Lecture 6 : Op Amp Output Error

(Quiz)

0. Review
1. Input Bias Current
2. Input Offset Current
3. Input Offset Voltage

Textbook reading:

15-4 : Input characteristics of an op amp

- Today { Quiz / Lab 1 report due
- PreLab 3 due at lab session
  - ↳ Choose Design Project Topic, teammates, preliminary design
- HW3 due next Fri (Oct 11) in box outside my office.
  - ⇒ No class Oct 8 + 10

0. Review

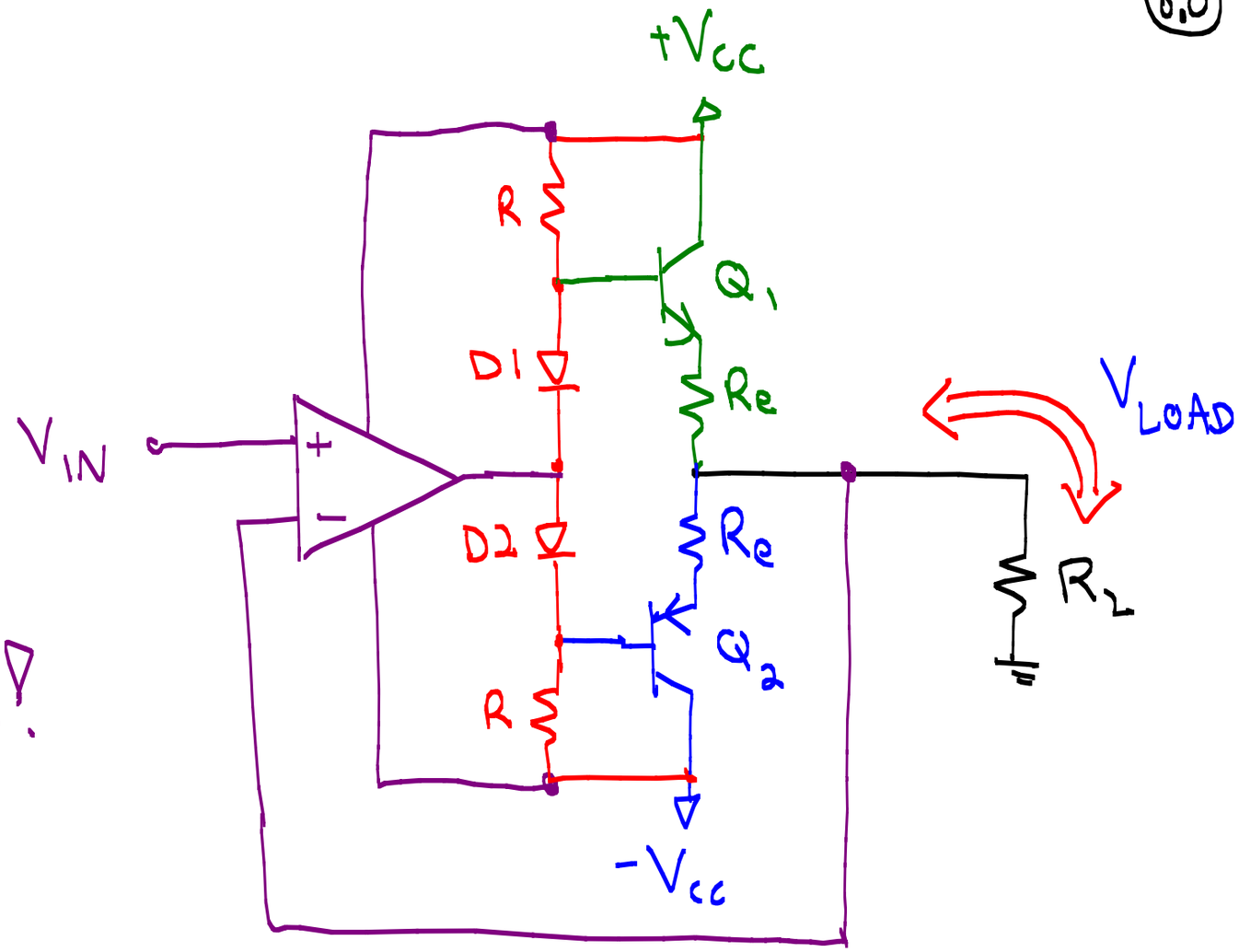
- **Class AB Output Stage**

→ Push-pull current booster

* Biasing diodes make Q_1 and Q_2 slightly on

⇒ Greatly reduces crossover distortion! ☺

* R must be low enough to provide sufficient current to diodes AND transistor bases

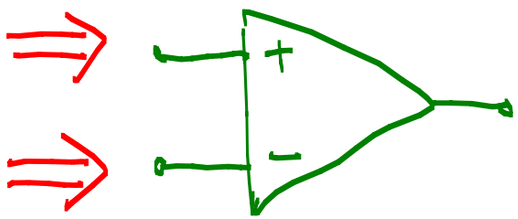


1. Input Bias Current

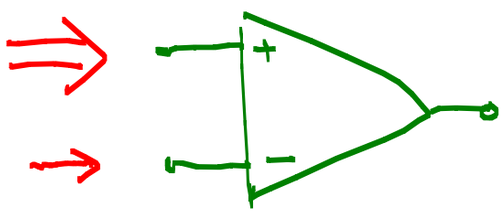
- Real op amps do NOT produce zero output when the input is zero.

Q: What causes ΔV_{IN}?

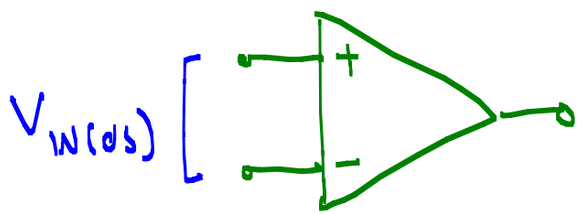
① Input bias current $I_{IN(BIAS)}$



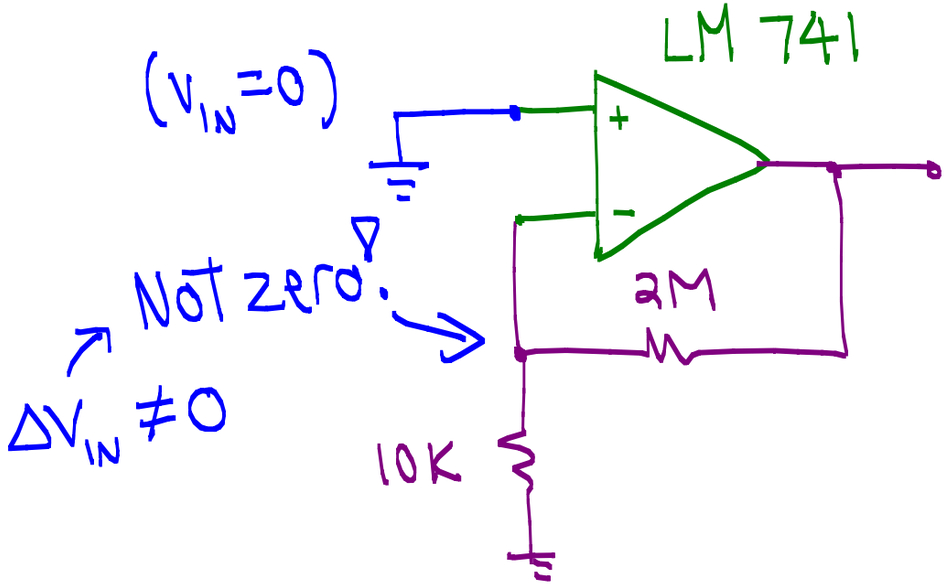
② Input offset current $I_{IN(OS)}$



③ Input offset voltage $V_{IN(OS)}$



Example

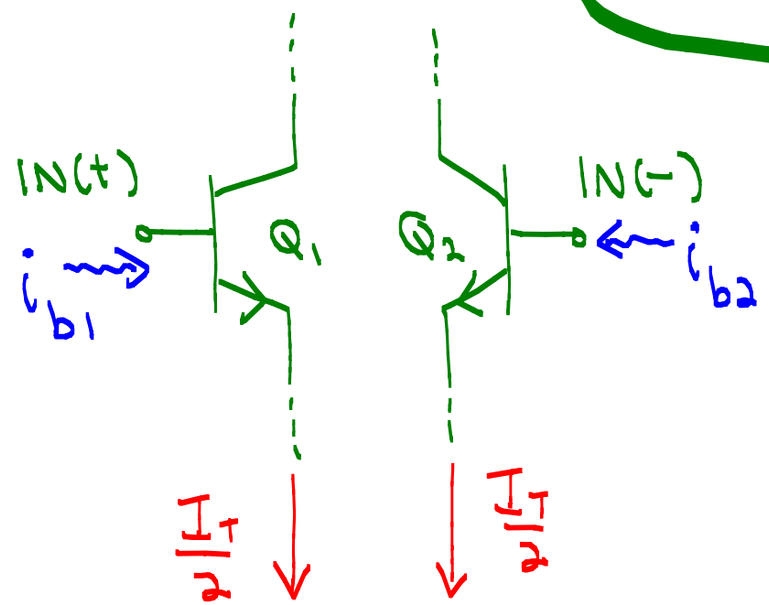


$\Delta V_{OUT} = G \Delta V_{IN}$

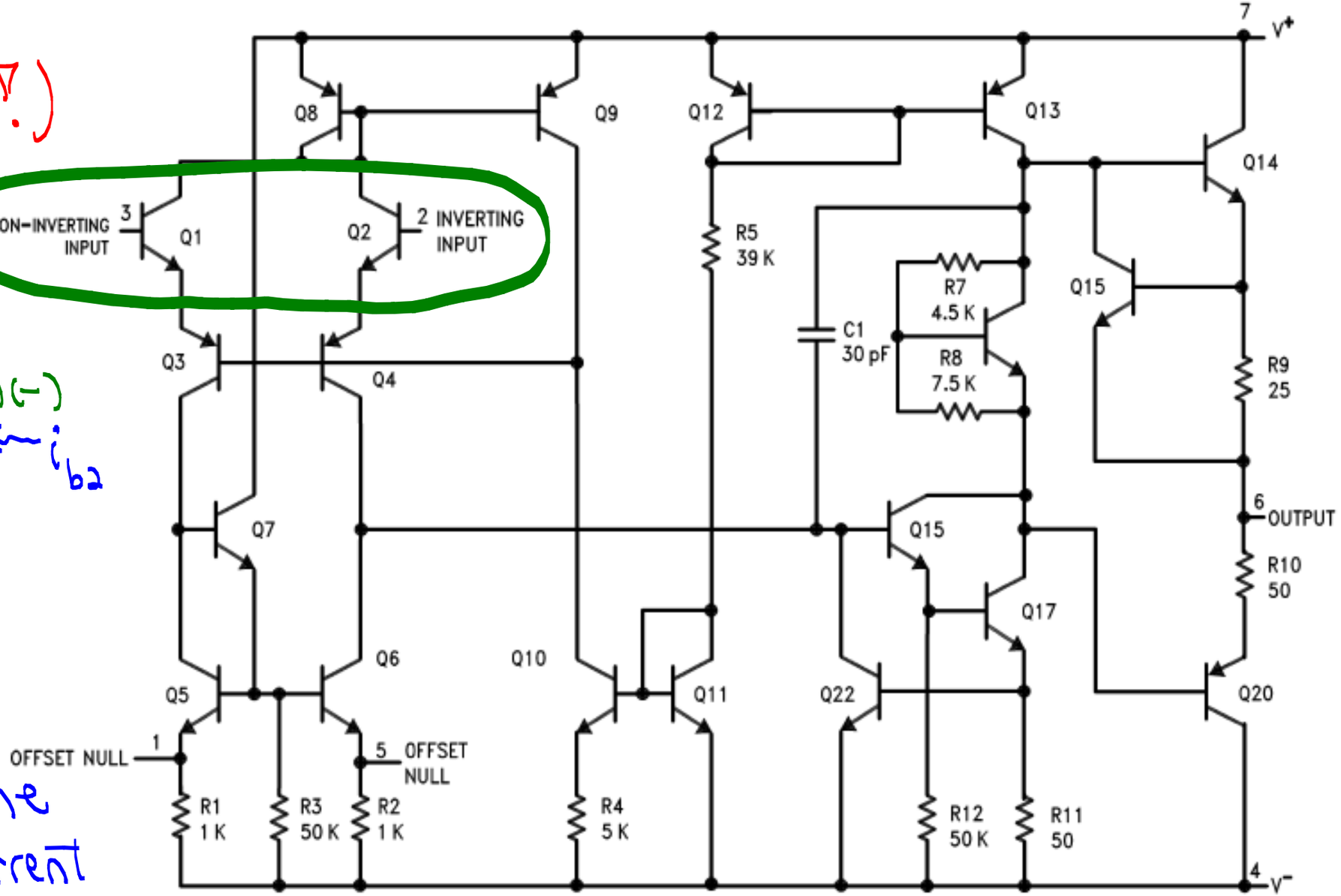
$1 + \frac{2M}{.01M} = 201$

- 741 op Amp

(over 20 transistors!)



Schematic Diagram

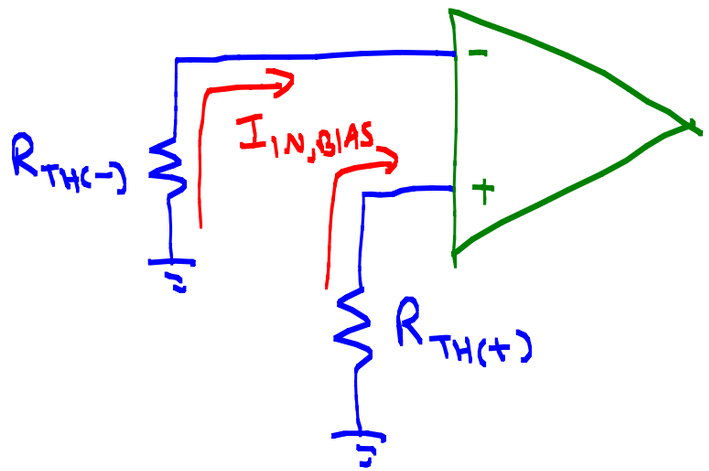


★ Bias current is the quiescent base current of Q_1 and Q_2!

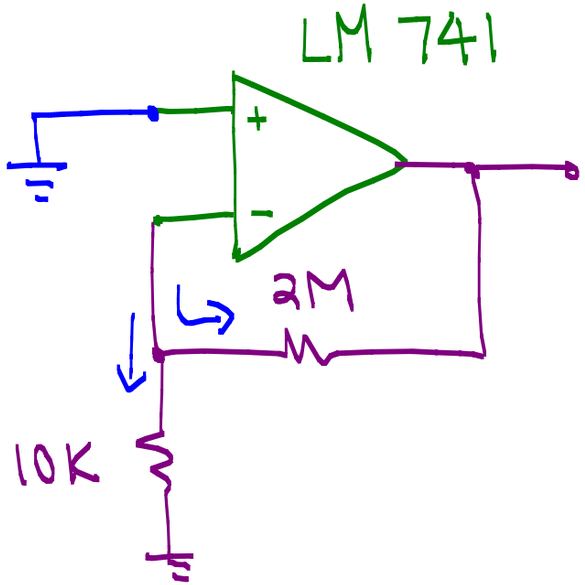
• Effect of input bias current $I_{IN(BIAS)}$

$$\Delta V_{IN} = I_{IN(BIAS)} \times \left[R_{TH(-)} - R_{TH(+)} \right]$$

Difference in Thevenin resistance seen by (-) and (+) inputs



Example LM741: $I_{IN(BIAS)} = 80\,nA$ (TYP) $(V_{IN}=0)$



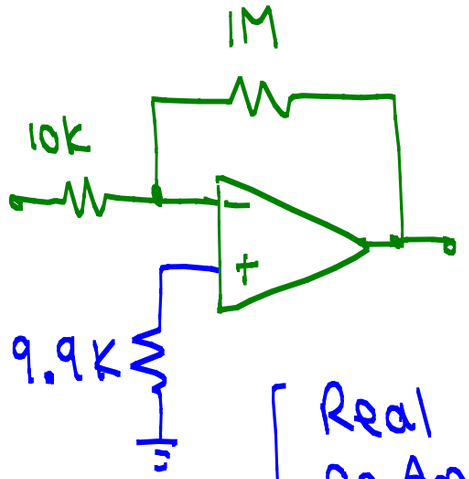
$R_{TH(-)} = 10K \,//\, 2M = 9.95K$

$R_{TH(+)} = 0$

$\Rightarrow \Delta V_{IN} = (80\times10^{-9})(9.95\times10^{3} - 0) = \underline{\underline{0.8mV}}$

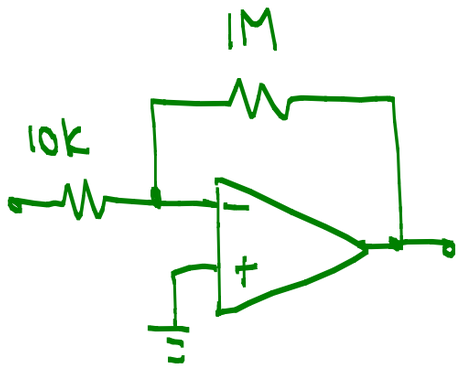
Q: How to minimize error due to $I_{IN(BIAS)}$?

① Try to make $R_{TH(+)} = R_{TH(-)}$ ∇!



[Real op Amp]

VS.

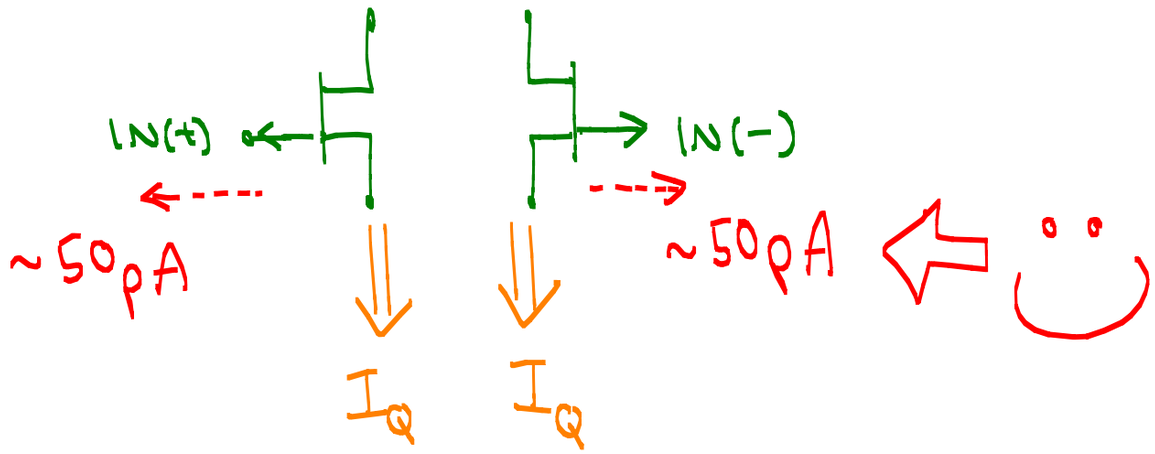


[Ideal op Amp]

② use a JFET-input op amp

Recall that Field Effect Transistors (FETs) have negligible gate current...

Ex: LF356, LF411, TL081



Example Transimpedance Amplifier

741C: $I_{BIAS} = 80\ nA\ (typ)$

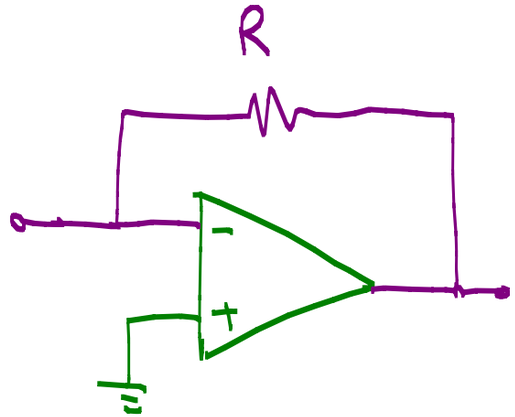
LF356: $I_{BIAS} = 30\ pA\ (typ)$ ↖!

If $R = 1M$,

$V_{out} = 80\ mV$ (741C) ☹

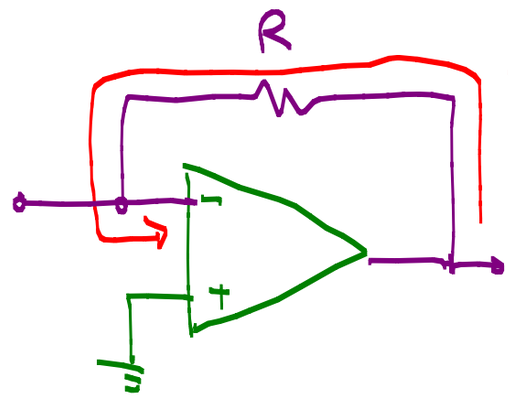
$= 30\ \mu V$ (LF356) ✓ ↖!

Ideal ($i_{IN} = 0$)



$V_{out} = 0$

Actual ($i_{IN} = 0$)



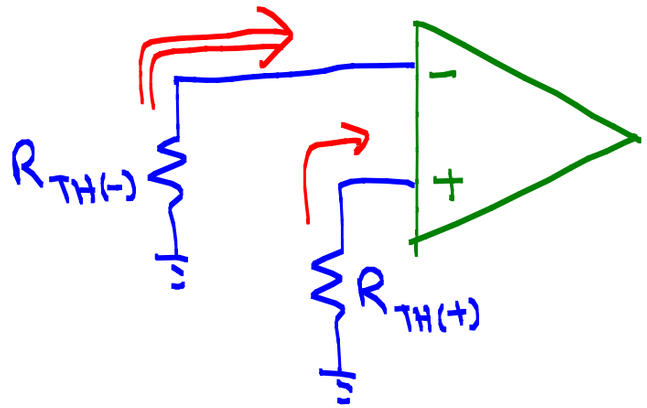
I_{BIAS}

$V_{out} = I_{BIAS} \times R$

NOTE: The LF356 is a really good general purpose op amp (MUCH better than 741...)

2. Input offset current

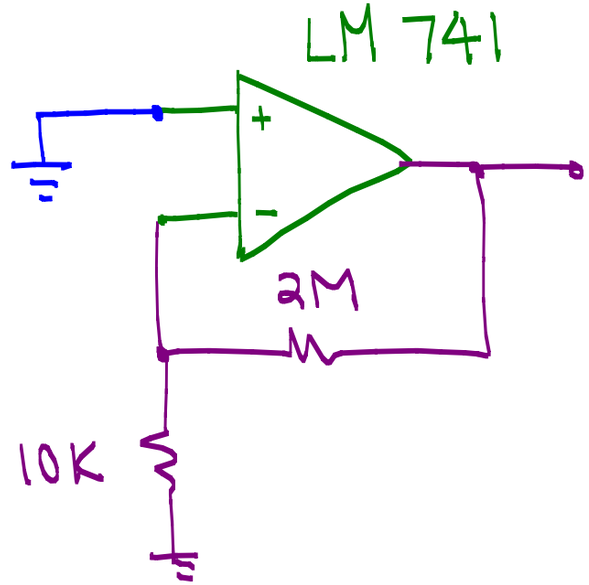
$$\Delta V_{IN} = I_{IN(OS)} \times \left[\frac{R_{IN(-)} + R_{IN(+)}}{2} \right]$$



Average Thevenin resistance seen by op amp inputs

Example LM741: $I_{IN(OS)} = 20\,nA$ (TYP) $(V_{IN} = 0)$

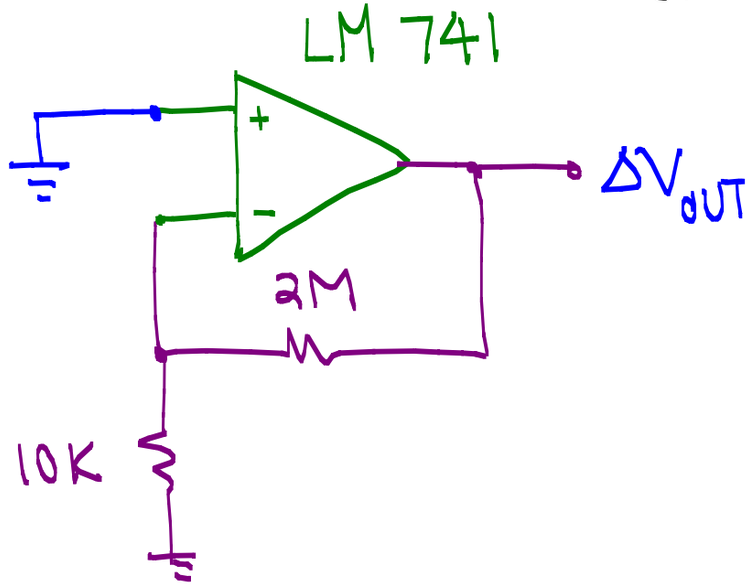
$$\Delta V_{IN} = (20 \times 10^{-9}) \times \left[\frac{9.95 \times 10^{3} + 0}{2} \right] = 0.1\,mV$$



✡ Once again, JFET-input op amps have $I_{IN(BIAS)}$ and $I_{IN(OS)} \sim 50\,pA$!

3. Input offset Voltage

Example LM741: $V_{IN(OS)} = 1\,mV$ (TYP) $(V_{IN}=0)$



- Putting it all together:

  $I_{IN(BIAS)}$: $\Delta V_{OUT} = 201 \times 0.8\,mV = 160.8\,mV$

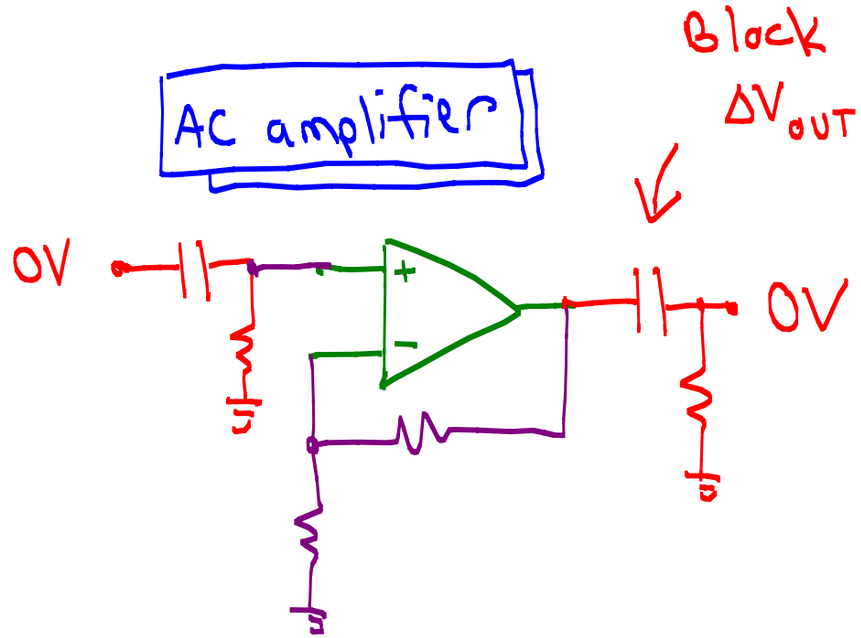
  $I_{IN(OS)}$: $\Delta V_{OUT} = 201 \times 0.1\,mV = 20.1\,mV$

  $V_{IN(OS)}$: $\Delta V_{OUT} = 201 \times 1\,mV = 201\,mV$ ← Largest error

- Sometimes, the ΔV_{OUT} cancel each other ☺

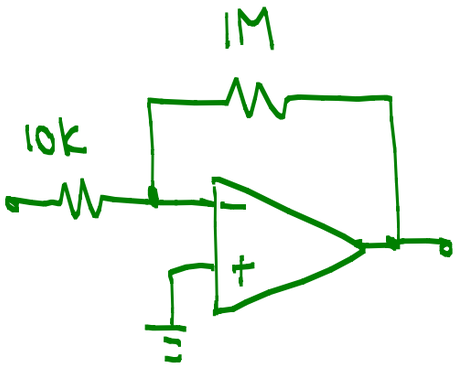
  other times, they add together ☹

★ NOTE: ΔV_{OUT} error is only a problem for DC amplifiers!

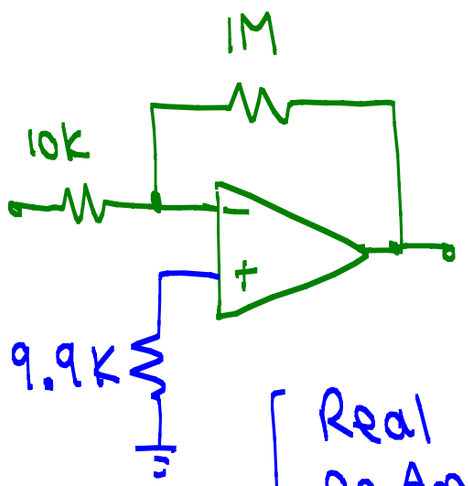


- Techniques to reduce ΔV_{OUT} error.

① Make $R_{TH(+)} = R_{TH(-)}$ ← Reduce error from $I_{IN(Bias)}$



VS.



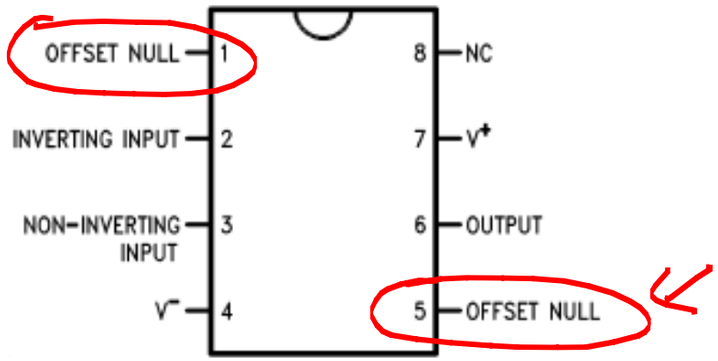
[Ideal op Amp]

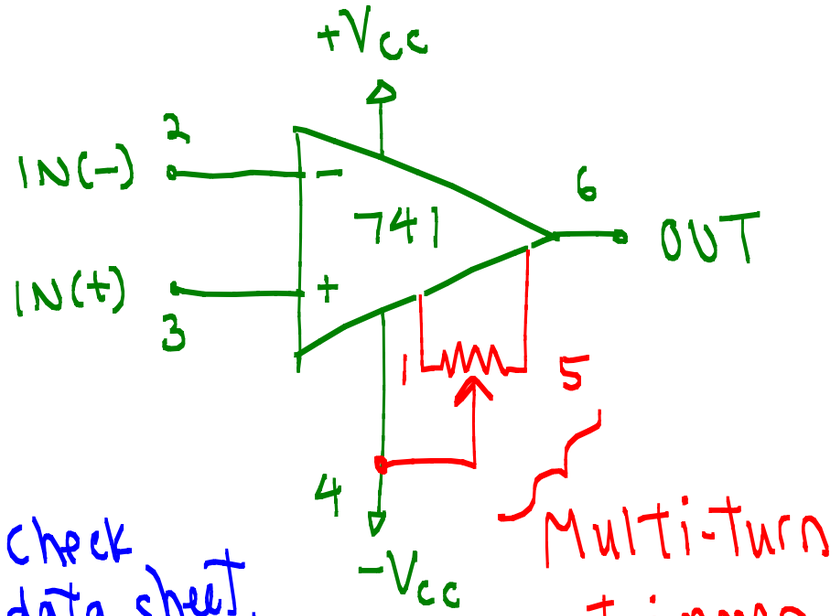
[Real op Amp]

② Use JFET-input op amp ← Reduce error from $I_{IN(Bias)} + I_{IN(OS)}$

LF356 (30 pA) vs. LM741 (80 nA)

③ Due to $V_{IN(OS)}$: Trim the op amp!





check data sheet for suggested approach