Reverse Classroom: Op Amps Quiz 2

REV 0; August 18, 2019

1 Golden Rules vs. the Diff-Amp View of an Op Amp

Now you know that an op amp is "simply" a very good difference amp: one with

- lots of gain;
- high R_{in};
- low R_{out}

If we extrapolate these parameters to their most favorable limit, we get the:

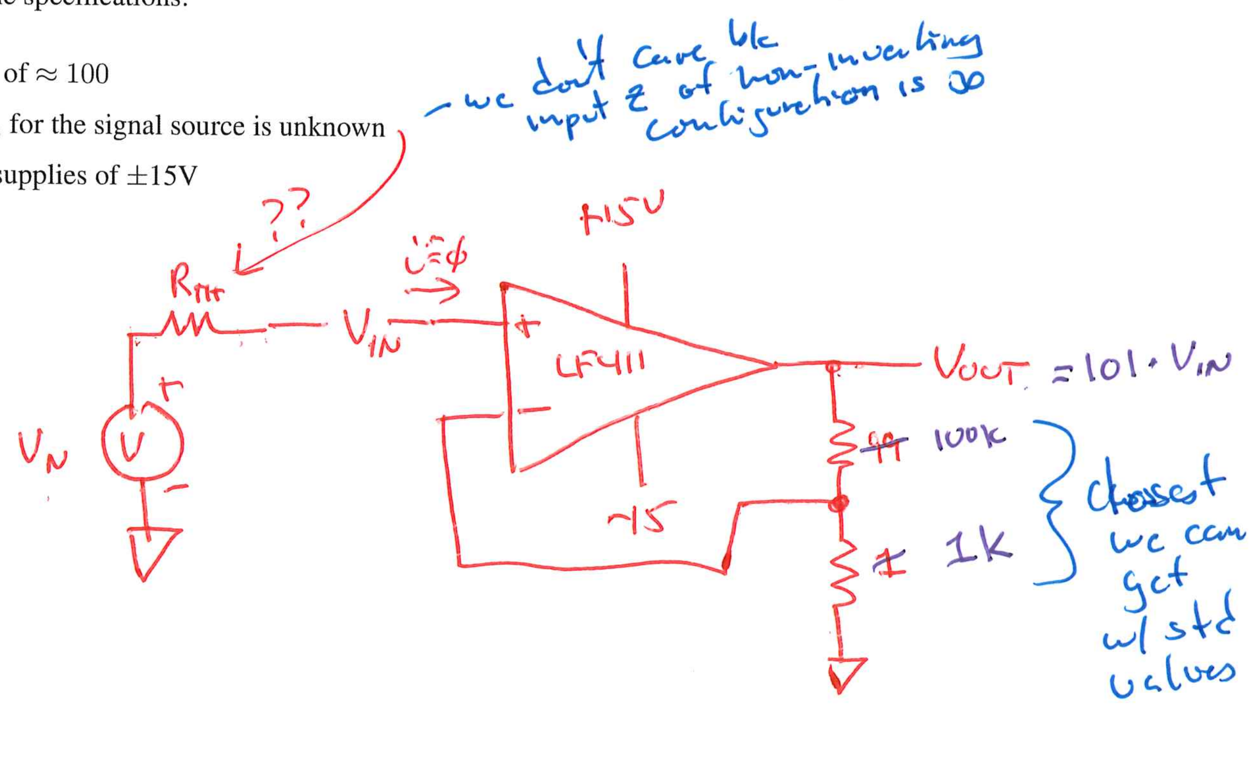
Perfect Op Amp Design Rules

1. No current flows into or out of the inputs (V_- and V_+) of an op amp.
2. If there is negative feedback, the op amp keeps the negative input at the same voltage as the positive input, so you can assume that $V_- = V_+$.
3. The inputs of an op amp should always be kept between V_{CC} and V_{EE} (i.e., $V_{EE} \leq V_-, V_+ \leq V_{CC}$).
4. The output of an op amp cannot be greater than V_{CC} or less than V_{EE}.

1.1 Design

Apply the Golden Rules to design a non-inverting amp using an LF411 op amp. Use standard value resistors. Here are the specifications:

- gain of ≈ 100
- R_{out} for the signal source is unknown
- use supplies of ± 15V



1.2 Amplifier Input Impedance

What is the input impedance of your amplifier according to the golden rules?

$i_{IN} = \phi \qquad \frac{V_{IN}}{i_{IN}} = \infty$

1.3 Amplifier Output Impedance

What is the approximate output impedance of your amplifier?

$\sim \phi\,\Omega$

1.4 ...analyzed according to the golden rules...

According to the golden rules, what is the voltage difference between the two op amp terminals, marked "+" and "-"? (Assume an input signal of 0.1V)

$V_+ = V_-$

$(V_+ - V_-) = \phi V$

1.5 ...analyzed according to your understanding of differential amplifiers...

Let's assume that the op amp's open-loop gain, A, is 10,000 (as it is, at some particular frequency).

According to your understanding of differential amplifiers, what is the voltage difference between the two terminals, marked "+" and "-", if your design of §1.1 is fed an input signal of 0.1V?

$V_o = 10{,}000\,(V_+ - V_-)$

$V_- = V_o \cdot \frac{1k}{1k + 100k} \approx \frac{V_o}{101} \qquad V_o \approx 101 \cdot V_-$

$101 \cdot V_- = 10{,}000\,(V_+ - V_-) = 10{,}000\,V_+ - 10000\,V_-$

$V_-\,(10{,}000 + 101) = 10000\,V_+$

$10101 \cdot V_- = 10{,}000\,V_+$

$V_- \approx \frac{10{,}000}{10{,}101}\,V_+$

so if

$V_+ = .1V$

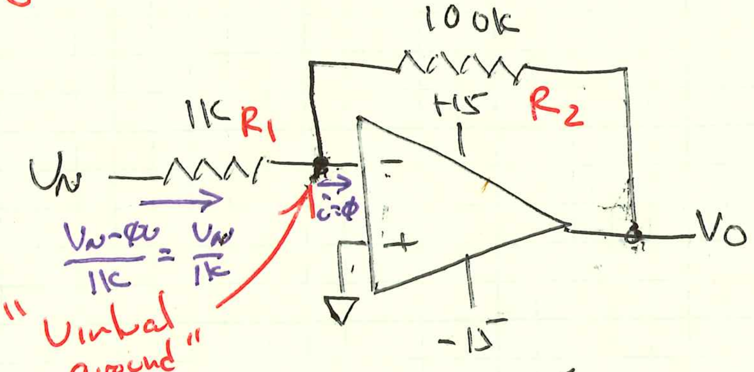
$V_- = 0.099V$

$V_+ - V_- \simeq 1mV$

Now complete Lab 6 through part 6L.4

The Inverting Configuration

$$\frac{0V - V_{OUT}}{100k} = \frac{-V_{OUT}}{100k}$$



$$\frac{V_{IN} - \phi V}{1k} = \frac{V_{IN}}{1k}$$

$$\frac{V_{IN}}{1k} = \frac{-V_{OUT}}{100k}$$

$$\frac{V_{OUT}}{V_{IN}} = -\frac{100k}{1k} = -100$$

neg feedback? ✓ yes

$V_+ = V_-$ but $V_+ = \phi V$ so $V_- = \phi V$

inverting gain of 100 amplifier (inverting configuration)

$$G = -\frac{R_2}{R_1}$$

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what is the input impedance of the inverting configuration?

$$\frac{V_{IN}}{I_{IN}} = \frac{V_{IN}}{\frac{V_{IN}}{R_1}} = \underline{R_1}$$

even though op amp has very high input Z, the circuit does not

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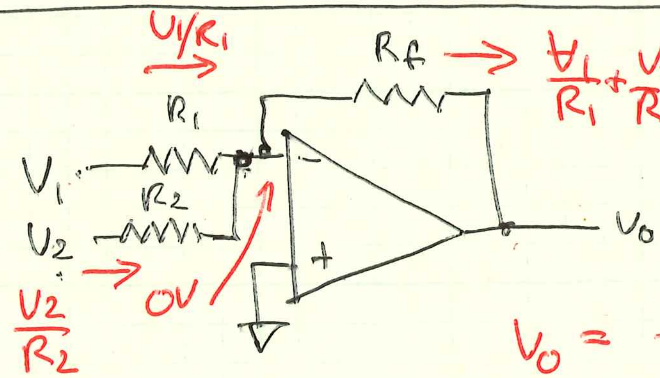
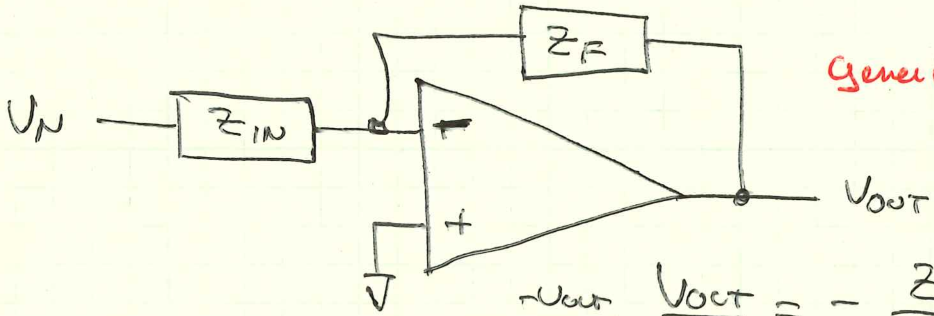


$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = \frac{-V_O}{R_f}$$

$$V_O = -\left(\frac{R_f}{R_1} \cdot V_1 + \frac{R_f}{R_2} V_2\right)$$

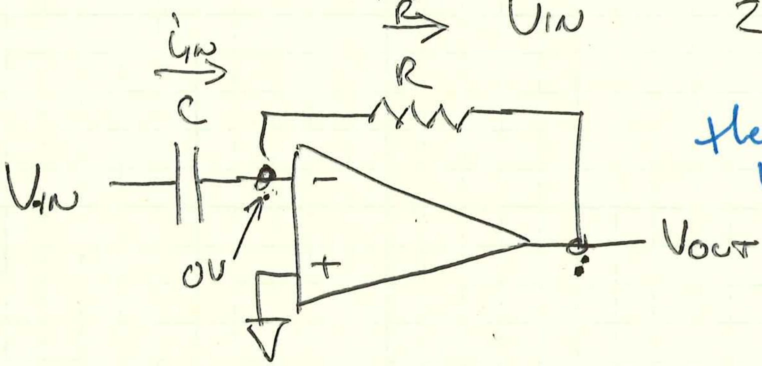
inverting summing amplifier

we can add as many inputs as we want to sum multiple voltages



generic inverting configuration

$$\frac{V_{OUT}}{U_{IN}} = -\frac{Z_F}{Z_{IN}}$$



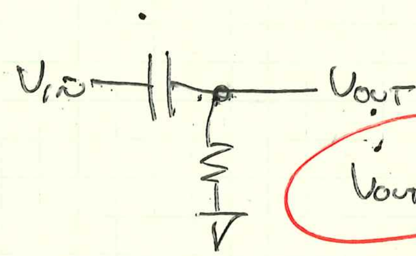
there is neg feedback ✓

op amp differentiator

$$i = C\frac{dv}{dt} \qquad i_{IN} = C\frac{dU_{IN}}{dt} = -\frac{V_{OUT}}{R}$$

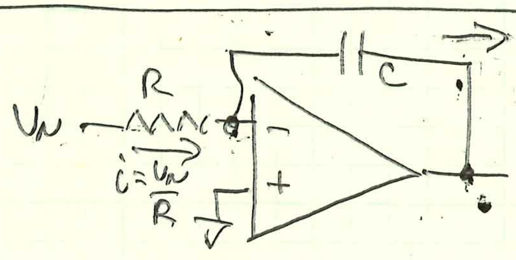
$$\boxed{V_{OUT} = -RC\frac{dU_{IN}}{dt}}$$

inverting differentiator



fixes this

$V_{OUT} \ll U_{IN}$



$$C\frac{d\,(-V_{OUT})}{dt}$$

there is neg feedback (except at DC)

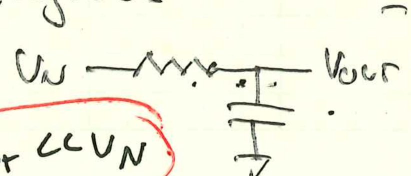
$$\frac{U_N}{R} = -C\frac{dV_{OUT}}{dt}$$

inverting integrator

$$\frac{1}{-RC}\int U_N = \cancel{-RC}\int\frac{dv_{OUT}}{dt}$$

$$\boxed{V_{OUT} = \frac{-1}{RC}\int V_N\,dt}$$

fixes this



$V_{OUT} \ll V_N$