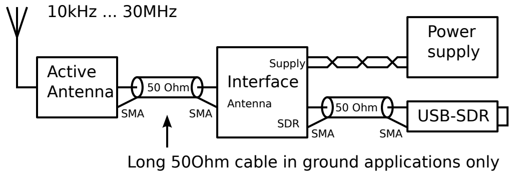
Design of a LF-HF Active Antenna in CMOS18 technology

Radio astronomy antenna for space applications



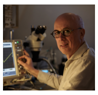
Long 50Ohm cable in ground applications only

Antenna length: max 0.5m
E-field antenna-referred noise:

10kHz	: 100n	$\left[\frac{\mathrm{V}}{\mathrm{m}\sqrt{\mathrm{Hz}}}\right]$
100KHz	: 10n	
1MHz	: 5n	
30MHz	: 5n	

Output 1dB compression level:
0dBm in 50Ohm
Antenna gain (-3dB: 10kHz-30MHz)
0dB

Features
ESD discharge protected
Low-power 1.8V CMOS technology



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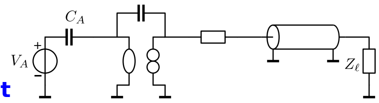
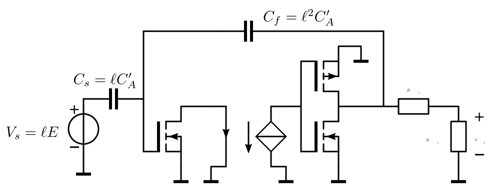
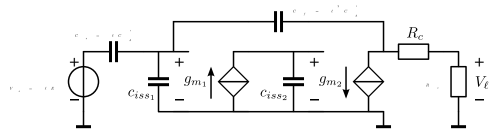
https://www.analog-electronics.eu

Amplifier concept



Design of a dual stage controller





$$L = -\frac{2g_{m_1}g_{m_2}R_c\frac{C_f}{C_f+C_s+c_{iss_1}}}{sc_{iss_2}\left(1+s2R_c\frac{C_f\left(C_s+c_{iss_1}\right)}{C_f+C_s+c_{iss_1}}\right)}$$

$$LP_2 = \frac{g_{m_1}g_{m_2}}{c_{iss_2}\left(C_s+c_{iss_1}\right)}$$

$$g_{m_1} = 15.36\mathrm{m}$$
$$g_{m_2} = 23.62\mathrm{m}$$
$$C_s = 5\mathrm{p}$$
$$c_{iss_1} = 7.568\mathrm{p}$$
$$c_{iss_2} = 0.4386\mathrm{p}$$
$$B_f = \frac{1}{2\pi}\sqrt{LP_2} = 1.29\mathrm{GHz}$$
$$p_1 = 0,\ p_2 = -\frac{C_f+C_s+c_{iss_1}}{4\pi R_c C_f\left(C_s+c_{iss_1}\right)} = -763\mathrm{MHz}$$

sum of poles (abs) increased as a result of pole-splitting
in the second stage (first stage is shorted)

PZ analysis

PZ analysis results

Gain type: gain

DC gain = -1.000

```
pole    Re [Hz]      Im [Hz]    Mag [Hz]     Q
 p1   -3.513e+8   -1.207e+9   1.257e+9   1.789
 p2   -3.513e+8    1.207e+9   1.257e+9   1.789
zero    Re [Hz]  Im [Hz]   Mag [Hz]  Q
 z1    2.176e+9            2.176e+9
 z2   -3.978e+9            3.978e+9
```

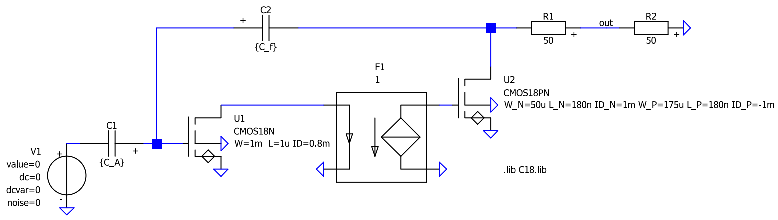
PZ analysis results

Gain type: loopgain

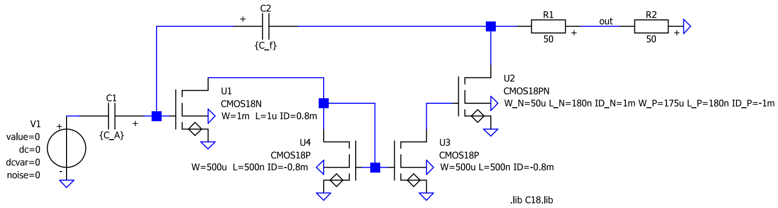
DC gain = oo

```
pole    Re [Hz]  Im [Hz]   Mag [Hz]  Q
 p1           0                  0
 p2   -1.038e+9           1.038e+9
zero    Re [Hz]  Im [Hz]    Mag [Hz]  Q
 z1    5.315e+9             5.315e+9
 z2   4.979e+10            4.979e+10
```

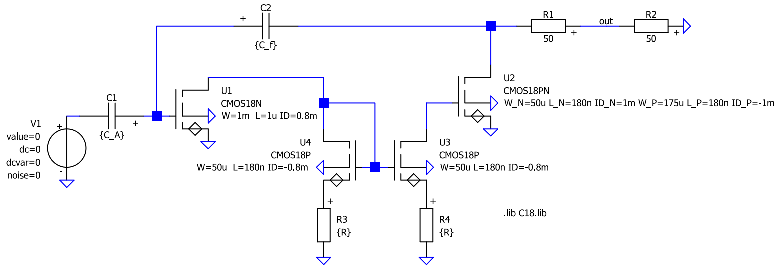
DualStage.py



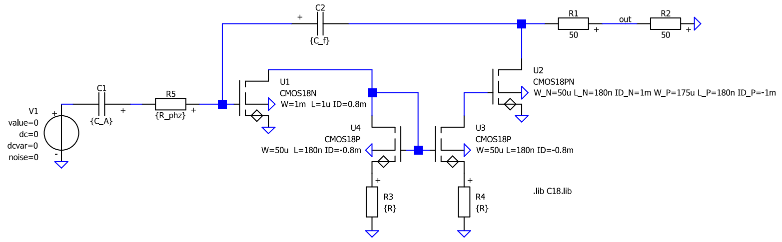
DualStageMirror.py



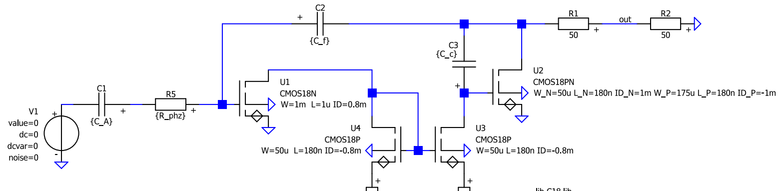
DualStageMirrorRes.py



DualStageMirrorResComp1.py



DualStageMirrorResComp2.py



$$R_{phz} = 40\Omega$$
$$C_c = 270\mathrm{fF}$$

Current mirror requirements

- Low noise:
  . Transconductance low compared to input stage
  . Low cut-off frequency (flicker noise)

- No dominant pole in loop gain
  . Current mirror introduces a pole at half the cut-off frequency
  . High cut-off frequency may conflict with low flicker noise

PZ analysis

PZ analysis results

Gain type: gain

DC gain = -0.9934

```
pole    Re [Hz]      Im [Hz]    Mag [Hz]     Q
 p1   -3.829e+7   -5.721e+8   5.734e+8   7.488
 p2   -3.829e+7    5.721e+8   5.734e+8   7.488
 p3   -1.399e+9               1.399e+9
zero    Re [Hz]      Im [Hz]    Mag [Hz]      Q
 z1    1.113e+9               1.113e+9
 z2   -8.226e+8   -1.190e+9   1.447e+9   0.8793
 z3   -8.226e+8    1.190e+9   1.447e+9   0.8793
```

PZ analysis results

Gain type: loopgain

DC gain = -151.5

```
pole    Re [Hz]  Im [Hz]   Mag [Hz]  Q
 p1   -6.324e+6           6.324e+6
 p2   -4.850e+8           4.850e+8
 p3   -9.838e+8           9.838e+8
zero    Re [Hz]  Im [Hz]    Mag [Hz]  Q
 z1   1.106e+10           1.106e+10
 z2   4.979e+10           4.979e+10
```

MFM bandwidth
B_1 = 963MHz
B_2 = 684MHz
B_3 = 772MHz

Orthogonolize

- Separate the function (inverting unity-gain current amplifier) from its noise performance (low transconductance)

- Fix the transadmittance with negative feedback

PZ analysis

PZ analysis results

Gain type: gain

DC gain = -0.9930

```
pole    Re [Hz]      Im [Hz]     Mag [Hz]     Q
 p1   -7.126e+7   -9.490e+8    9.517e+8   6.677
 p2   -7.126e+7    9.490e+8    9.517e+8   6.677
 p3   -2.320e+9                2.320e+9
 p4  -3.258e+10               3.258e+10
zero    Re [Hz]      Im [Hz]     Mag [Hz]      Q
 z1    1.674e+9                1.674e+9
 z2   -1.533e+9   -1.996e+9    2.516e+9   0.8209
 z3   -1.533e+9    1.996e+9    2.516e+9   0.8209
 z4  -3.261e+10               3.261e+10
```

Frequency compensation

- Second order system
- Influence of third pole cannot be ignored
- Compensation with phantom zero at the source introduces a fourth pole (resistor breaks loop of capacitors)
- Combination of pole-splitting and phantom-zero compensation