Duke University
Department of Physics

Physics 271 Spring Term 2017

WUN2K FOR LECTURE 20

These are notes summarizing the main concepts you need to understand and be able to apply.

- Real-life op-amps deviate from ideal behavior. The following parameters characterize non-ideal properties of op-amps, which will be defined for a particular type of op-amp:
  - *Saturation voltage*: the output voltage is only provided by the op-amp within the range $V_{\rm sat}^- < V_{\rm out} < V_{\rm sat}^+$.
  - *Maximum output current:* the op-amp can only provide up to a maximum current at the output.
  - *Input bias currents:* the inputs draw small but non-zero currents up to I_B^+ and I_B^-. The effects can be mitigated by an appropriate resistor at the input, so that $V_{\rm out} = R_f(I_B^- - I_B^+)$, where R_f is the feedback resistor; the difference between bias currents tends to be smaller than the bias currents themselves.
  - *Input offset current:* this is $I_{OS} = I_B^- - I_B^+$.
  - *Input offset voltage:* this is an intrinsic voltage offset at the input, which must be corrected in order to have $V_{\rm out} = 0$ for inputs tied together.
  - *Slew rate:* this is the speed with which the output voltage can change. Fast signals can get distorted if slew rate is low.
- You should understand the operation of the following circuit elements made using op-amps.
  - *Active filters:* Op-amps can be added to passive filter circuits in order to provide gain, reduce output impedance, increase input impedance, and optimize frequency response. They can be

added as buffers between input stages. Integrator and differentiator feedback configurations can also be intrinsic components of active filters. These circuits can be analyzed making use of the ideal op-amp rules (and Ohm's Law).

- *General feedback elements:* the feedback network in an op-amp circuit can perform a nonlinear function $V_{\text{out}} = F(V_{\text{in}})$, in which case the general circuit with feedback yields $V_2 = F^{-1}(V_1)$. The "function-inversion" property enables circuits that provide logarithmic, division, and square root operations on the inputs.
- *Negative Impedance Converter (NIC):* this op-amp circuit has resistors between each op-amp input and the output, as well as an impedance Z between the non-inverting op-amp input and one of the circuit imputs: this gives a circuit input impedance of $-Z$. For a resistive impedance, this acts like a negative resistance, adding energy to a circuit. Such a configuration is useful to "cancel" impedances in LRC configurations, improving Q value.
- *Gyrator:* this circuit, making use of five impedances Z_1 through Z_5 in series and two op-amps, has input impedance $Z_{in} = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4}$. By selecting some elements to be capacitors and some to be resistors, one can create an circuit element that acts like an inductor, or a "double capacitor".