EE 105

Microelectronic Devices and Circuits

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Small & Large Signals

• Why the fuss?
  – Example: Gain

• Definitions & Nomenclature

• Simplifying life:
  – Small-signal models

• Design: break a hard problem into two simpler ones!
  – Small-signal characteristics
    Usually the stuff we care about:
    Gain, input/output resistance, bandwidth, …
  – Large-signal characteristics (“biasing”)
    What we need to ensure so that our circuit works as expected,
    especially that it actually has all the small-signal characteristics we
    care about!
Gain 1: Ideal Amplifier

\[ V_i \rightarrow V_o \]

Generic Ideal Amplifier

\[ V_o \rightarrow V_i \]

Gain
Gain 2: Practical Amplifier

Realistic Amplifier (finite supply)
Gain 3: Common-Emitter Amplifier Example

Gain
Large- and Small-Signal Definitions

\[ V_o \]

\[ V_i \]
Large- and Small-Signal Nomenclature

\[
V_x \quad \text{Large Signal (rarely used)} \\
\quad \text{(lower case subscript)}
\]

\[= V_X \quad \text{Bias (constant)} \\
\quad \text{(upper case subscript)}
\]

\[+ v_x \quad \text{Small Signal (varying)} \\
\quad \text{(all lower case)}
\]

Nomenclature introduced in
Amplifier (Analog Circuit) Design

Design

small-signal characteristics

and

bias

separately

Break difficult problem into two simpler ones!
Example: voltage gain

Objective:

- Design amplifier with $a_v = v_o/v_i = -2$
- $R_L = 10k\Omega$
1) Amplifier Topology
2) Small-Signal Design
3) Bias Design
4) Verification (SPICE, lab)

**Circuit**

- .model npn105 npn(is=10fA bf=100 vaf=100V)
- .dc Vi 500mV 1.4V 1mV
- .step temp 0 70 35

- 5V
- 1V
- 10k

**Verification**

- T = 0, 35, 70°C

**Is Circuit Robust?**

- e.g. Temperature
Small-Signal Circuit Models

• Linearization of device characteristics around bias point (first-order Taylor series approximation)

• Example 1: ideal (linear) resistor
Example 2: NPN BJT

Large Signal Model

Small Signal Model

\[ + \quad V_{ce} \quad - \]

\[ + \quad V_{be} \quad - \]

\[ I_c \downarrow \]
## Example 3: Constant Voltage Source (e.g. Supply)

<table>
<thead>
<tr>
<th>Large-Signal Circuit</th>
<th>Small-Signal Model</th>
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What is the small-signal model of a constant current source?
Small-Signal Circuit Models

Large-Signal Circuit  Small-Signal Model

![Circuit Diagram]
Calculate the Small-Signal Gain
Determine Bias
(from Small-Signal Parameters)
Small & Large Signals Recap

- Why the fuss?
  - Example: Gain

- Definitions & Nomenclature

- Simplifying life:
  - Small-signal models

- Design: break a hard problem into two simpler ones!
  - Small-signal characteristics (linear)
    Usually the stuff we care about:
    Gain, input/output resistance, bandwidth, …
  - Large-signal characteristics (“biasing”, nonlinear)
    What we need to ensure so that our circuit works as expected, especially that it actually has all the small-signal characteristics we care about!