Problem 1: Op-Amp stable operation should maintain gain > 1 (simulation error)
Solution: upgrade sense resistor value.

Afterwards, we can use differential amplifier to amplify voltage across small value sense resistor

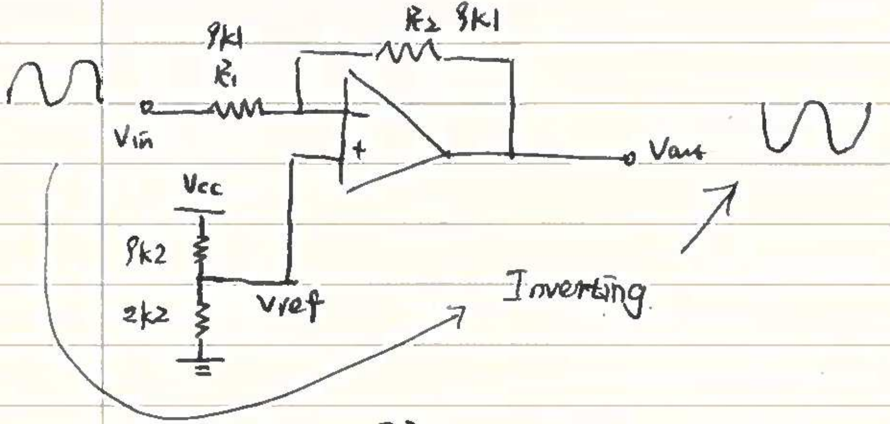
One of these allegro sensors is recommended for my circuit:

https://www.allegromicro.com/en/products/sense/current-sensor-ics/zero-to-fifty-amp-integrated-conductor-sensor-ics

Main task:

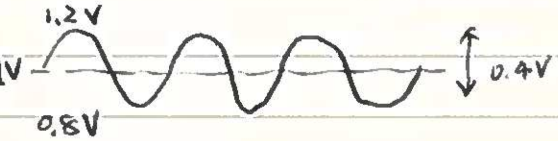
Study performance of Op-Amp LM741 and FDS9926A dual N-channel MOSFET for building test circuit.
The frequency chosen is 1KHz, which is suitable for LM741 (with around 200KHz bandwidth product)
FDS9926A: spice model found from
https://www.onsemi.com/design/resources/technical-documentation?rpn=FDS9926A#ZHQ9TW9kZWxzO3N3PUZEUzk5MjZBO3N0PXR5cGU7c2Q9ZGVzYzs=

The same structure



$$V_{ref} = 5 \times \frac{2.2}{9.2+2.2} \approx 0.965$$

V_{in} = sine wave →

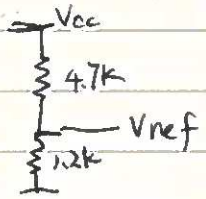


freq = 322.2 kHz

V_{out} = 1.8 ~ 2V sine   freq = 322.6 kHz

↕ 0.2V

$V_{output\ offset}$ = 1.9V → ≈ 2 × 0.965 = 1.930 V



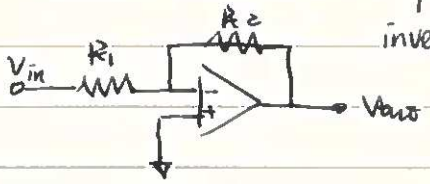
V_{ref} = 1V

V_{in} = 1V offset 0.4mV amplitude

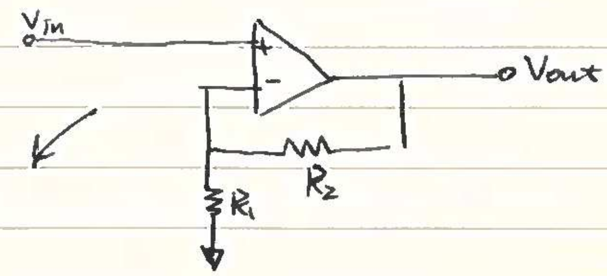
V_{out} = 1.9V offset 0.2mV amplitude

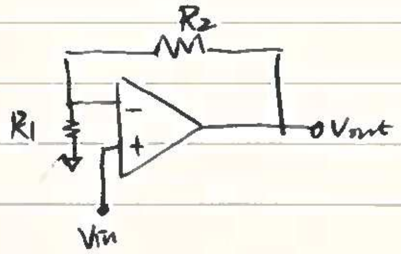
★ Gain caculated wrong : for inverting amplifier $A_V = -\frac{R_2}{R_1}$

inverted

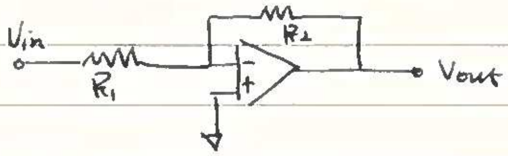


for non-inverting amplifier. $A_V = 1 + \frac{R_2}{R_1}$





Verification by simplest circuit

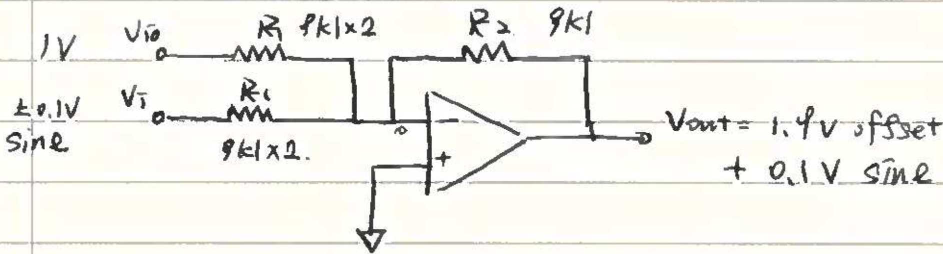


$R_2 = R_1 = 9k1$

V_{in} = 1V offset with ±0.1V amplitude   0.9 ~ 1.1V.

V_{out} = 1.8V ~ 2V → 1.9 offset with ±0.1V amplitude.

V_{in} with offset



$$\frac{V_{out} - V_-}{R_2} = \frac{0 - V_{io}}{R_1}$$

$$V_{out} = -\frac{V_{io}}{R_1} \times R_2$$

$$\frac{V_{out}}{V_{io}} = -\frac{R_2}{R_1} = -\frac{9k1 \times 2}{9k1} = -2$$

inverting but for offset → No effect for inverting.

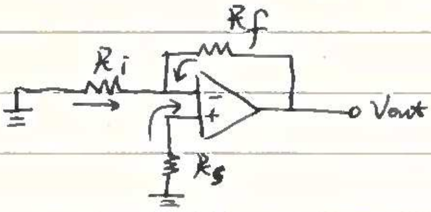
V_{out_offset} = 1.9V $V_{io\_}$ = 1V   ?   1.9 gain rather them 2

why

⇒ If op-amp input is DC

lets put V_{in} = 1V_DC ⇒ V_{out} = 1.9V

⇒ Amplification for DC input.



bais current → Ri & Rs doesn't match

current different at V_- & V_+

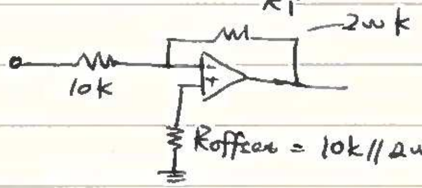
① Ri & Rs matched

→ current V_- & V_+ identical

Rs = Ri parallel with Rf → DC offset

$$V_{out\_offset} = \underbrace{A_n}_{\text{noise gain}} \times \overbrace{V_{OS}}^{\text{Input offset}} + \overbrace{I_{OS}}^{\text{offset current}} \times R_f$$

$$A_n = 1 + \frac{R_f}{R_i}$$



$R_{offset} = 10k // 200k \approx 15k$

Datasheet : $V_{OS} = 5\,mV \rightarrow$ LM741 : 15mV.

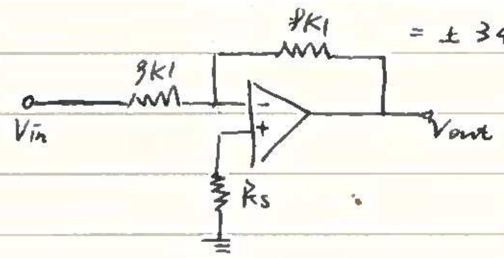
$I_{OS} = 0.1\,\mu A \rightarrow$ 80~500nA

$\rightarrow A_v = -\frac{R_f}{R_i} = -20$

$A_n = 1 + \frac{R_f}{R_i} = 21$

$$V_{outoffset} = 21 \times 5mV + 0.1\mu A \times 200k$$
$$= 105mV + 20mV$$
$$= \pm 125mV$$

In my case : $V_{outoffset} = 2 \times 15mV + (80 \sim 500nA) \times 9k1$
$$= 30mV + 4.5mV$$
$$= \pm 34.5mV$$



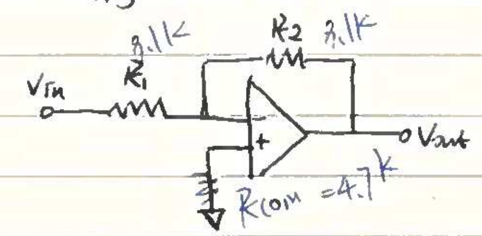
$I_{offset} = \frac{1V}{9k1} = \frac{1}{9k1}$ A

1 output offset · input.

$\Rightarrow V_{offset} = \frac{1}{9k1} \times R_f$

$= 1V$

Power supply should be double sided $\rightarrow \pm 15V$



$A_v = -\frac{R_2}{R_1} = -1$ gain

Vin = ± 0.5V sine wave with 333.3kHz

Vout = ± 0.3V sine wave.

1.5MHz Bandwidth_typical.