

ECE 523/421 – Analog Electronics

Lecture 7: Analog IC Building Blocks: Cascode Amplifier

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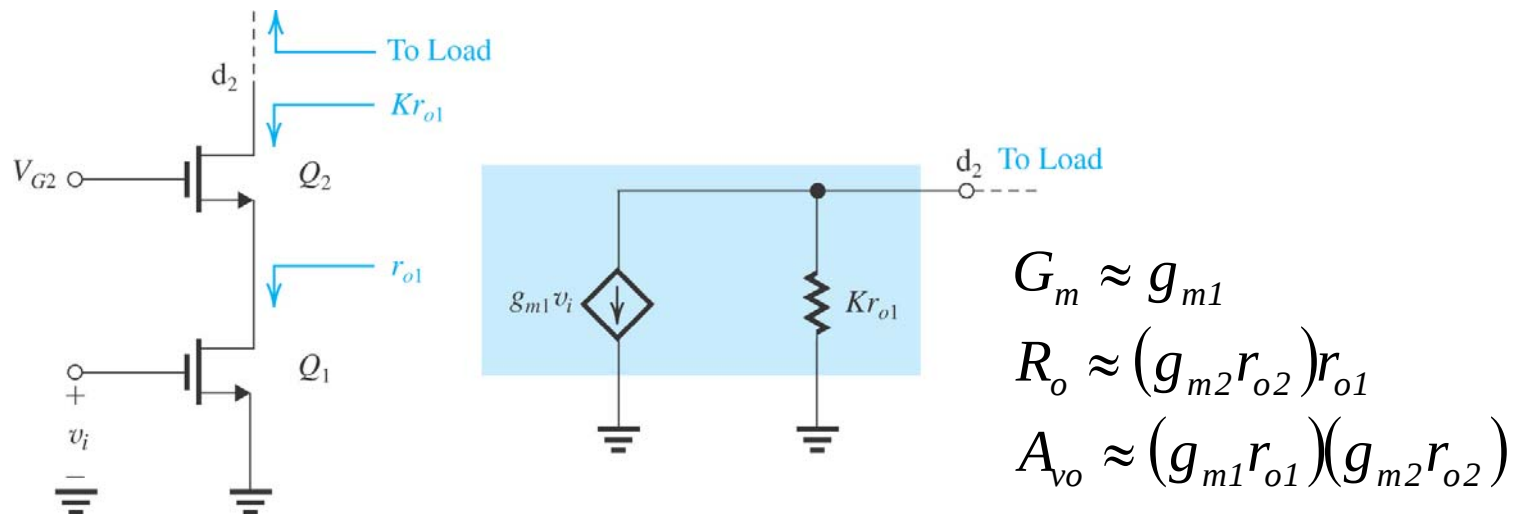
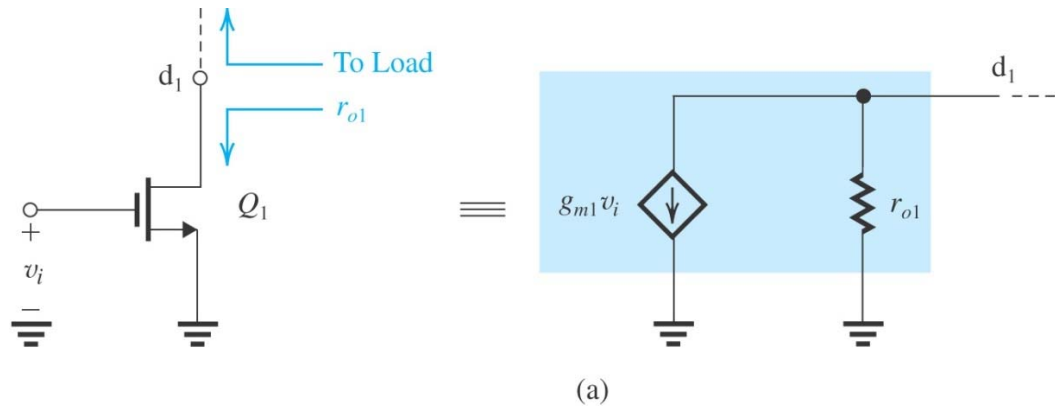
Review of Last Lecture

- ☐ **Intrinsic NMOS and BJT Gain**
- ☐ **CS and CE Amplifiers with Active Load**

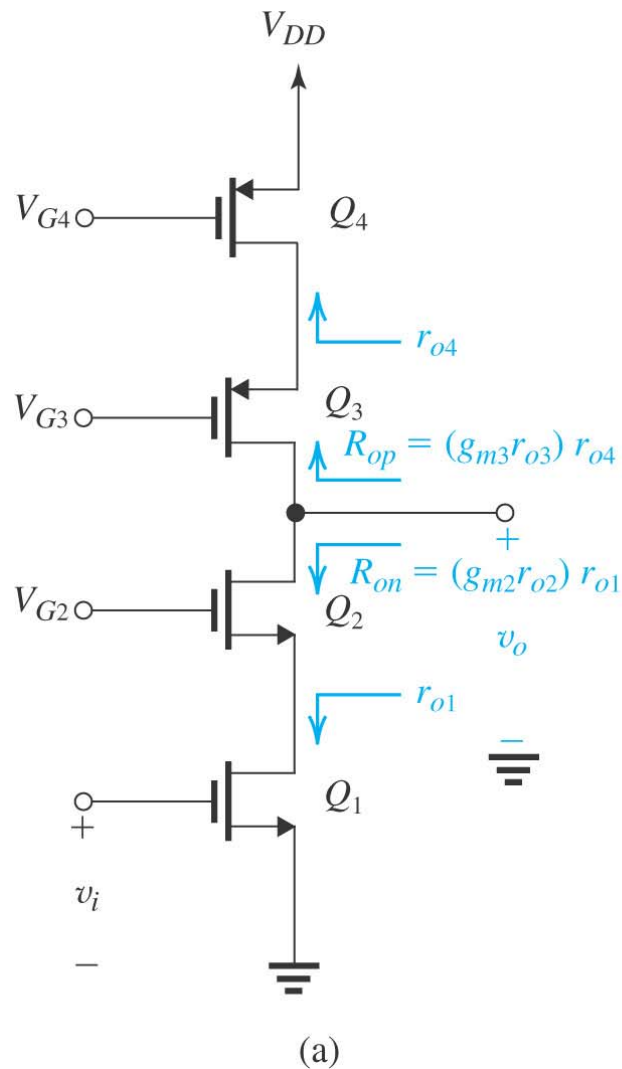
Today's Lecture

- ☐ **Cascode Amplifiers and Current Sources**
- ☐ **Cascode in CMOS, BJT, and BiCMOS**

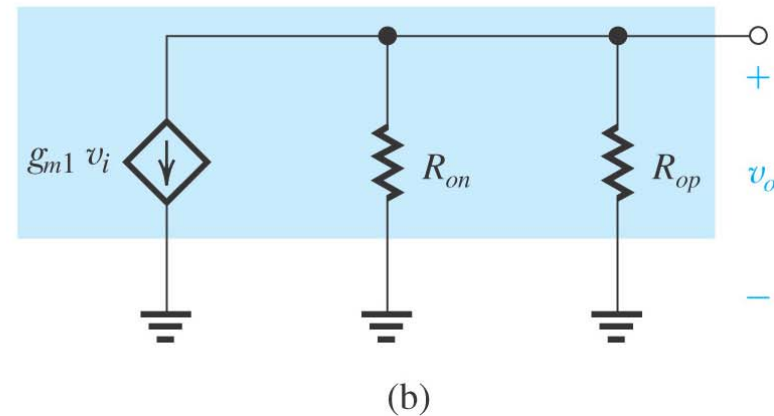
Intrinsic Gain Improvement Technique



Cascode Amplifier with Cascode Active Load

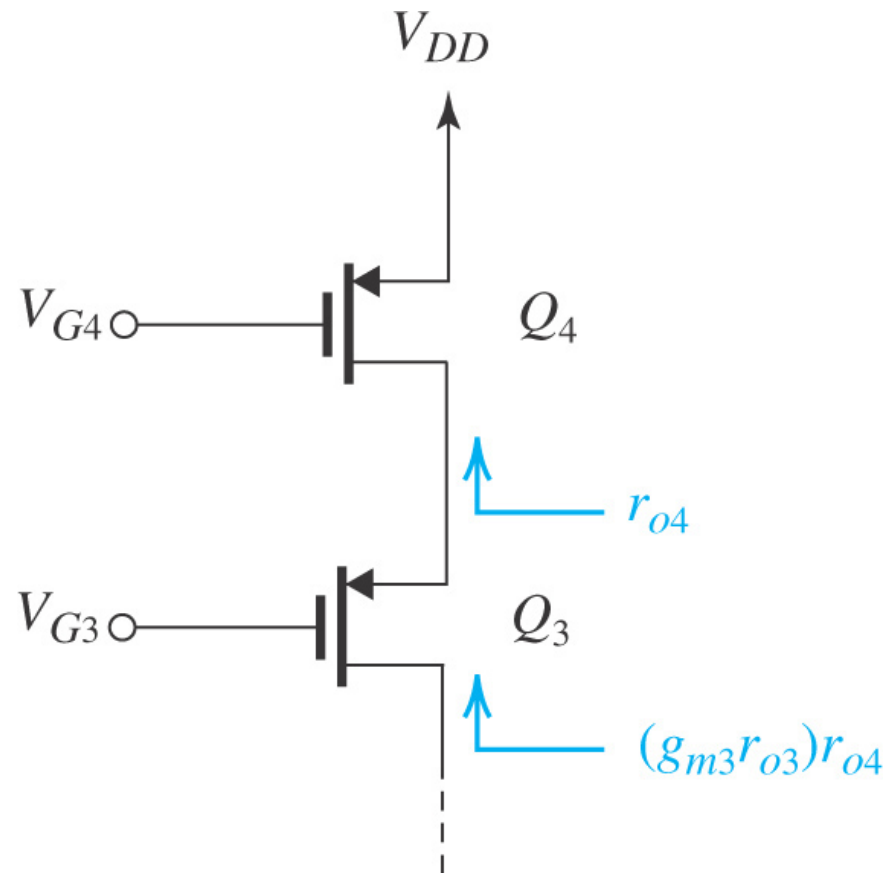


$$A_{vo} = -g_{m1} (R_{on} \parallel R_{op})$$



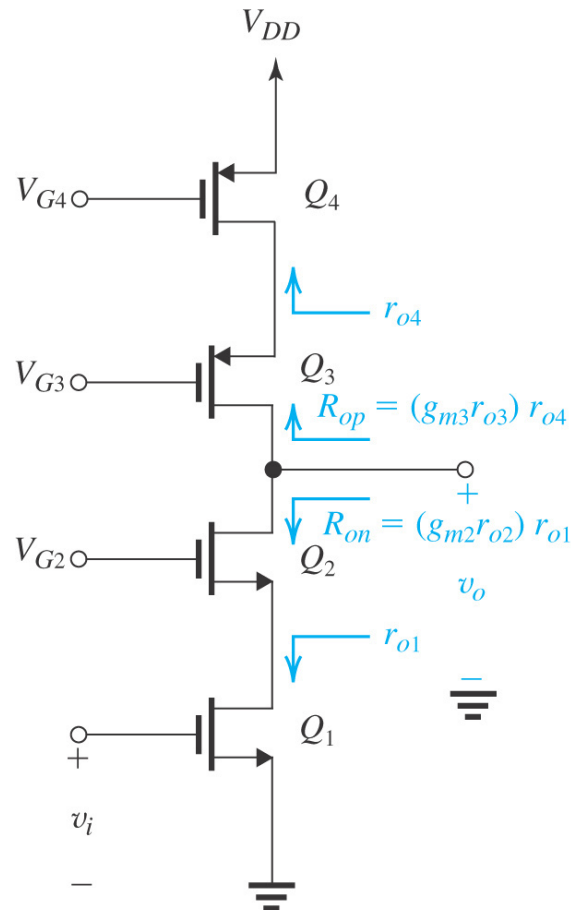
Example: Cascode Current Source Design I

- 1) Design a Cascode current source of $I=100\mu\text{A}$ and $R_o=500\text{K}\Omega$. Assume that $V_{DD}=1.8\text{V}$, $V_{tp}=-0.5\text{V}$, $K'_p=90\mu\text{A}/\text{V}^2$, $V'_A=-5\text{V}/\mu\text{m}$, and $V_{OV}=-0.3\text{V}$.

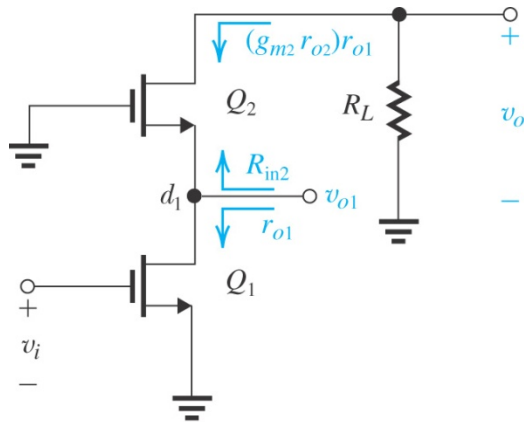


Example: Cascode Amplifier Analysis I

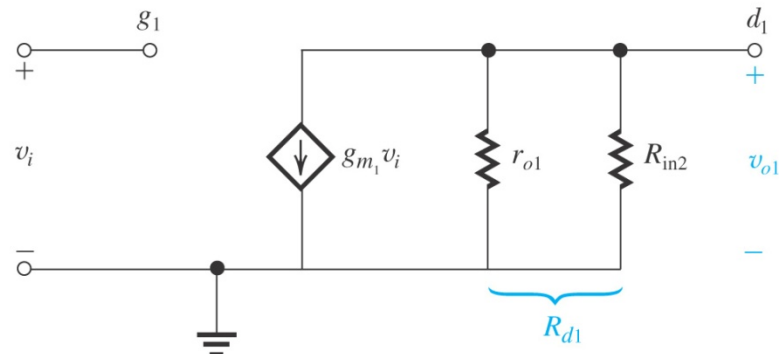
- 1) The following Cascode amplifier operates at 0.2mA. For all devices, $V_{OV}=0.2V$ and $V_A=2V$. Find g_{m1} , R_{on} , R_{op} , and A_v .



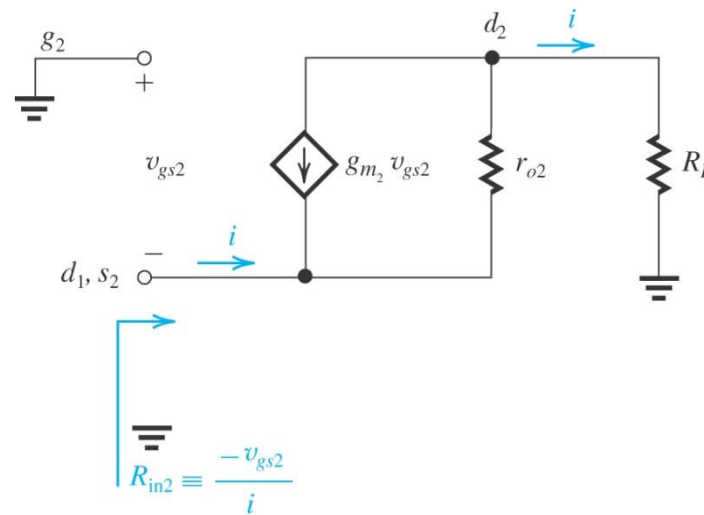
Voltage Gain in Cascode Amplifier



(a)

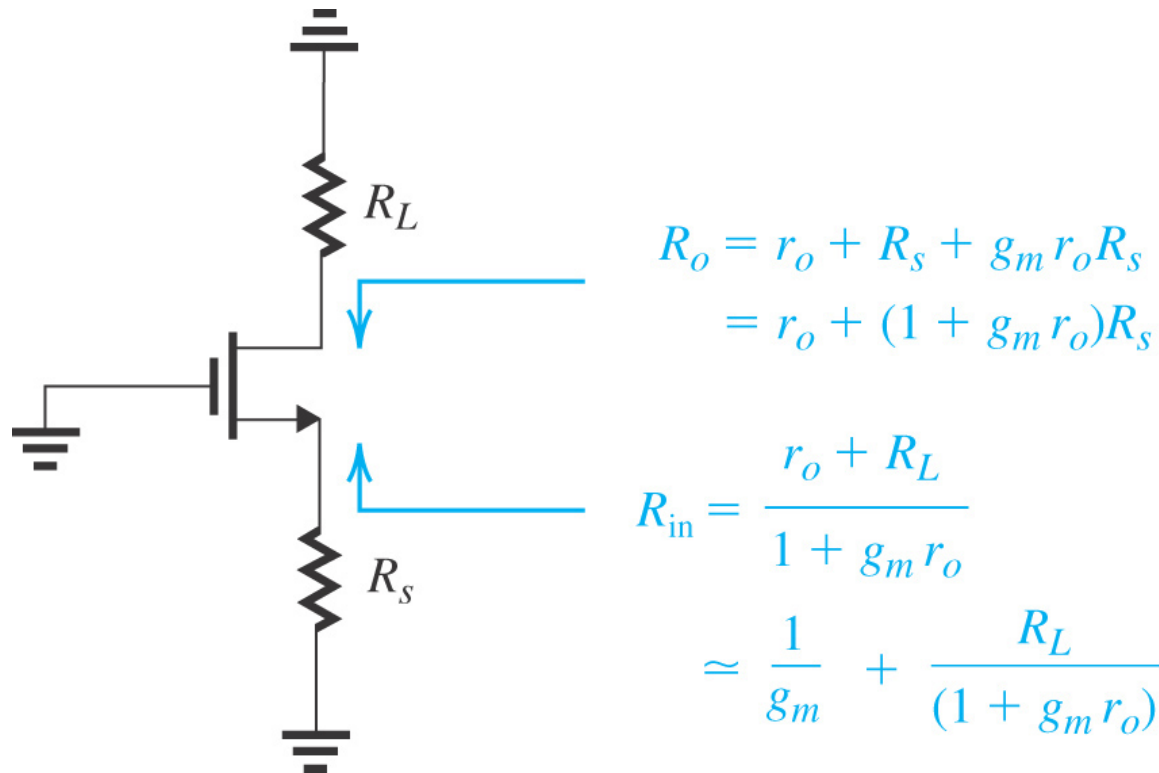


(b)



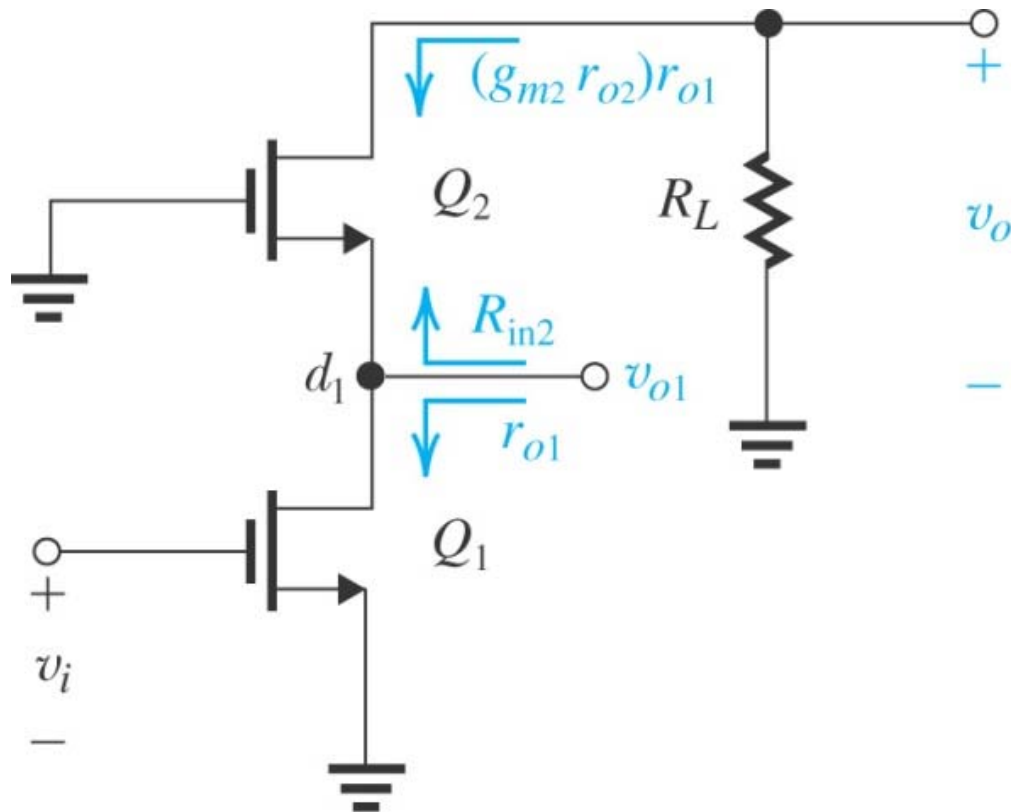
(c)

Impedance Transformation in MOSFET

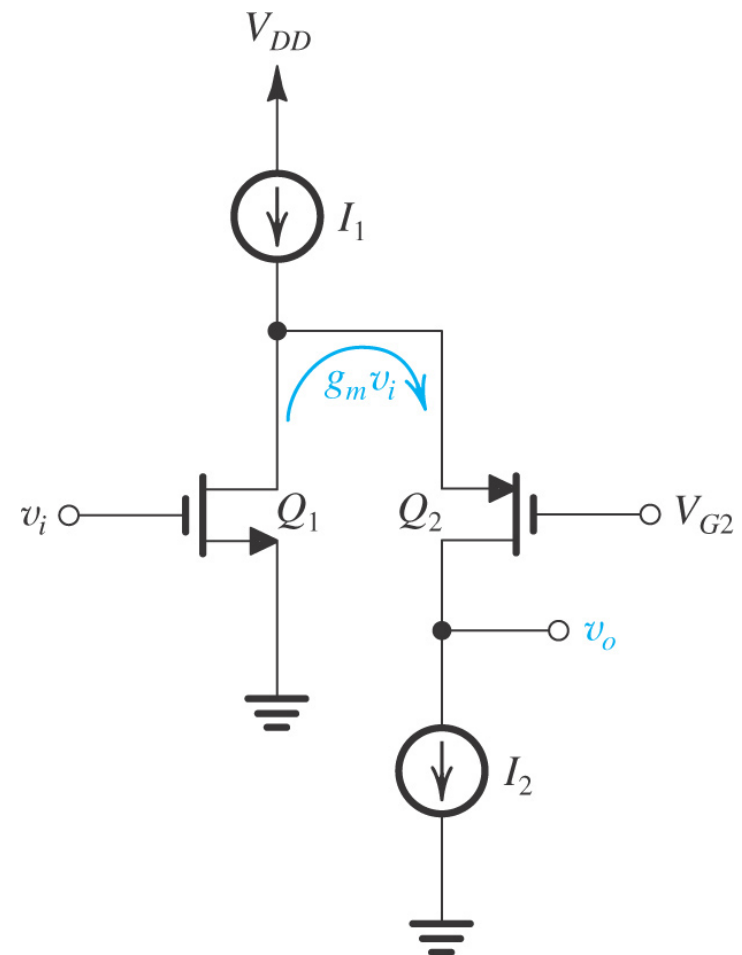
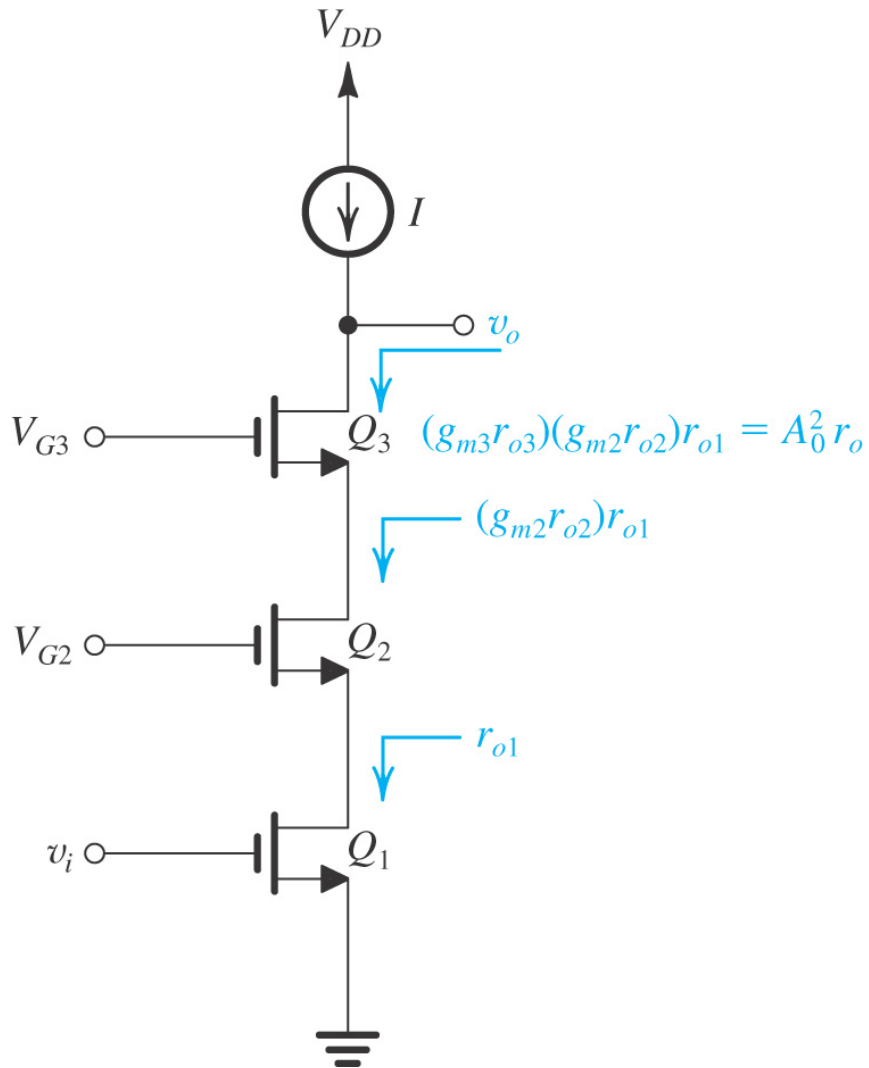


Example: Cascode Amplifier Analysis I

- 1) The following Cascode amplifier operates at 0.1mA. For all devices, $V_{OV}=0.2\text{V}$ and $V_A=2\text{V}$. Find A_{v1} , A_{v2} , and A_v when $R_L=400\text{k}\Omega$.

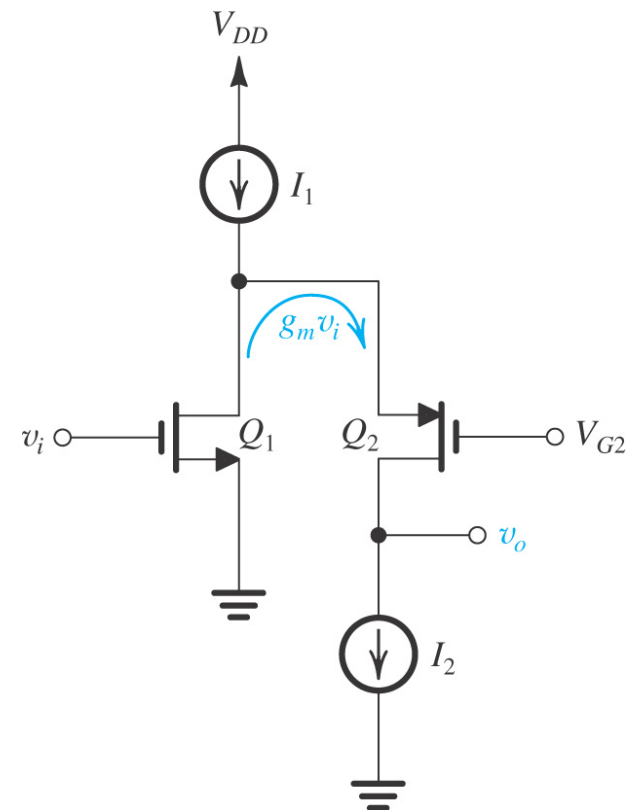


Double Cascoding & Folded Cascode

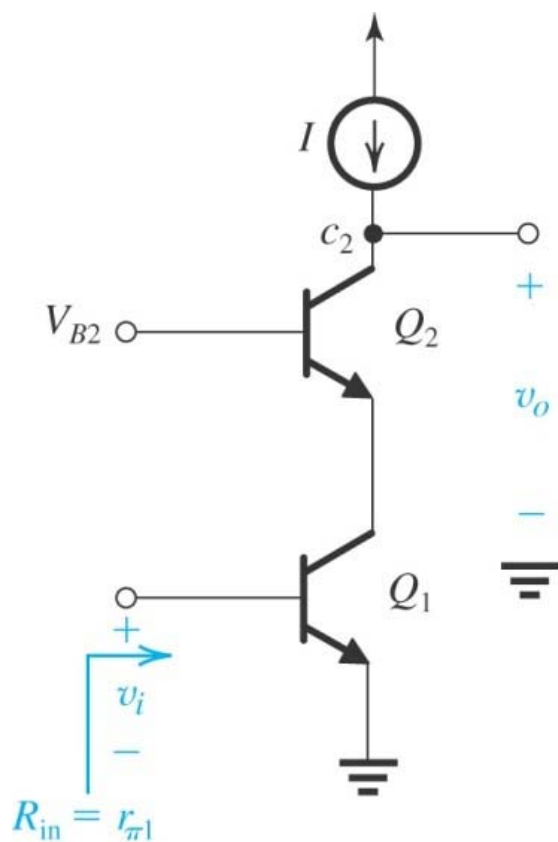


Example: Folded Cascode Analysis

- 1) Consider: $V_{DD}=1.8V$, $K'_p=(1/4)K'_n$, $V_{tn}=-V_{tp}=0.5V$, $V_{OV}=0.2V$. I_1 is a simple current source and I_2 is a cascode current source where $I_1=2I_2=2I$.
- A) Find the relationship between $(W/L)_1$ and $(W/L)_2$
- B) Find minimum voltage across I_1 . If Drain of Q_1 swing with $0.1V_{pp}$, what should it be biased at?
- C) What is VSG of Q_2 and find V_{G2} .
- D) What is the minimum voltage across I_2
- E) What is the maximum output swing



Cascode BJT

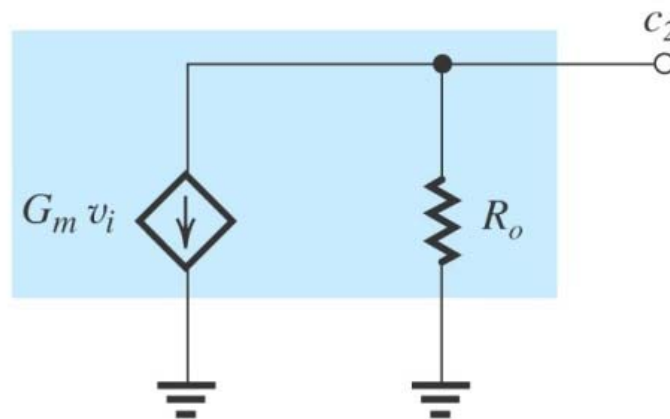


(a)

$$G_m \approx g_{m1}$$

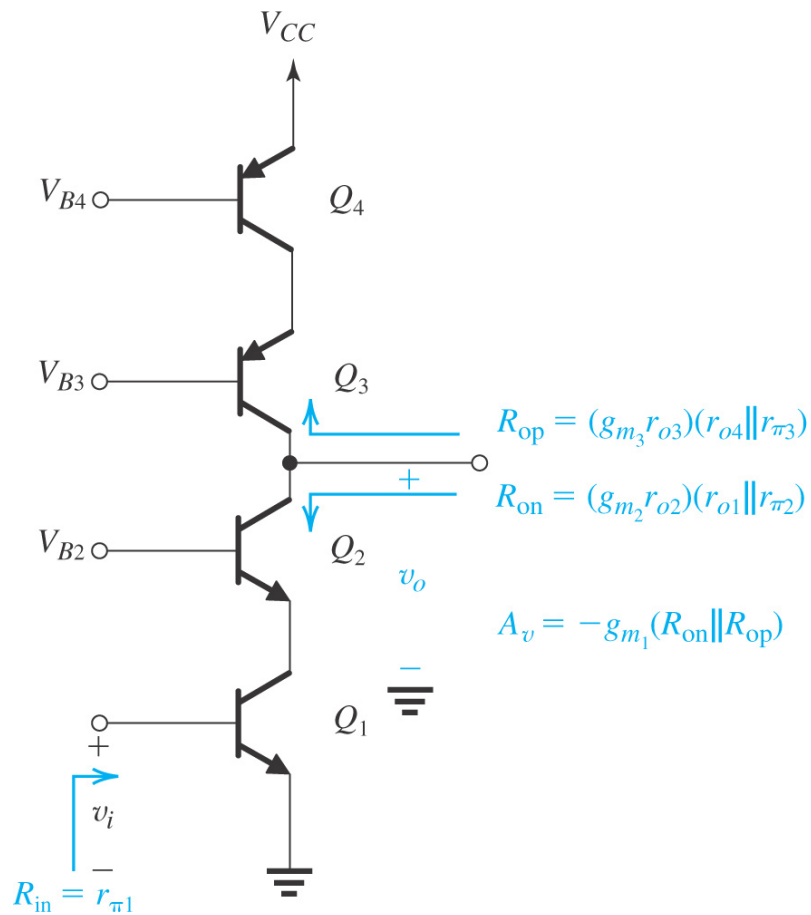
$$R_o \approx (g_{m2} r_{\pi 2}) r_{o2} = \beta_2 r_{o2}$$

$$A_{vo} \approx g_{m1} (\beta_2 r_{o2})$$

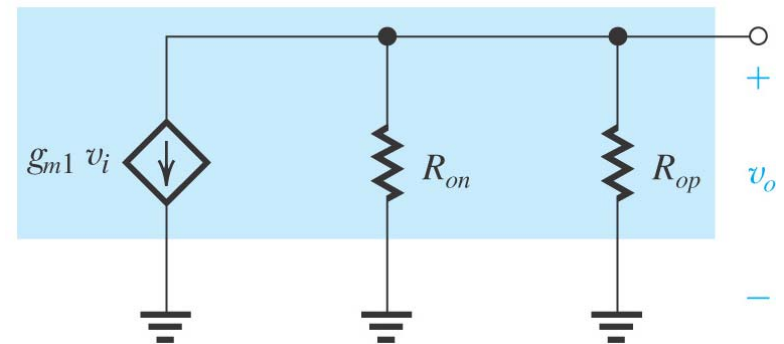


(b)

Cascode Amplifier with Cascode Active Load

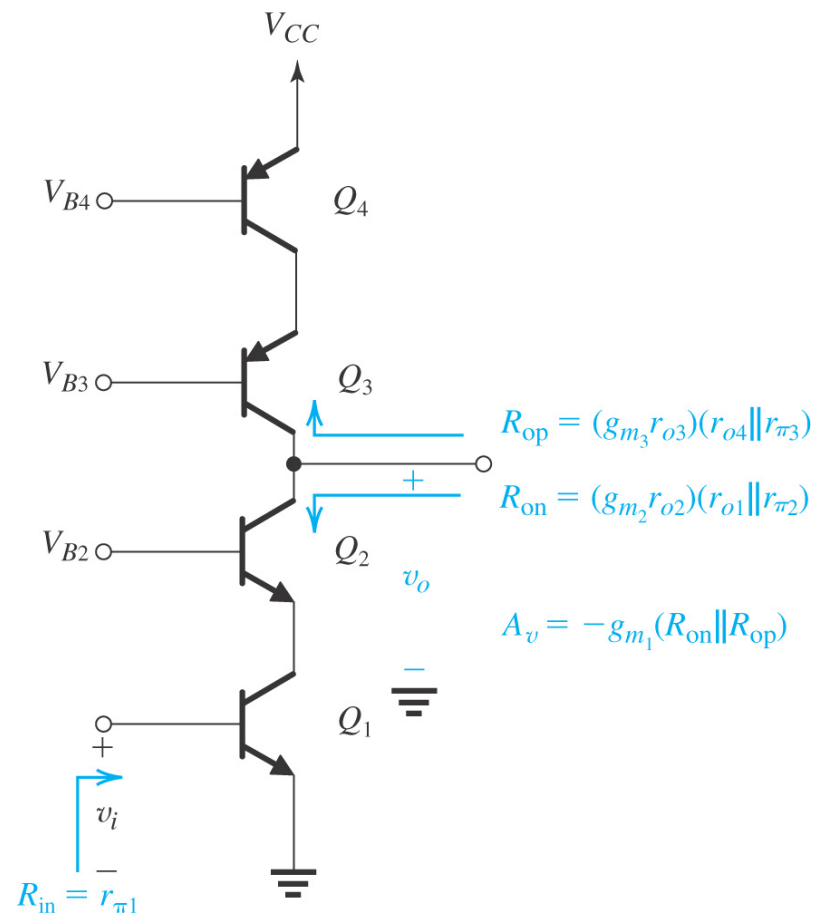


$$A_{vo} = -g_{m1} (R_{on} \parallel R_{op})$$

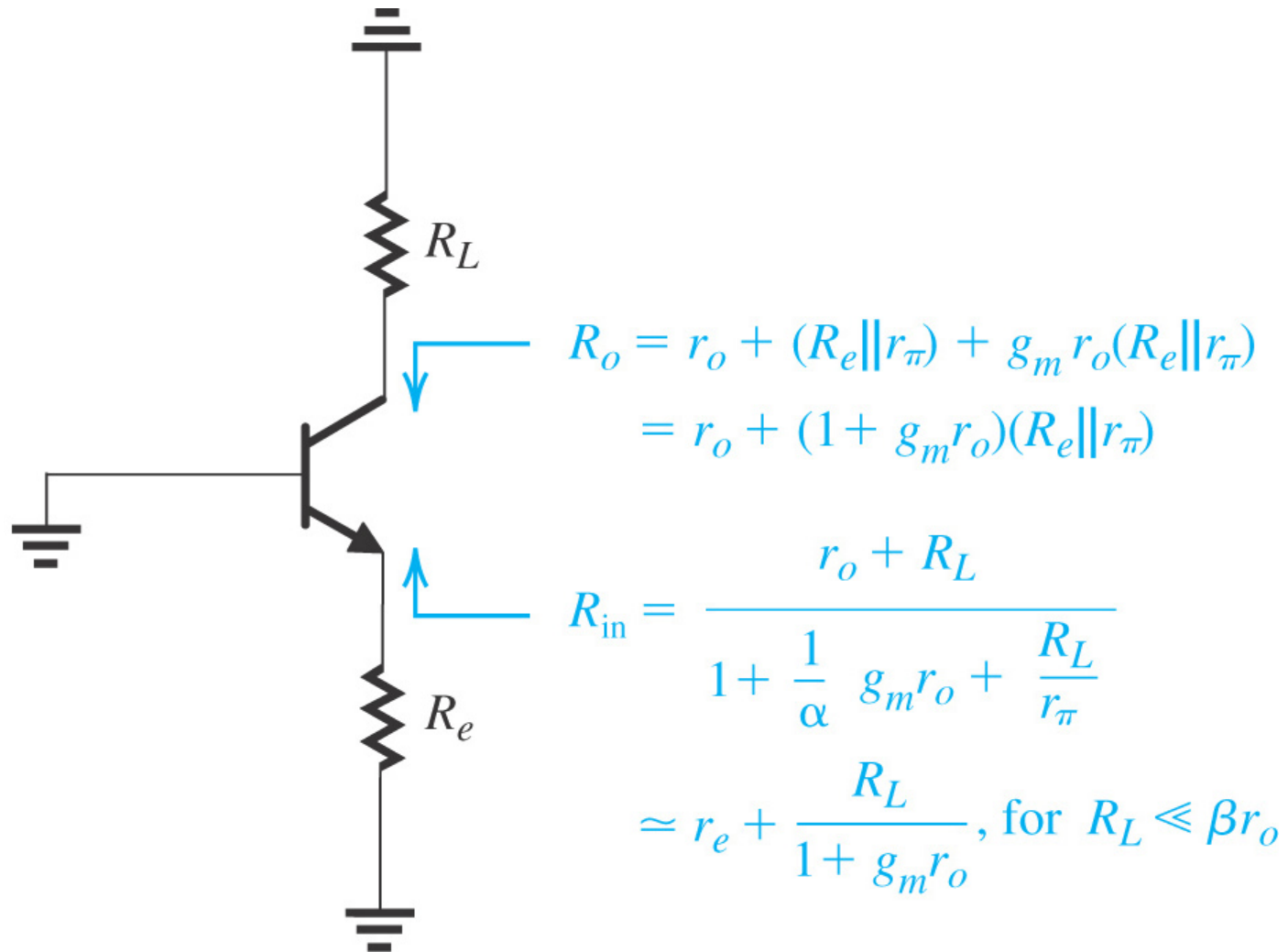


Example: BJT Cascode Analysis

- 1) Find R_{on} , R_{op} , and A_v , of the following cascode amplifier. For npn transistors let $\beta=100$ and $V_A=5V$, and for pnp transistors let $\beta=50$ and $V_A=-4V$. What is the maximum achievable gain.

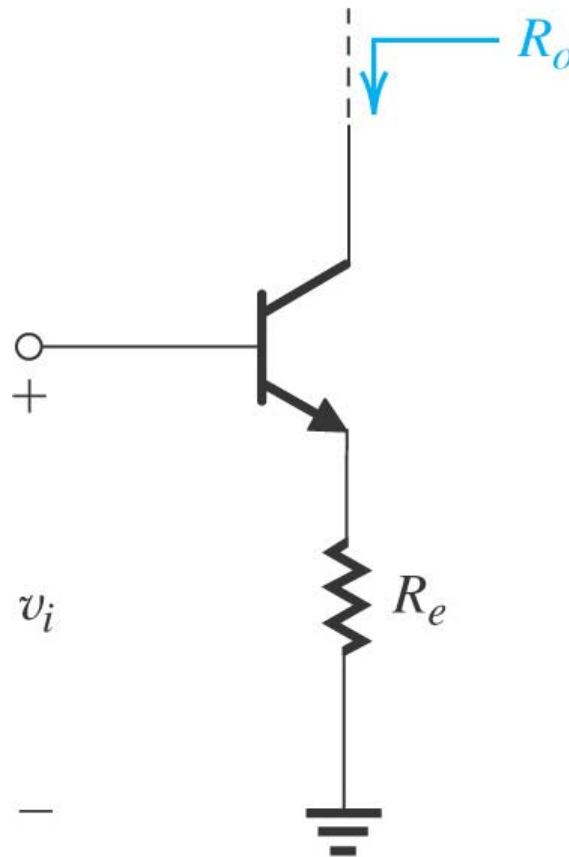


Impedance Transformation in BJT

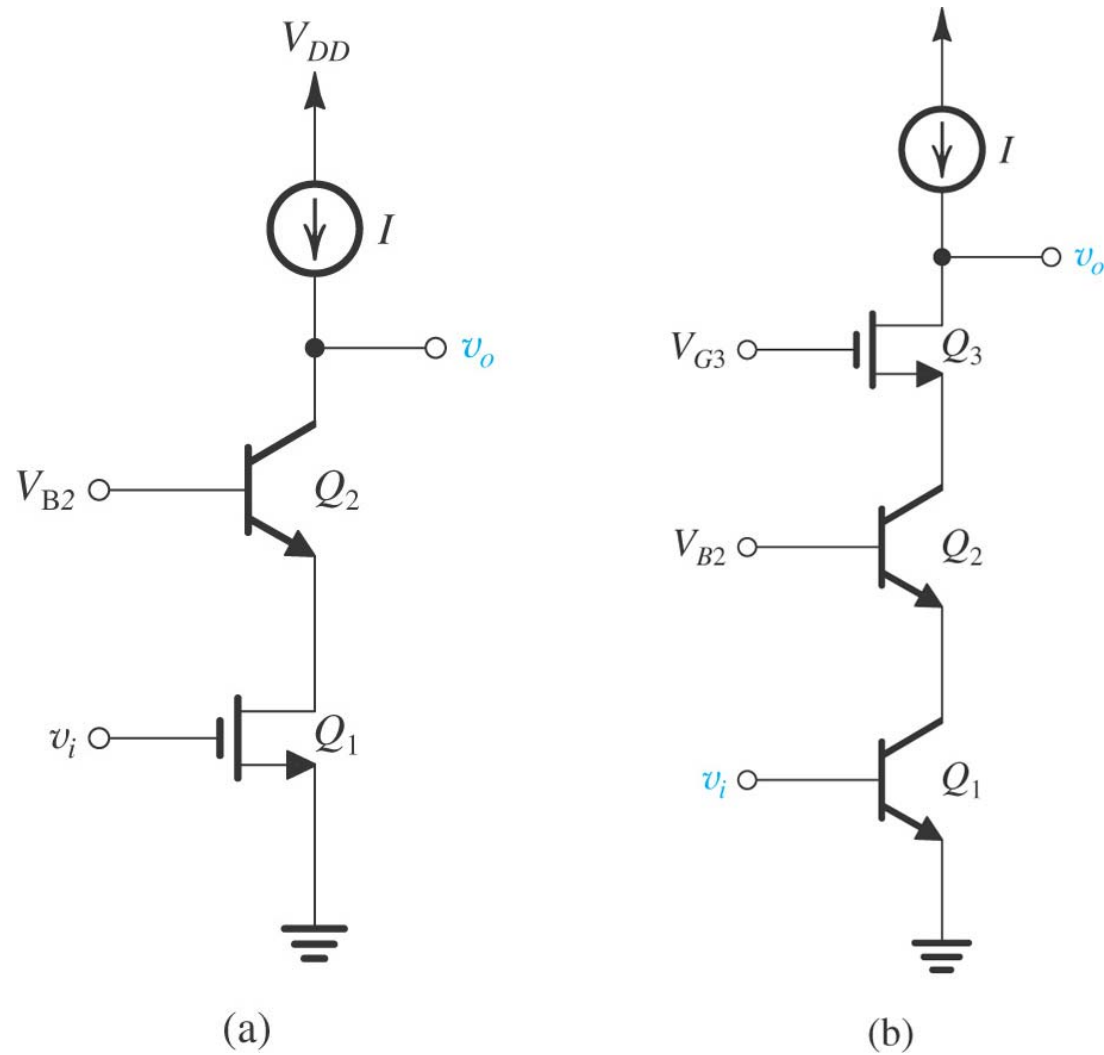


Example: BJT Resistance Transformation

- 1) Find the output resistance of the following degenerated CE amplifier when $R_e = 500\Omega$, $V_A = 10V$, and $\beta = 100$.



BiCMOS Cascodes



Example: BiCMOS Cascode Analysis

- 1) Find G_m , R_o , and A_{v_o} of the following BiCMOS Cascode amplifiers operates at $100\mu\text{A}$. Let $V_A=5\text{V}$ (for both devices), $\beta=100$, $K'_n=200\mu\text{A}/\text{V}^2$, and $W/L=25$.

