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
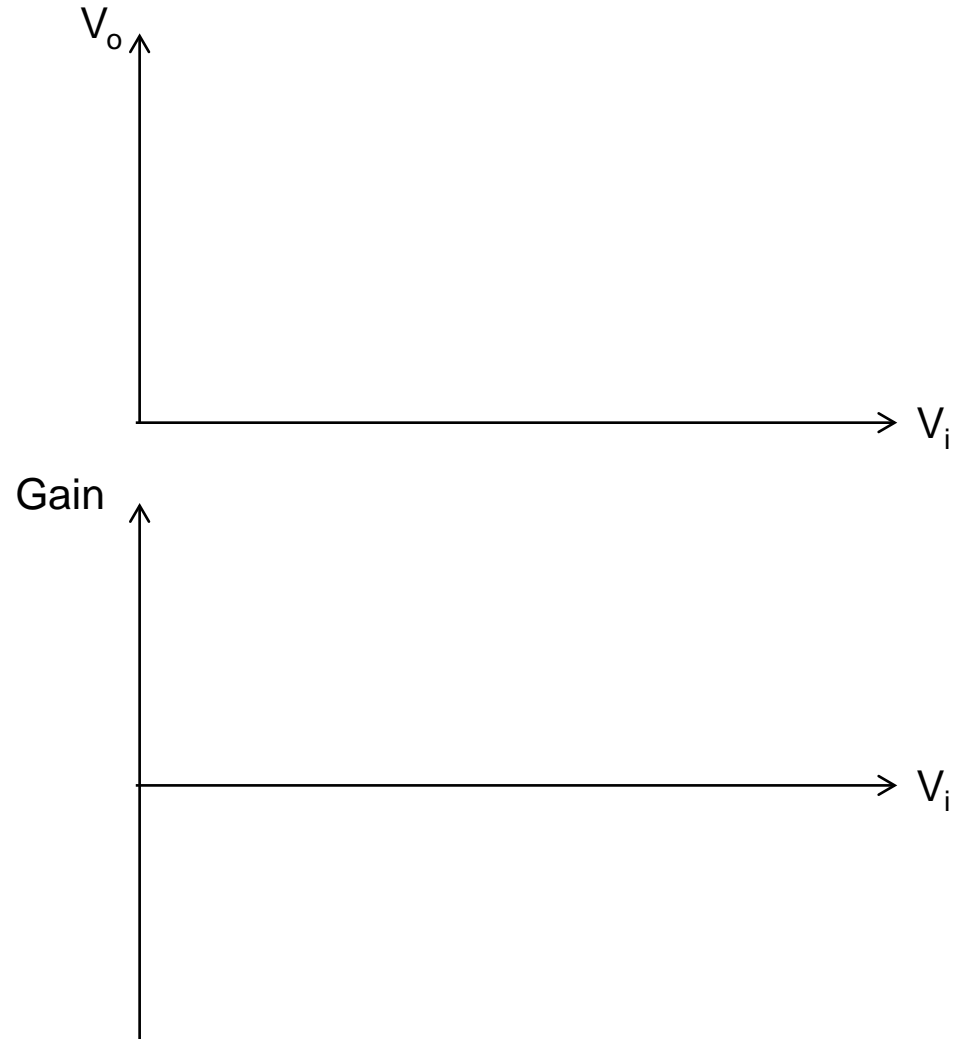   care about!

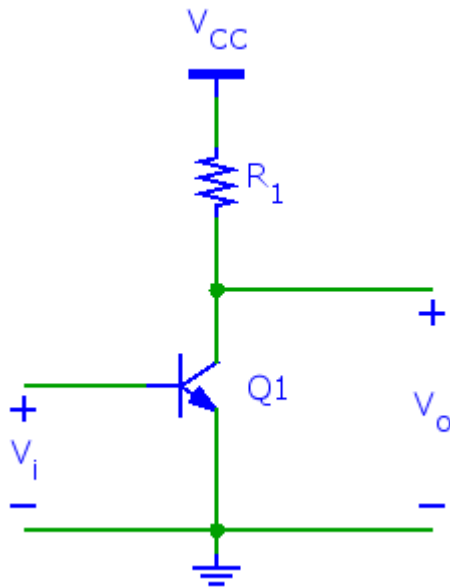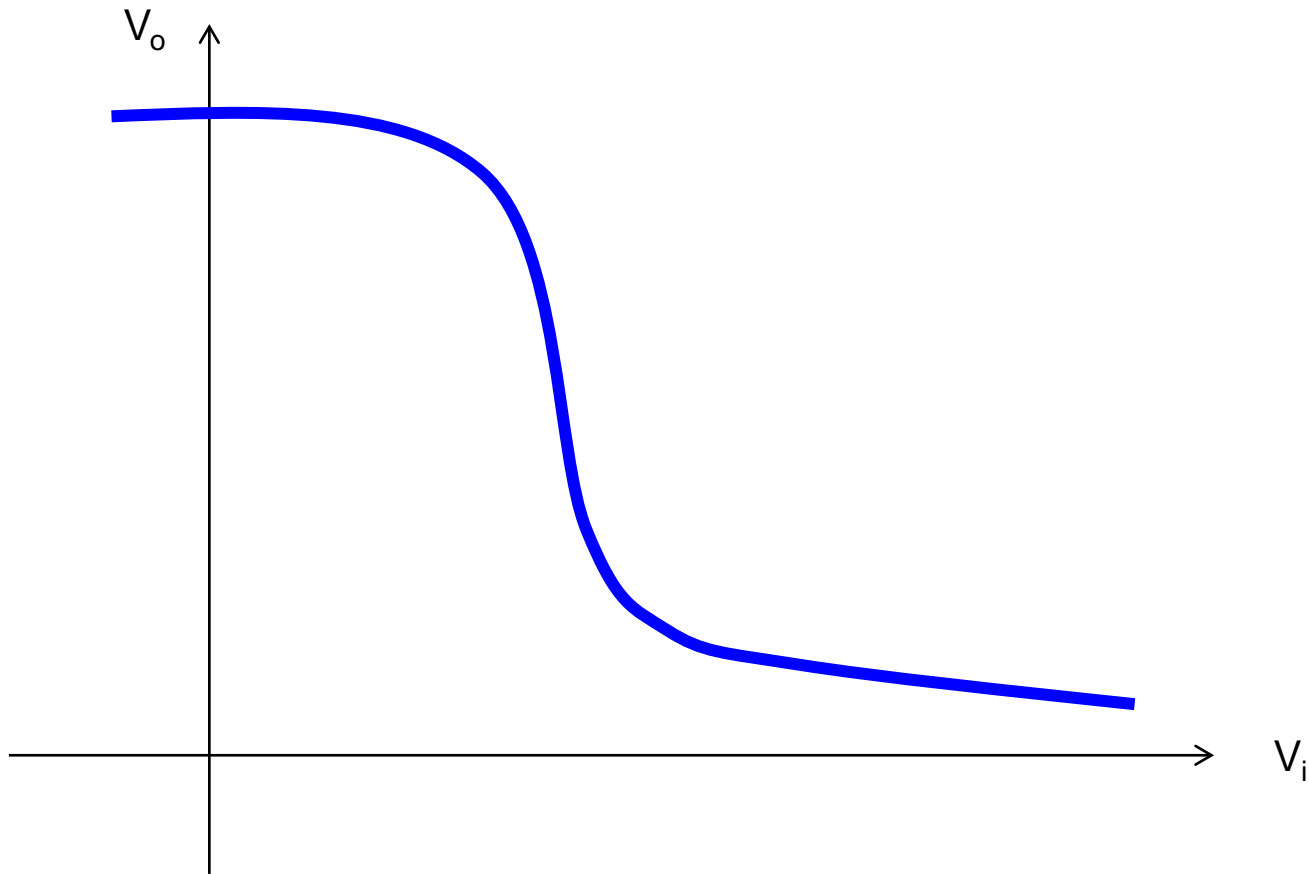# Gain 1: Ideal Amplifier

Generic Ideal Amplifier
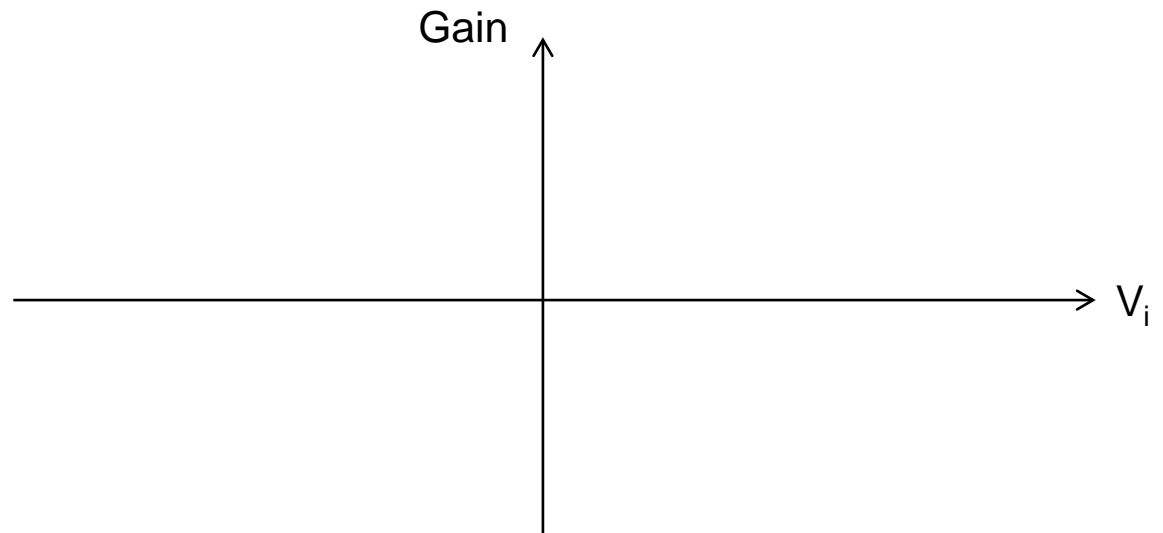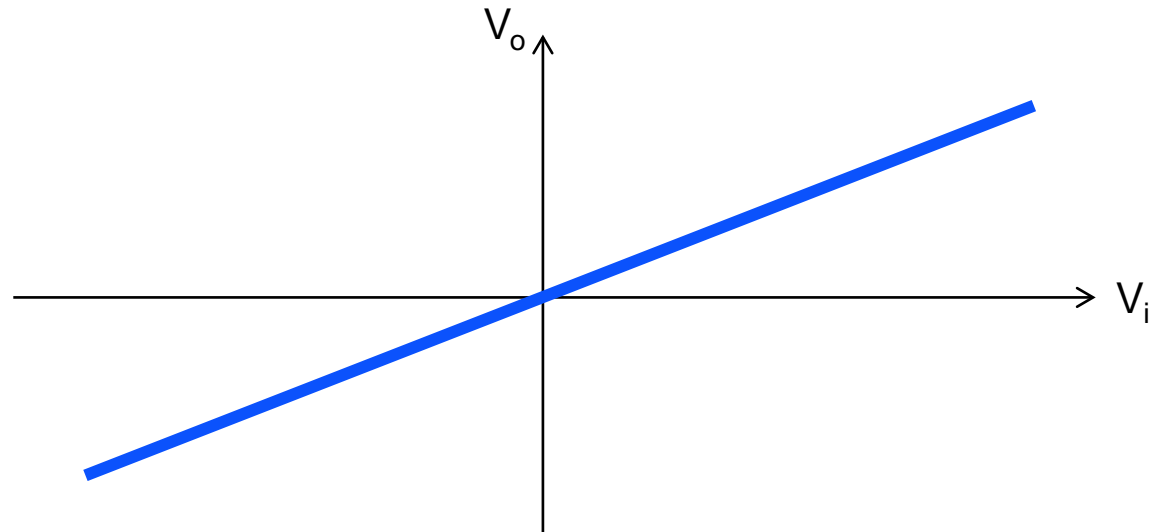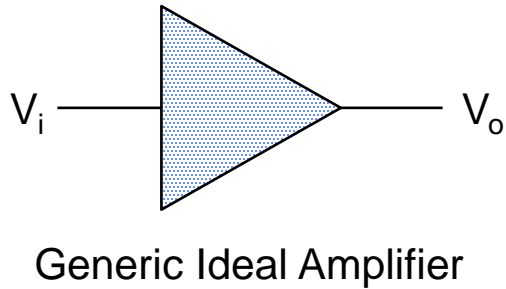
Gain 2: Practical Amplifier

V_i —▷— V_o

Realistic Amplifier
(finite supply)

V_o

V_i

Gain

V_i
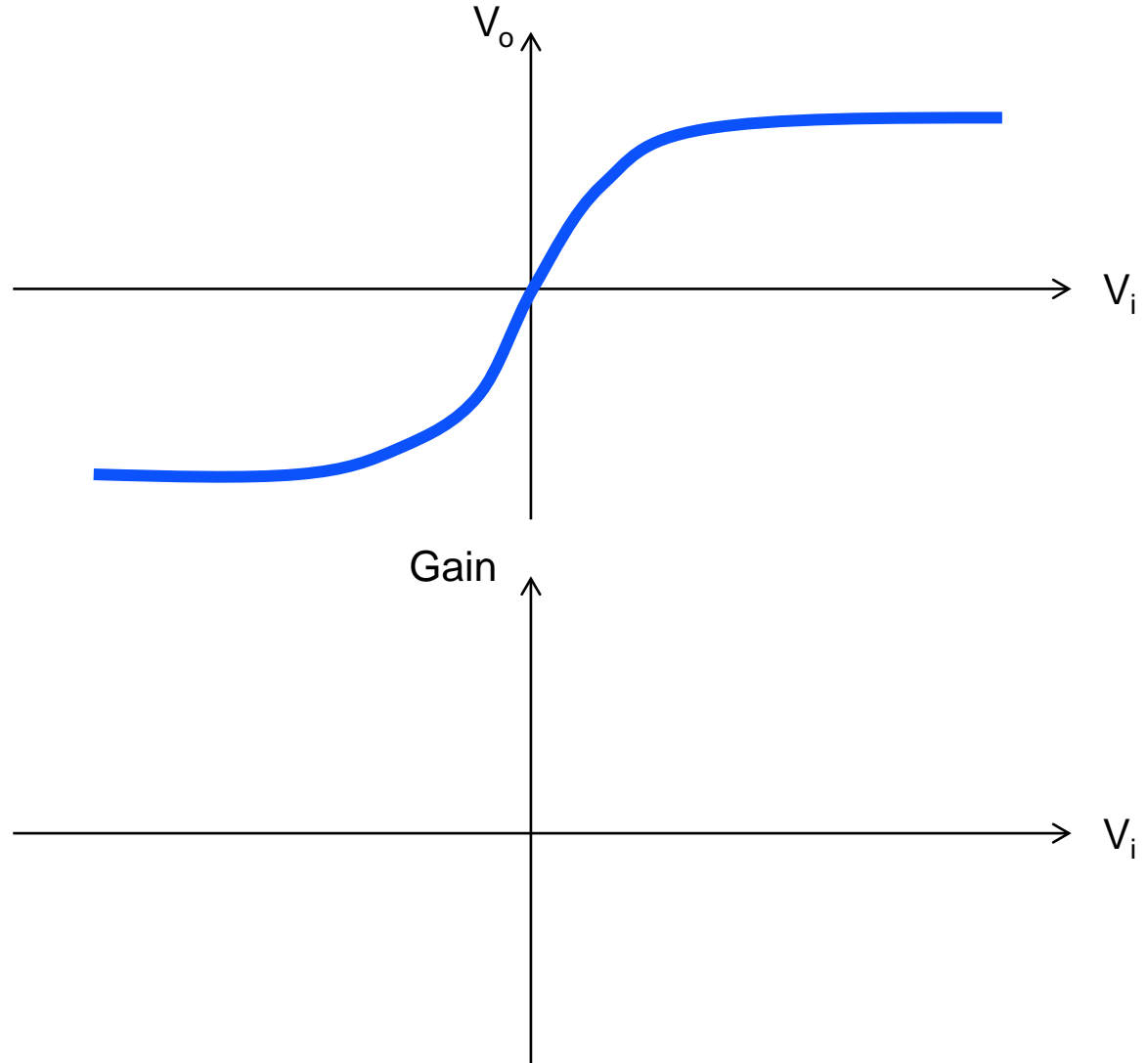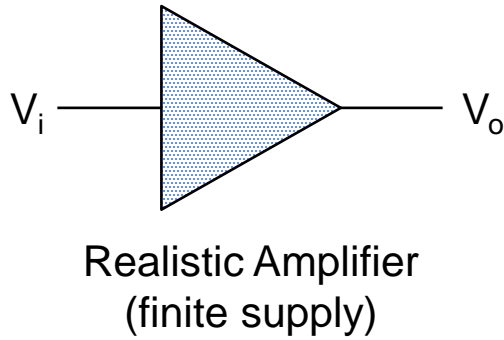
Gain 3: Common-Emitter Amplifier Example

Large- and Small-Signal Definitions

Large- and Small-Signal Nomenclature

V_x Large Signal (rarely used)
                (lower case subscript)

= V_X Bias (constant)
                (upper case subscript)

+ v_x Small Signal (varying)
                (all lower case)

Nomenclature introduced in
Gray & Meyer, *Analysis and design of analog integrated circuits,* Wiley 1974.

Amplifier (Analog Circuit) Design

Design

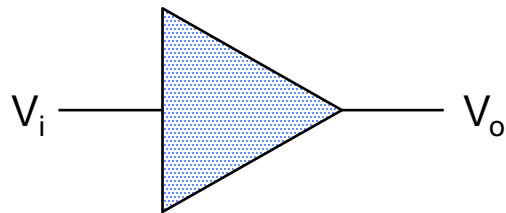small-signal characteristics

and

bias

separately

Break difficult problem into two simpler ones!

Example: voltage gain

Objective:

- Design amplifier with
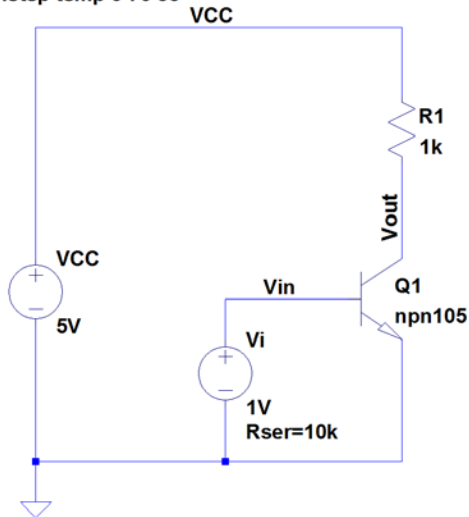 $a_v = v_o/v_i = -2$

- $R_L = 10k\Omega$

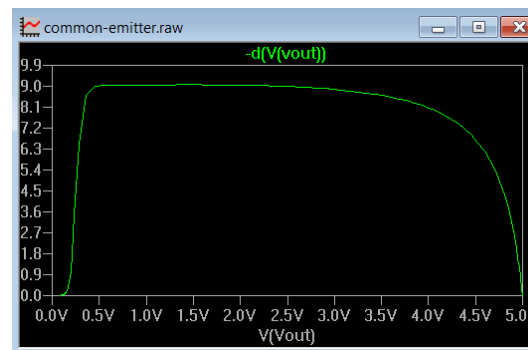# 1) Amplifier Topology

2) Small-Signal Design

3) Bias Design
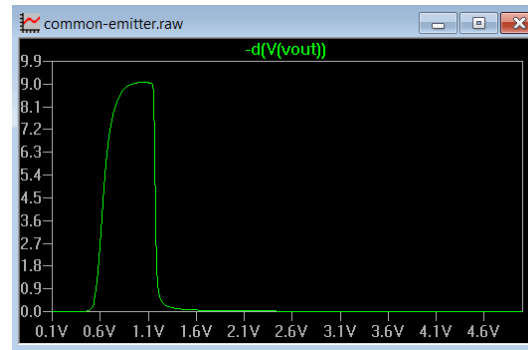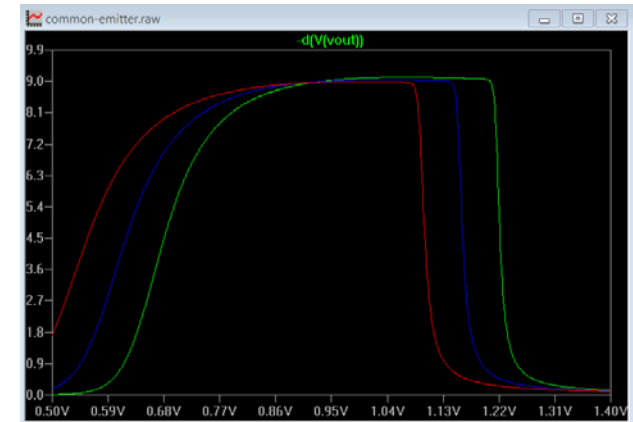
4) Verification (SPICE, lab)

Circuit

Verification

Is Circuit Robust?
e.g. Temperature

.model npn105 npn(is=10fA bf=100 vaf=100V)
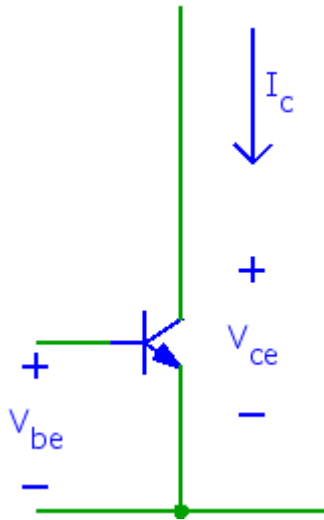
.dc Vi 500mV 1.4V 1mV

.step temp 0 70 35

T = 0, 35, 70C

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

Example 3: Constant Voltage Source (e.g. Supply)

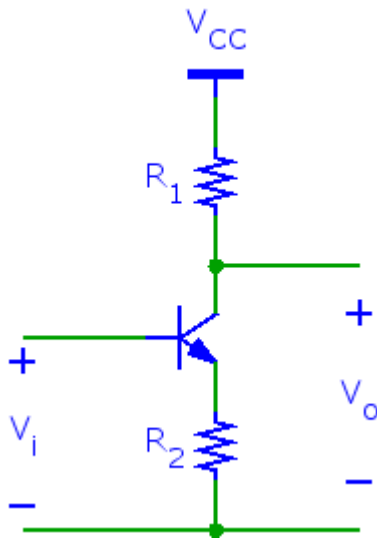**Large-Signal Circuit**   **Small-Signal Model**

What is the small-signal model of a constant current source?

Small-Signal Circuit Models

Large-Signal Circuit   **Small-Signal Model**

Calculate the Small-Signal Gain

Determine Bias
(from Small-Signal Parameters)

Design Bias Circuit

Small & Large Signals Recap

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  - 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!