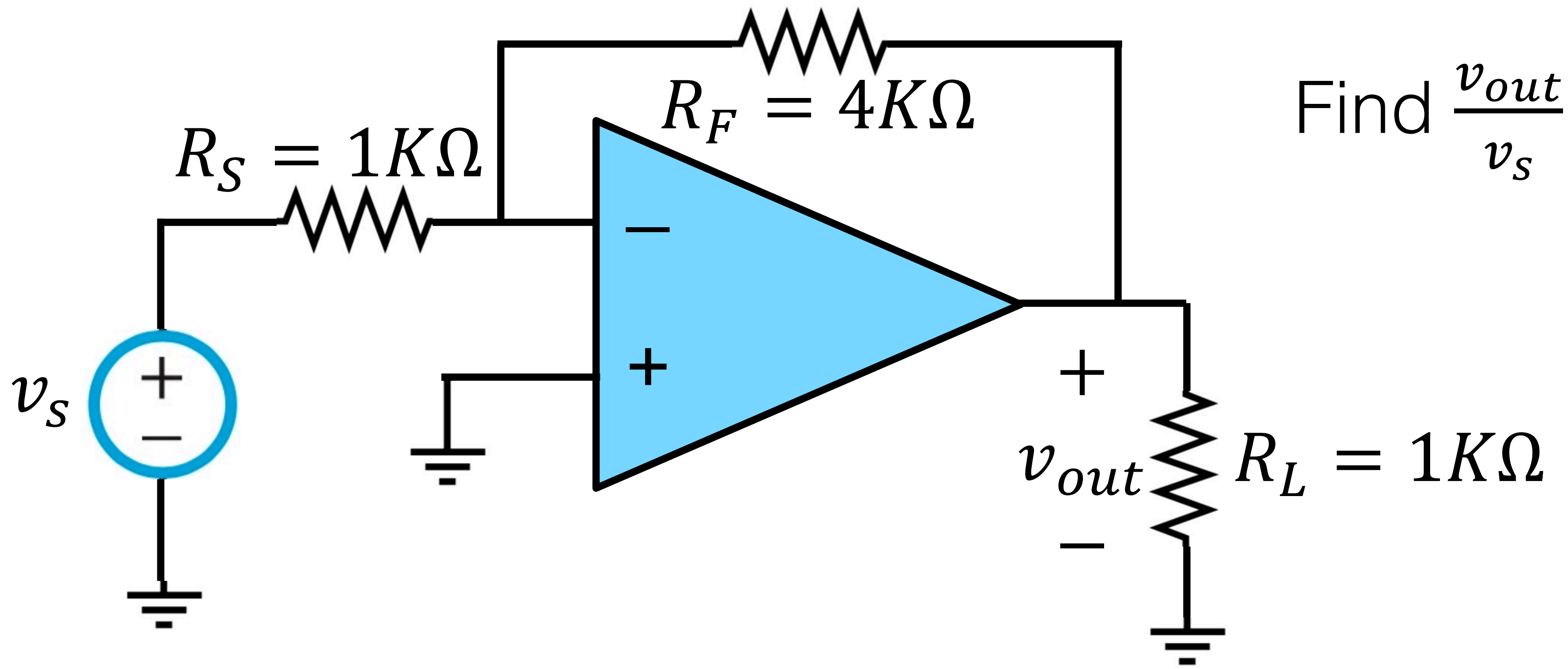
Last Class…



Find $\frac{v_{out}}{v_s}$ given that:

$R_{in} = 10^6\Omega$

$R_{out} = 100\Omega$

$A_{vol} = 10^6$

THE OHIO STATE UNIVERSITY

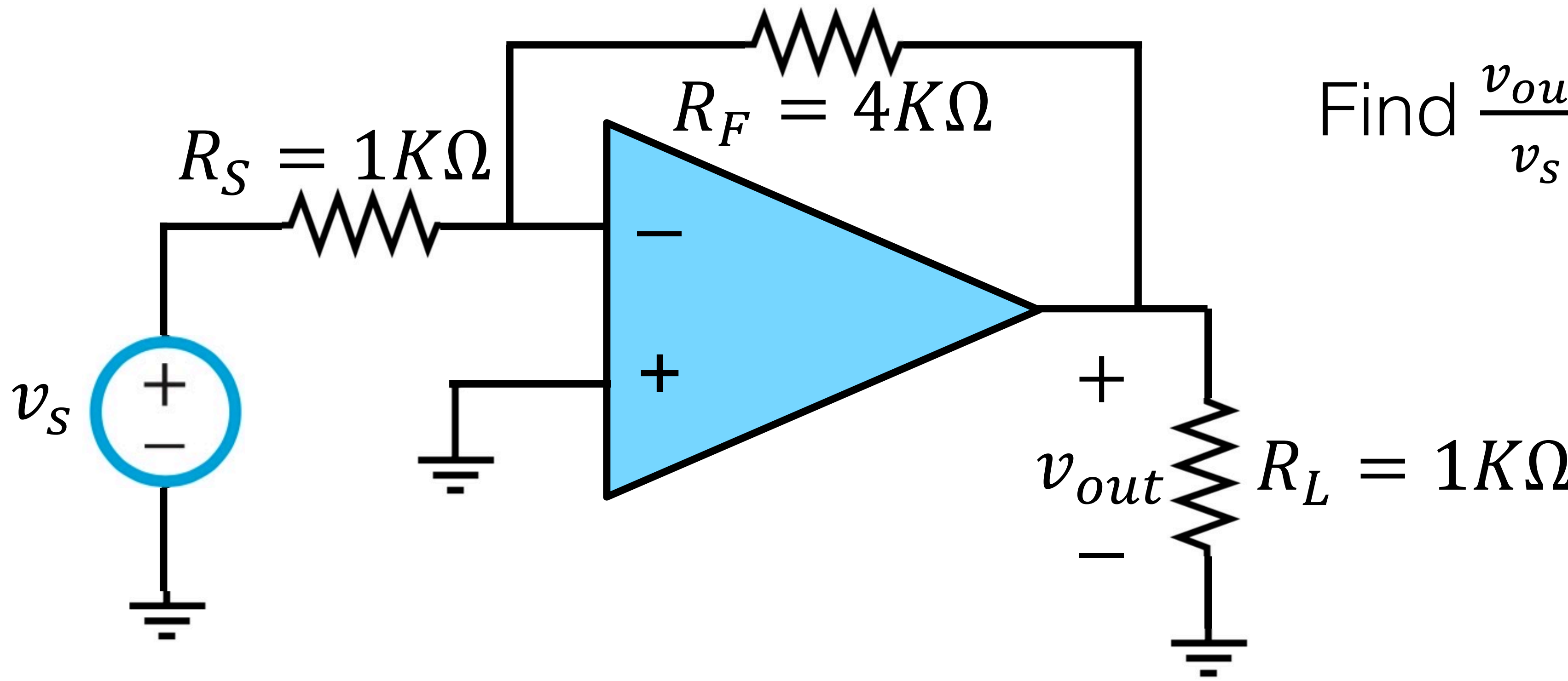
COLLEGE OF ENGINEERING

Op-amp models

This Lecture…

- Learning Objectives:
  - Analyze a circuit using the behavioral and ideal model of the op-amp.
  - Identify the voltage gain of a non-inverting and an inverting amplifier.

Example



Find $\frac{v_{out}}{v_s}$ given that:

open circuit

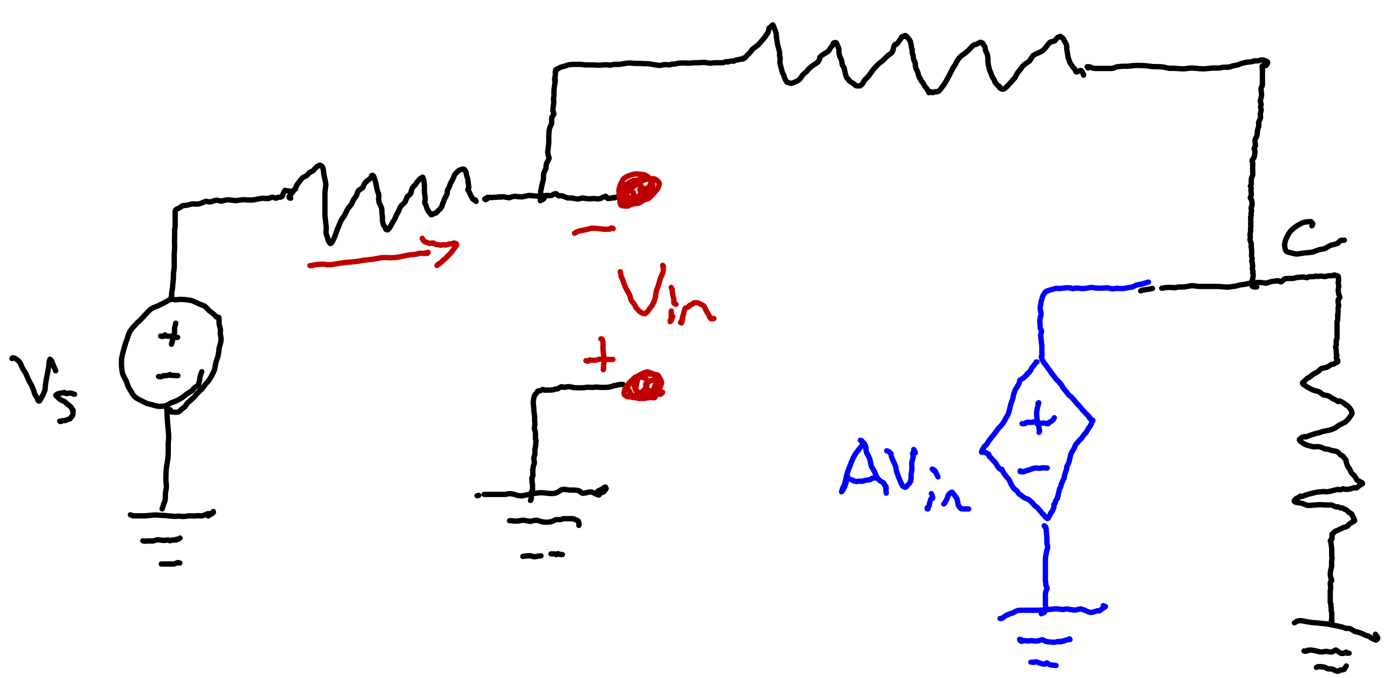
$R_{in} = \infty\Omega$

$R_{out} = 0\Omega$

short circuit

$A_{vol} = \infty$

Behavioral Model



Node Voltage Analysis (4 nodes)

$$V_0 = 0V \qquad V_C = AV_{in} = A(\cancel{V_0} - V_B)$$

$$V_A = V_S \qquad V_C = -AV_B$$

KCL @ B:

$$i_{RS} = i_{RF}$$

$$\frac{V_S - V_B}{R_S} = \frac{V_B - V_C}{R_F}$$

$$R_F V_S - R_F V_B = R_S V_B - R_S V_C$$

$$R_F V_S + R_S V_C = (R_S + R_F) V_B$$

$$V_B = \frac{R_F V_S + R_S V_C}{R_S + R_F} \quad 2$$

2 in 1

$$V_C = -A \cdot \frac{R_F V_S + R_S V_C}{R_S + R_F}$$

$$(R_S + R_F) V_C = -AR_F R_S - AR_S V_C$$

$$(R_S + R_F + AR_S) V_C = -AR_F V_S$$

$$\frac{V_c}{V_s} = \frac{-AR_F}{R_s + R_F + AR_s}$$

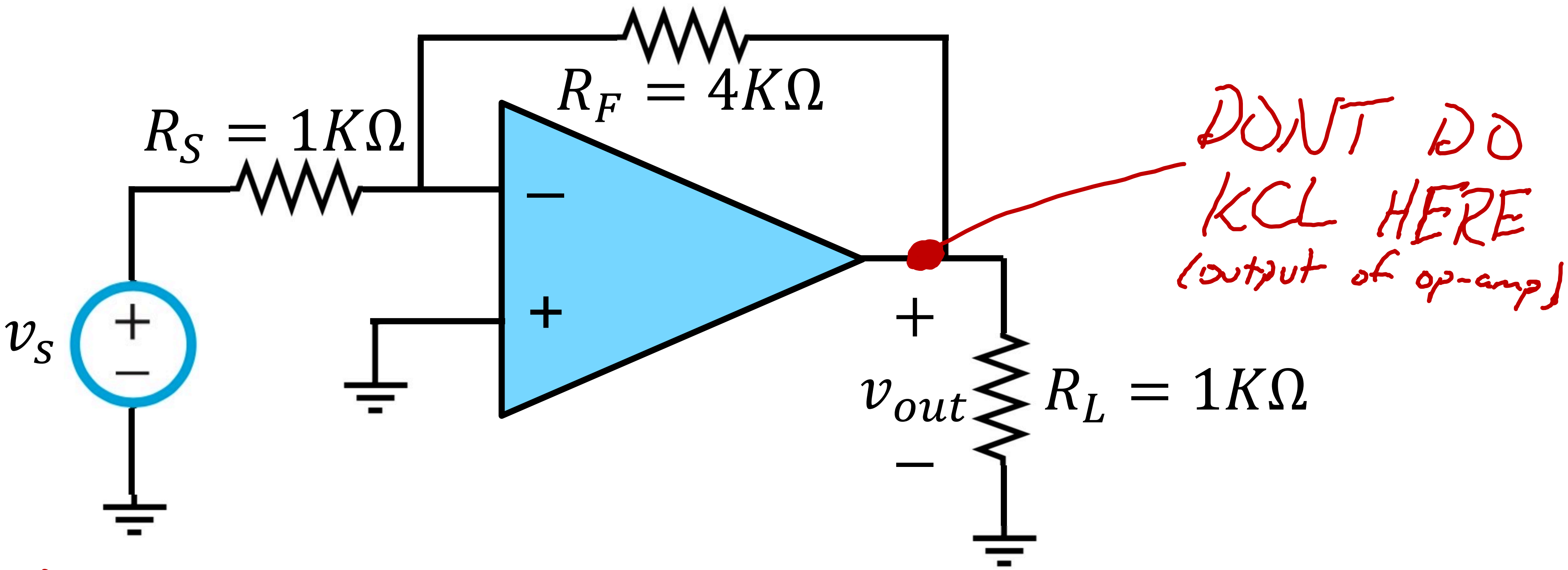
$A \to \infty$

$$\frac{V_c}{V_s} = \lim_{A \to \infty} \frac{-AR_F}{R_s + R_F + AR_s}$$

$$\frac{V_c}{V_s} = \frac{-R_F}{R_s} = -\frac{4000}{1000} = -4$$

This is an inverting amplifier

Ideal Model



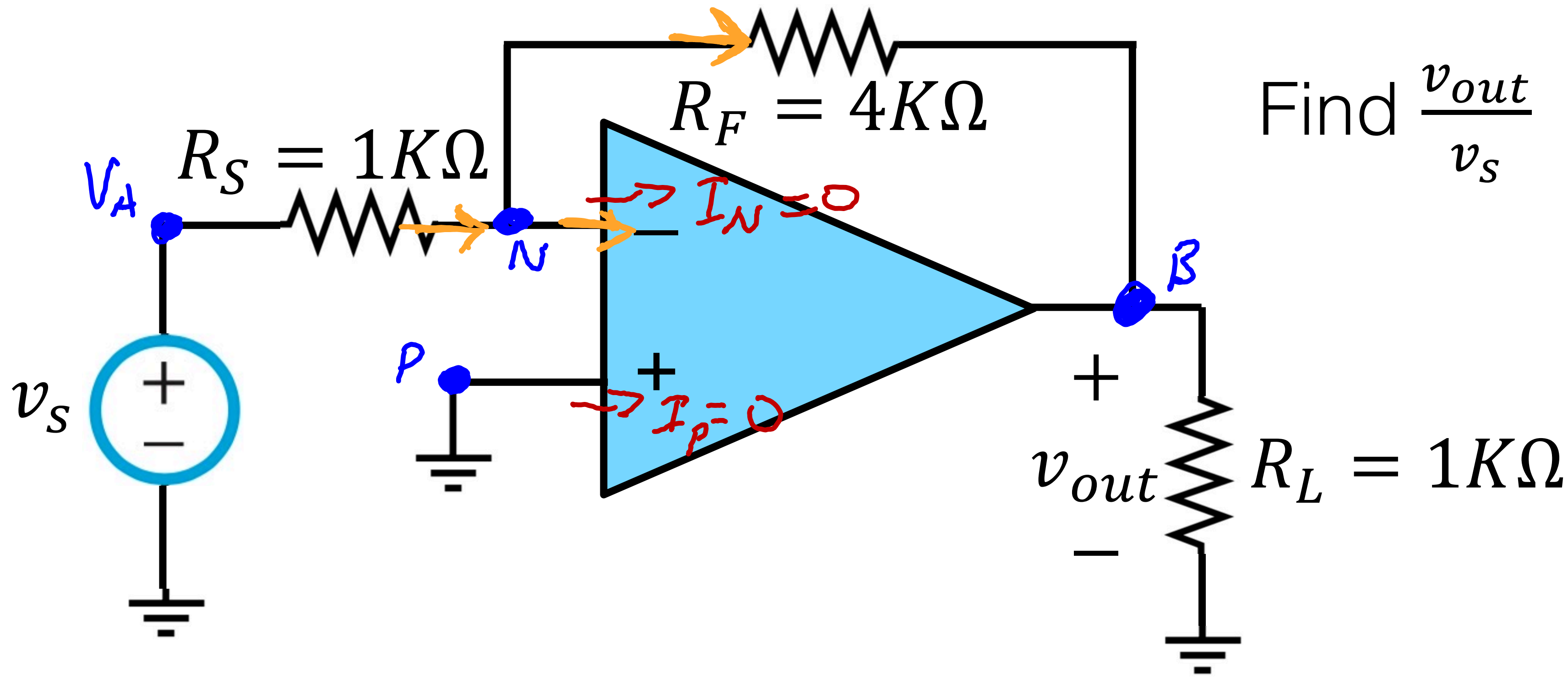
Assumptions

1. $i_p = i_n = 0A$

2. $v_p = \mathrm{v_n}$ (voltage is the same, different node).

- Use nodal analysis as before, but with using the conditions stated above.
- Do not apply KCL at op-amp output unless calculating $\mathrm{i_0}$.

Inverting Amplifier



Find $\frac{v_{out}}{v_S}$

Ideal Model

1. $i_p = i_N = 0$
2. $V_P = V_N = 0$ ← For this example

Node Voltage Analysis   4 nodes

$V_P = 0$

DO NOT DO KCL @ B BASED ON IDEAL MODEL

$V_A = V_S$

KCL @ N

$i_{RS} = i_{RF} + 0$

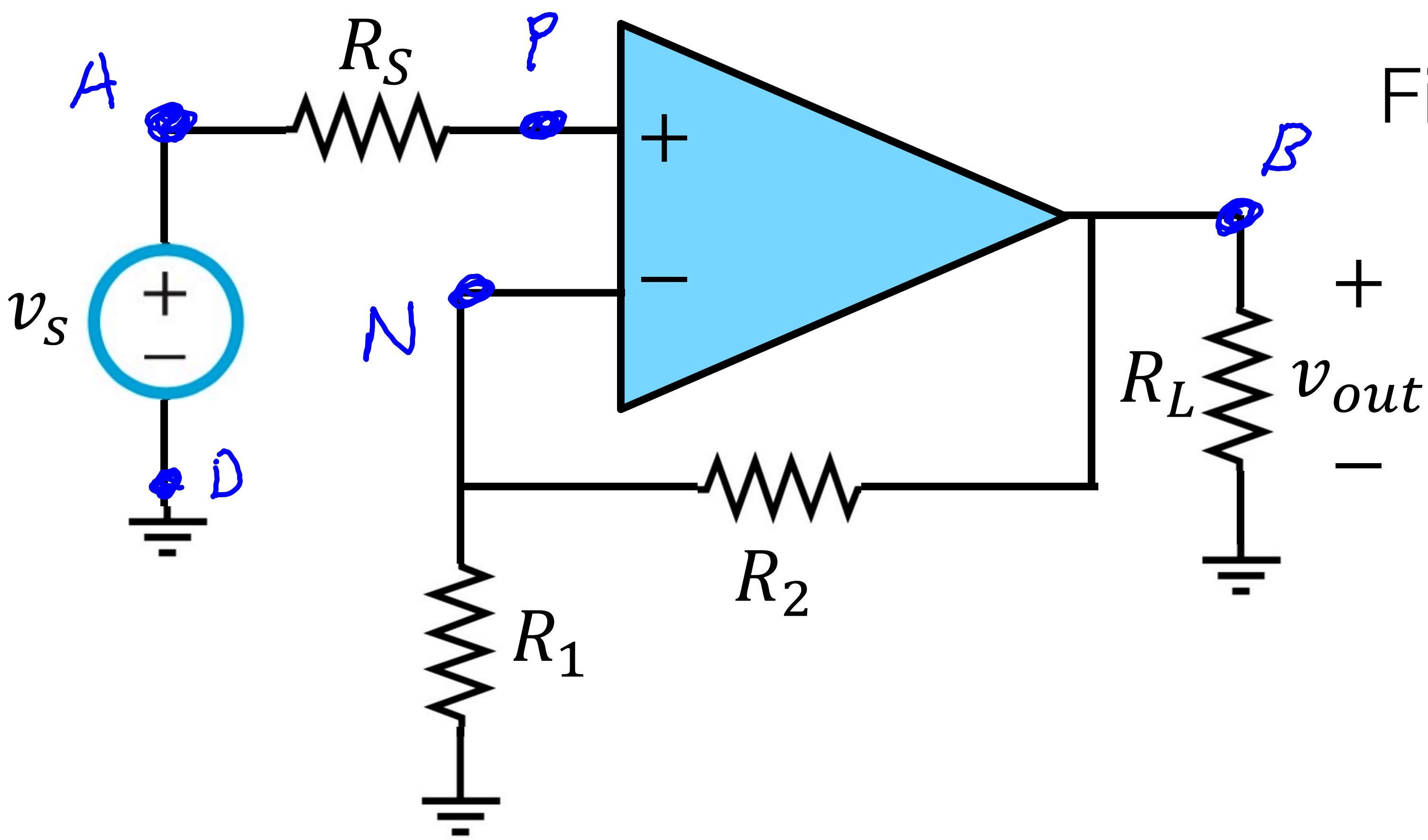
$$\frac{V_A - V_N}{R_S} = \frac{V_N - V_B}{R_F}$$

ideal model $V_N = V_P = 0$

$$\frac{V_s}{R_s} = \frac{-V_B}{R_F}$$

$$\frac{V_B}{V_s} = \frac{-R_F}{R_s}$$

Non-Inverting Amplifier



Find $\frac{v_{out}}{v_s}$

ideal model

1. $i_p = i_n = 0$
2. $V_p = V_N$

NVA

$V_D = 0$

$V_A = V_S$

Don't do KCL @ B

KCL @ P

KCL @ N

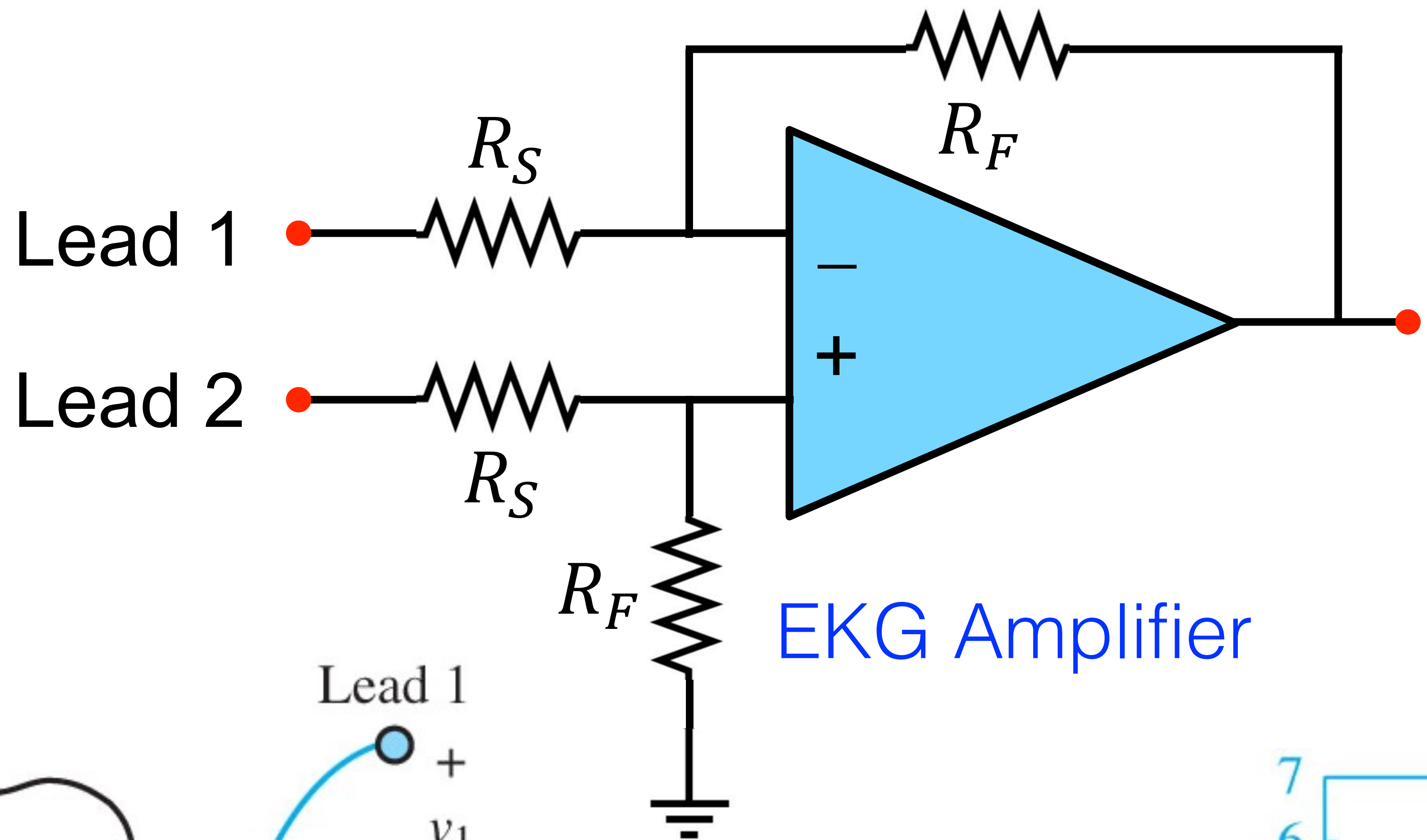
$$i_{RS} = 0$$

$$\frac{V_s - V_p}{R_s} = 0$$

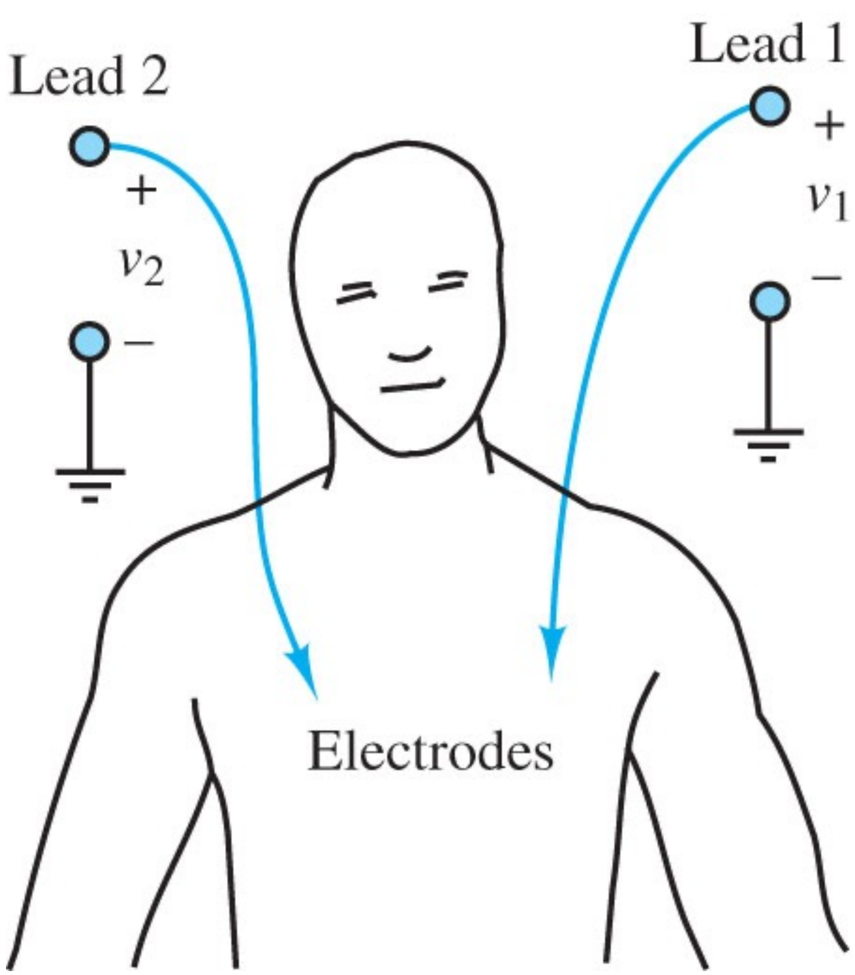
$$V_s - V_p = 0$$

$$\boxed{V_s = V_p = V_N}$$

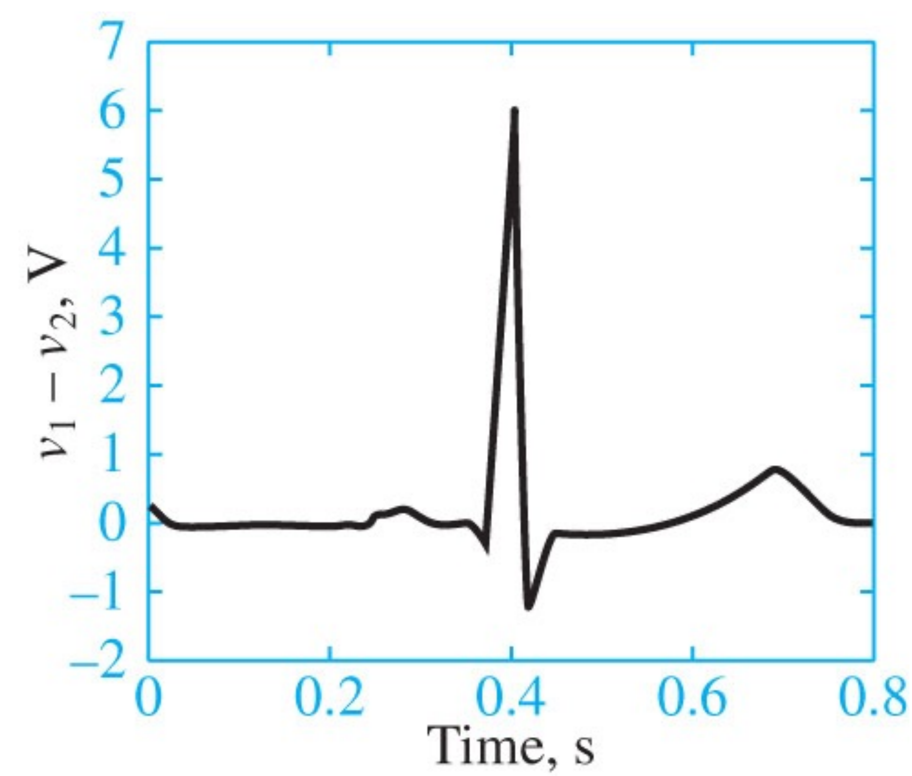
Differential Amplifier



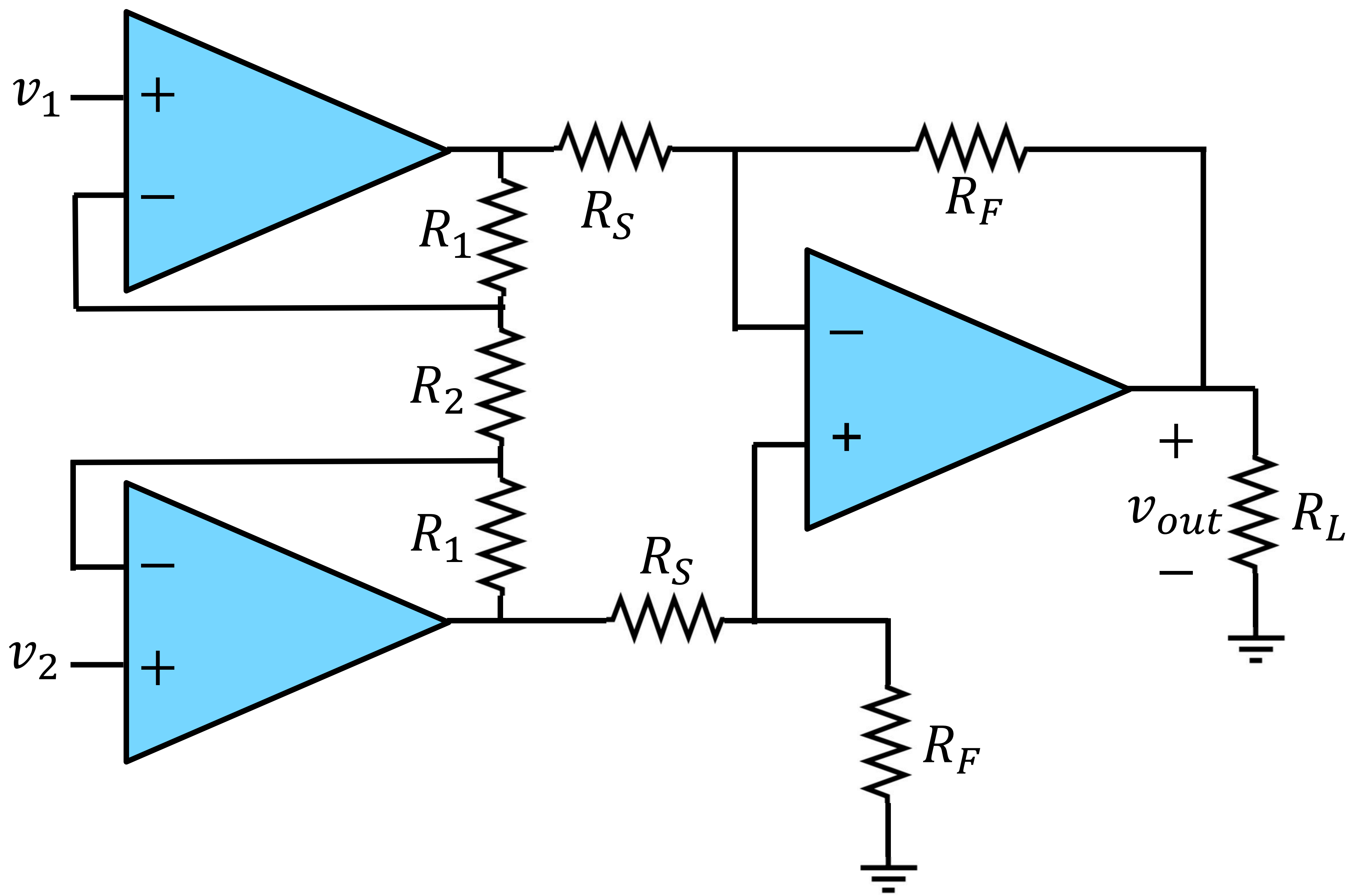
EKG Amplifier



Better version:
Instrumentation
Amplifier



Instrumentation Amplifier



Differential Amplifier