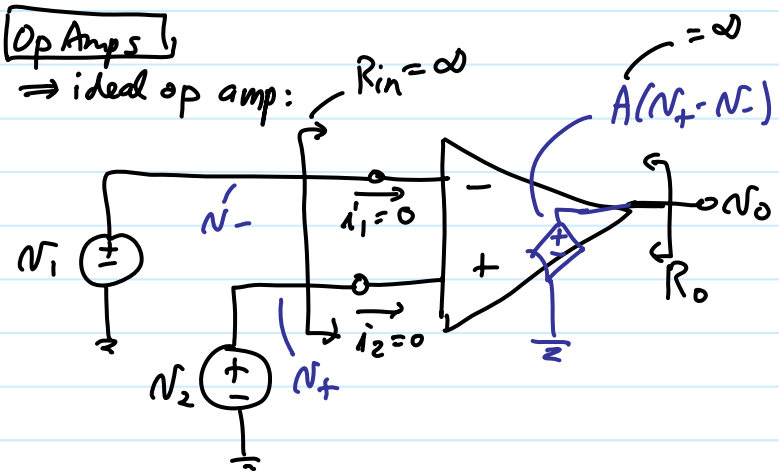
- Handed out course information sheet and syllabus
- Went through course information sheet
- Went through syllabus
- Can we eliminate Discussion Section 101, W 4-5, 212 Cory?
  - *Problem*: no one can register for the Discussions!
  - Will look into this
    - Reason: these aren't discussions; rather, they are supplementary, so students are not required to register
    - We will make them discussions, since it will be good to have discussion sections
  - We will still need to change the time and room of discussion section 101
  - Move to 2:30-3:30 or 5-5 → ask class next time
- Monday lab: move to 5-7?
  - One person cannot do this; this can probably be fixed

Op Amps

⇒ ideal op amp:



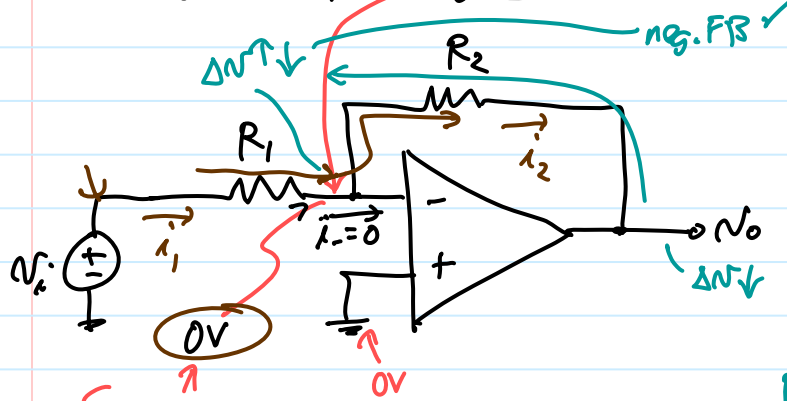
Properties of Ideal Op Amps

① $R_{in}=\infty \longrightarrow$ ④ $i_+ = i_- = 0$

② $R_o = 0$

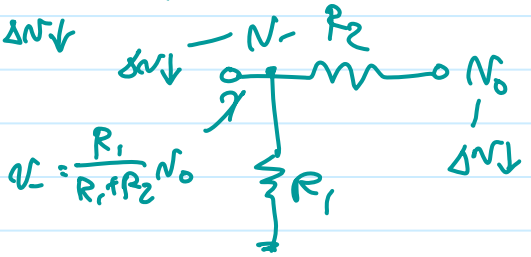
③ $A=\infty \longrightarrow V_+ = V_-$ → assuming you have neg. Feedback (FB)
↳ which means V_o = finite

Ex. Neg. FB → **Inverting Amplifier**



Do we have neg. FB?
↳ do a perturbation analysis!

FB Path:



Virtual Ground

① Verify neg. FB ✓

② ∴ V_o = finite → $V_+ = V_-$ → V_- is virtual ground

③ $i_- = 0$ ∴ $i_1 = i_2$

$$i_1 = \frac{V_i - 0}{R_1} = \frac{V_i}{R_1} = i_2$$

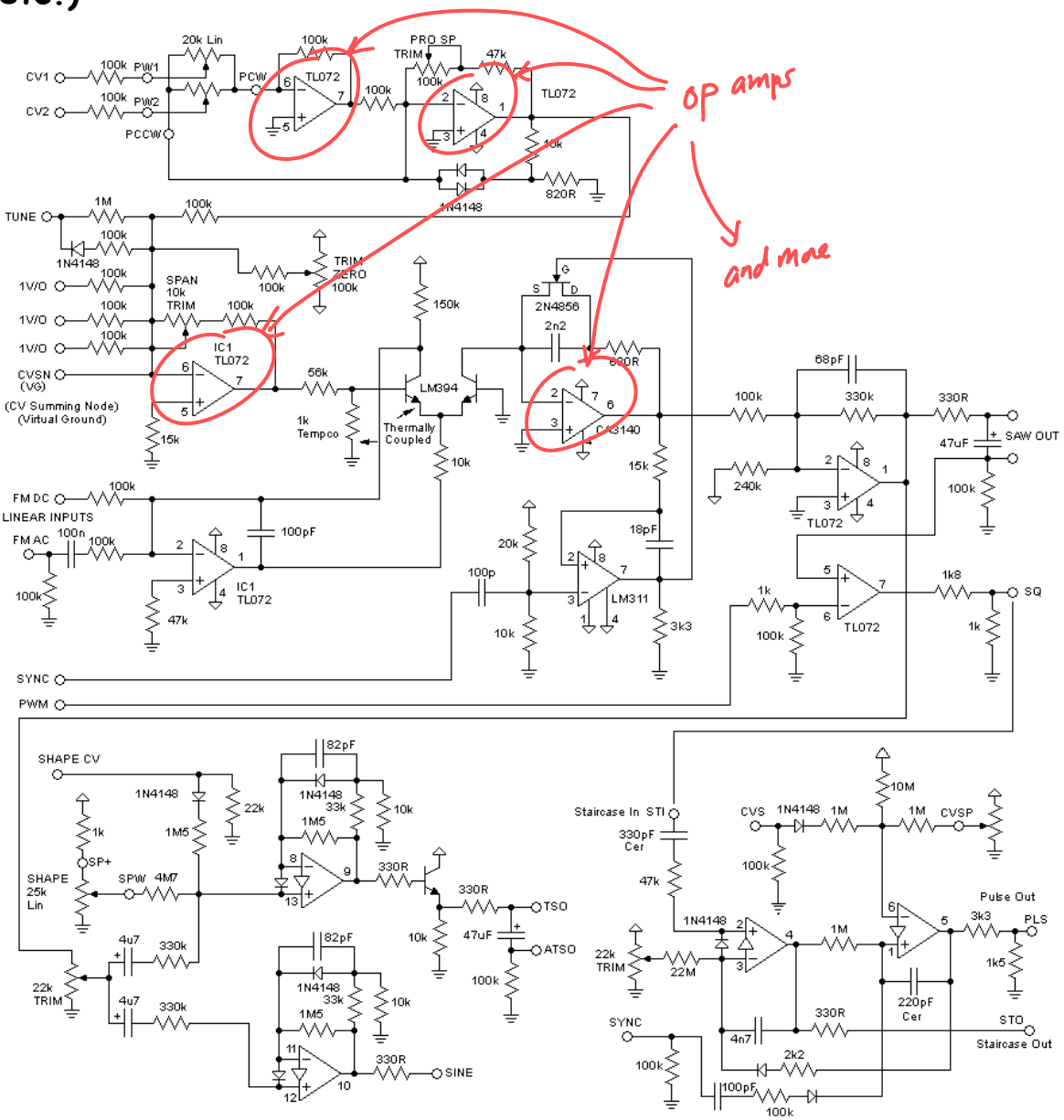
V_- ⟶ $V_o = 0 - i_2 R_2 = -i_2 R_2$

$$V_o = -\left(\frac{V_i}{R_1}\right) R_2 = -\frac{R_2}{R_1} V_i \quad \therefore \quad \boxed{\frac{V_o}{V_i} = -\frac{R_2}{R_1}}$$

Non-Ideal Op Amps

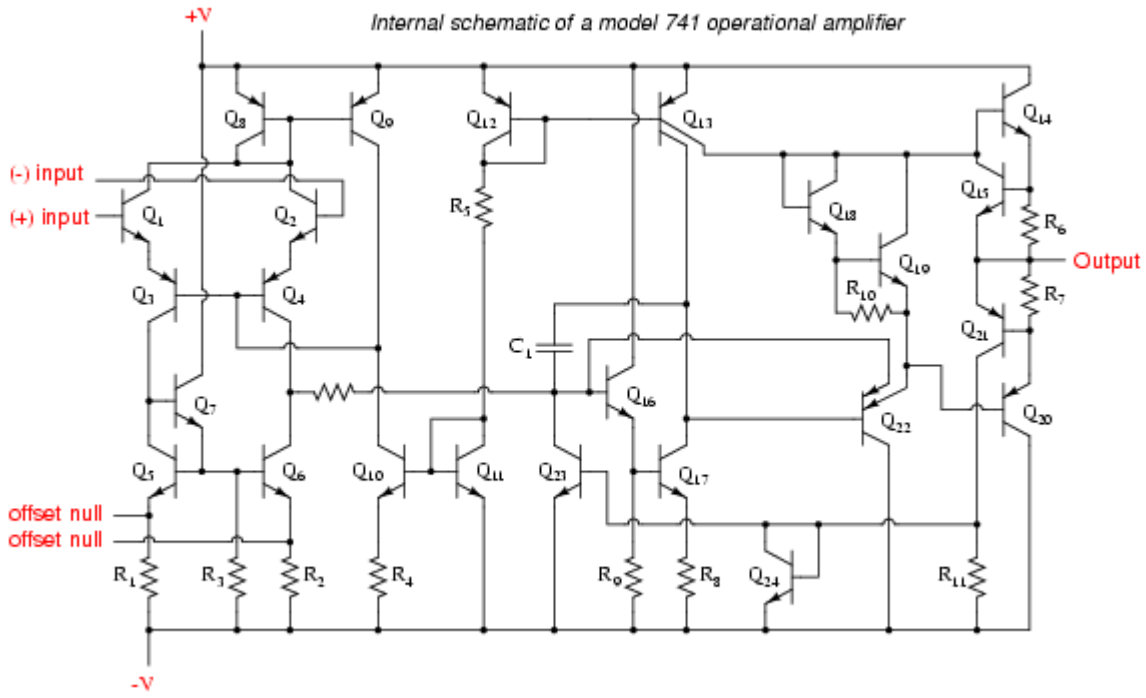
- Actual op amps, of course, are not ideal; rather, they …
  - Have finite gain, A_o
  - Have finite bandwidth, BW
  - Have finite input resistance, R_i
  - Have finite input capacitance, C_i
  - Have finite output resistance, R_o
  - Generates noise
  - Have input bias currents (because R_i is not infinite)
  - Have input offset currents and voltages
  - Have finite slew rate
  - Have finite output swing
- All of the above can be temperature dependent!
- A major objective of this class is understand what gives rise to the above non-idealities and to teach design strategies to get around them

- Op amps are everywhere in practical circuits: (e.g., for solid-state guitar amplifiers, instrumentation, measurement tools, etc.)

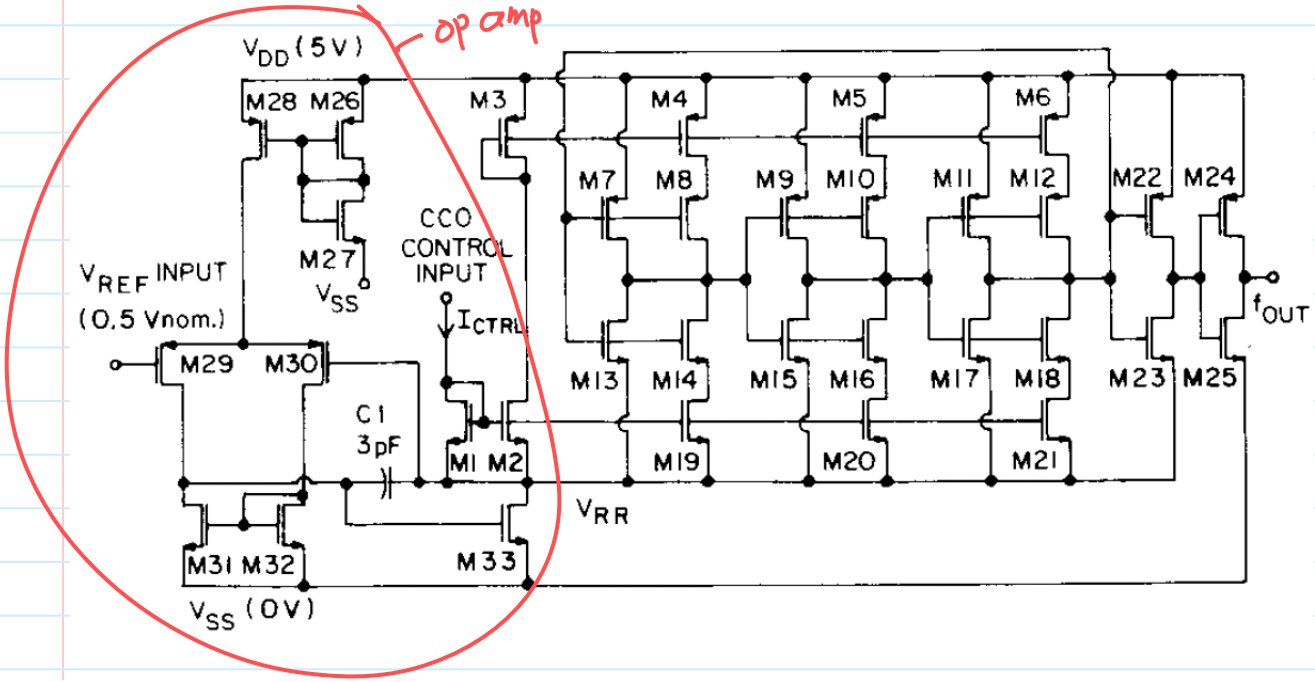


- Op amps that can be used to build practical board-level circuits are often implemented via bipolar junction transistor technology

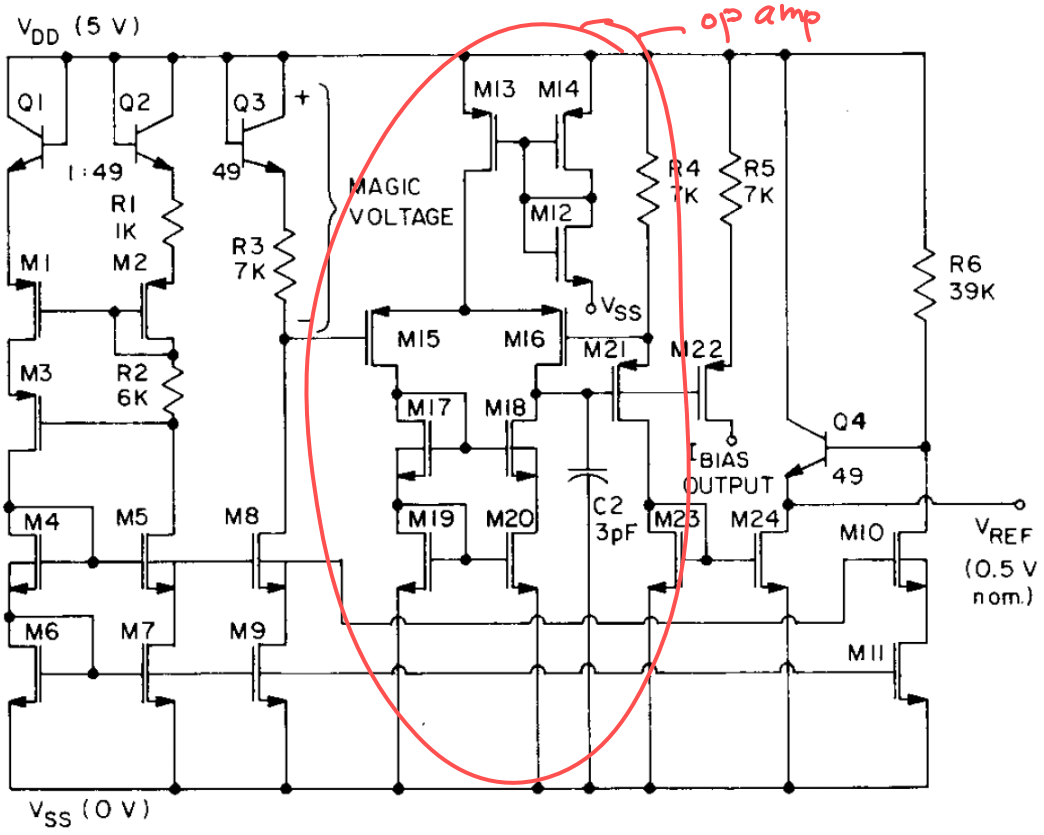
- e.g., the 741 op amp, which has been a workhorse instrumentation op amp for decades



- Today, application specific integrated circuits (ASICs) for mixed analog/digital signal applications (e.g., A/D converters) utilize many op amps on the die level
  - ↳ such ASICs generally utilize CMOS op amps



- **Below**: bandgap reference using a CMOS op amp



- Again, this course will focus mainly on the innards of op amps
- **Focus**: CMOS, with some BJT coverage so you can work with practical board-level circuits, as well
- The first step towards analyzing and designing op amps is to understand the transistor technologies upon which they are based