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Exercise:
Low Noise Charge Amplifier

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Goal

- In this concluding exercise for the charge amplifier, we want to design a MOS-only (i.e. no more stuff from analogLib..) charge amplifier and determine its noise.
  - Only idc and vdc sources for bias will be left.

- 'Specifications':
  - C_{det} = 10 pF
  - CR-RC shaper
  - Peaking time T_{peak} = 100 ns
  - Supply: 1.8 V
  - Power: <5 mW

- For the feedback of the CSA, use the transconductor from exercise 2

The Amplifier

- For the main amplifier, use the following straight cascode design, followed by a source follower:

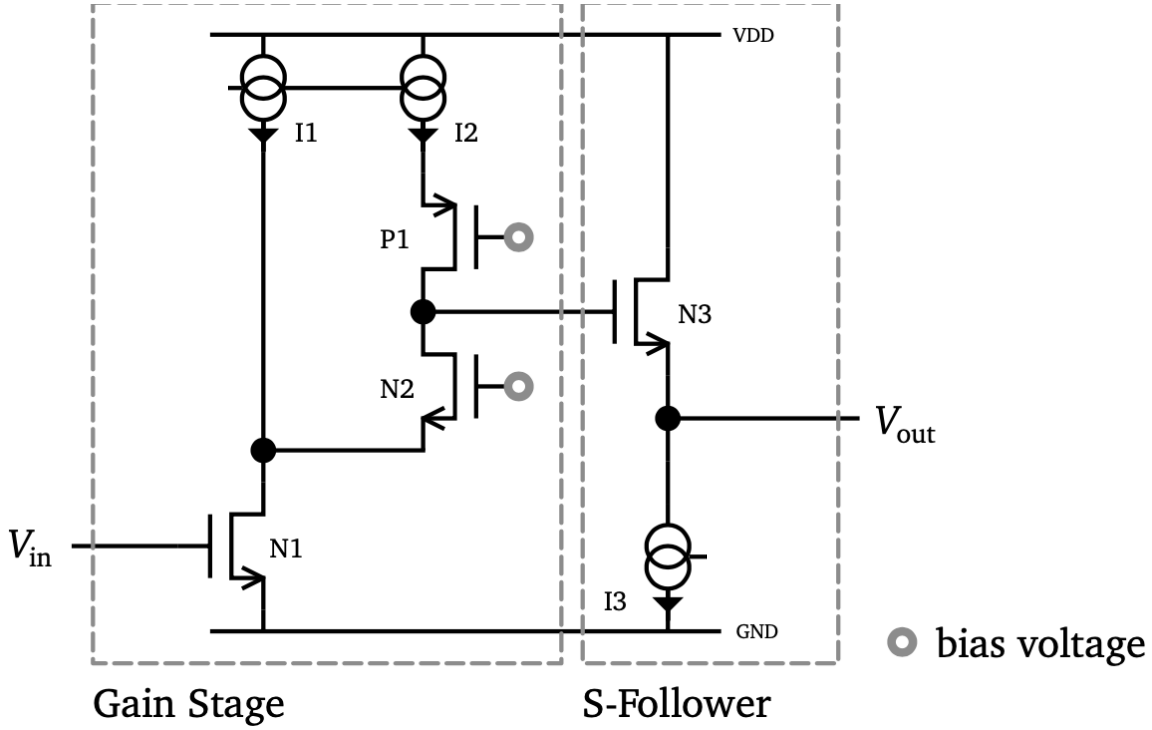


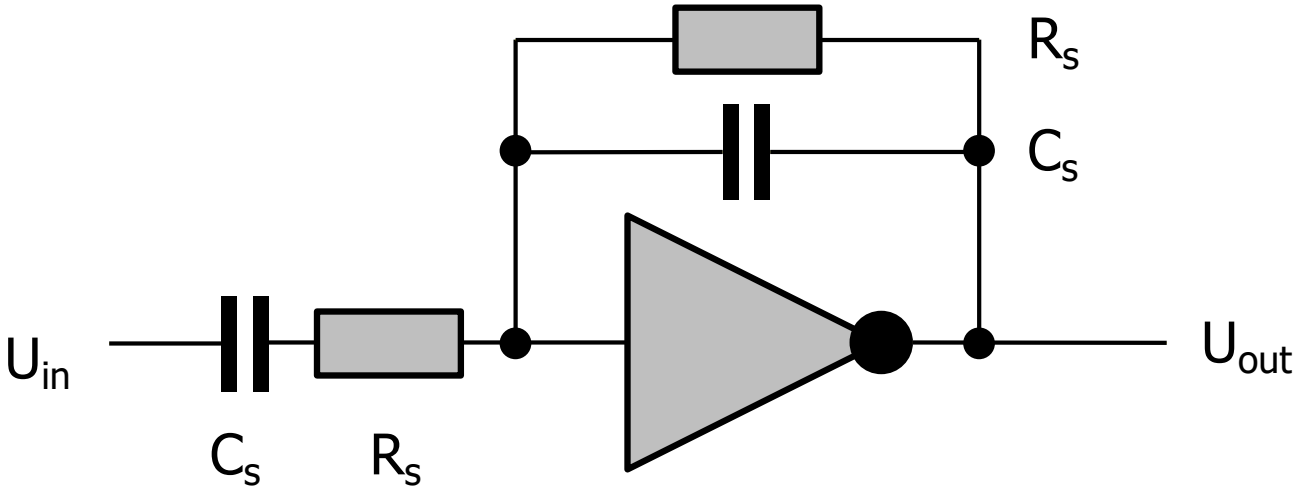
Image taken from PhD of Tim Armbruster

The Amplifier

- Current source I1 provides the major current of input MOS N1. Use >1mA. Make its noise as small as possible (low g_m).
  - The saturation of I1 voltage can be high!
- Input MOS N1 is critical for noise.
  - Increase its gm. Do not use minimal length
- Cascode N2 must bias N1 into saturation
- I2 provides the current for the gain branch. Use ~1/10 of the main current. Its output resistance must be high for gain. You may achieve this with cascode P1 (but you can do without).
- The source follower has at least two tasks:
  - Shift the output voltage down so that DC feedback (V_{out}=V_{in}) is possible
  - Buffer the gain node so that we can put a resistive load (i.e. draw current)
- Bias the source follower with ~100 µA

The Shaper

- You can use the following simple shaper topology
- The amplifier can be the same as for the CSA, maybe with smaller current.



- Calculate the transfer function. Is it CR-RC?
- Can you change the component value keeping the time constant and CR-RC, but adding (voltage) gain?
- Chose Rs large enough so that it does not load the source follower of the CSA too much!

Comments

- Use C_f as small as possible, but such that the CSA still reaches 'nearly' its nominal gain at a larger C_{in} of 30 pF.
- You can try to connect C_f to the node between amplifier and source follower.
- Make the CSA discharge much slower than T_{peak}.
  - (What happens if you discharge too fast? How do the shaper pulses look like? There are tricks to get rid of this effect ('pole-zero-cancellation')
- Make sure the cascodes are biased correctly!

Final results

- Inject increasing charges and look at the pulse shapes at the output of the CSA and the shaper
- Check that this does NOT depend a lot on
  - C_{det}
  - The bias current in the amplifier
  - The bias of the source follower
  - The bias current in the shaper

- Determine overall noise at the shaper output (noise integral), referred back to the input (i.e. the ENC)
- Check how the noise depends on
  - C_{det}
  - The bias current in the amplifier
  - The bias current in the shaper
  - …