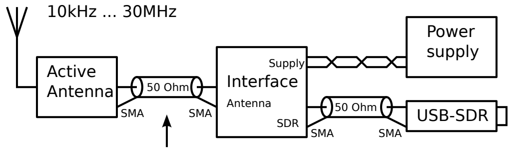
Design of a LF-HF Active Antenna in CMOS18 technology

Radio astronomy antenna for space applications

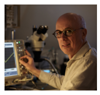


Long 50Ohm cable in ground applications only

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

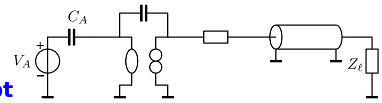
10kHz	: 100n	$\left[\frac{V}{m\sqrt{Hz}}\right]$
100KHz	: 10n	
1MHz	: 5n	
30MHz	: 5n	

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



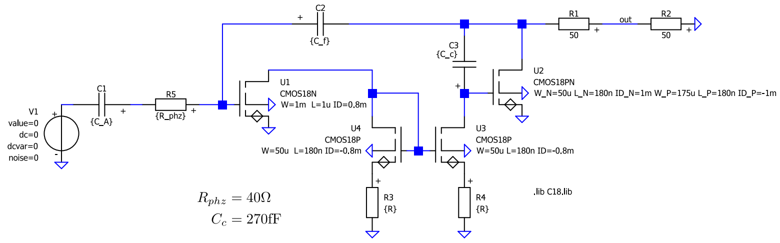
anton@montagne.nl
https://www.analog-electronics.eu

Features
ESD discharge protected
Low-power 1.8V CMOS technology



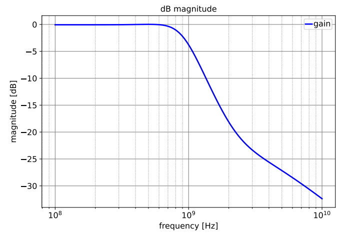
Amplifier concept

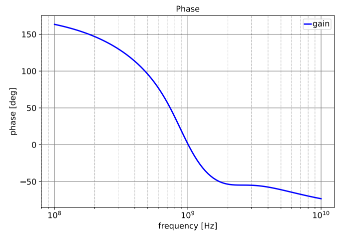
DualStageMirrorResComp2.py



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

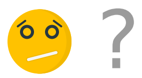
Frequency compensation with input phantom zero and pole-splitting in output stage.





Bandwidth much larger than required:
- High-frequency, out-of-band interference contributes to IM distortion
- Bandwidth limitation with input phantom zero is a powerful decrease the susceptibility for high-frequency interference:
  1. Input phantom zero at band edge attenuates out-of-band, high-frequency interference
     - Distortion is reduced as a result smaller signal excursions
  2. Phantom zero increases the high-frequency loop gain:
     - Distortion is reduced as a result of an increased loop gain

Bandwidth limitation with phantom zeros



A phantom-zero is a zero in the loop gain that coincides with a pole in the asymptotic gain
As a consequence, it is not observable in the gain
If we limit the bandwidth of the amplifier with a phantom zero, the bandwidth limitation is observable
What do we observe?

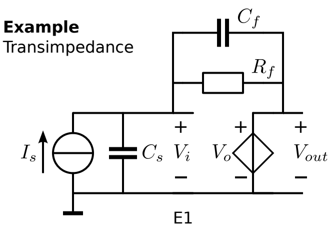
$$A_f = \frac{A_{f\infty}}{1+s\tau_{phz}} \frac{-L(1+s\tau_{phz})}{1-L(1+s\tau_{phz})}$$

phantom zero changes the characteristic equation

If the loop gain is large at the frequency of the zero, a pole moves towards the phantom zero in the loop gain

This pole sets the bandwidth limitation

Example
Transimpedance



E1
$$\frac{V_o}{V_i} = \frac{A}{s(1+s\tau_2)}$$

$C_f = 0$
$\tau_2 = 0$
$A = -10 \cdot 10^6$
$R_f = 10 \cdot 10^3$
$C_s = 300 \cdot 10^{-12}$

Loop gain reference: E1

$$p_1 = 0,\ p_2 = -\frac{1}{2\pi R_f(C_s + C_f)} = -53\text{kHz}$$

$$B_f = \frac{1}{2\pi}\sqrt{\left|\frac{A}{R_f C_s}\right|} = 291\text{kHz}$$

Sum of the poles much smaller than sqrt(2) times the achievable MFM bandwidth

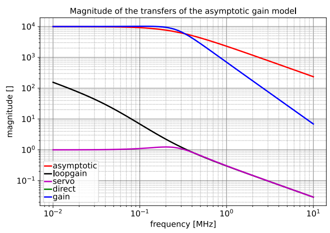
$$C_f = \frac{\sqrt{2}B_f + p_1 + p_2}{2\pi B_f^2 R_f} = 67\text{pF}$$

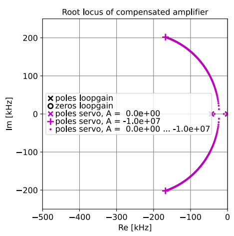
Phantom zero compensation

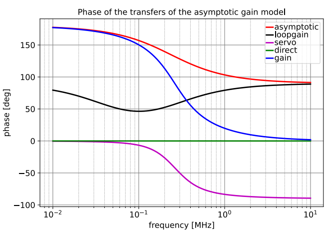
Result of phantom zero compensation

Compensation capacitance reduces the product of the poles (300pF , 67pF)

Minor adjustment required



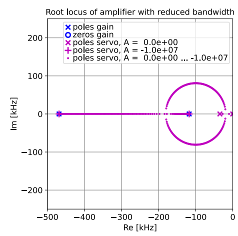


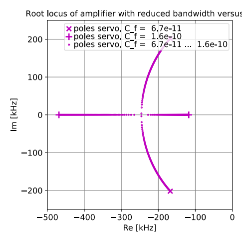


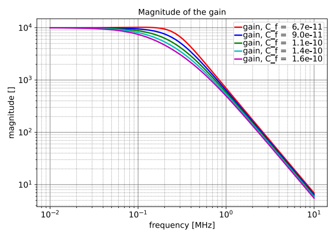
Bandwidth limitation with phantom zero

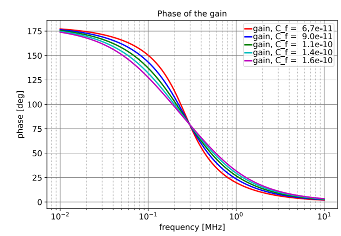
Large loop gain at frequency of the zero

1. One pole of the loop gain appoaches zero
2. Zero is ineffective because it introduces a pole at the same frequency





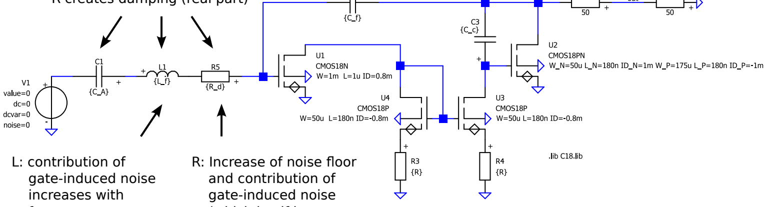




DualStageMirrorBwLimit1.py

2nd order bandwidth limitation 30MHz

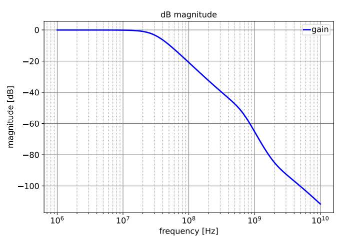
L and C: two phantom zeros
R creates damping (real part)

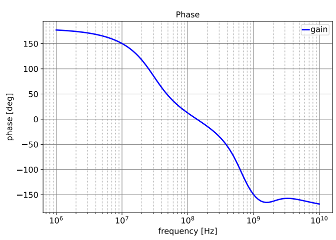


L: contribution of gate-induced noise increases with frequency (which itself increases with frequency)

R: Increase of noise floor and contribution of gate-induced noise (which itself increases with frequency)

$R_d = 1500\Omega$
$L_f = 5.6\mu\text{H}$

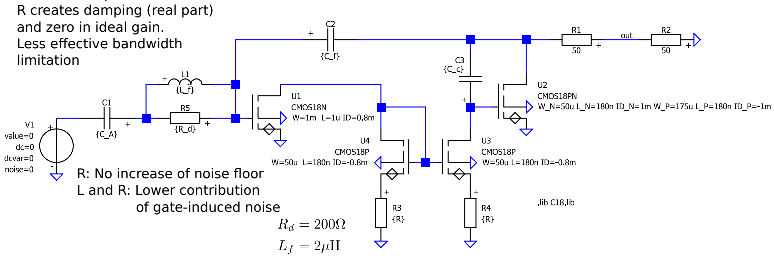




DualStageMirrorBwLimit2.py

1st order Bandwidth limitation 100MHz

L and C: two phantom zeros
R creates damping (real part) and zero in ideal gain.
Less effective bandwidth limitation



R: No increase of noise floor
L and R: Lower contribution of gate-induced noise

$R_d = 200\Omega$
$L_f = 2\mu\text{H}$