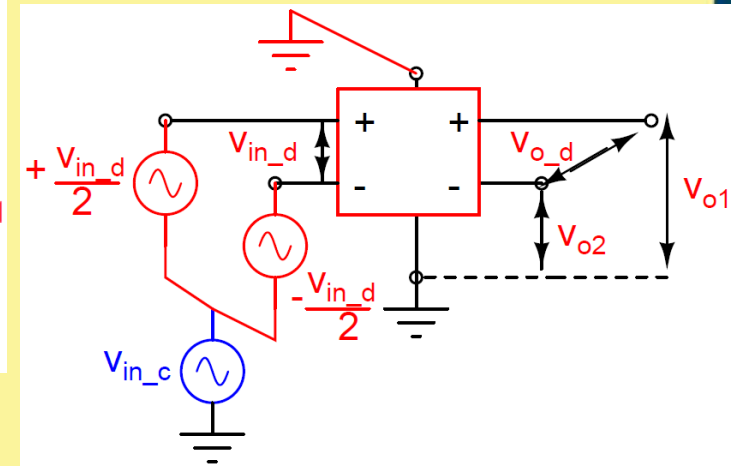
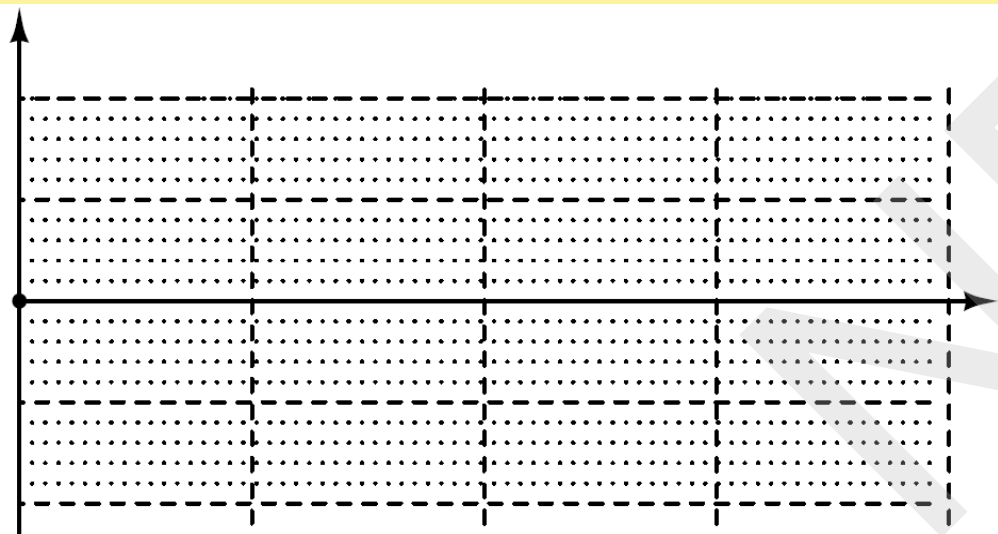
Case II: $A_d = 40$, $A_c = 0$, $A_{d_c} = 0$ and $A_{c_d} = 0.5$
Find V_{o1} and V_{o2}



Numerical example on Basic Model of differential amplifier (contd.)

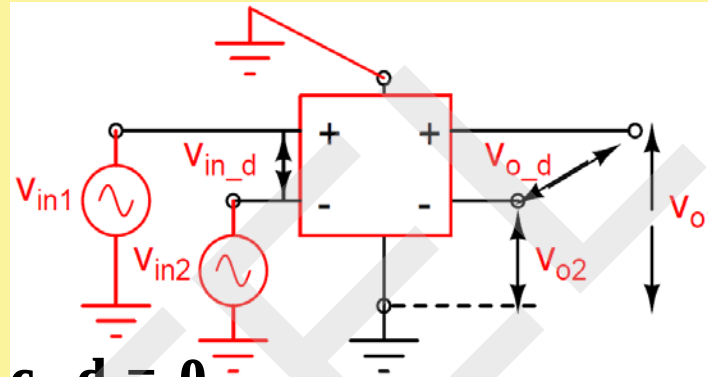
$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
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Case III: $A_d = 40$, $A_c = 0$, $A_{d_c} = 2$ and $A_{c_d} = 0$
Find V_{o1} and V_{o2}

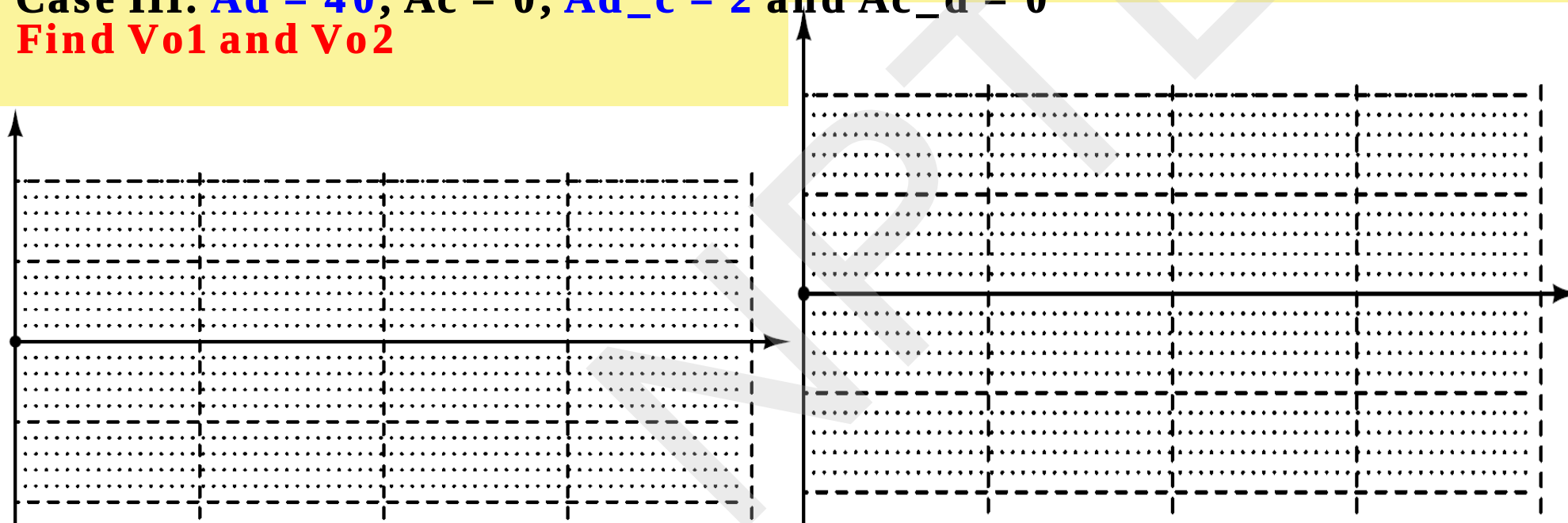


Numerical example on Basic Model of differential amplifier (contd.)

$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
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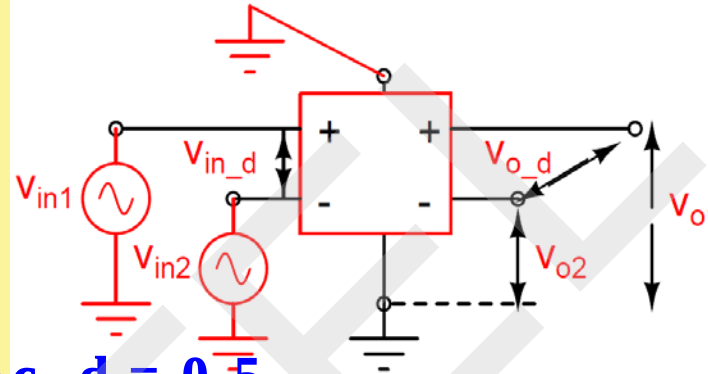
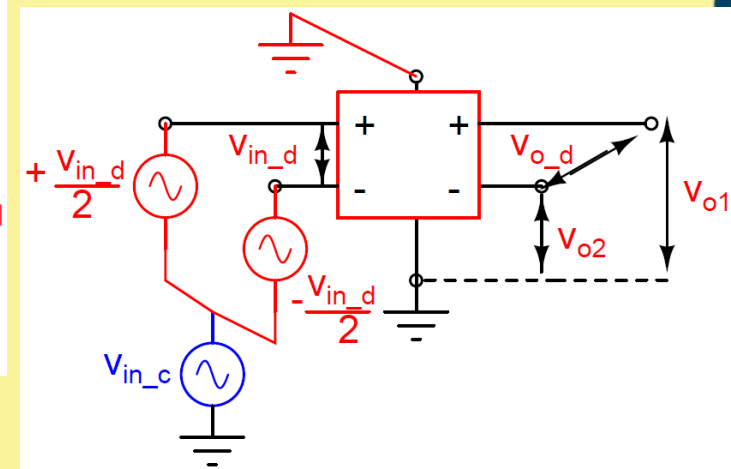
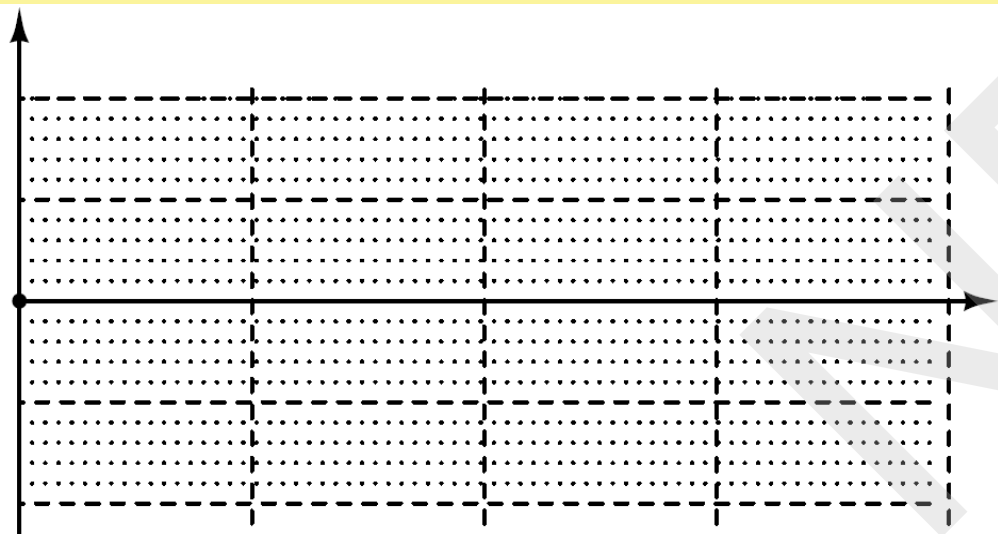
Case III: $A_d = 40$, $A_c = 0$, $A_{d_c} = 2$ and $A_{c_d} = 0$
Find V_{o1} and V_{o2}



Numerical example on Basic Model of differential amplifier (contd.)

$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
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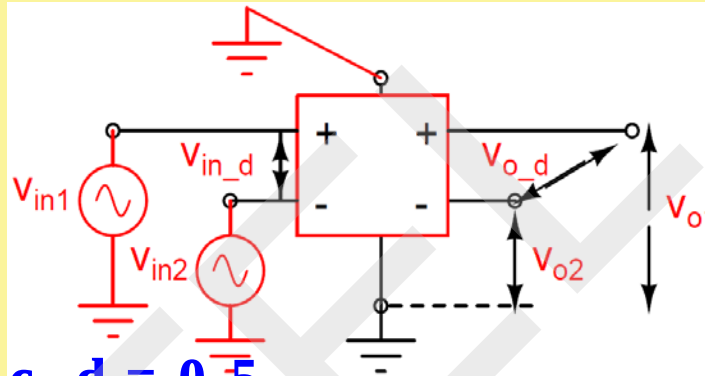
Case IV: $A_d = 40$, $A_c = -1$, $A_{d_c} = 2$ and $A_{c_d} = 0.5$
Find V_{o1} and V_{o2}



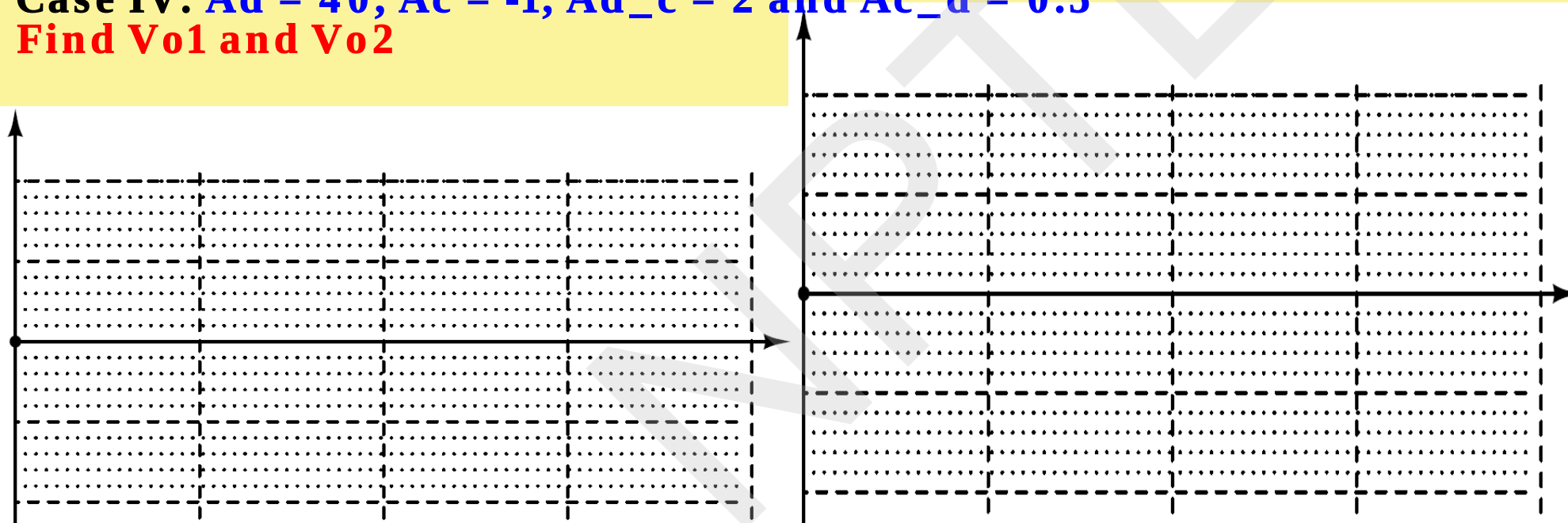
Numerical example on Basic Model of differential amplifier (contd.)

$$v_{in1} = 0.05 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.5 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

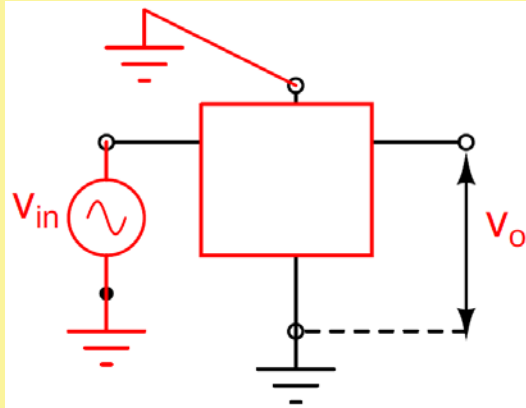
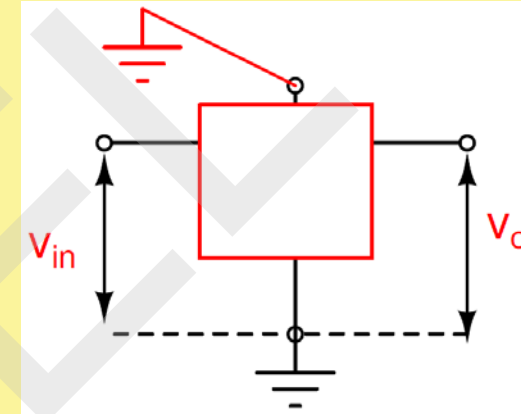
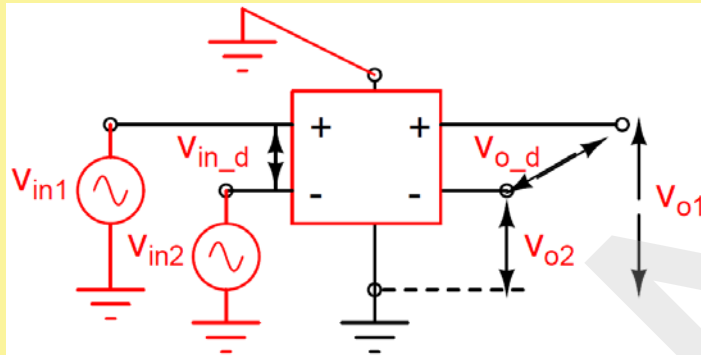
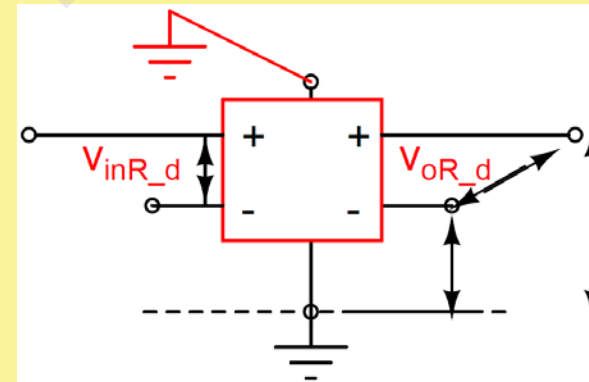
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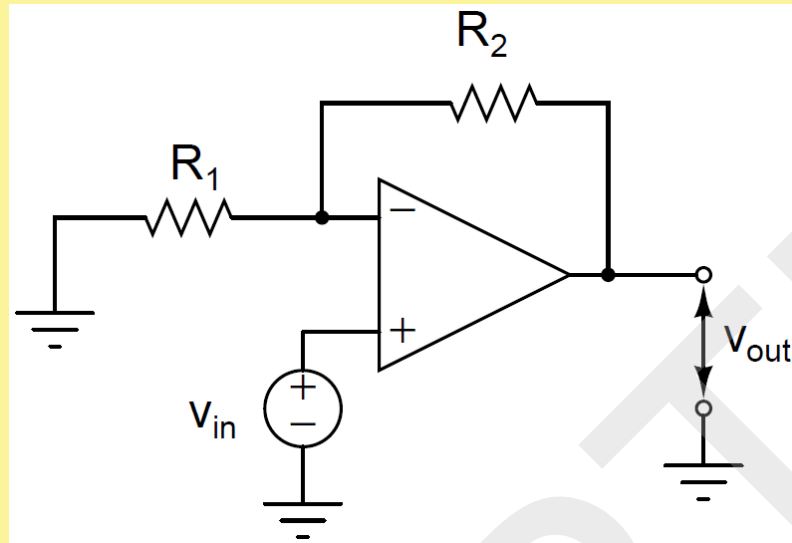
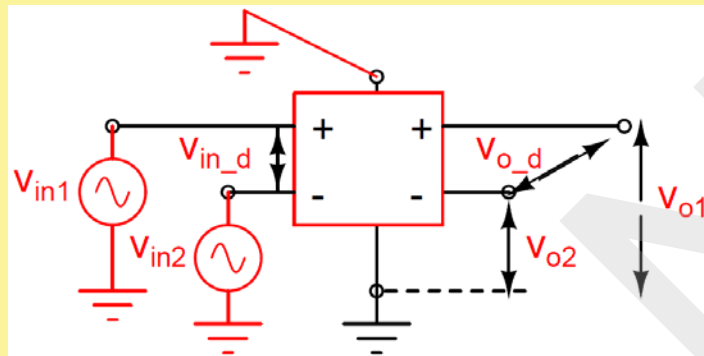
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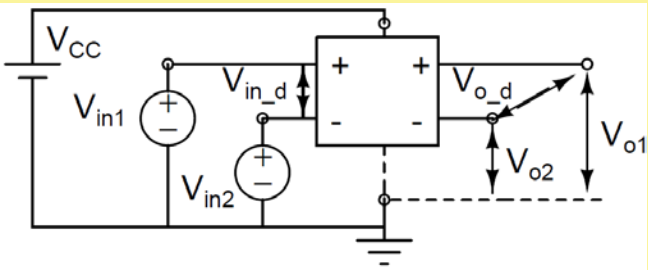
Motivation of using differential amplifier and differential signaling



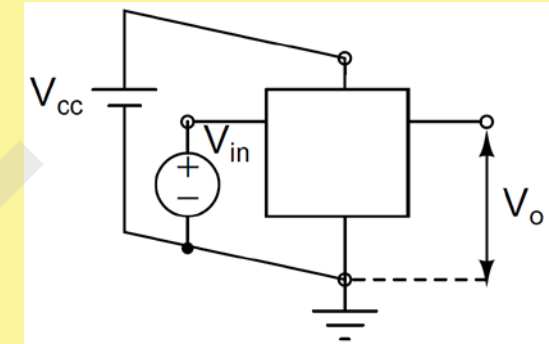
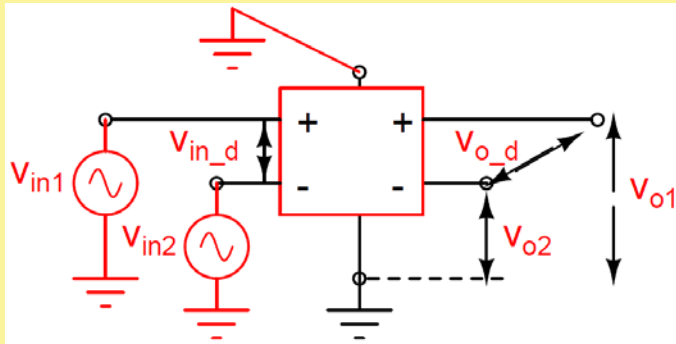
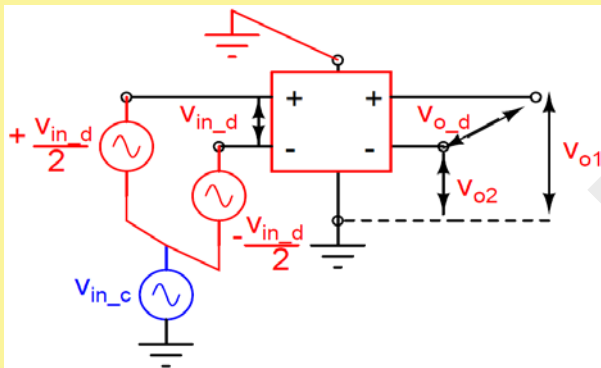
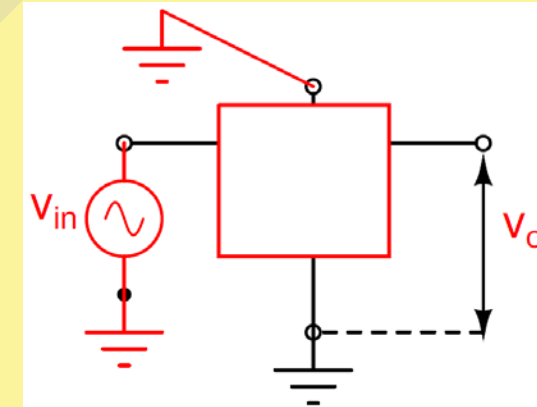
Very common application of differential amplifier: *Operational amplifier*



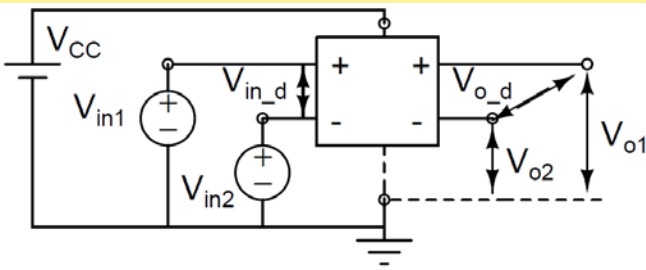
Different variants of amplifiers



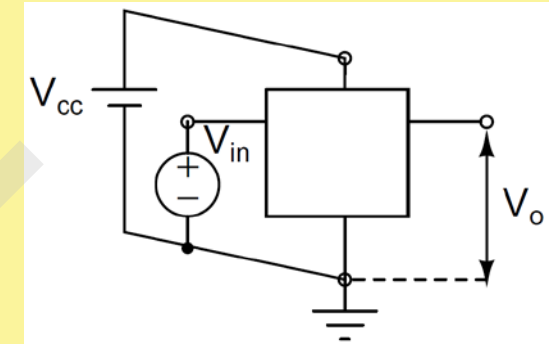
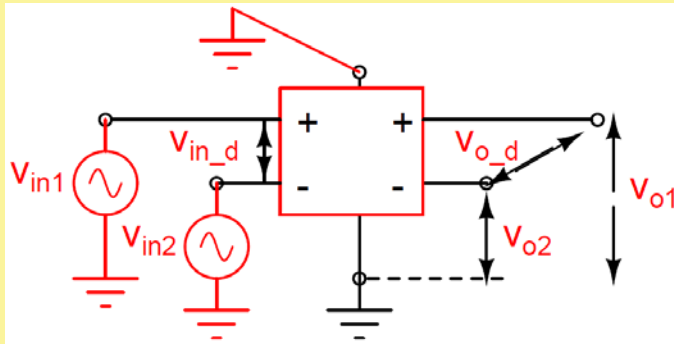
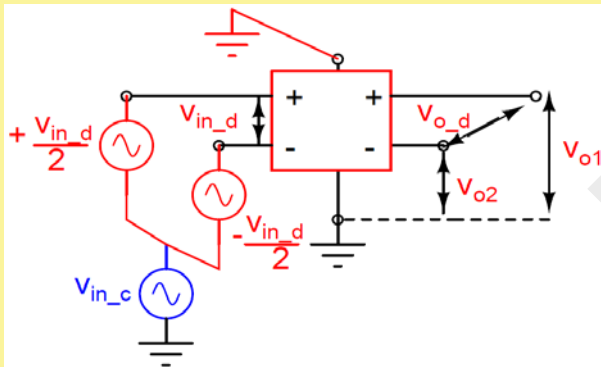
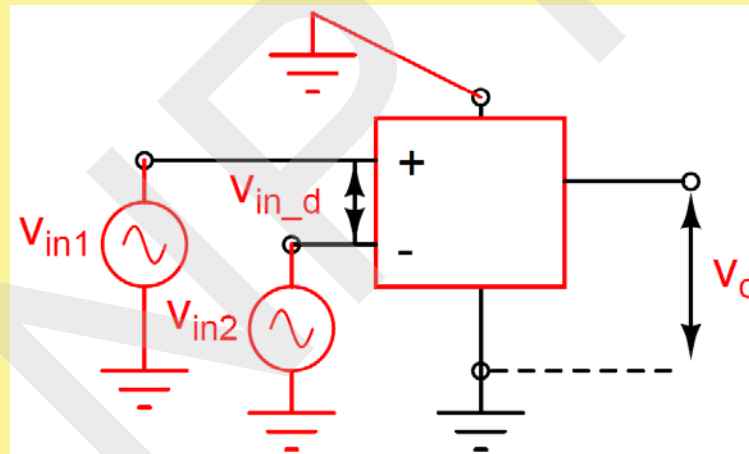
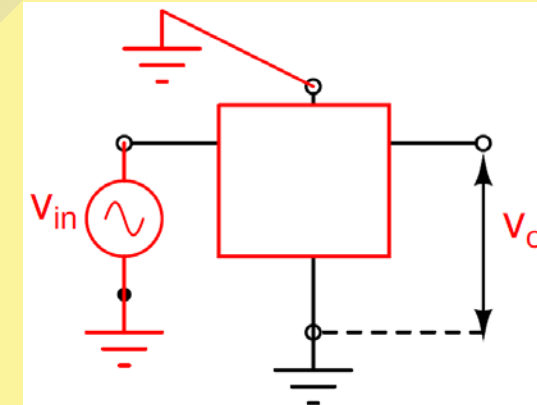
- Fully differential
- Single-ended to single-ended



Different variants of amplifiers

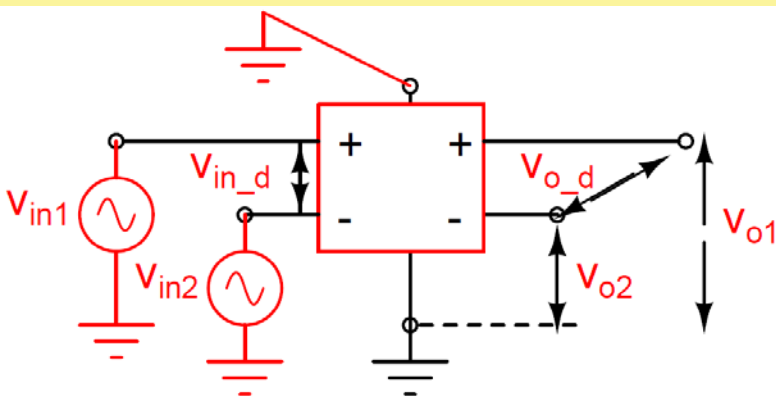
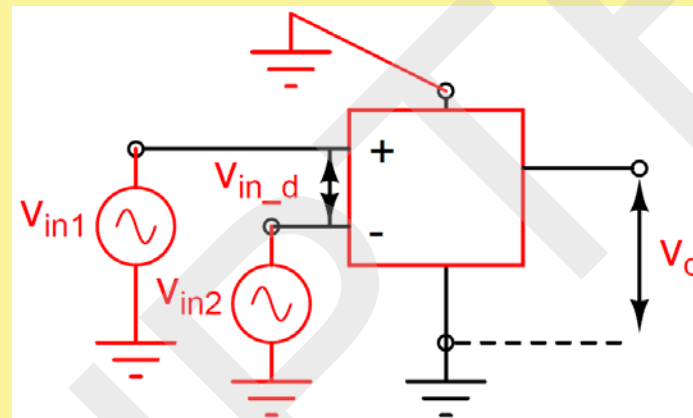
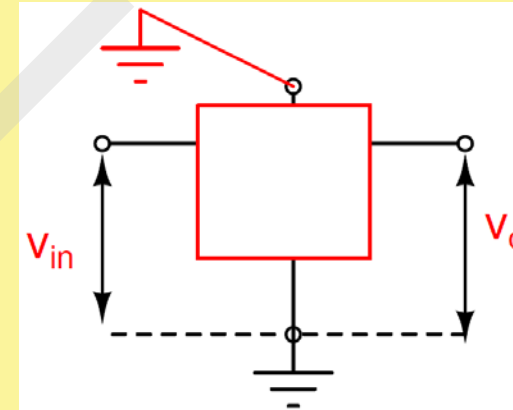


- Fully differential
- Single-ended to single-ended
- Differential to single-ended



When to use what variants of amplifiers !

Fully differential --- Differential to single-ended --- Single-ended to single-ended



Conclusion

Conclusion:

- ☐ **Numerical examples on Basic model of diff. amp.**
 - Significance of different parameters
- ☐ **Motivation of using diff. amp**
- ☐ **Variants of diff. amp**
 - Fully differential
 - Differential to single-ended
 - Single-ended to single-ended
- ☐ **When to use what variants of amplifiers**





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*Thank
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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:

Differential Amplifier:

Basic structure and principle of operation

Flow of Discussion (Bottom-up) - Modules

- **System/Sub-systems** (*for specific application*)

- **Modules** (*performing specific tasks*)

- **Building blocks** (*having specific characteristics*)

- **Components** (*devices/circuit elements*)

- **Week 7:**

- **Single-ended signaling vs. differential signaling**

- **Basic model of Differential amplifier**

- **Differential amplifier:**

- **Basic structure and principle of operation,**
- **analysis for differential mode gain, common mode gain,**
- **ICMR and output swing**



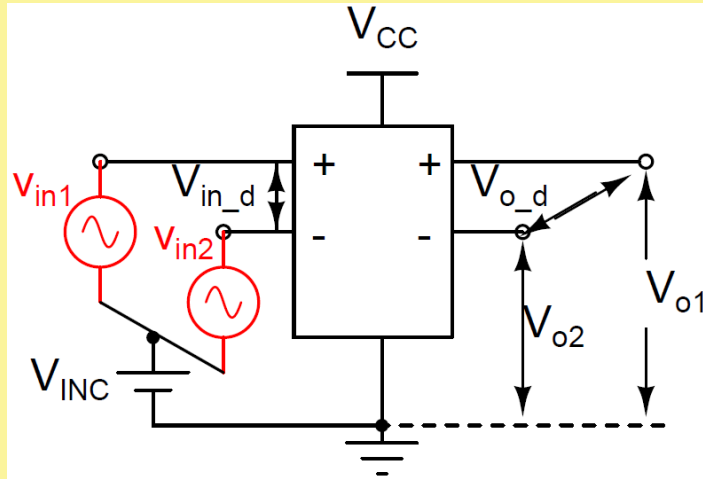
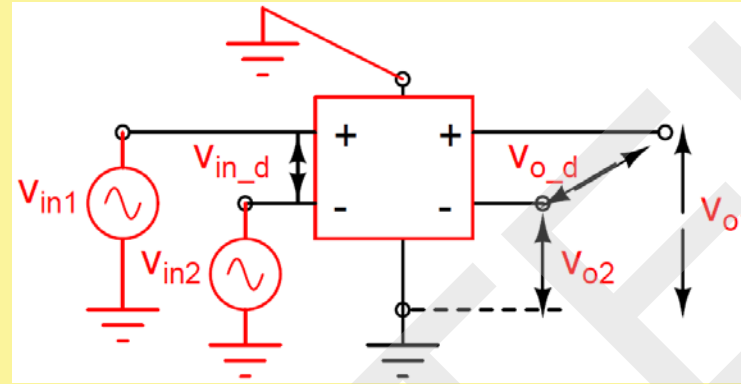
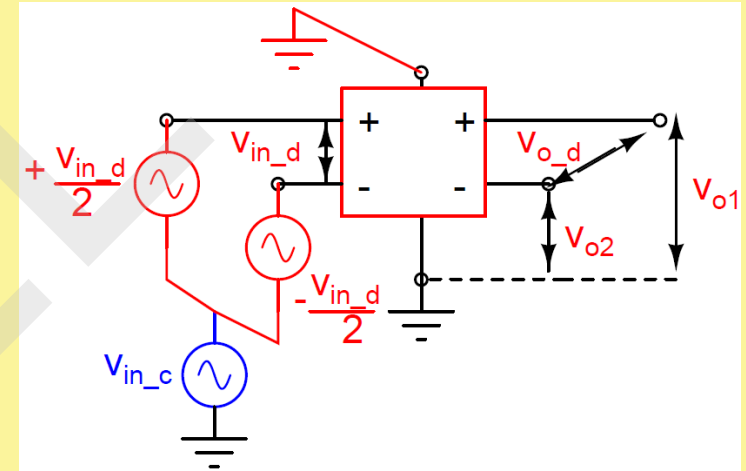
CONCEPTS COVERED

Concepts Covered:

- ☐ Basic operation and characterization of a differential amplifier
- ☐ Realization of differential amplifier using transistors
- ☐ Variants of differential amplifier
- ☐ Operating principle of realized structures

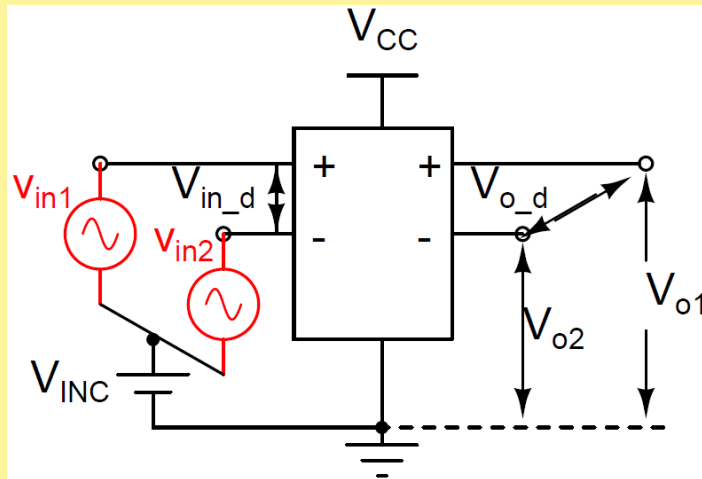
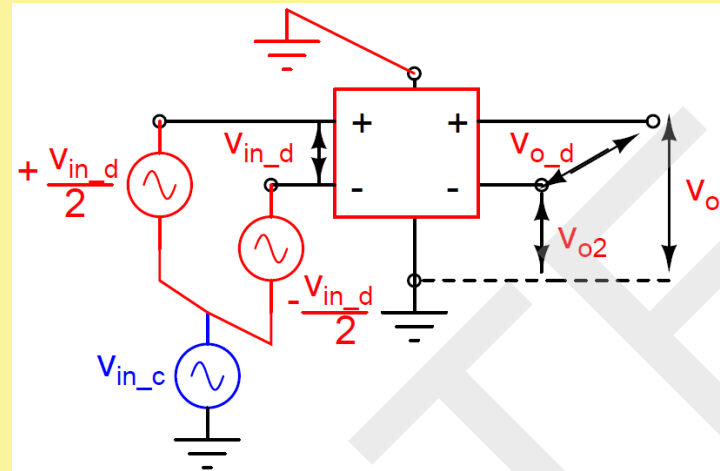
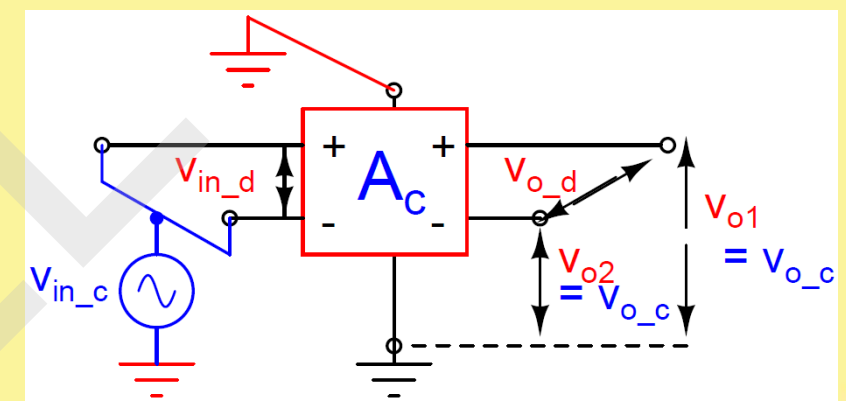


Recapitulation: Basic Operation of a differential amplifier

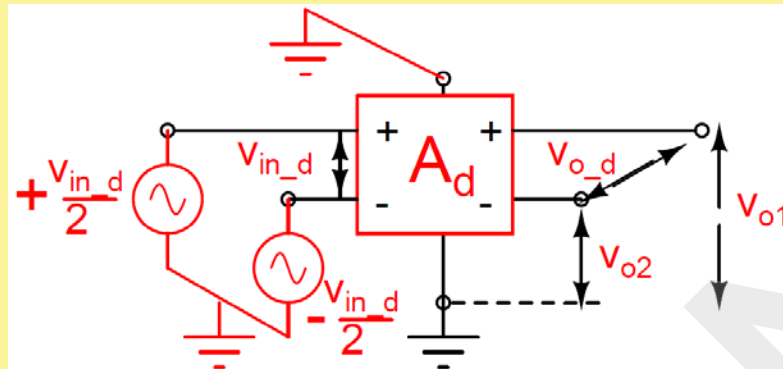


- Differential mode gain, A_d should be high
- Common mode gain, A_c should be small
- Other two parameters assumed to be zero ($A_{c_d} = 0$ and $A_{d_c} = 0$)

Basic Operation and characterization of a differential amplifier

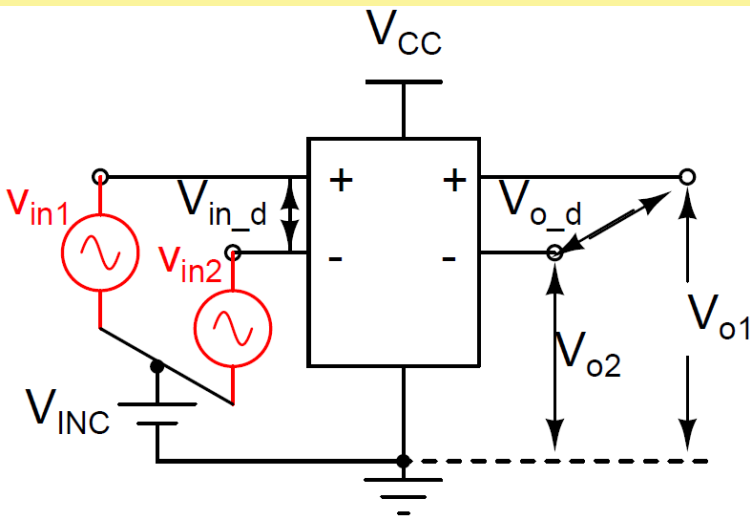
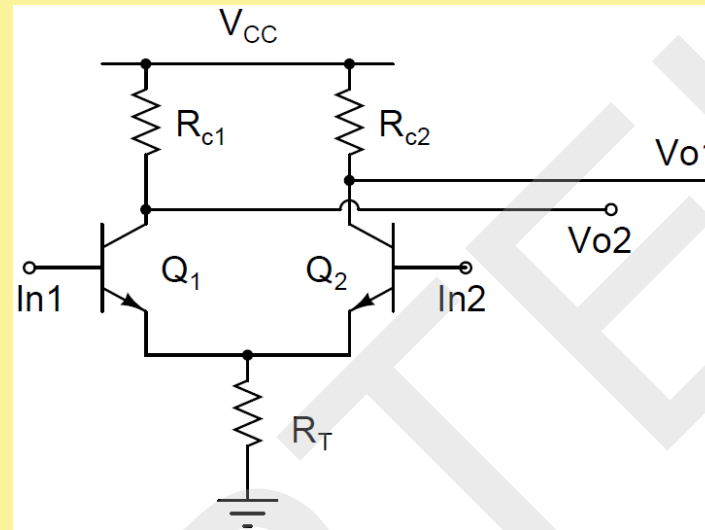
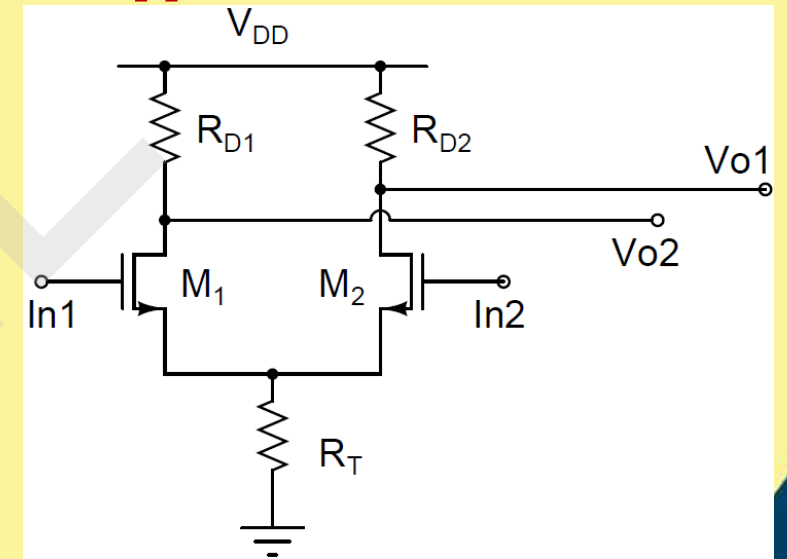


Common mode of stimulus:
for **A_c**

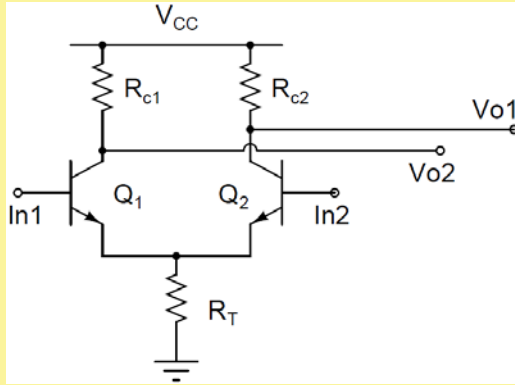
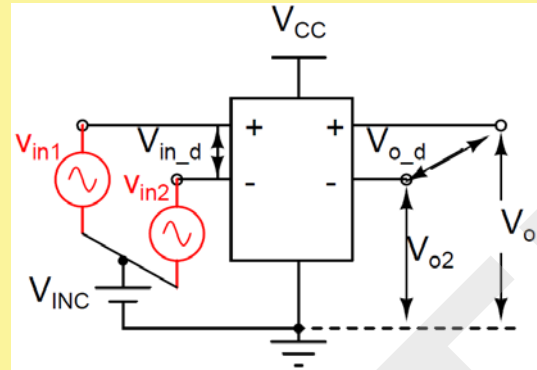
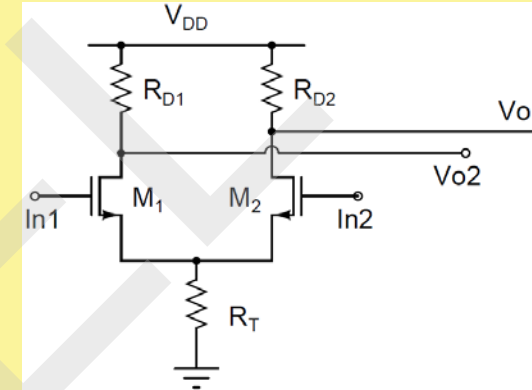
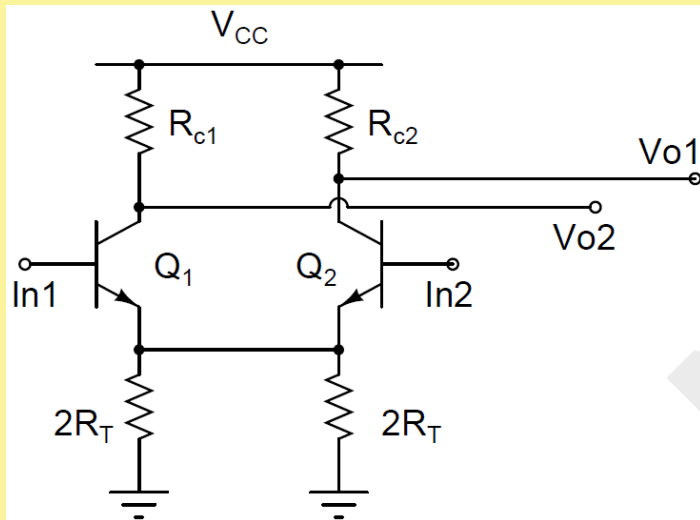
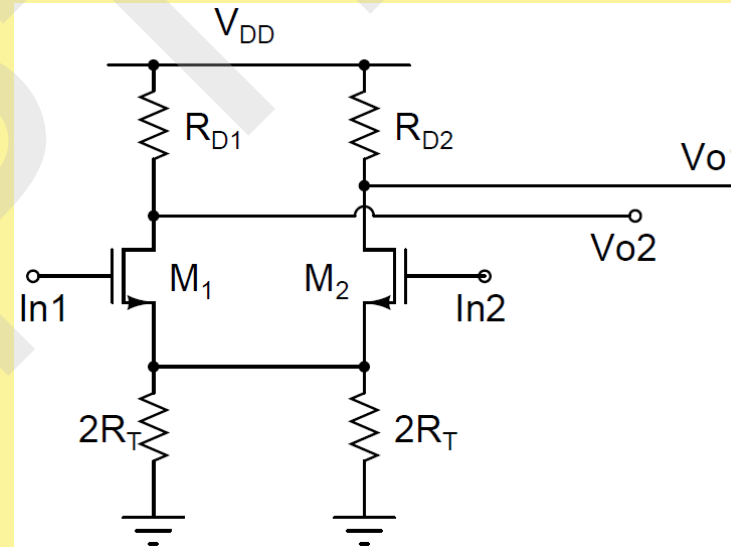


Differential mode of stimulus: for **A_d**

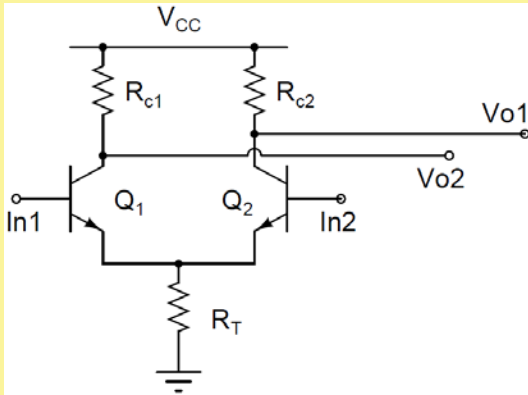
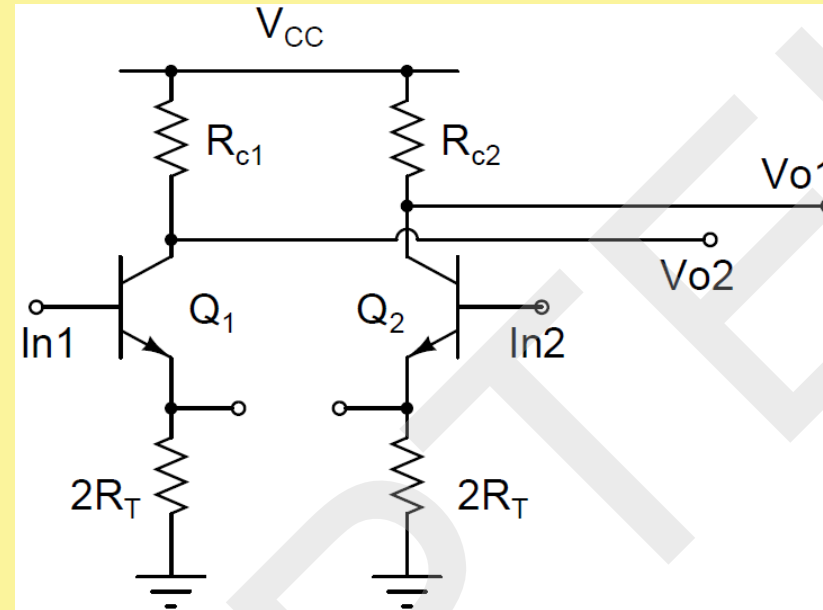
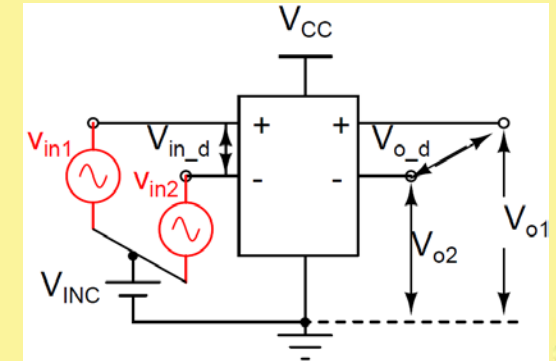
Realization of differential amplifier *and different variants*



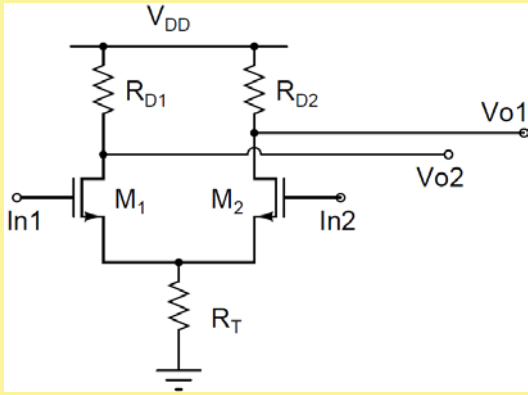
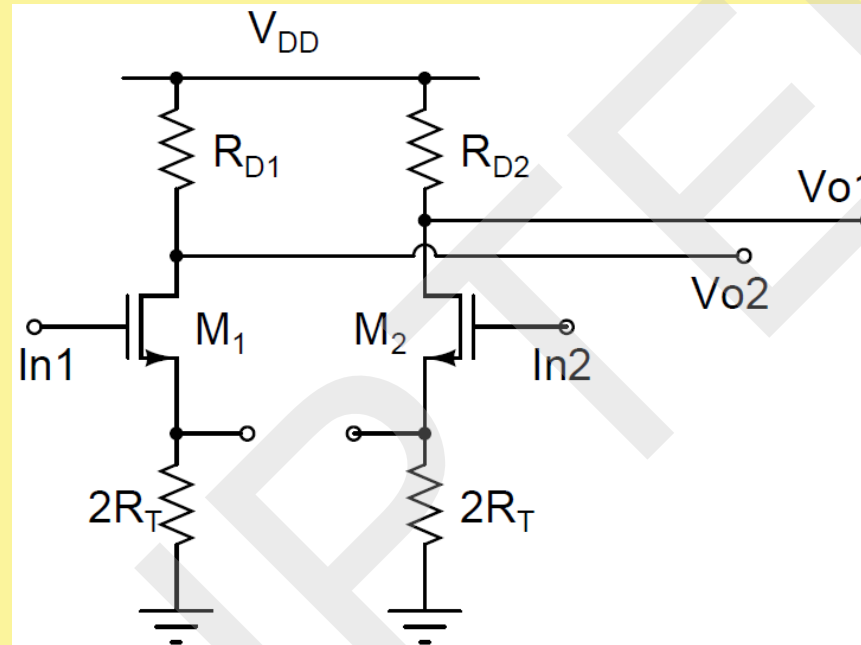
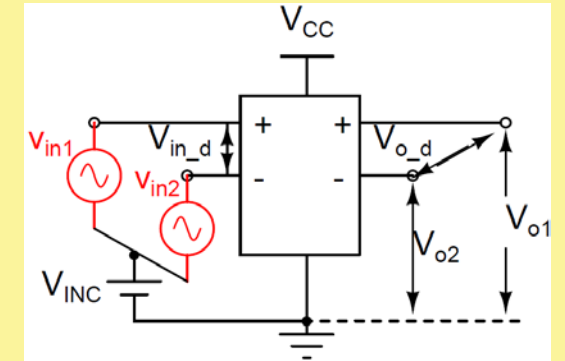
Realization of differential amplifier (*contd.*)



Operation of differential amplifier realized using BJTs



Operation of differential amplifier realized using MOSFETs



Conclusion

Conclusion:

- ☐ Basic operation and characterization of a differential amplifier
- ☐ Realization of differential amplifier using transistors
- ☐ Variants of differential amplifier
- ☐ Operating principle of realized structures





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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:

Differential Amplifier: Analysis and Numerical examples

Flow of Discussion (Bottom-up) - Modules

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- **Single-ended signaling vs. differential signaling**
- **Basic model of Differential amplifier**
- **Differential amplifier:**
 - **Basic structure and principle of operation,**
 - **Analysis for differential mode gain, common mode gain,**
 - **ICMR and output swing**



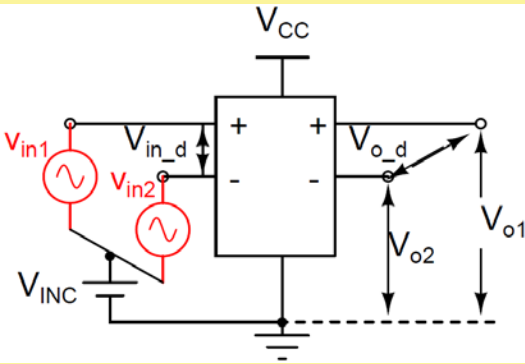
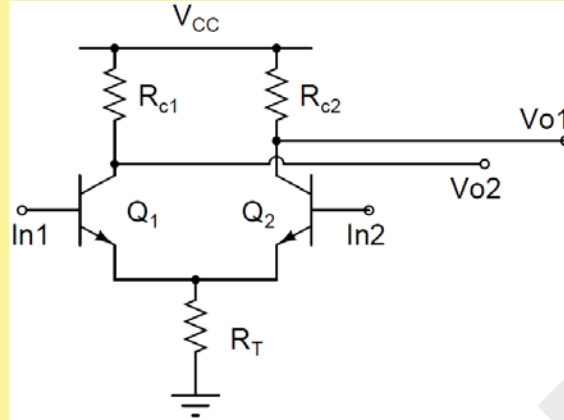
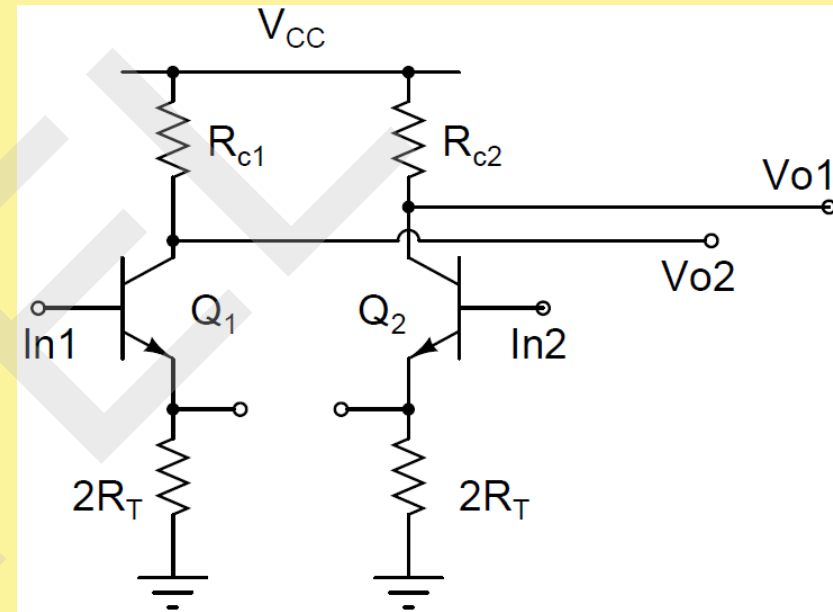
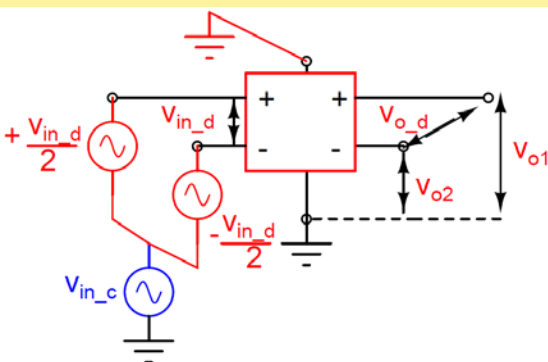
CONCEPTS COVERED

Concepts Covered:

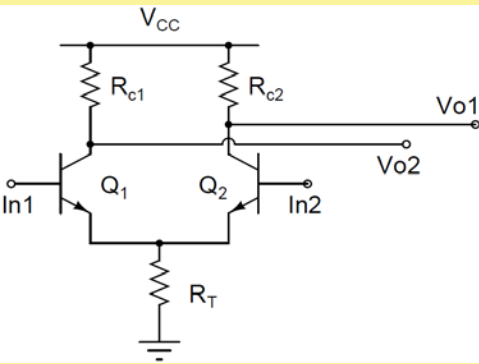
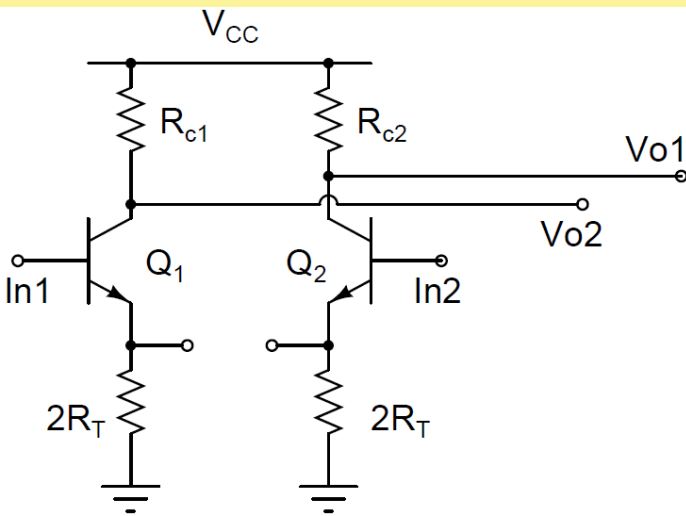
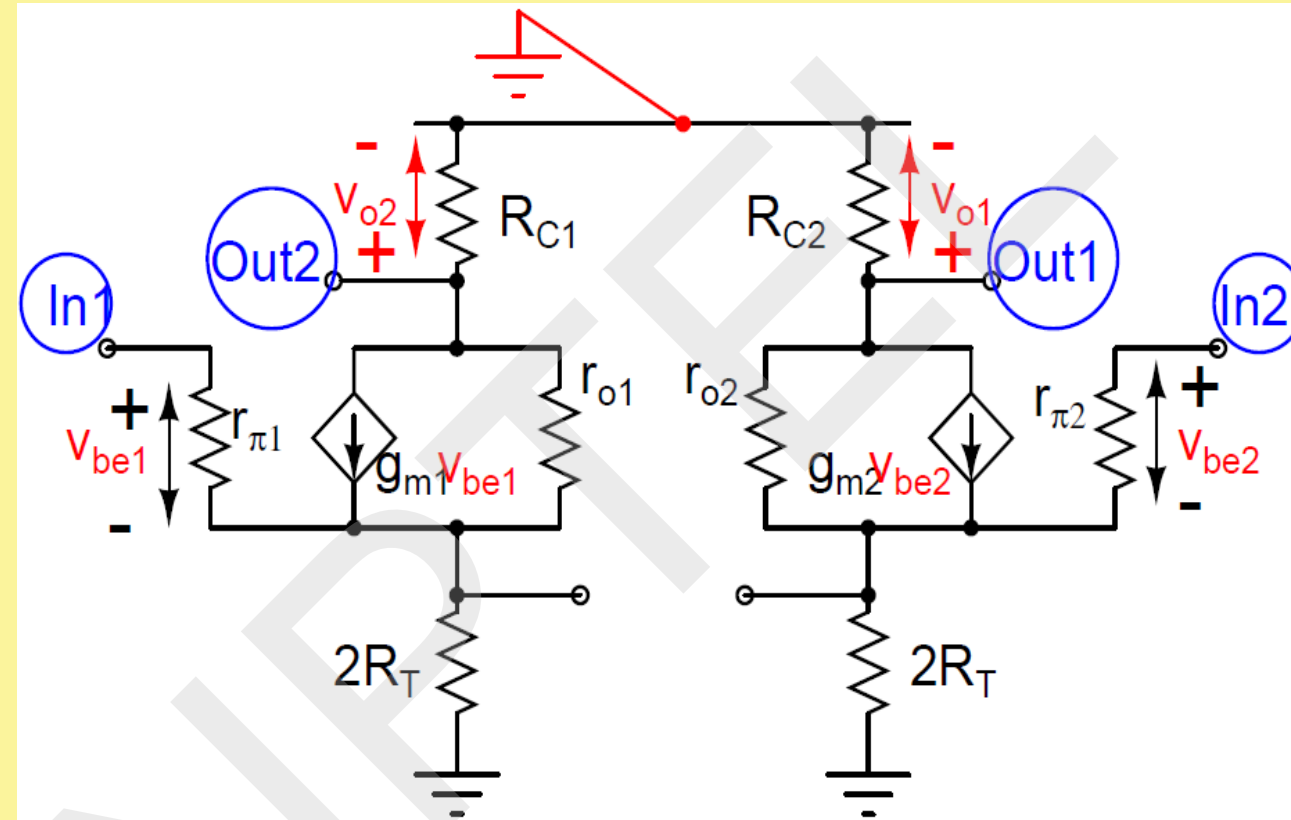
- ☐ Small signal equivalent circuits of differential amp.
- ☐ Small signal analysis of diff. amp. for
 - Differential mode of stimulus (operation)
 - Common mode of stimulus (operation)
 - Generalized and pseudo-differential stimulus (operation)
- ☐ Large signal analysis for
 - D.C. operating point
 - Input common mode range and
 - Output signal swing
- ☐ *Numerical examples*



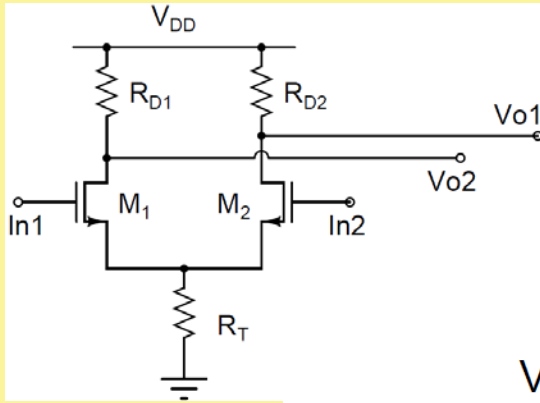
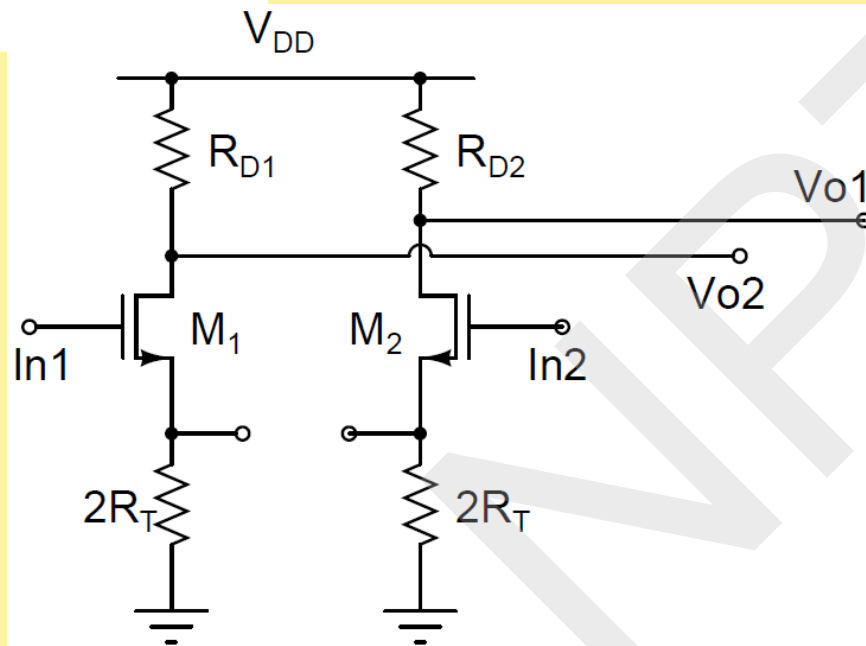
Small signal equivalent circuit of differential amplifier realized by BJTs



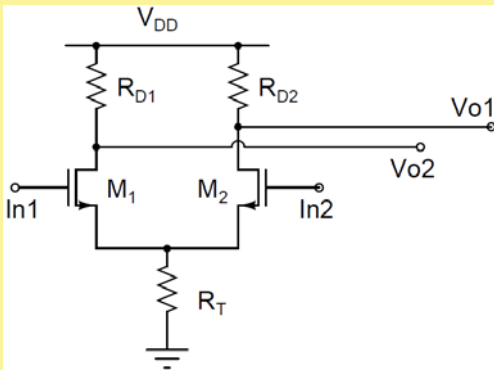
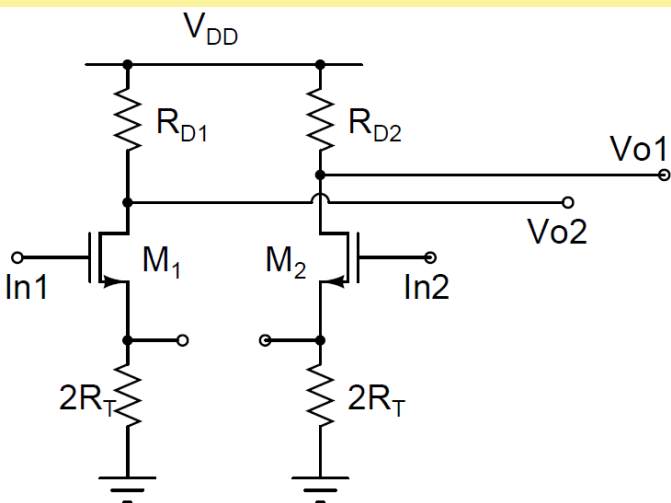
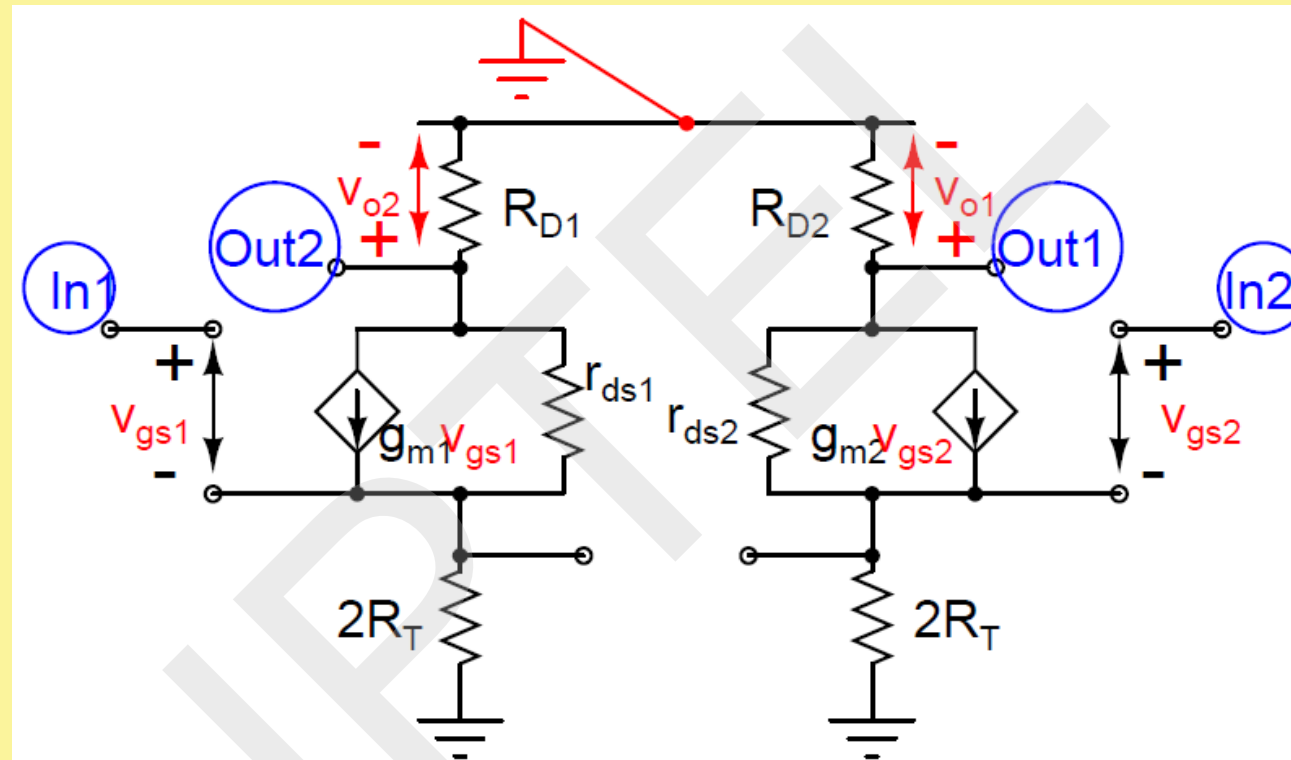
Small signal equivalent circuit of differential amplifier realized by BJTs (contd.)



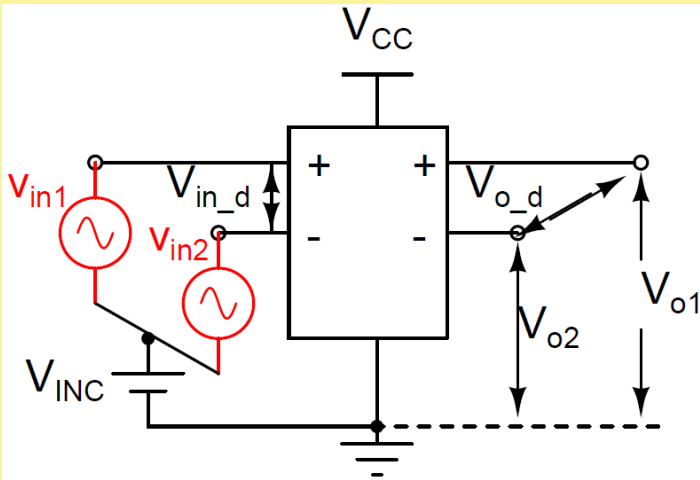
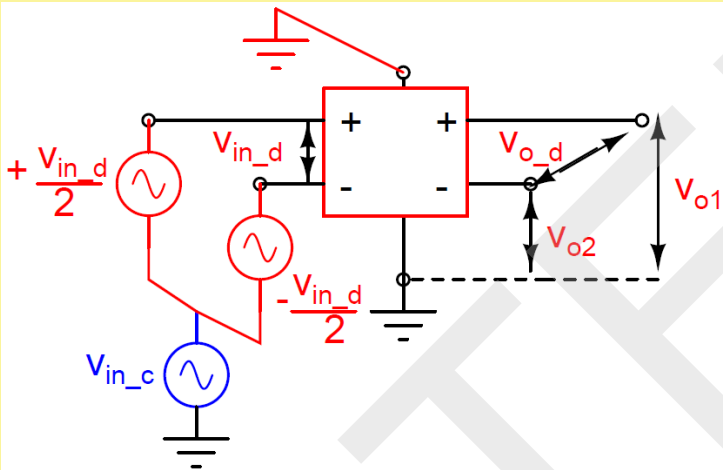
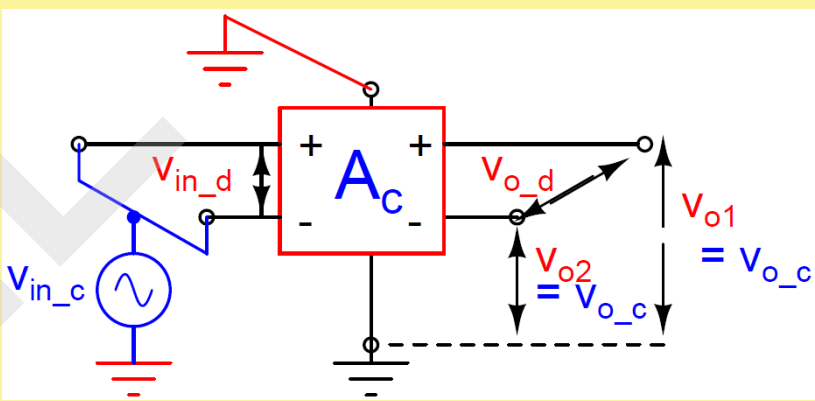
Small signal equivalent circuit of differential amplifier realized by MOSFETs



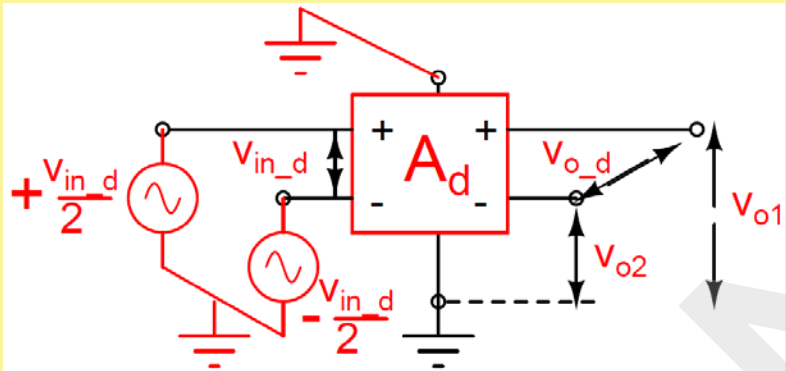
Small signal equivalent circuit of differential amplifier realized by MOSFETs (*contd.*)



Recapitulation: Different modes of stimulus of a differential amplifier



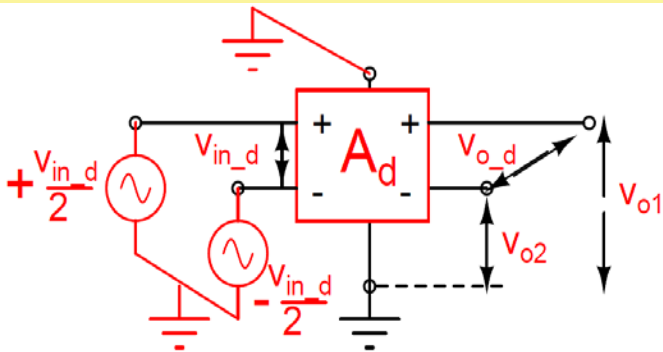
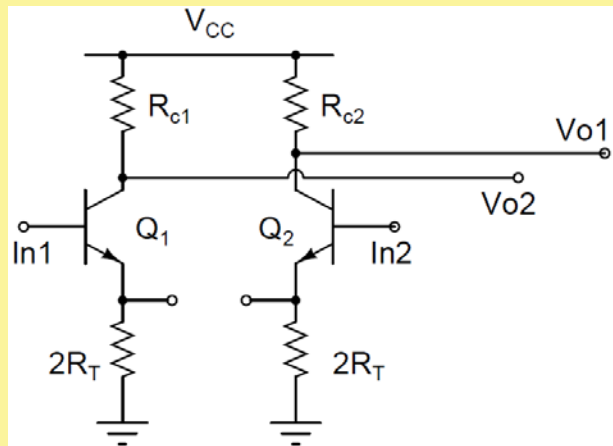
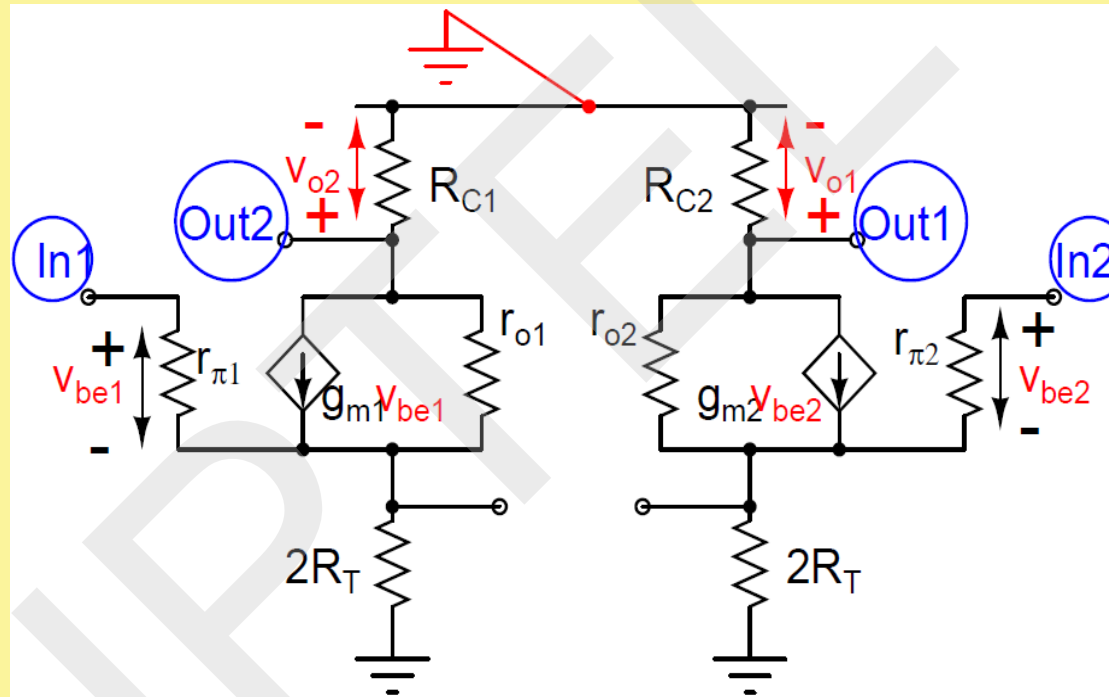
Common mode of stimulus



Differential mode of stimulus

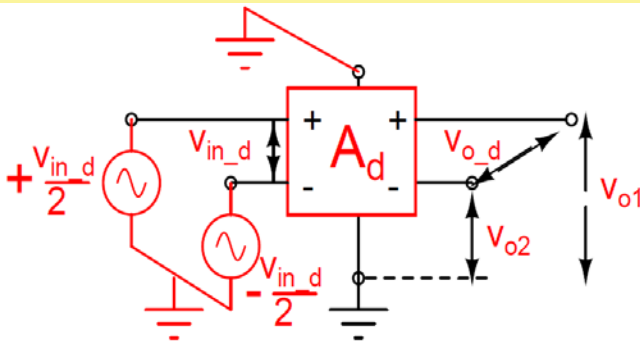
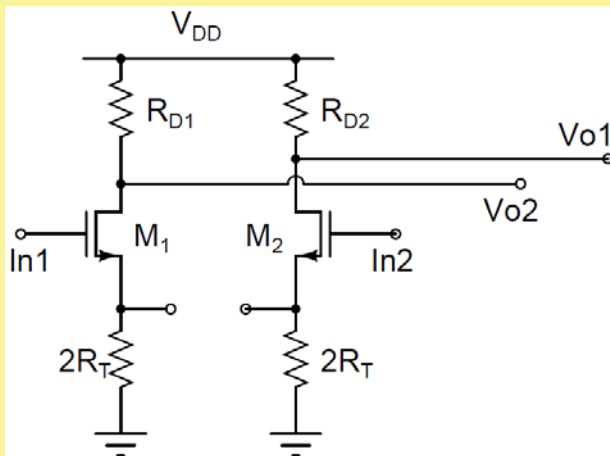
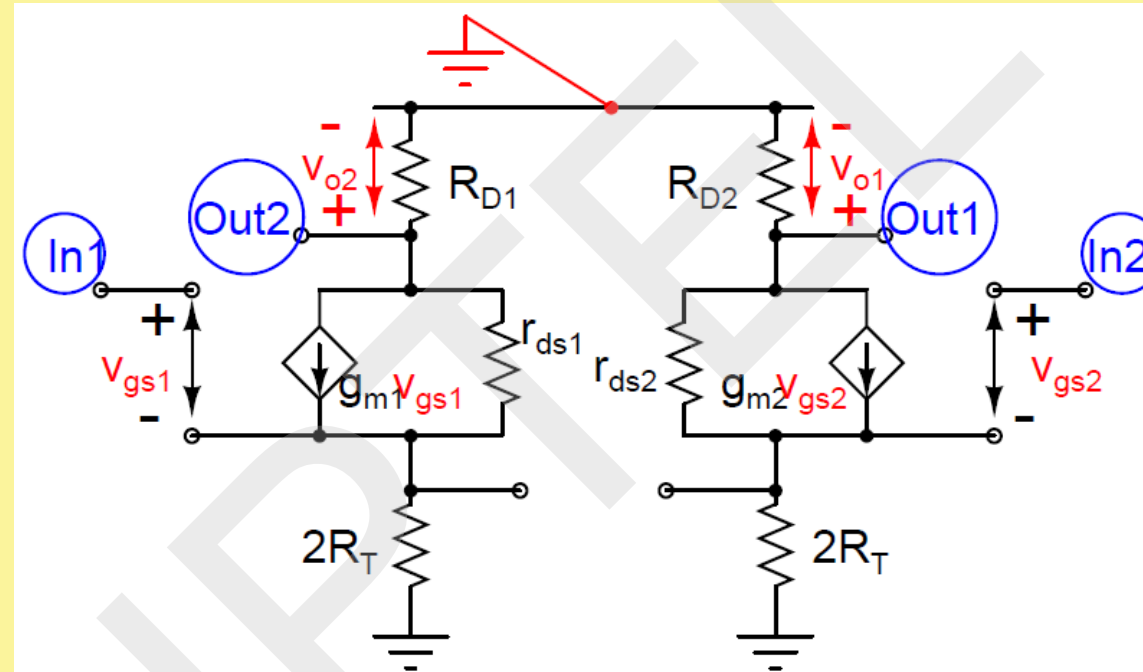
Small signal analysis of differential amplifier realized by BJTs

Differential mode of stimulus:



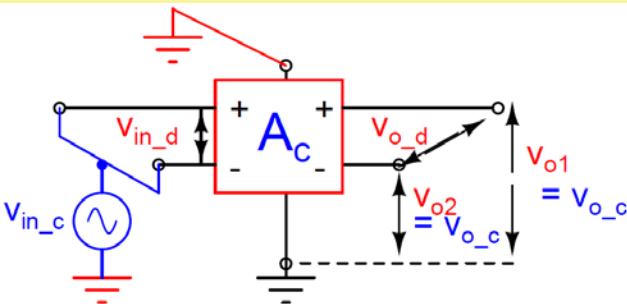
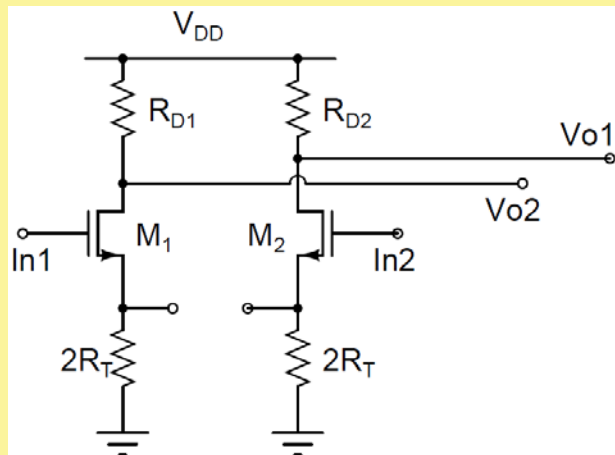
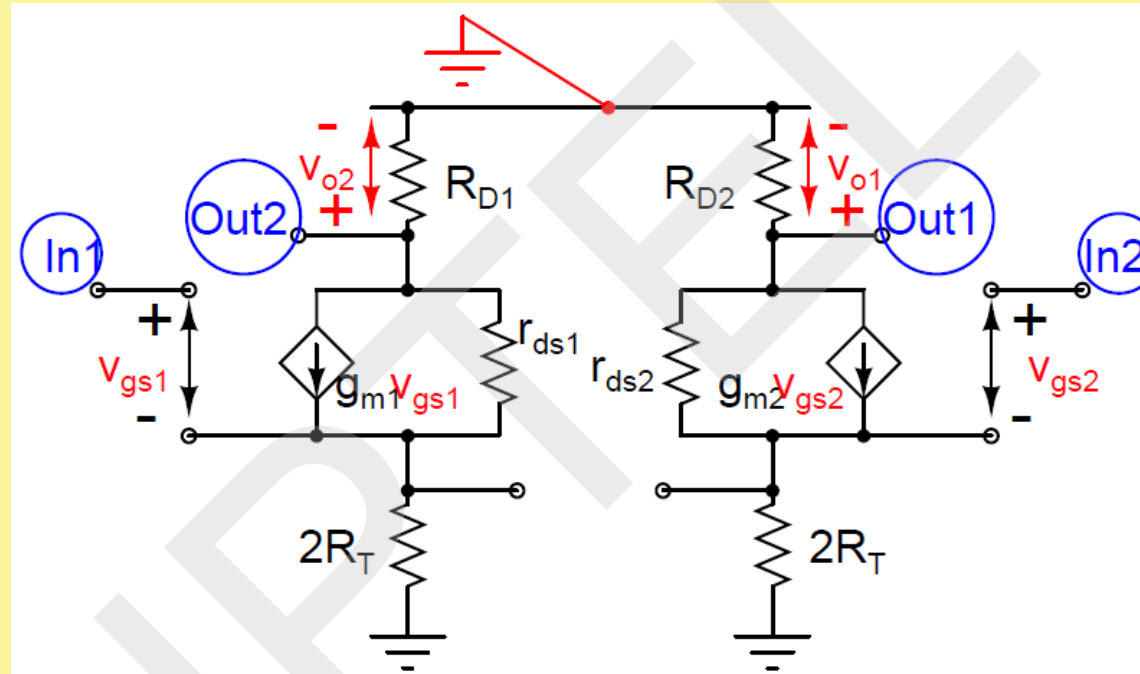
Small signal analysis of differential amplifier realized by MOSFETs

Differential mode of stimulus:



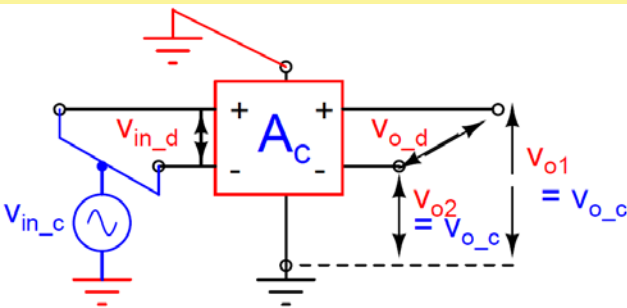
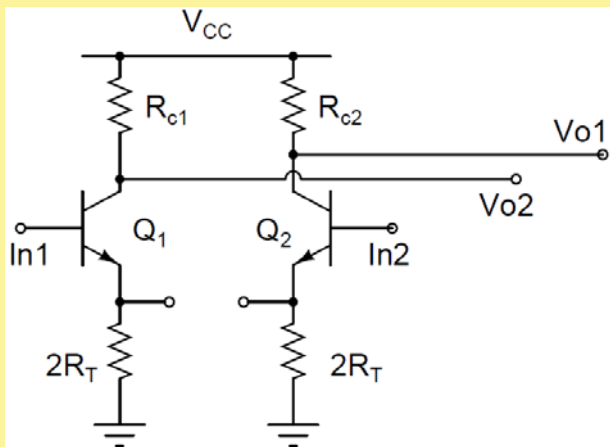
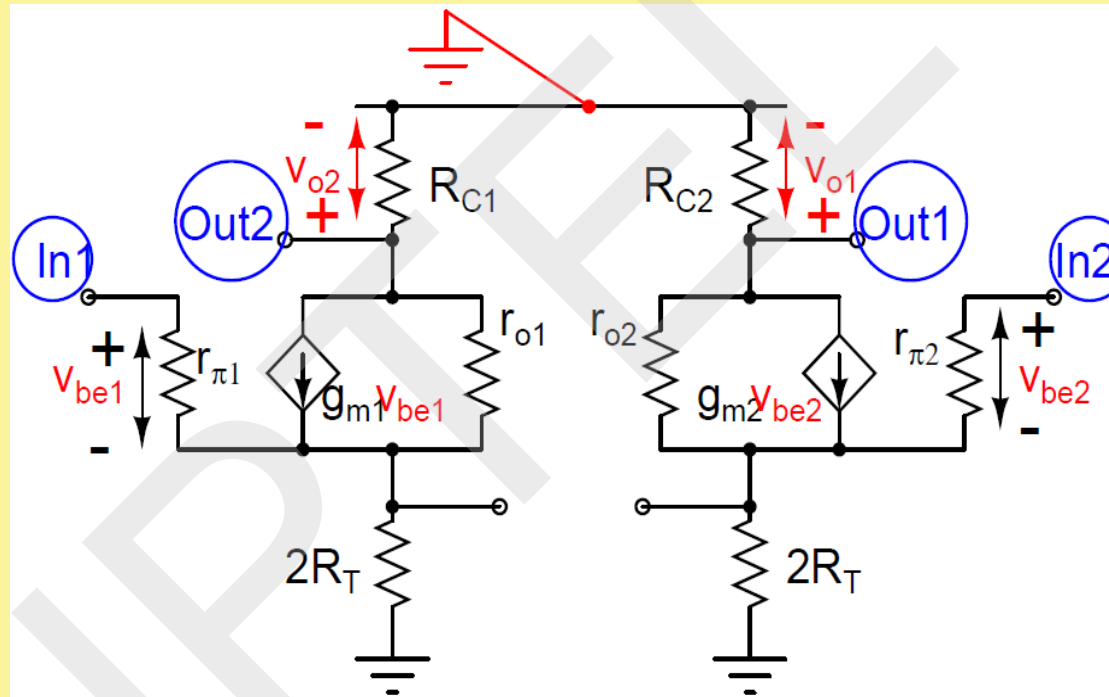
Small signal analysis of differential amplifier realized by MOSFETs

Common mode of stimulus:



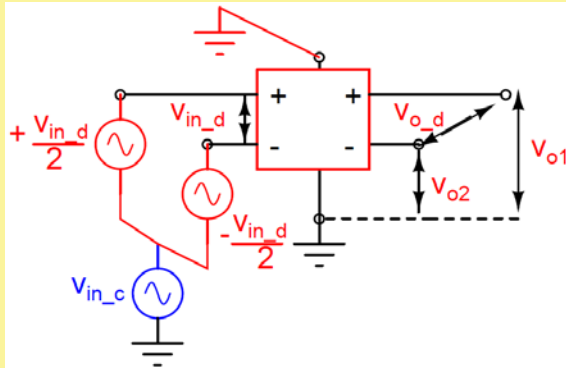
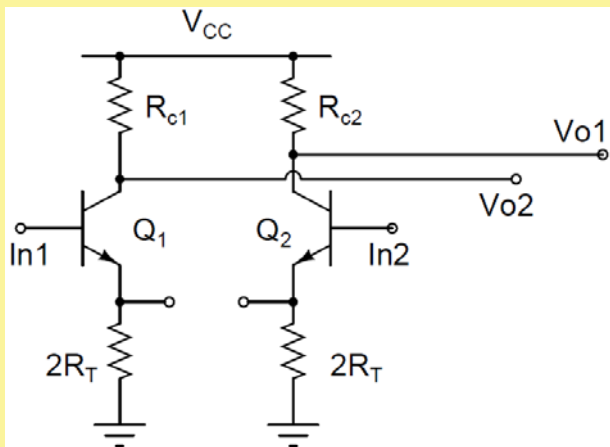
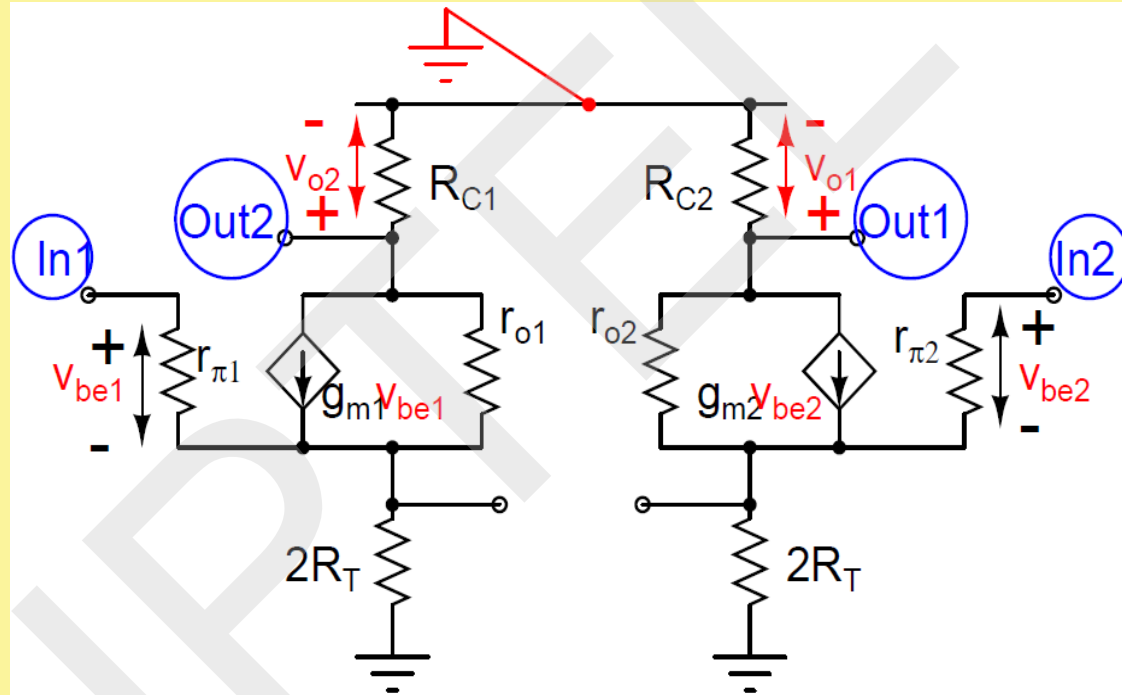
Small signal analysis of differential amplifier realized by BJTs

Common mode of stimulus:

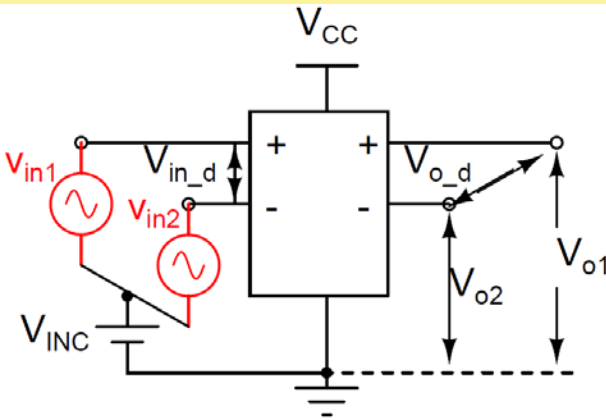
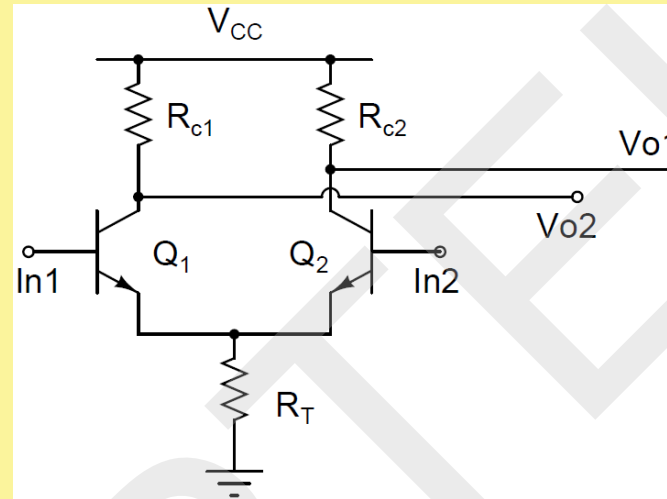
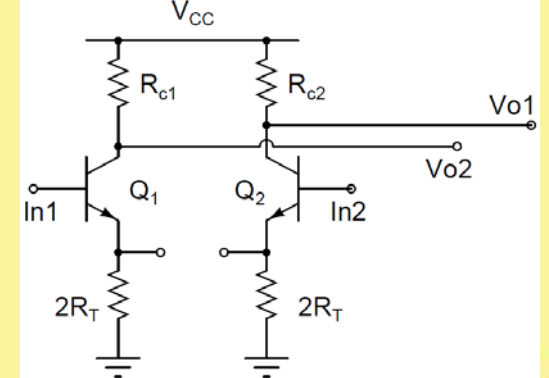


Small signal analysis of differential amplifier realized by BJTs

Generalized mode of stimulus:

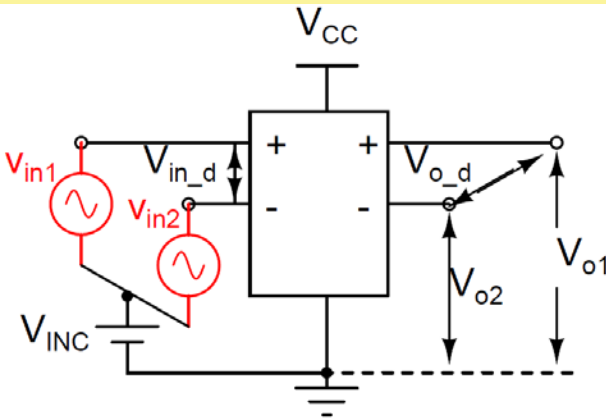
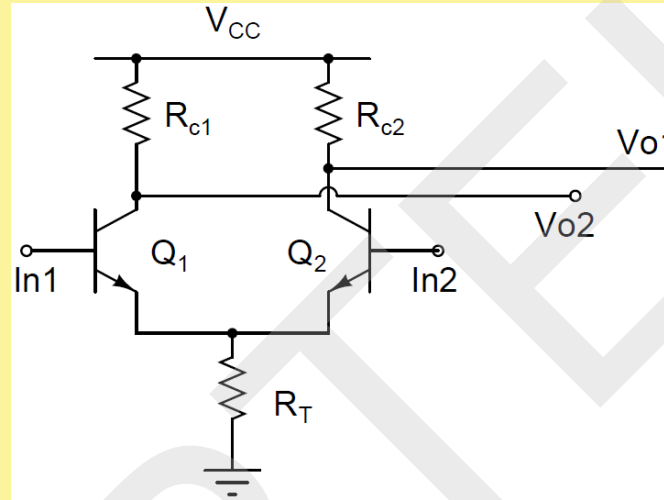


Large signal analysis of differential amplifier realized by BJTs



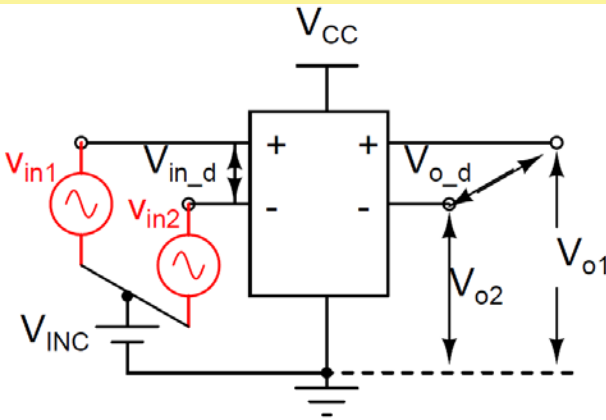
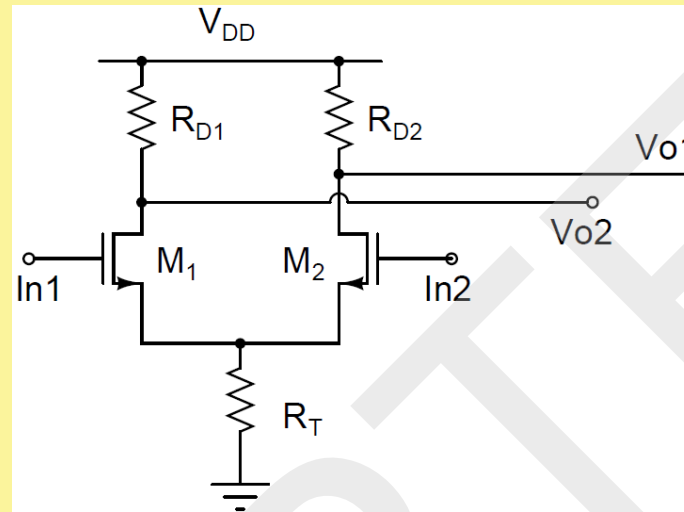
•D.C. operating point

Large signal analysis of differential amplifier realized by BJTs (*contd.*)



- **D.C. operating point**
- **Input common mode range**
- **Output swing**

Large signal analysis of differential amplifier realized by MOSFETs



- D.C. operating point
- Input common mode range
- Output swing

Conclusion

Conclusion:

- ❑ Small signal equivalent circuits of differential amp.
- ❑ Small signal analysis of diff. amp. for
 - Differential mode of stimulus (operation)
 - Common mode of stimulus (operation)
 - Generalized and pseudo-differential stimulus (operation)
- ❑ Large signal analysis for
 - D.C. operating point
 - Input common mode range and
 - Output signal swing
- ❑ *Numerical examples to be covered in next lecture*





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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:

***Differential Amplifier: Analysis and Numerical examples
(contd.)***

CONCEPTS COVERED

Concepts Covered:

- ☐ Small signal equivalent circuits of differential amp.
- ☐ Small signal analysis of diff. amp. for
 - Differential mode of stimulus (operation)
 - Common mode of stimulus (operation)
 - Generalized and pseudo-differential stimulus (operation)
- ☐ Large signal analysis for
 - D.C. operating point
 - Input common mode range and
 - Output signal swing
- ☐ Numerical examples
 - Differential amplifier using BJTs
 - Differential amplifier using MOSFETs
 - Differential amplifier using MOSFETs and BJTs

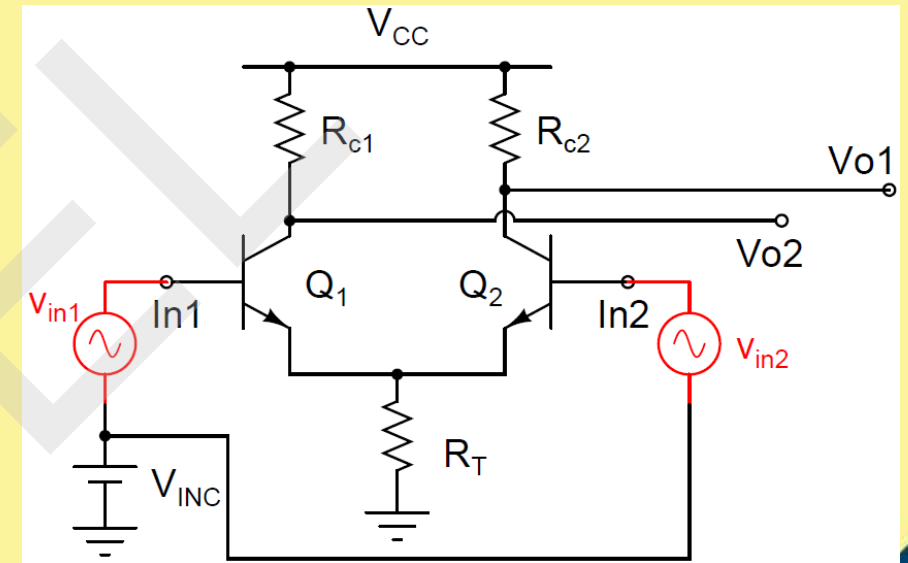


Numerical example: Differential amplifier realized by BJTs

- $\beta_1 = \beta_2 = 100$; $V_{BE(on)1} = V_{BE(on)2} \approx 0.6V$; $V_{A1} = V_{A2} = 100V$;
- $V_{CC} = 12V$; $R_{C1} = R_{C2} = 5.2\text{ k}\Omega$; $R_T = 1\text{ k}\Omega$
- $C_{L1} = C_{L2} = 100\text{ pF}$

➤ For $V_{INC} = 2.6V$, Find:

- Operating points of transistors
- Output d.c. voltage
- Values of small signal parameters of transistors
- Output swing (distortion free output signal)
- Differential mode gain
- Common mode gain



Numerical example: Differential amplifier realized by BJTs

- $\beta_1 = \beta_2 = 200$; $V_{BE(on)1} = V_{BE(on)2} \approx 0.6V$; $V_{A1} = V_{A2} = 100V$;

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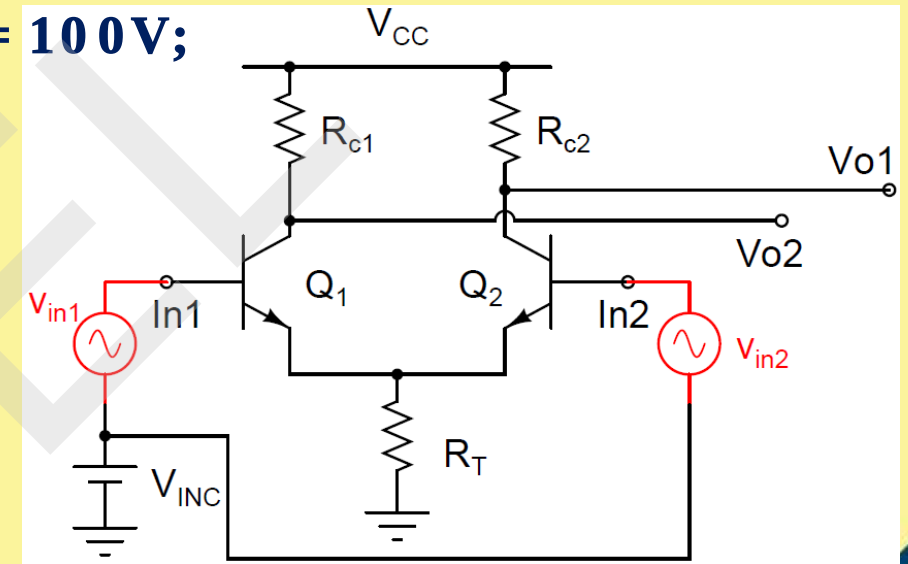
- $V_{INC} = 2.6V$,

- **For**
$$v_{in1} = 0.01 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.2 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.01 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.2 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

- **Find:**

- V_{o_d} and V_{o_c}

- V_{o1} and V_{o2}



Numerical example: Differential amplifier realized by BJTs

- $\beta_1 = \beta_2 = 200$; $V_{BE(on)1} = V_{BE(on)2} \approx 0.6V$; $V_{A1} = V_{A2} = 100V$;

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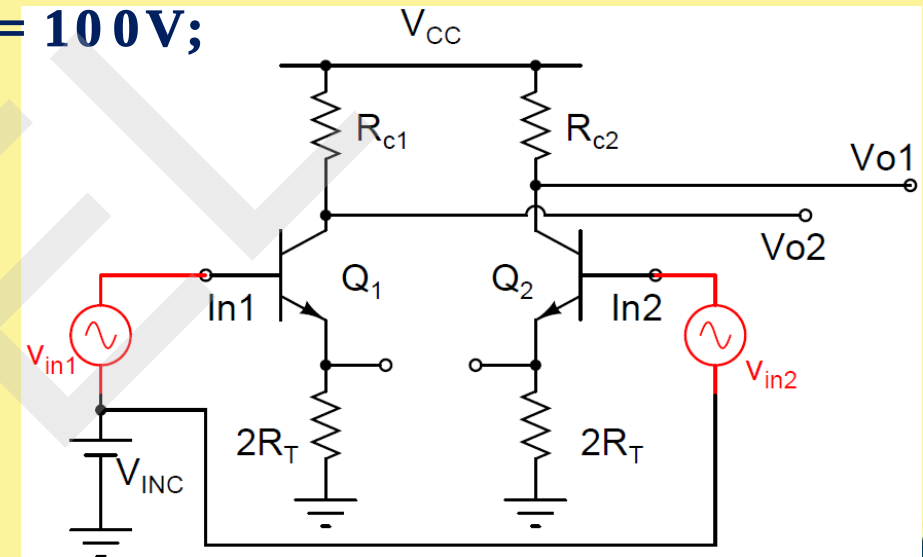
- $V_{INC} = 2.6V$,

- For
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$$v_{in2} = -0.01 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.2 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

- Find:

- V_{o1} and V_{o2}

- V_{o_d} and V_{o_c}



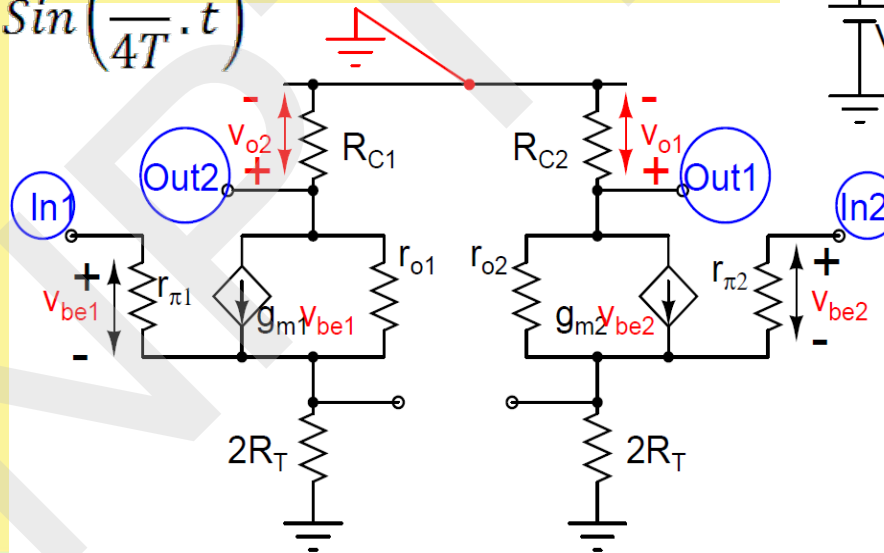
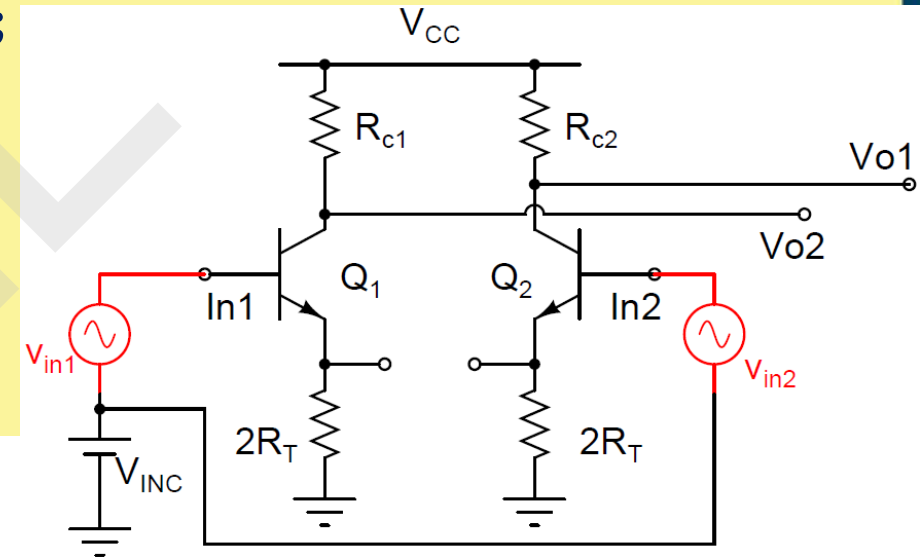
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- $C_{L1} = C_{L2} = 100\text{ pF}$
- $V_{INC} = 2.6V$,

- **For**
$$v_{in1} = 0.01 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.2 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.01 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.2 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

- **Find:**

- V_{o1} and V_{o2}
- V_{o_d} and V_{o_c}



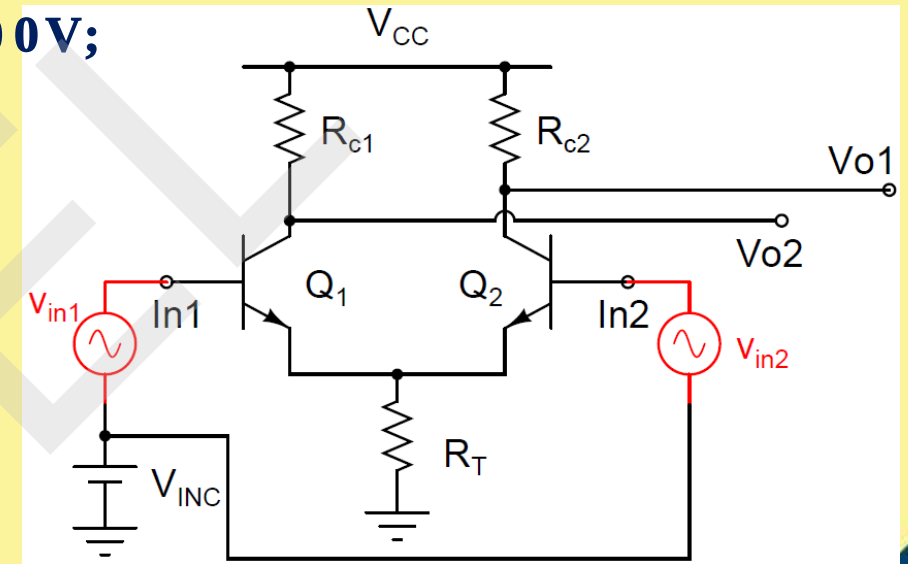
Numerical example: Differential amplifier realized by BJTs

- $\beta_1 = \beta_2 = 200$; $V_{BE(on)1} = V_{BE(on)2} \approx 0.6V$; $V_{A1} = V_{A2} = 100V$;
- $V_{CC} = 12V$; $R_{C1} = R_{C2} = 5.2\text{ k}\Omega$; $R_T = 1\text{ k}\Omega$
- $C_{L1} = C_{L2} = 100\text{ pF}$
- $V_{INC} = 0.8V$,

• For

$$v_{in1} = 0.01 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.2 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.01 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.2 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

- Find:
- **V_{o1} and V_{o2}**



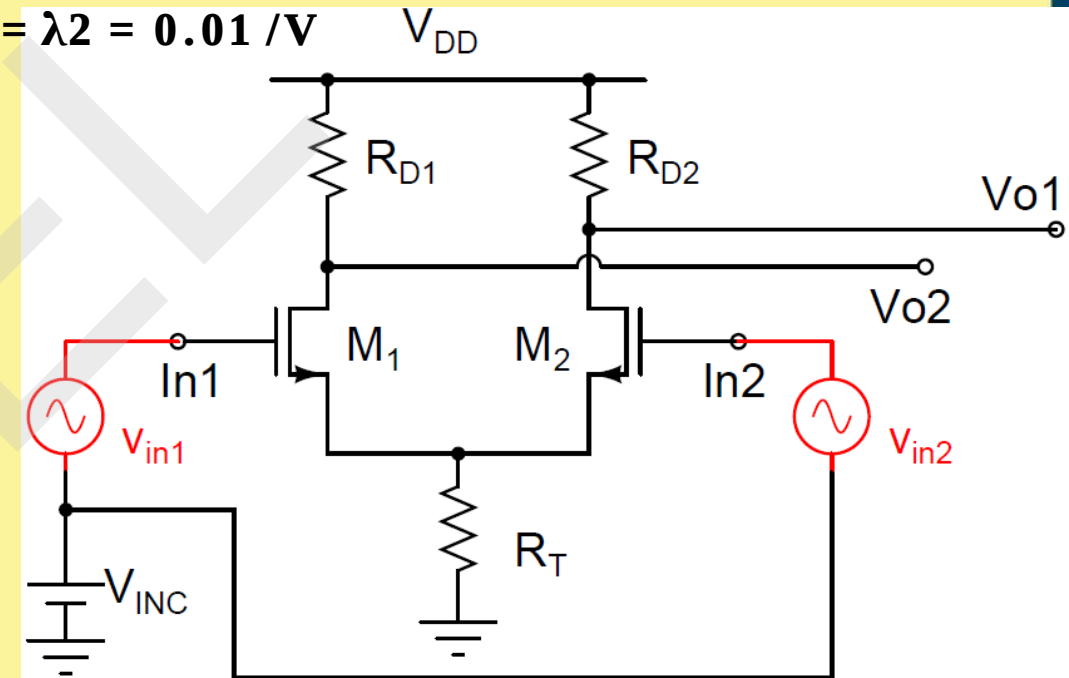
- What is the maximum value of V_{INC} keeping Q1 and Q2 in active region of operation?

Numerical example: Differential amplifier realized by MOSFETs

- $(K_n \cdot W1/L1) = (K_n \cdot W2/L2) = 2 \text{ mA/V}^2$; $V_{th1} = V_{th2} = 1\text{V}$, $\lambda_1 = \lambda_2 = 0.01/\text{V}$
- $V_{DD} = 12\text{V}$, $R_{D1} = R_{D2} = 4\text{k}\Omega$, $R_T = 1\text{k}\Omega$, $C_{L1} = C_{L2} = 100\text{pF}$

➤ **For $V_{INC} = 4V$, Find:**

- **Operating points of transistors**
- **Output d.c. voltage**
- **Values of small signal parameters of transistors**
- **Output swing (distortion free output signal)**
- **Differential mode gain**
- **Common mode gain**



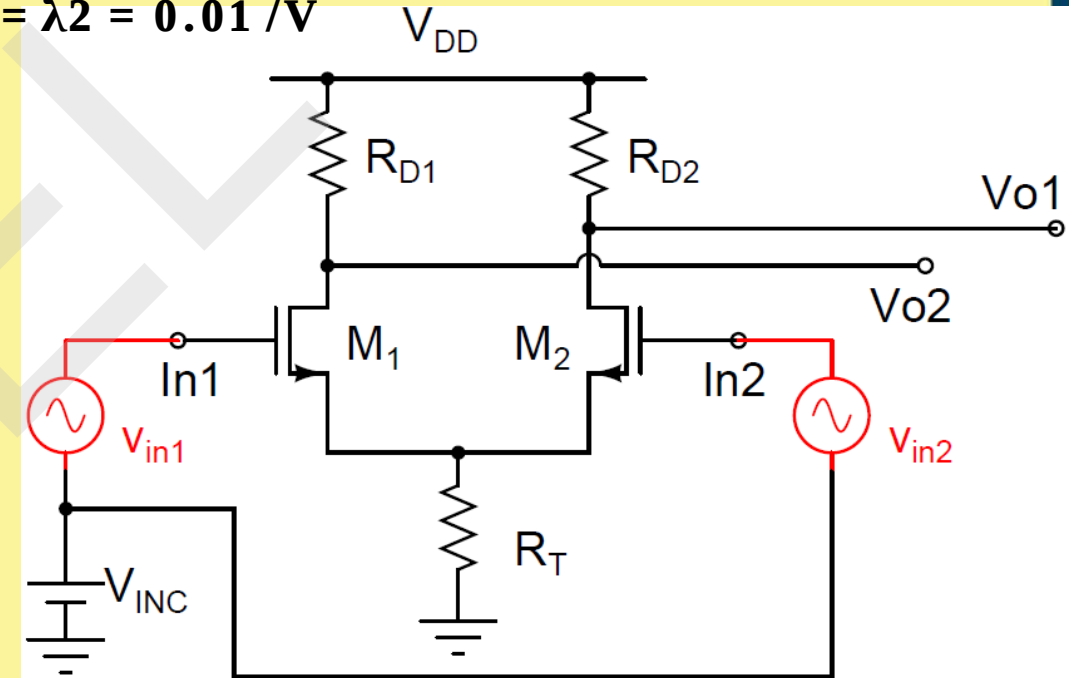
Numerical example: Differential amplifier realized by MOSFETs

- $(K_n.W1/L1) = (K_n.W2/L2) = 2 \text{ mA/V}^2$; $V_{th1} = V_{th2} = 1\text{V}$, $\lambda_1 = \lambda_2 = 0.01/\text{V}$
- $V_{DD} = 12\text{V}$, $R_{D1} = R_{D2} = 4\text{k}\Omega$, $R_T = 1\text{k}\Omega$, $C_{L1} = C_{L2} = 100\text{pF}$
- $V_{INC} = 4\text{V}$.

- **For**
$$v_{in1} = 0.25 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.3 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.25 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.3 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

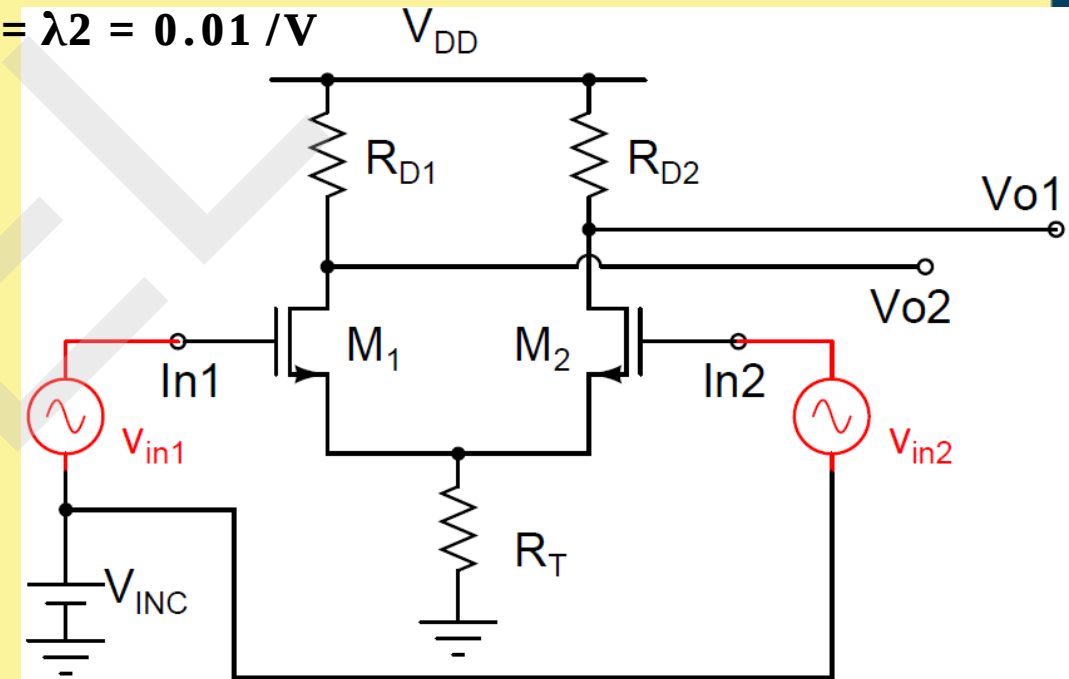
- **Find:**

- V_{o_d} and V_{o_c}
- V_{o1} and V_{o2}



Numerical example: Differential amplifier realized by MOSFETs

- $(K_n.W1/L1) = (K_n.W2/L2) = 2 \text{ mA/V}^2$; $V_{th1} = V_{th2} = 1\text{V}$, $\lambda_1 = \lambda_2 = 0.01/\text{V}$
- $V_{DD} = 12\text{V}$, $R_{D1} = R_{D2} = 4\text{k}\Omega$, $R_T = 1\text{k}\Omega$, $C_{L1} = C_{L2} = 100\text{pF}$
- $V_{INC} = 1.12\text{V}$,
- For $v_{in1} = 2.5 \sin\left(\frac{2\pi}{T} \cdot t\right) + 3 \sin\left(\frac{2\pi}{4T} \cdot t\right)$
 $v_{in2} = -2.5 \sin\left(\frac{2\pi}{T} \cdot t\right) + 3 \sin\left(\frac{2\pi}{4T} \cdot t\right)$
- Find:
 - V_{o1} and V_{o2}



➤ What is the maximum value of V_{INC} keeping $M1$ and $M2$ in saturation region of operation ?

Numerical example: Differential amplifier realized by MOSFETs & BJTs

- $(K_n \cdot W1/L1) = (K_n \cdot W2/L2) = 2 \text{ mA/V}^2$; $V_{th1} = V_{th2} = 1\text{V}$, $\lambda_1 = \lambda_2 = 0.01$

- $V_{DD} = 12\text{V}$, $R_{D1} = R_{D2} = 4\text{k}\Omega$, $R_T = 1\text{k}\Omega$, $C_{L1} = C_{L2} = 100\text{pF}$

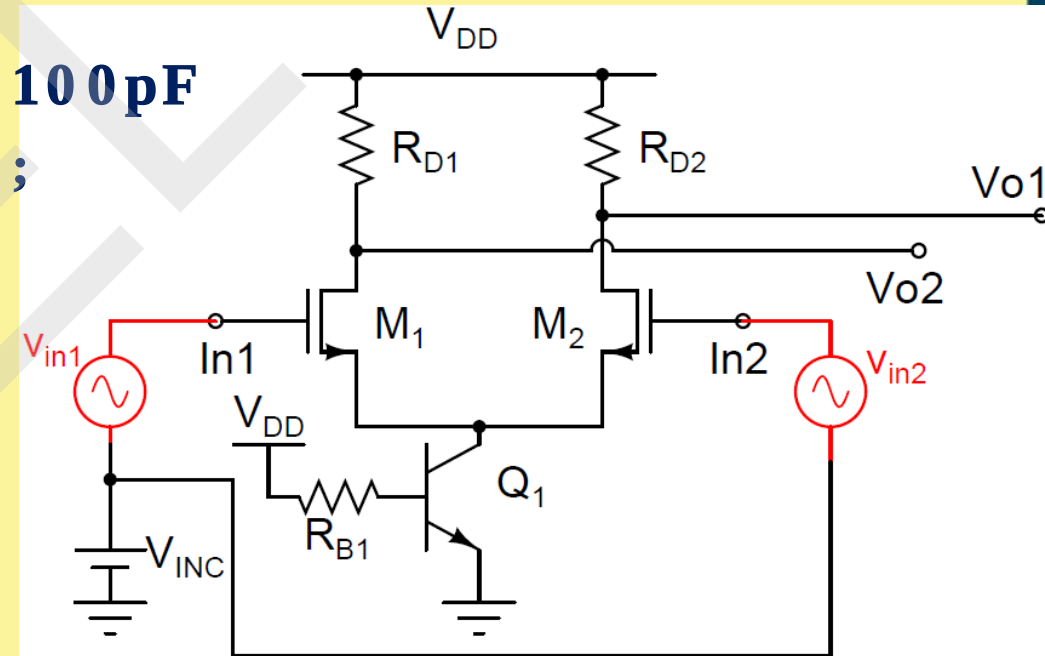
- $\beta_1 = 100$; $V_{BE(on)1} \approx 0.6\text{V}$; $V_{A1} = 100\text{V}$, $R_{B1} = 570\text{k}\Omega$;

- $V_{INC} = 4\text{V}$.

- For
$$v_{in1} = 0.25 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.3 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$
$$v_{in2} = -0.25 \sin\left(\frac{2\pi}{T} \cdot t\right) + 0.3 \sin\left(\frac{2\pi}{4T} \cdot t\right)$$

- Find:

- V_{o_d} and V_{o_c}
- V_{o1} and V_{o2}



Conclusion:

- ❑ Small signal equivalent circuits of differential amp.
- ❑ Small signal analysis of diff. amp. for
 - Differential mode of stimulus (operation)
 - Common mode of stimulus (operation)
 - Generalized and pseudo-differential stimulus (operation)
- ❑ Large signal analysis for
 - D.C. operating point
 - Input common mode range and
 - Output signal swing
- ❑ Numerical examples (Opt. pt., small signal gains ...)
 - Differential amplifier using BJTs
 - Differential amplifier using MOSFETs
 - Differential amplifier using MOSFETs and BJTs

Conclusion





NPTEL ONLINE CERTIFICATION COURSES

*Thank
you*

