MIC511
Analysis and Design of Analog Integrated Circuits
Lecture 11

Examples

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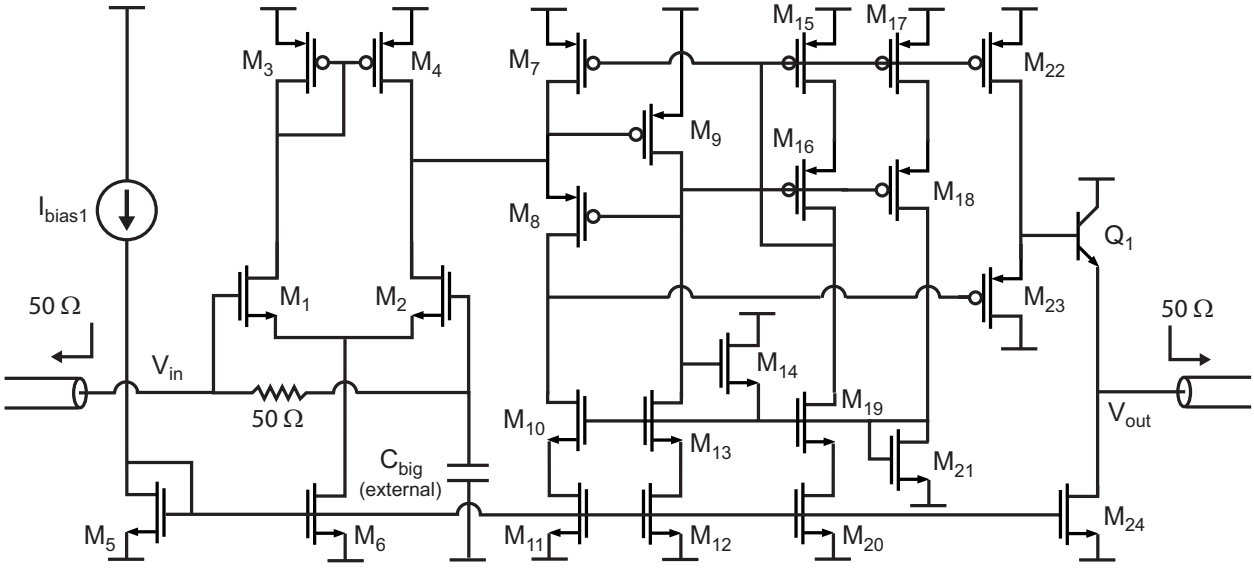
Example Analysis Circuit



- Assumptions

  1. Intrinsic gain of each device $\gg 1$

     $$g_m r_o \gg 1 \Longrightarrow 1/g_m \ll r_o$$

  2. Intrinsic gain of devices similar in value
  3. Output resistances of devices similar in value

     $$r_{o1} \approx r_{o2}$$

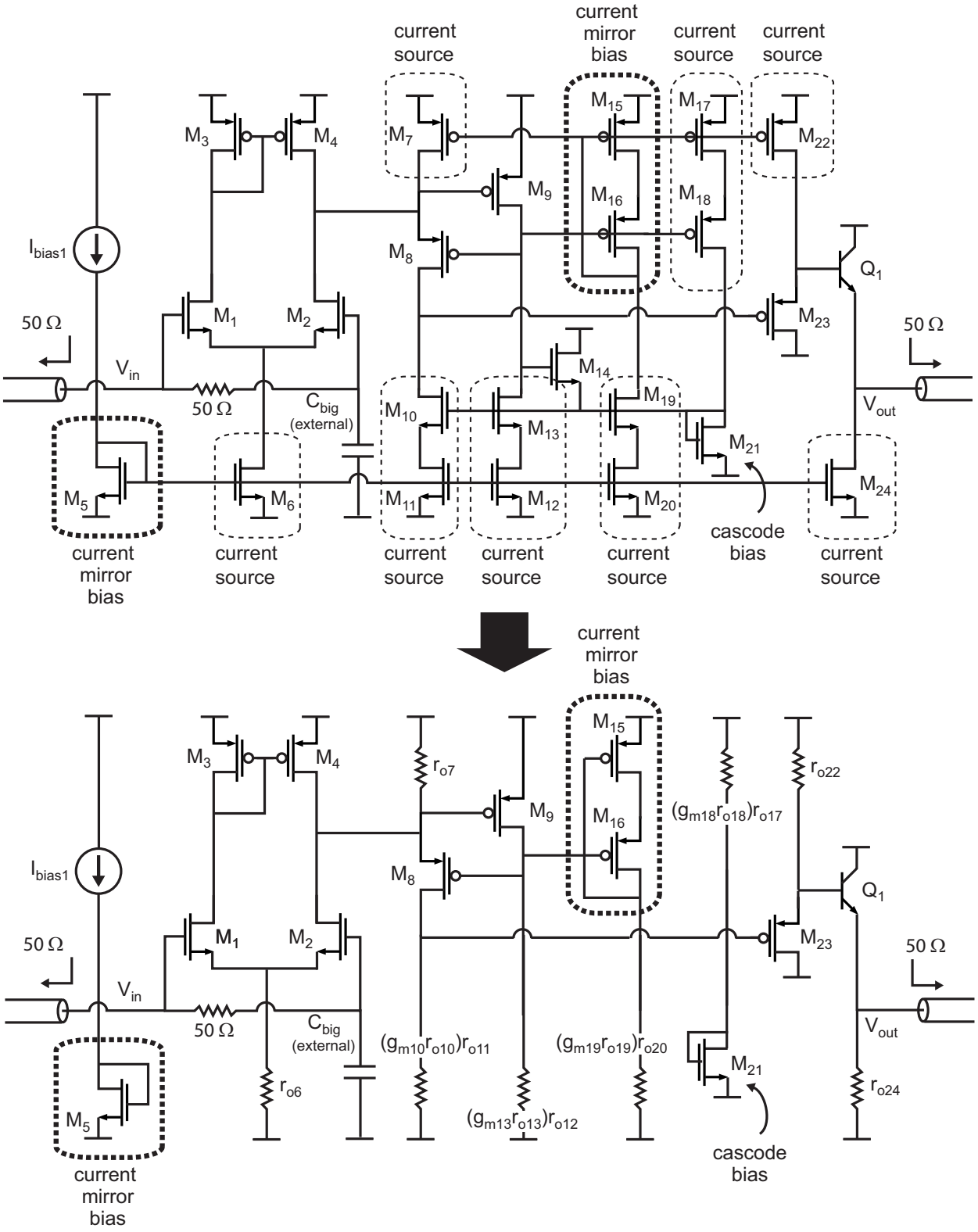
- Note:

  – Assumption 1 is reasonable in practice

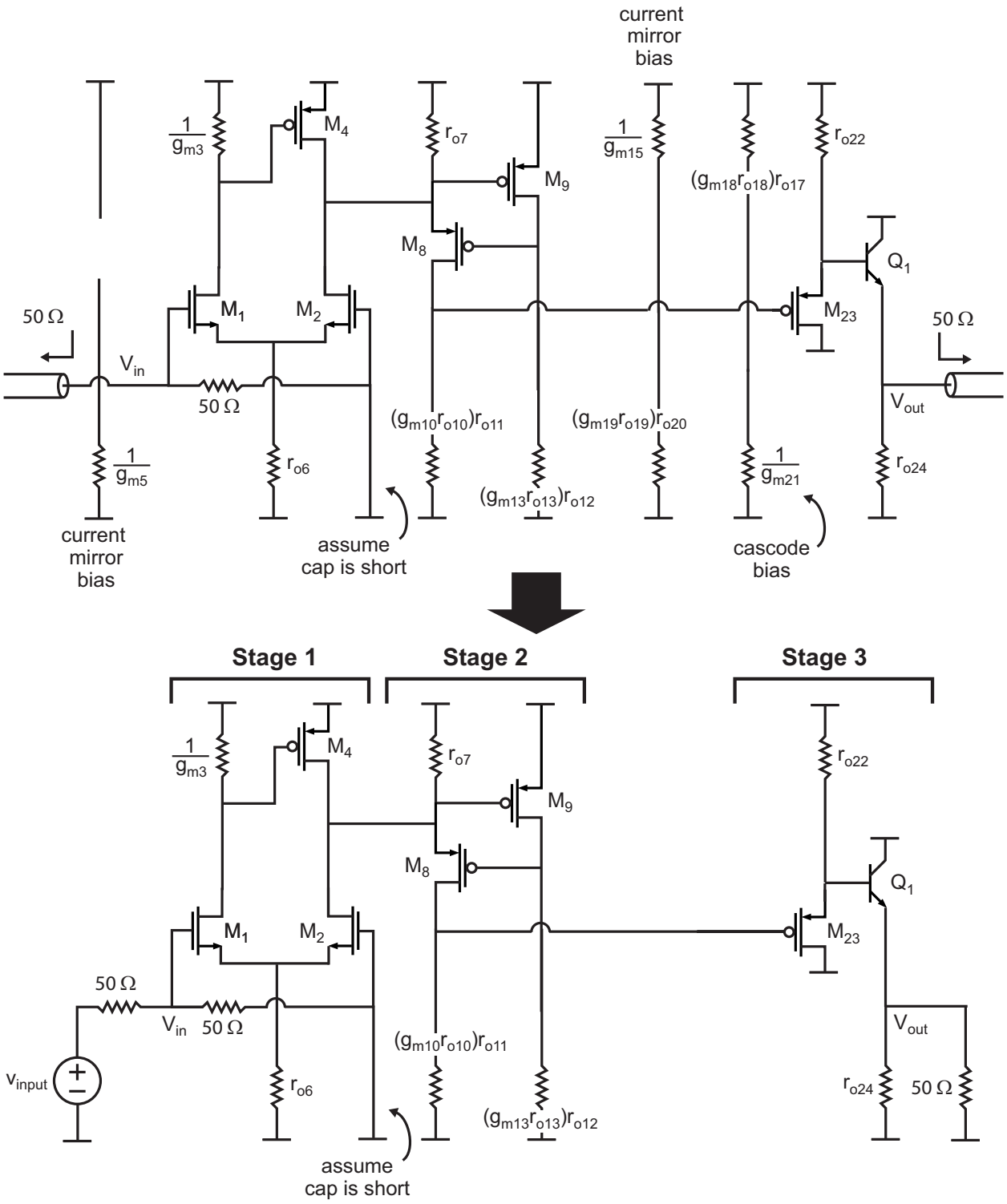
  – Assumptions 2 and 3 are invalid in practice

    ∗ Used here only for pedagogical reasons

Replace Current Sources



Remove Non-Signal-Path Biasing Circuitry



Bipolar Modeling is similar to CMOS

MOSFET

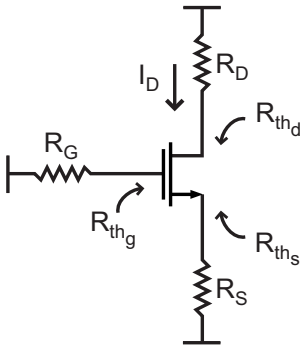
Key Small-Signal Parameters

$$g_m = \mu_n C_{ox}(W/L)(V_{GS} - V_{TH})$$
$$= \sqrt{2\mu_n C_{ox}(W/L) I_D}$$

$$g_{mb} << g_m$$

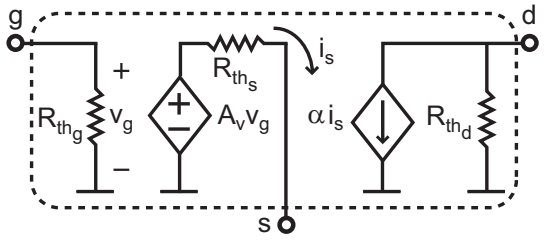
$$r_o = \frac{1}{\lambda I_D}$$

Thevenin Resistances



Approximation	Assumption
$R_{th_d} = r_o(1+g_m R_S)$	$g_{mb} << g_m$
R_{th_g} = infinite	
$R_{th_s} = \frac{1 + R_D/r_o}{g_m}$	$g_{mb} << g_m$

General Thevenin Model



Approximation	Assumption
$A_v = 1$	$g_{mb} << g_m$, $g_m r_o >> 1$
$\alpha = 1$	$R_d << R_{thd}$

BIPOLAR

Key Small-Signal Parameters

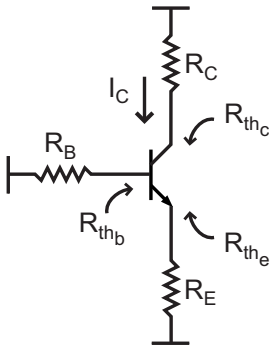
$$g_m = \frac{I_c}{V_t}, \quad V_t = \frac{kT}{q}$$

$V_t \approx 25$ mV at room temp

$$r_\pi = \frac{\beta_o}{g_m}, \quad \beta_o \approx 100 \text{ to } 200$$

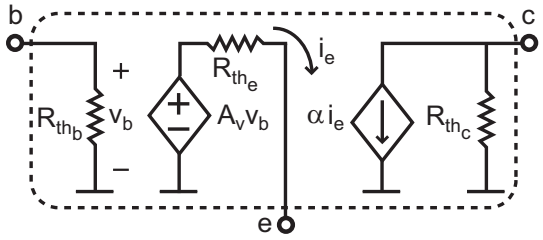
$$r_o = \frac{V_A}{I_c}, \quad V_A \approx 100 \text{ to } 200 \text{ V}$$

Thevenin Resistances



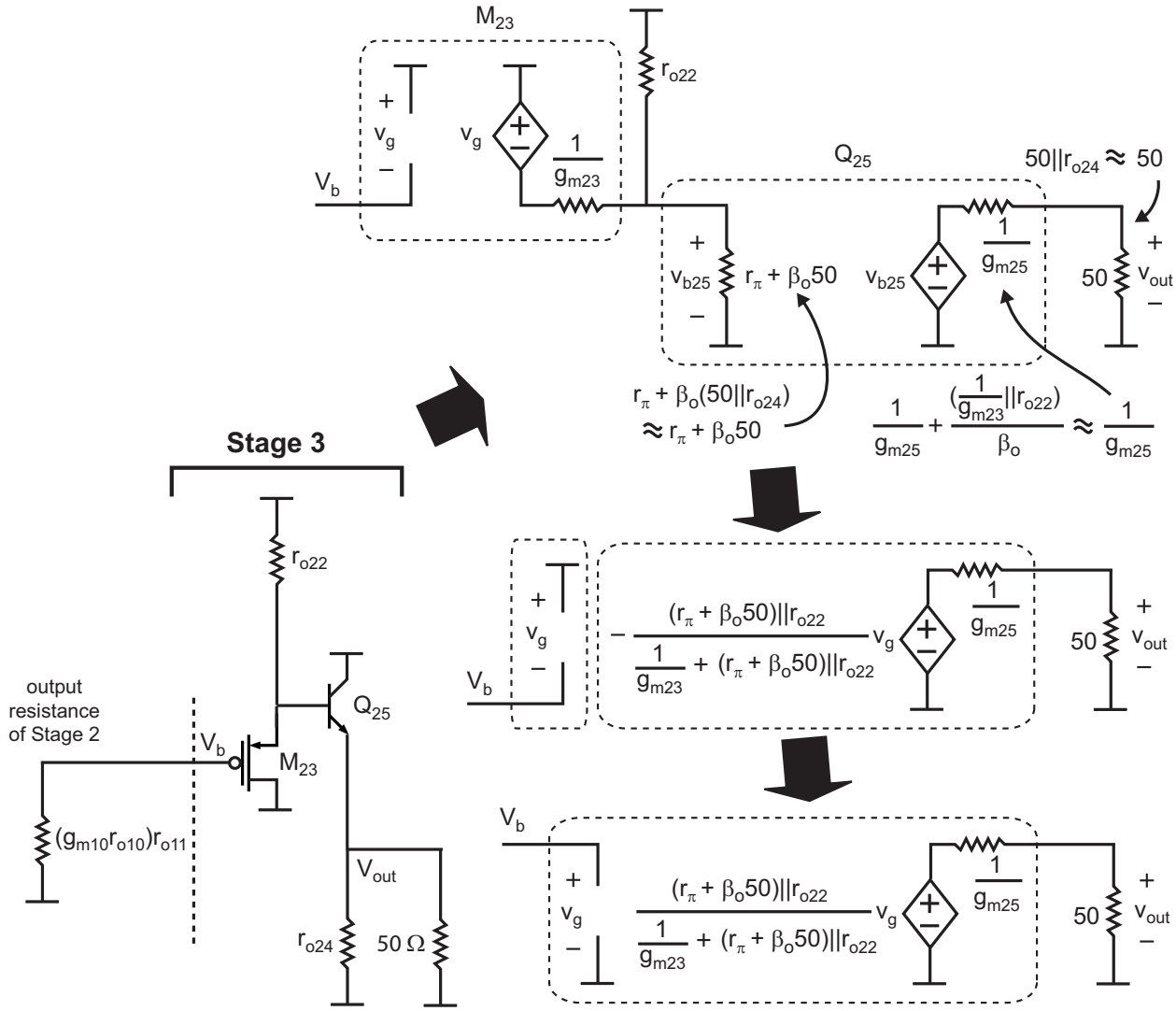
Approximation	Assumption
$R_{th_c} = r_o(1+g_m(r_\pi \| R_E))$	$R_B << r_\pi$
$R_{th_b} = r_\pi + \beta_o R_E$	$R_C + R_E << r_o$
$R_{th_e} = 1/g_m + R_B/\beta_o$	$R_C << \beta_o r_o$

General Thevenin Model

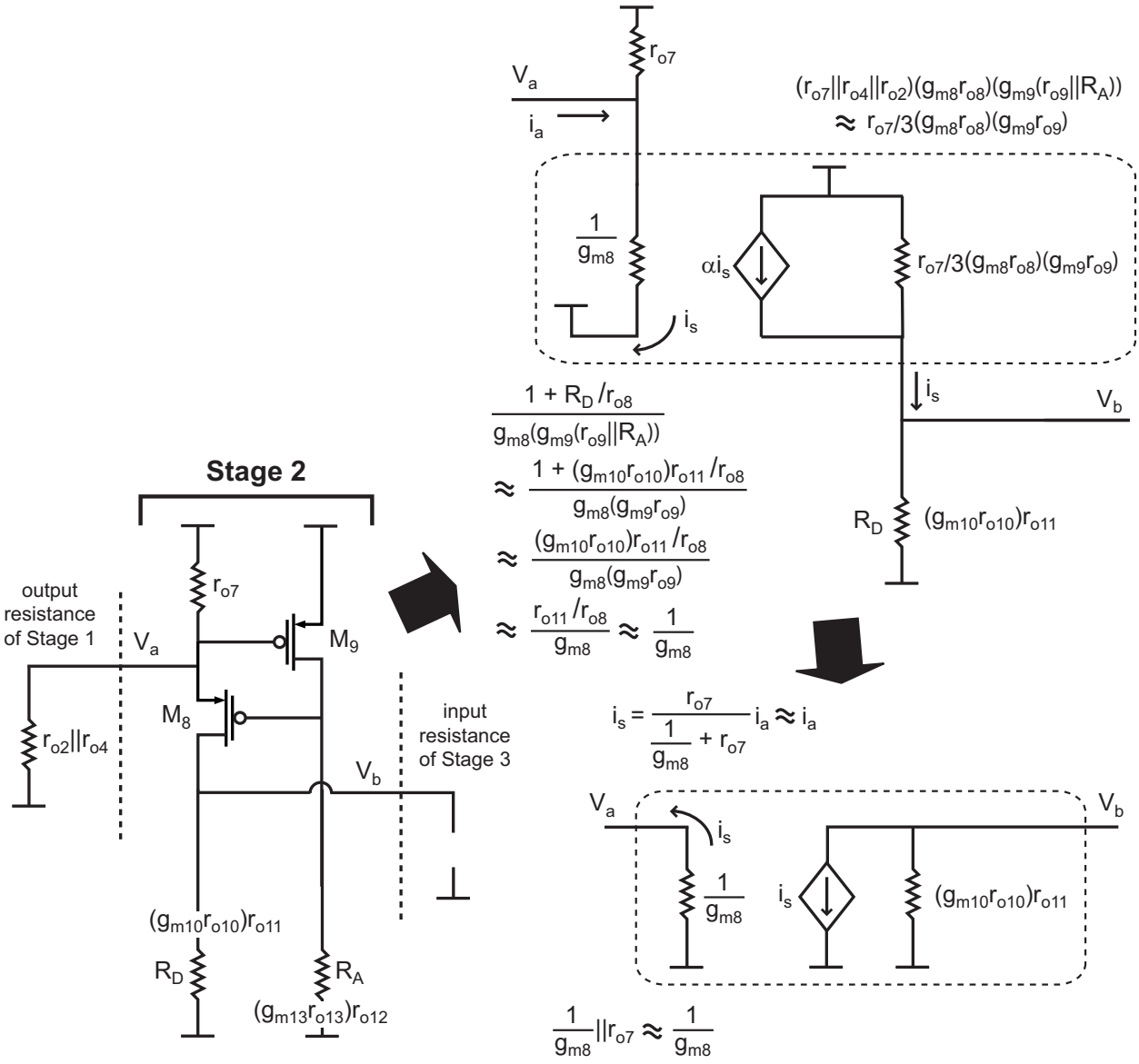


Approximation	Assumption
$A_v = 1$	$R_C + R_E << r_o$, $R_B << r_\pi$
$\alpha = 1$	$R_C + R_E << \beta_o r_o$

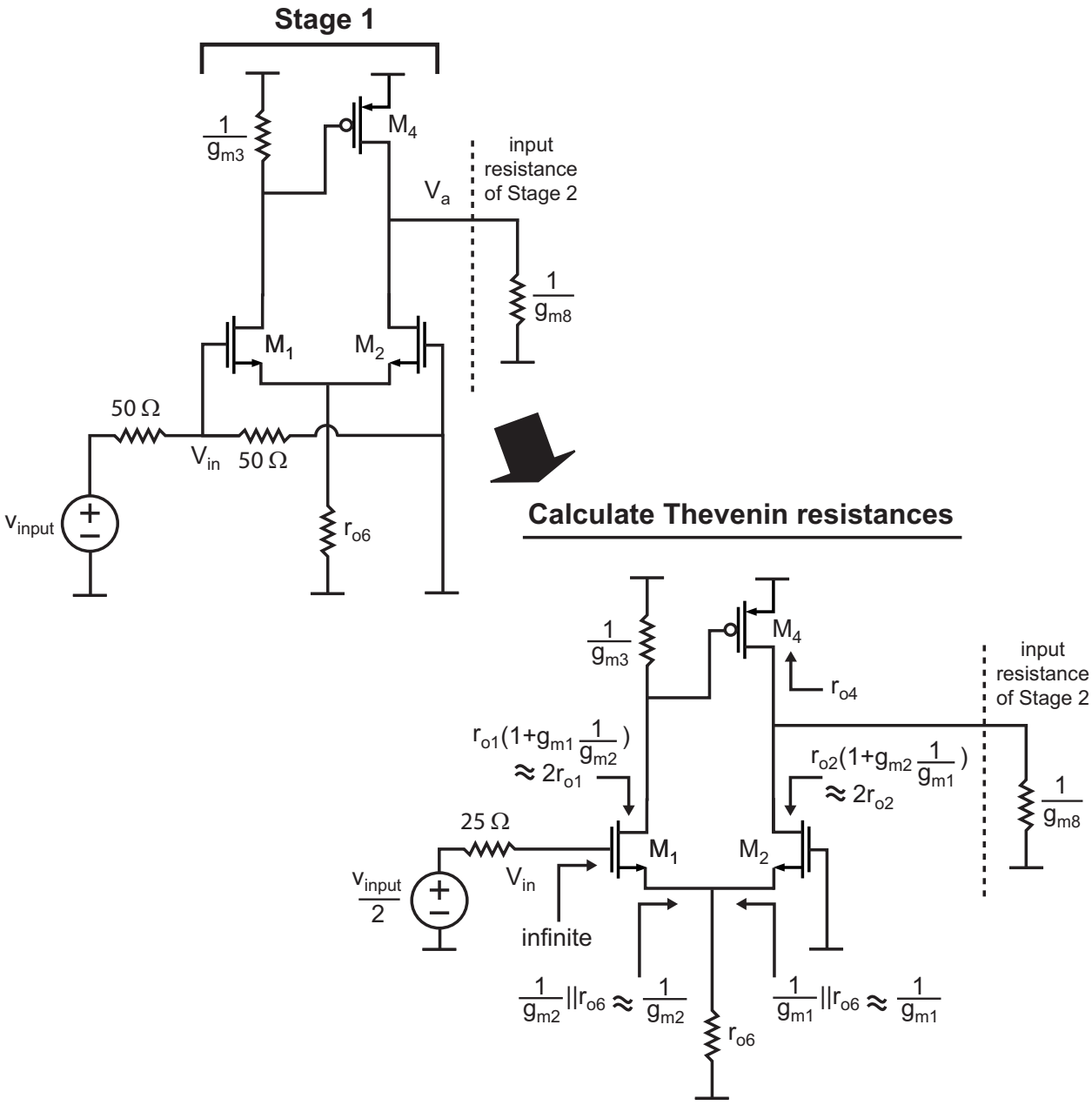
Compute 2-port for Stage 3



Compute 2-port for Stage 2

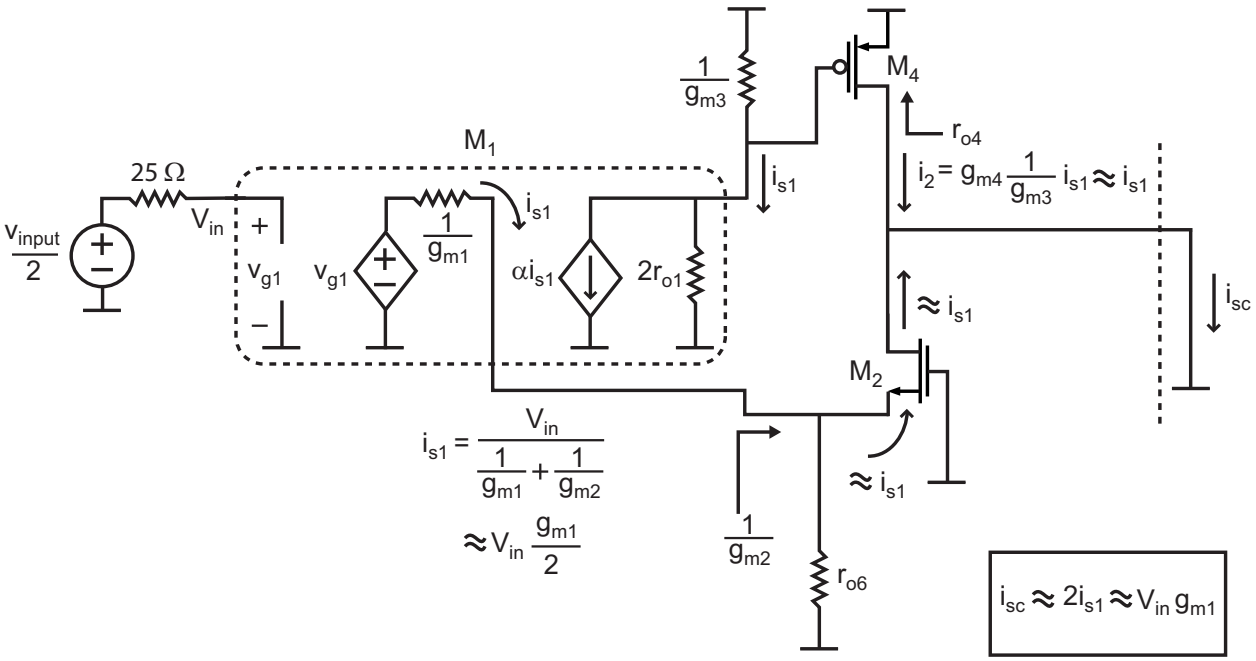


Compute 2-port for Stage 1 (Step 1)

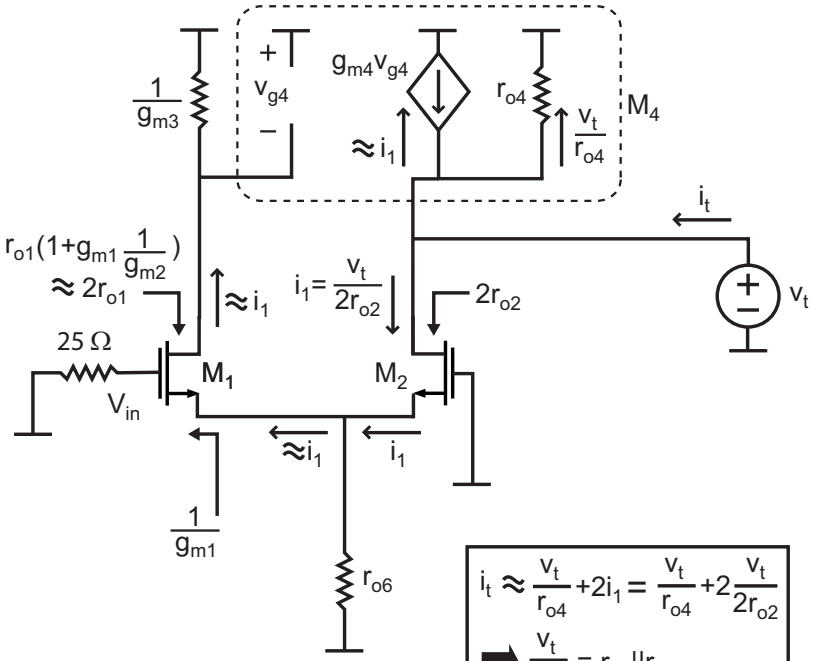


Compute 2-port for Stage 1 (Step 2)

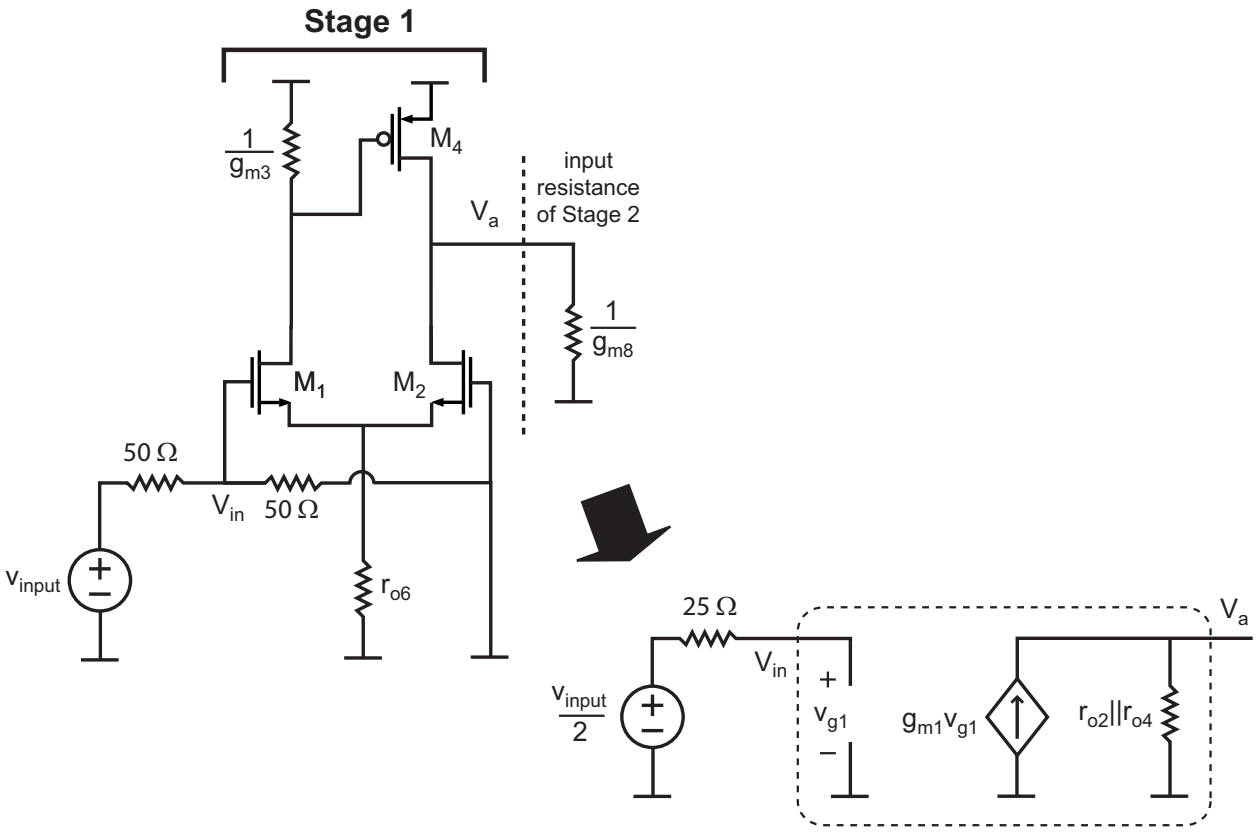
Calculate short circuit current at output



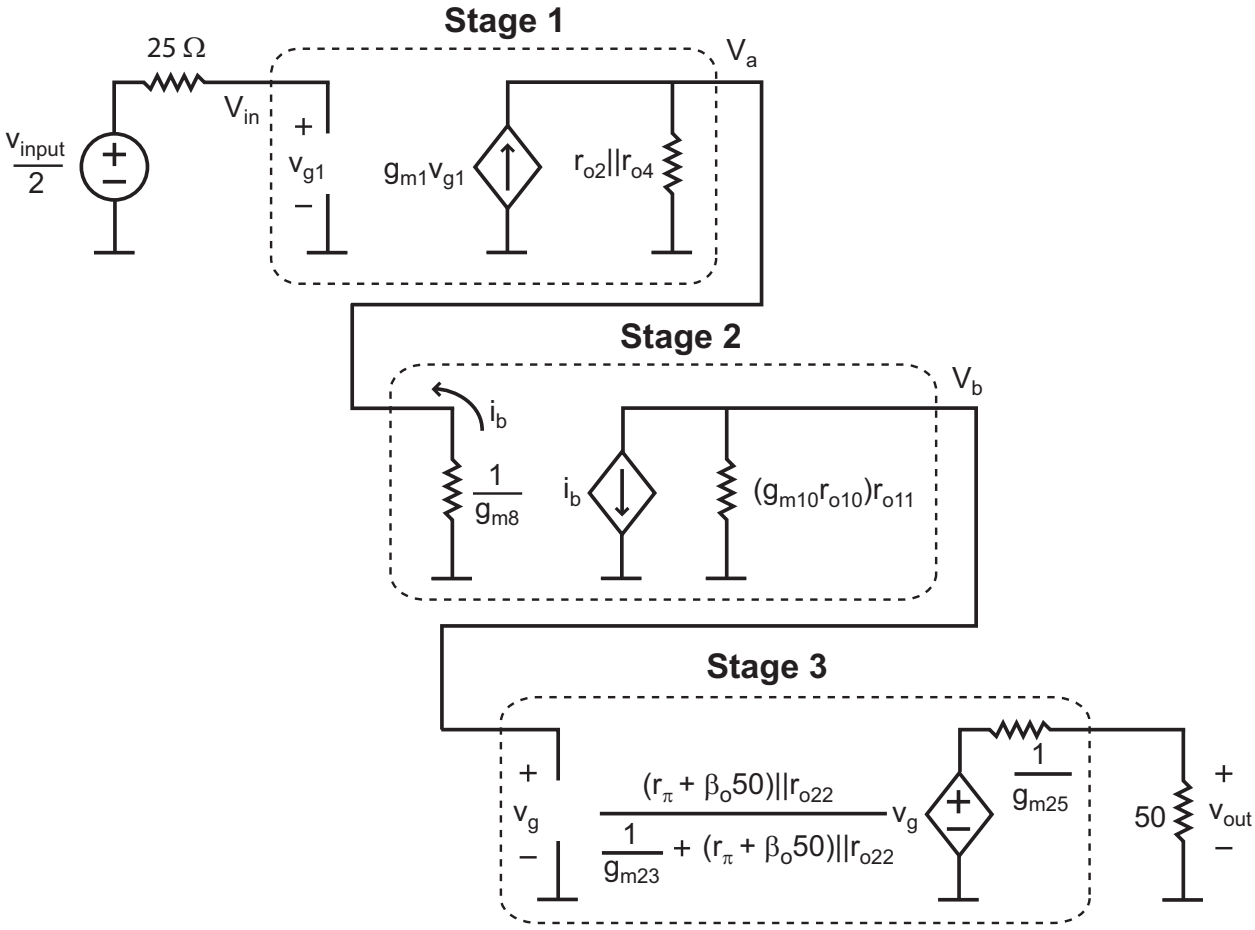
Calculate output resistance



Compute 2-port for Stage 1 (Final Step)



Overall Cascade of 2-ports for Amplifier



- What is the overall input/output resistance of the amp?
- What is the overall gain?
- Which stage contributes the most gain?
- What is the function of each stage?