Outline

• Op Amp
  – What does it do?
  – How do we use it?

Op Amp circuits

• Op amp is a very high gain amplifier (typically 80-100 dB ~10^4-5).
• One does not use the full gain potential of op amps in an amplifier circuit – you trade in the gain and get linearity (HiFi), stability, prevision, etc.
• They have some limitations. Like 741 cannot amplify signal of frequencies much above 100 kHz. \( f_T = 1.2 \text{ MHz} \) – gain down to 1!
  – This is due to the limitations of the transistors they use internally.
  – In emitter-common circuit, for example, capacitors (internal to transistor) set the limitation.
  1. Base to emitter together with input resistance
  2. Collector to base leading to negative feedback
  3. collector to emitter, together with load impedance (and current source) forms a low-pass filter) HW?
• Input impedance is very high (741 –MΩ, 411 –TΩ); alternatively, input currents are nA for 741 and pA for 411. So most voltage dividers in front of an op amp work as intended.

How do we use them?

• Inverting amp

\[ V_{out} = G(V_+ - V_-) \]
\[ V_- = \frac{[R_1*V_{out} + R_2*V_{in}]/(R_1+R_2)}{R_1*G(V_+ - V_-) + R_2*V_{in}} \]
\[ (R_1+R_2)V_- = R_1*G(-V_-) + R_2*V_{in} \]
\[ ((1+G)(R_1+R_2)V_- = R_2*V_{in} \]
• \( V_\text{in} \cdot R_2/[(1+G)R_1+R_2] \sim V_\text{in} \cdot R_2/[(1+G)R_1] \), which is very small as long as \( G \sim 10^4 \).
• \( V_\text{out} = G(– V_\text{in}) = V_\text{in} \cdot G \cdot R_2/[(1+G)R_1+R_2] \sim V_\text{in} \cdot G \cdot R_2/[(1+G)R_1] \sim V_\text{in} \cdot R_2/R_1 \)
• So this is an amp of gain \( R_2/R_1 \).

Differentiator-high pass filter

\[ I_\text{in} = C \frac{d}{dt}(V_\text{in} – V_\text{out}) = -V_\text{out}/R. \]
• \( V_\text{out} = -RC \frac{dV_\text{in}}{dt} + A \exp(-Gt/RC) \) (…) if one does not neglect \( V_\text{in} \).
• \( OR \)
• \( I_\text{in} = V_\text{in}/(1/j\omega C) = -V_\text{out}/R. \)
• \( V_\text{out}/V_\text{in} = -j\omega RC. \)

HW – due Monday

• How does the non-inverting amp work?
  ➢ What is \( V_\text{in} \)? What is \( V_\text{out} \)? What is the gain? First, do the full algebra, and then ignore \( 1/G \) terms unless it is the leading term.
• How does the integrator work?
  ➢ What are the equations? You may assume that \( V_\text{in} = 0. \)
  ➢ What is \( V_\text{out} \)?