POLITECNICO DI MILANO

Electronics – 96032





Zero-drift OAs

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Disclaimer

Slides are supplementary material and are NOT a replacement for textbooks and/or lecture notes

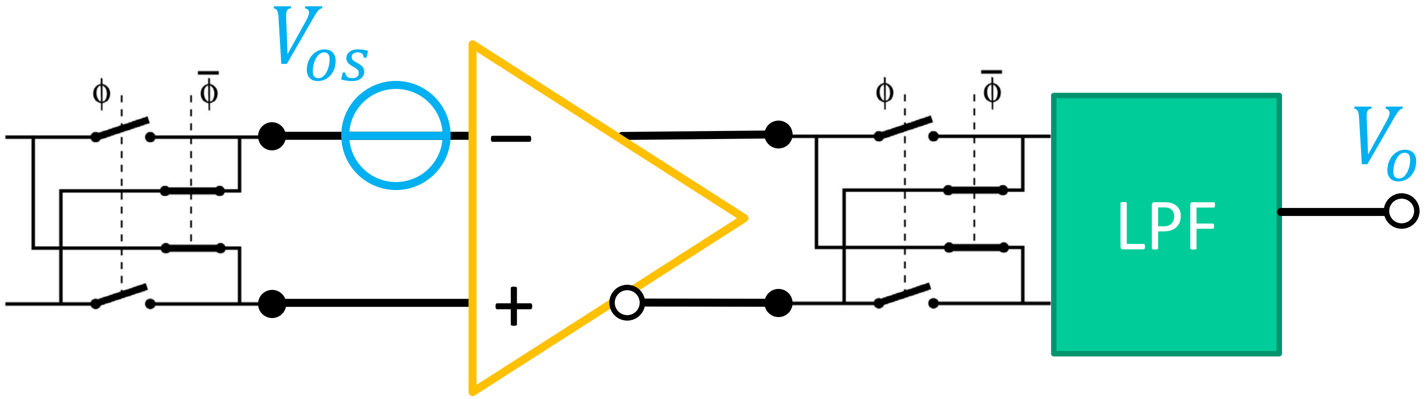
Purpose of the lesson

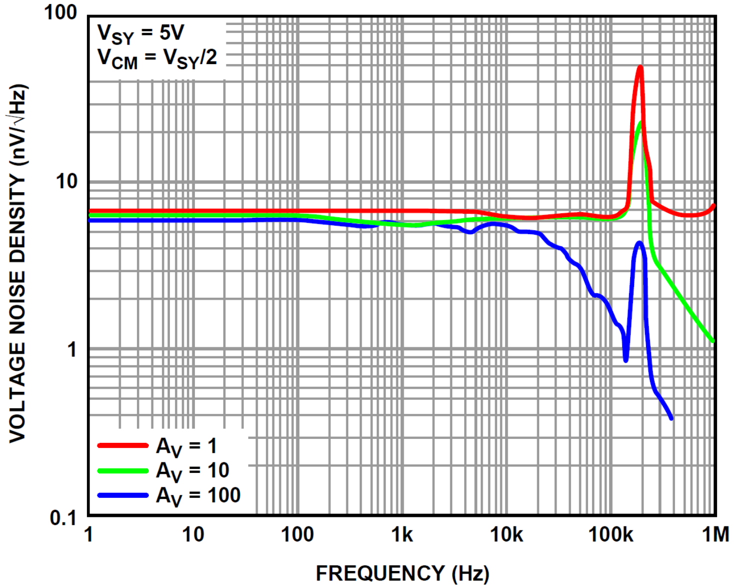
- To briefly show how the previous approaches to LF noise filtering have been implemented in OA design

Zero-drift OAs

- They are a class of OAs employing the techniques just discussed for reducing LF noise (incl. offset)
- We have seen two techniques
  - Sampling (BLR/CDS) $\Rightarrow$ auto-zero amplifiers
  - Modulation/demodulation $\Rightarrow$ chopper amplifiers

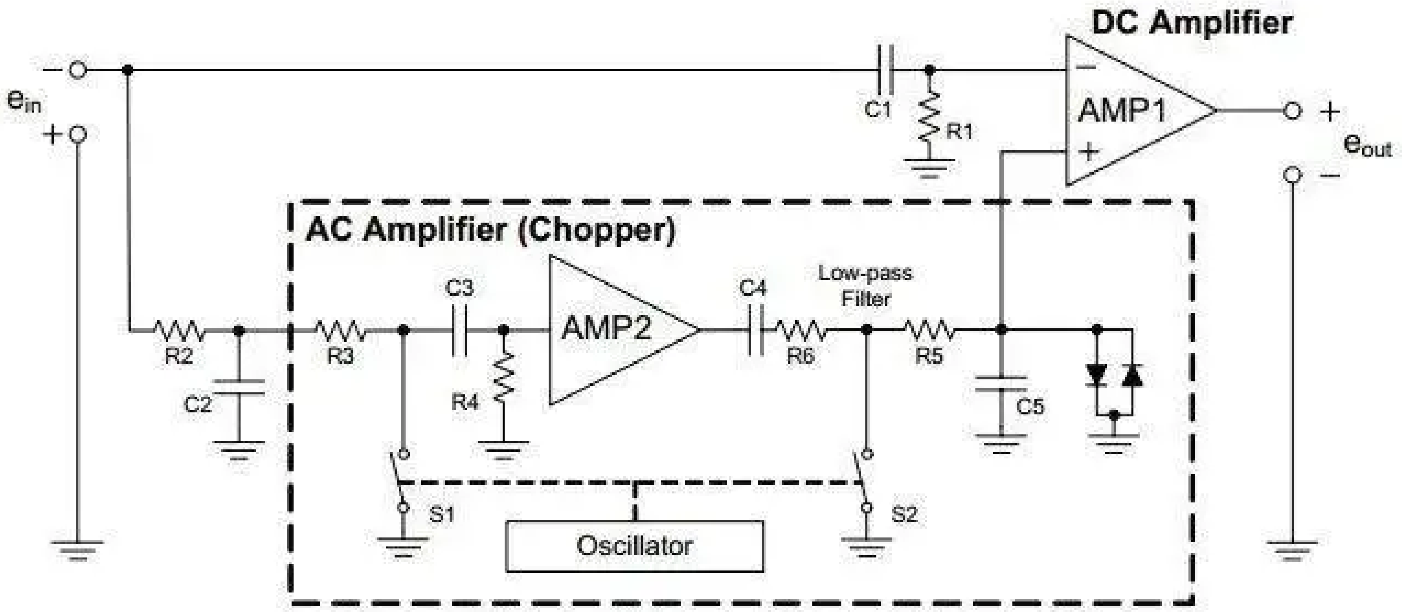
Chopper OAs





- Residual offset is due to clock skew and charge injection, and can be kept below 1 µV
- Output noise contains a peak at the chopping frequency
- BW limited by the chopping frequency

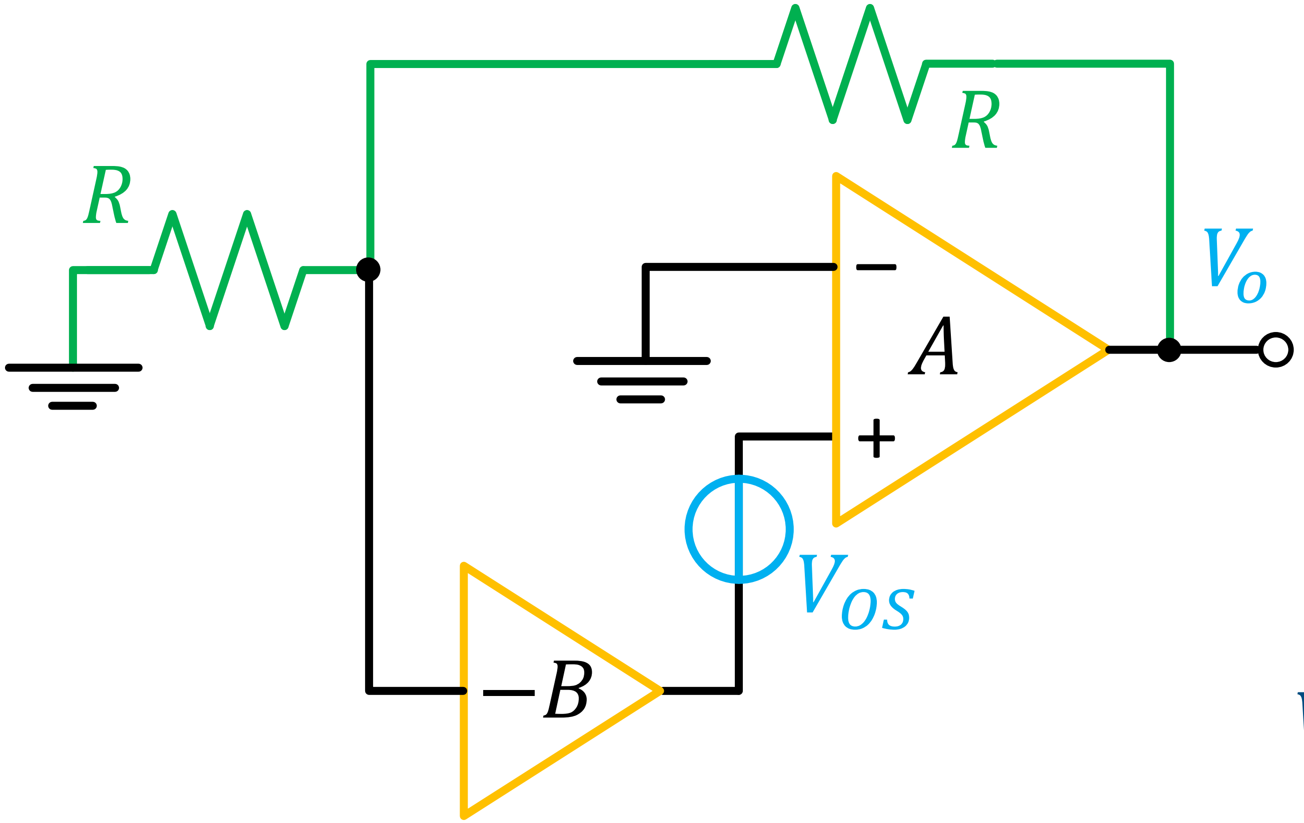
Chopper-stabilized OAs



From [1]

- AC-coupled amplifier plus a DC chopper amplifier (see [1])
- Only inverting operation allowed

Offset cancellation idea



$$V_o = A\left(V_{OS} - \frac{BV_o}{2}\right)$$

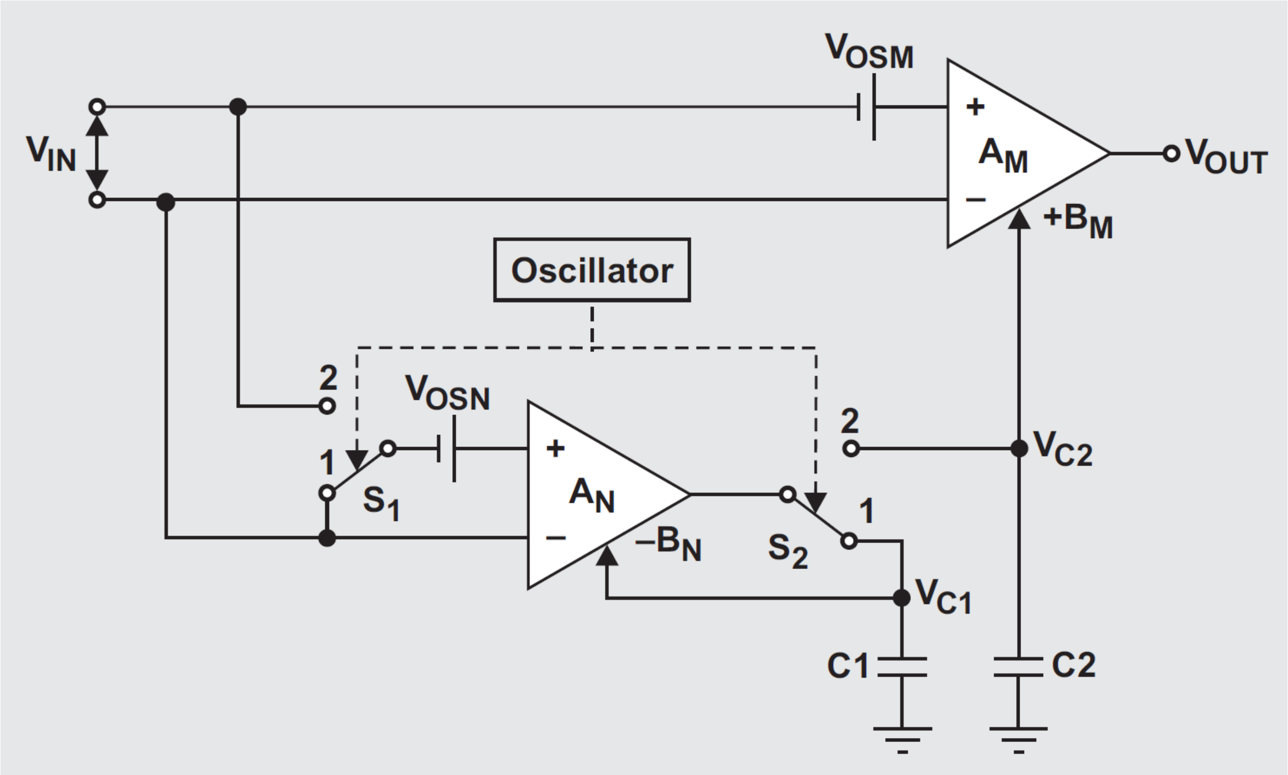
$$V_o = \frac{A}{1 + \frac{AB}{2}} V_{OS} \approx \frac{2}{B} V_{OS}$$

Auto-zero OAs

- Several trade-offs were to be made in CSAa
- Modern approach is to employ a nulling amplifier to compensate for the offset and LF noise (see [2,3])
  - As the approach is different, such amplifiers are also known as auto-zero
  - As usual, terminology changes a bit from one manufacturer to the other…

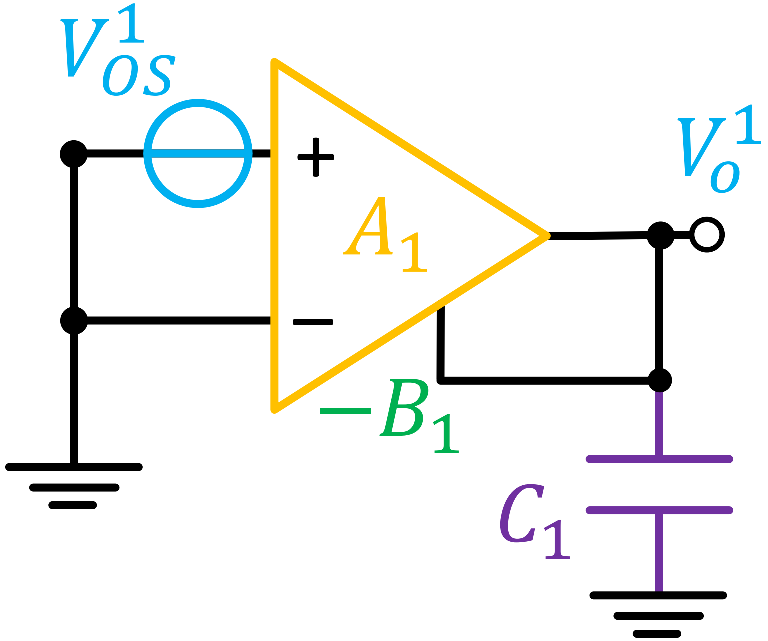
Auto-zero OAs

- During phase 1, A_N cancels its own offset
- During phase 2, A_N cancels A_M's offset



From [3]

Phase 1



$$V_O^1 = A_1 V_{OS}^1 - B_1 V_O^1$$

$$V_O^1 = V_{OS}^1 \frac{A_1}{1+B_1} = V_{C_1}$$

- The value is stored on capacitor C_1
- When the switches commute, we store on C_2 the value

$$V_O^1 = A_1 V_i + A_1 V_{OS}^1 - B_1 V_{C_1} = A_1 V_i + V_{OS}^1 A_1 \left(1 - \frac{B_1}{1+B_1}\right)$$

$$= A_1 \left(V_i + \frac{V_{OS}^1}{1+B_1}\right)$$

Phase 2

- The output is now

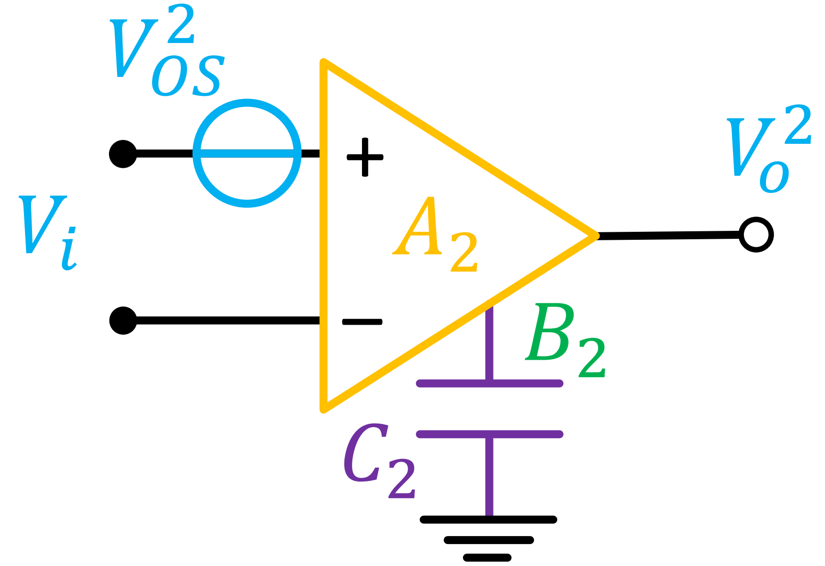
$$V_O^2 = A_2 V_i + A_2 V_{OS}^2 + B_2 V_{C_2}$$

- C_2 is connected to V_O^1, leading to

$$V_O^2 = A_2 V_i + A_2 V_{OS}^2 + B_2 A_1 \left(V_i + \frac{V_{OS}^1}{1 + B_1} \right)$$

$$= V_i (A_2 + B_2 A_1) + A_2 V_{OS}^2 + V_{OS}^1 A_1 \frac{B_2}{1 + B_1} \approx 1$$

$$\approx ABV_i + A\left(V_{OS}^1 + V_{OS}^2\right) = AB\left(V_i + \frac{V_{OS}^1 + V_{OS}^2}{B} \right)$$



Comment

- Auto-zero OAs have very high gain and reduce the offset down to the μV range
- Note that the signal is NOT modulated $\Rightarrow$ AZ technique is more similar to a BLR or CDS approach
- A comparison can be found in [4]

Typical parameters

- GBWP ≈ 1 – 3 MHz
- Chopping frequency: 100 Hz – kHz
- Offset voltage drift ≈ nV/°C
- Flat noise spectrum (no 1/f noise), but higher WN level

References

1. https://www.eeweb.com/chopper-stabilized-operational-amplifiers/
2. https://www.analog.com/media/en/training-seminars/tutorials/MT-055.pdf
3. https://www.ti.com/lit/an/slyt204/slyt204.pdf
4. https://www.analog.com/en/technical-articles/to-chop-or-auto-zero-that-is-the-question.html