

Microelectronics Circuit Analysis and Design

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Chapter 9

Ideal Operational Amplifiers and Op-Amp Circuits

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Chapter 9-1

In this chapter, we will:

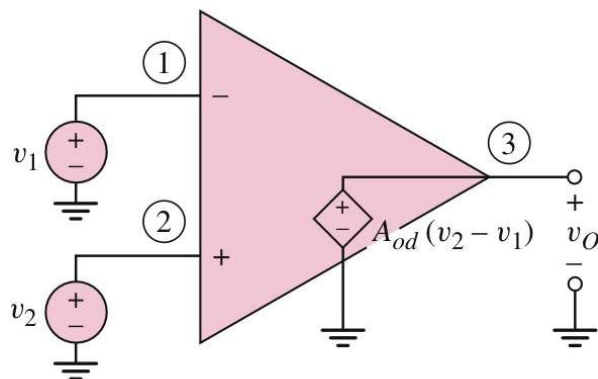
- Develop the parameters and characteristics of the ideal operational amplifier, and determine the analysis method of ideal op-amp circuits.
 - inverting operational amplifier
 - summing operational amplifier
 - noninverting operational amplifier
- Analyze several ideal op-amp circuits including the difference amplifier and the instrumentation amplifier.
- Design several ideal op-amp circuits with given design specifications.

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Ideal Op-Amp Equivalent Circuit



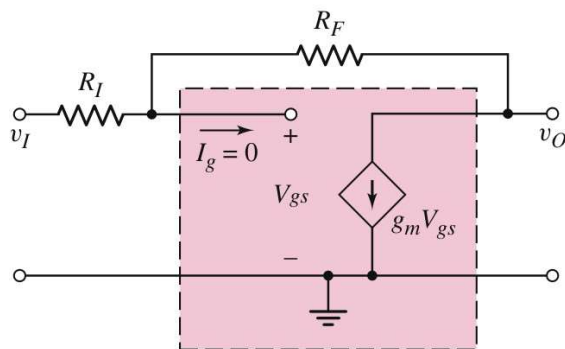
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Small-Signal Equivalent Circuit: MOSFET with Input and Output Feedback



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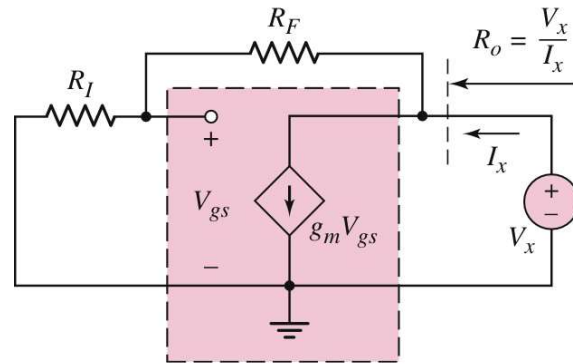
$$\frac{v_O}{v_I} = -\frac{R_F}{R_I}$$

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Output Impedance : MOSFET with Input and Output Feedback



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$$R_o = \frac{R_I + R_F}{1 + g_m R_I}$$

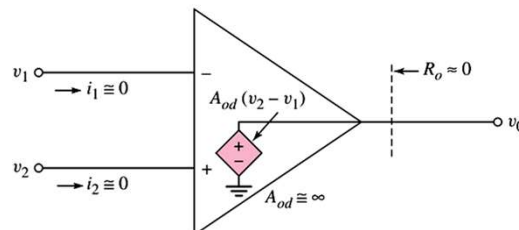
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Ideal Op-Amp Characteristics

1. Internal differential gain A_{od} is infinite.
2. Differential input voltage ($v_2 - v_1$) is zero.
3. Effective input resistance is infinite.
4. Output resistance is zero, so output voltage is connected directly to dependent voltage source.



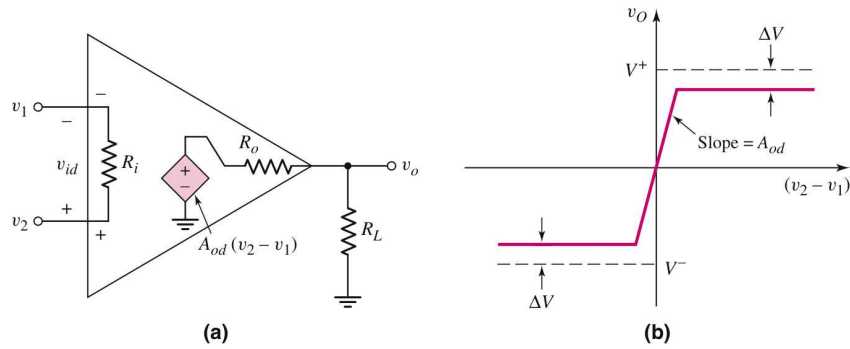
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Equivalent Circuit of Op-Amp



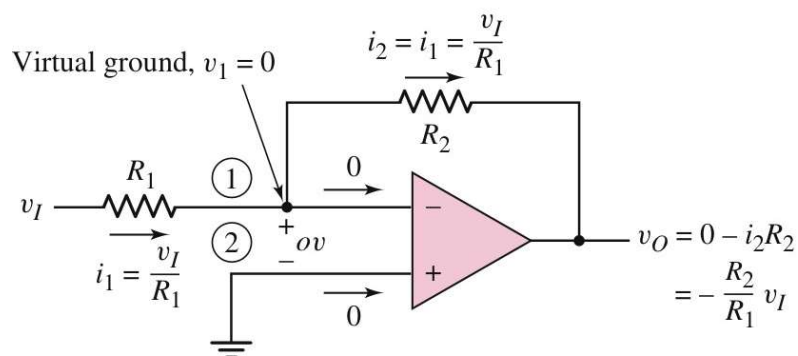
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Inverting Op-Amp



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Problem-Solving Technique: Ideal Op-Amp Circuits

1. If noninverting terminal is grounded, then inverting terminal is virtual ground.
 - a. Sum currents at node assuming no current enters Op Amp.
2. If noninverting terminal is not grounded, then inverting terminal voltage is equal to that of the noninverting terminal.
 - a. Sum currents at node assuming no current enters Op Amp.
3. Output voltage is determined from either Step 1 or 2.

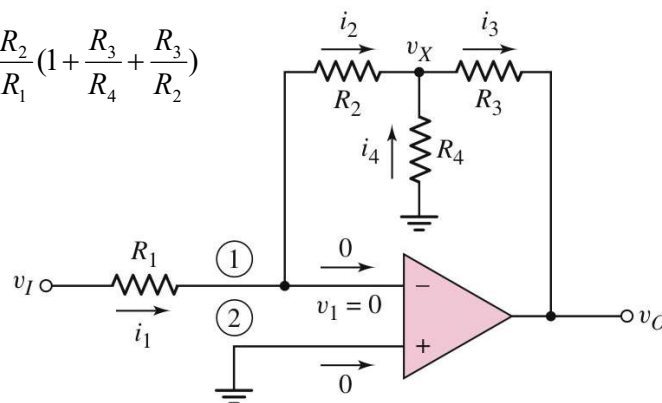
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Inverting Op-Amp with T-Network

$$A_v = -\frac{R_2}{R_1} \left(1 + \frac{R_3}{R_4} + \frac{R_3}{R_2} \right)$$



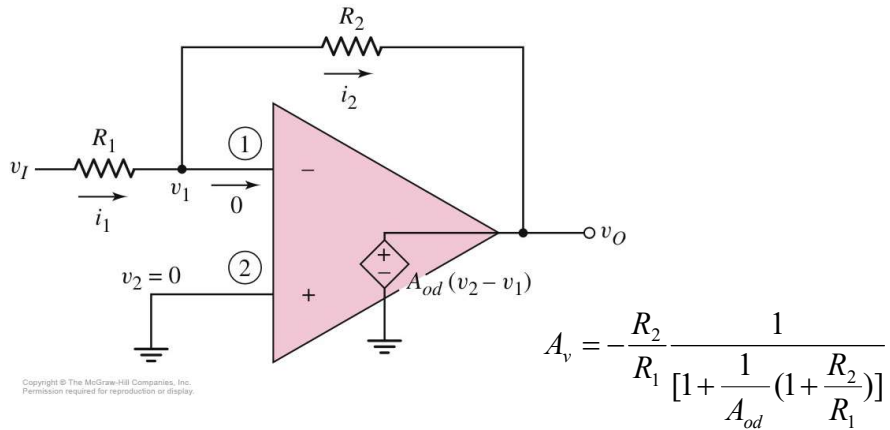
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Inverting Op-Amp with Finite Differential-Mode Gain

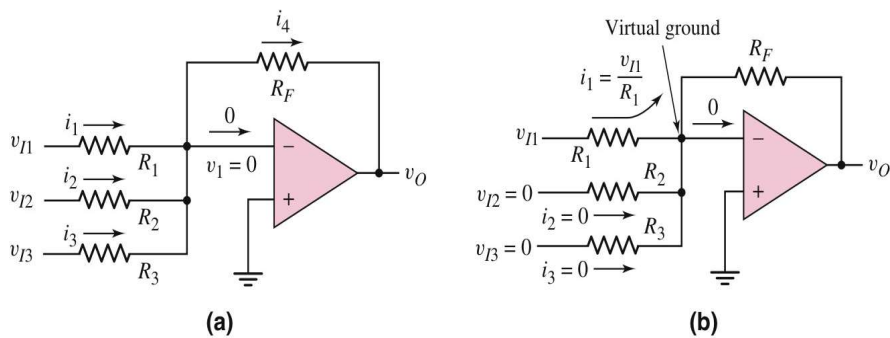


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Summing Op-Amp



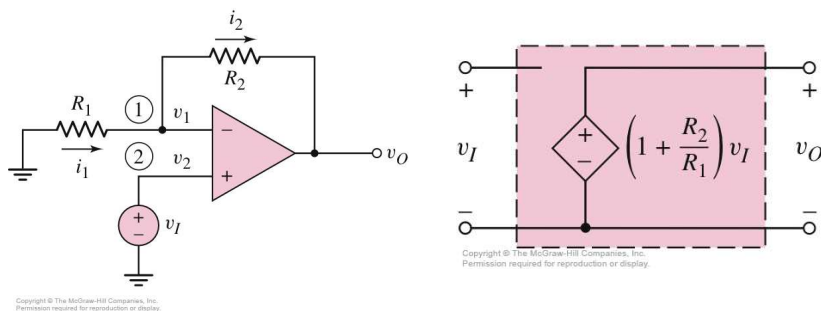
$$v_O = -\left(\frac{R_F}{R_1} v_{I1} + \frac{R_F}{R_2} v_{I2} + \frac{R_F}{R_3} v_{I3}\right)$$

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Noninverting Op-Amp

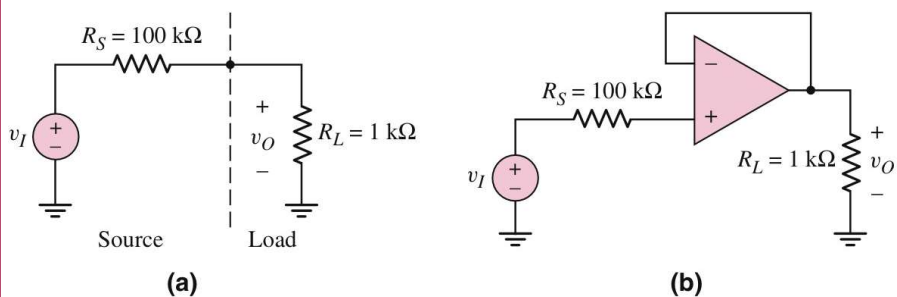


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Voltage Follower



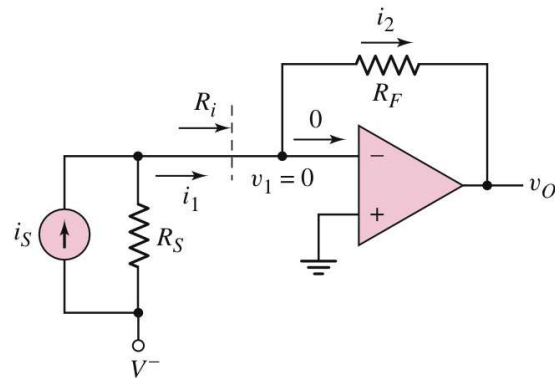
$$\frac{v_O}{v_I} = \frac{R_L}{R_L + R_S}$$

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Current-to-Voltage Converter



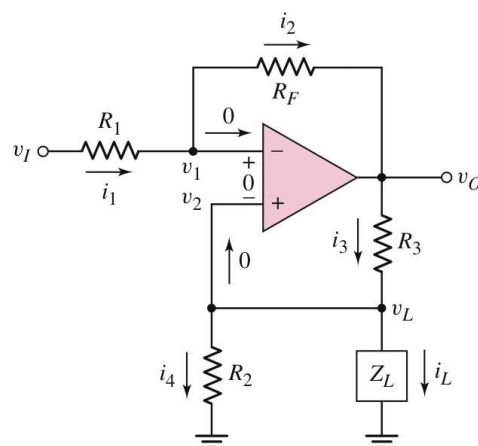
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Voltage-to-Current Converter



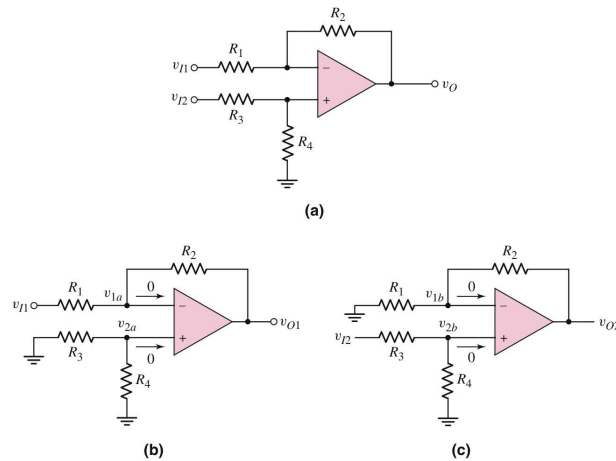
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Op-Amp Difference Amplifier



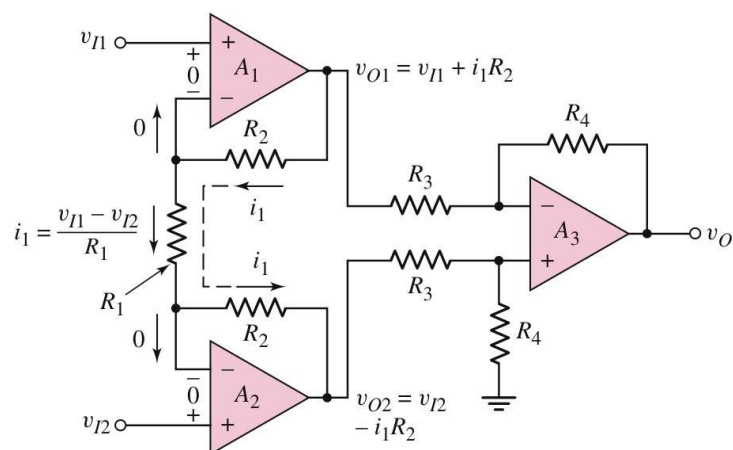
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Instrumentation Amplifier



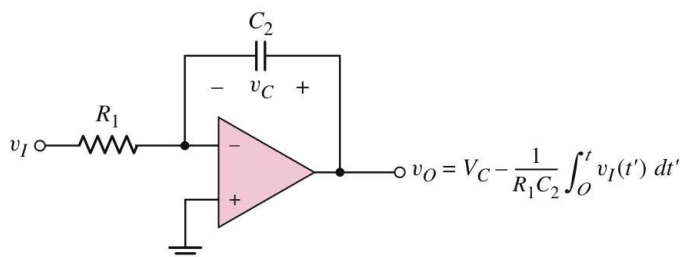
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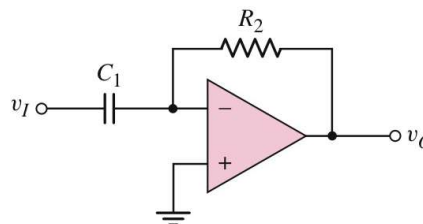
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Op-Amp Integrator and Differentiator



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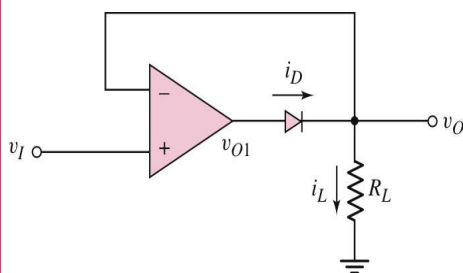
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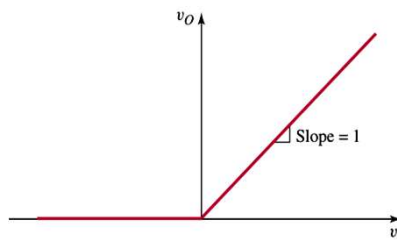
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Precision Half-Wave Rectifier



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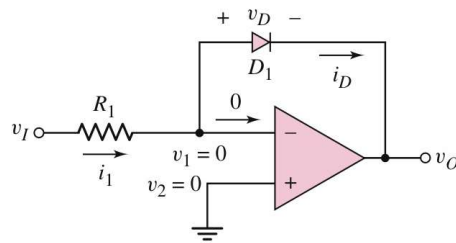
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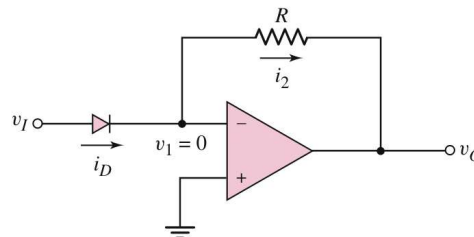
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Log and Antilog Amplifiers



Log Amplifier

Antilog Amplifier

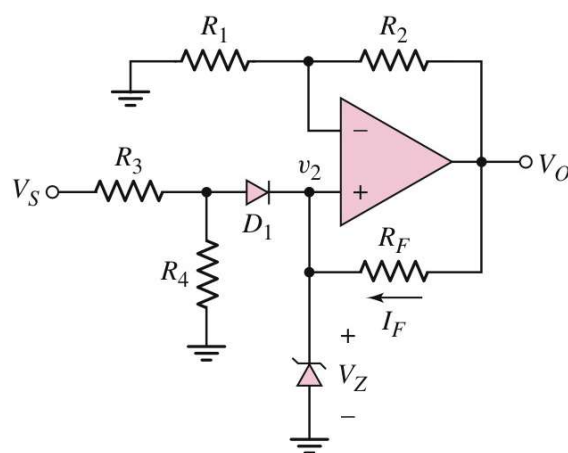


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Op-Amp Voltage Reference Circuit



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