Operational-Amplifier and Data-Converter Circuits
Outline

- The Two-Stage CMOS Op Amp
- The Folded-Cascode CMOS Op Amp
- The 741 Op-Amp Circuit
- DC Analysis of the 741
- Small-Signal Analysis of the 741
- Gain, Frequency Response, and Slew Rate of the 741
- Data Converters- An Introduction
- D/A Converter Circuits
- A/D Converter Circuits
**Input & Output Ranges**

Input common-mode range:

\[ V_{ICM, \text{max}} = V_{D1} + V_{Tn} = V_{DD} - 1V_{OV1} \]

\[ V_{ICM, \text{min}} = V_{D11} - V_{OV1} \]

\[ V_{ICM, \text{max}} - V_{D11} - V_{OV1} = V_{OV1} \]

\[ V_{ICM, \text{min}} = V_{DD} - V_{OV1} \]

\[ V_{DD} = V_{SS} + V_{OV1} + V_{OV2} \]

\[ V_{OV1} = V_{DD} - V_{OV1} \]

Output swing:

\[ V_{O, \text{max}} = V_{DD} - 1V_{OV1} - |1V_{OV4}| \]
Increase the input common-mode range
The Wide-Swing Current Mirror

Increase the output voltage range
V_{BIAS} Generation

1) Q5 has a W/L ratio equal to $\frac{1}{4}$ that of the transistors in the wide-swing current mirror

2) Same $I_{REF}$ utilized in both circuits
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The 741 Op-Amp Circuit

Bias Generation

Widlar Current Source

Input Stage

Second Stage

Output transistors

Short-Circuit Protection
Class A and B Output Stage

Class A output stage

Class B output stage
Class AB Output Stage
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Bias Generation Stage

Reference Bias Current

Widlar Current Source

\[ R_s = 39 \, \text{k}\Omega \]

\[ I_{REF} \]

\[ Q_{11} \]

\[ Q_{12} \]

\[ I_{C10} \]

\[ -V_{EE} \]

\[ Q_{10} \]

\[ R_4 \]
Input Stage

Input Bias Current:
Input Offset Current:
Second Stage

\[ R_9 = 50 \text{ k}\Omega \]
\[ R_8 = 100 \text{ } \Omega \]
Output Stage
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Input Stage

\[ R_{id} = \]  

\[ G_{m1} = \]
Small-Signal Equivalent Circuit

Output Resistance

\[ R_{o1} = \]