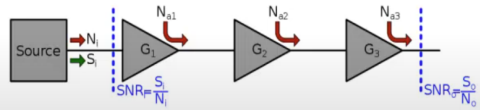
LNA Theory & Fundamentals – Quick Review

Friis's formula is used to calculate the total noise factor of a cascade of stages, each with its own noise factor and power gain (assuming that the impedances are matched at each stage). The total noise factor can then be used to calculate the total noise figure.

The total noise factor is given as:

$$F_{\text{total}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \cdots + \frac{F_n - 1}{G_1 G_2 \cdots G_{n-1}}$$

where F_i and G_i are the noise factor and available power gain, respectively, of the i-th stage, and n is the number of stages.
Both magnitudes are expressed as ratios, not in decibels.

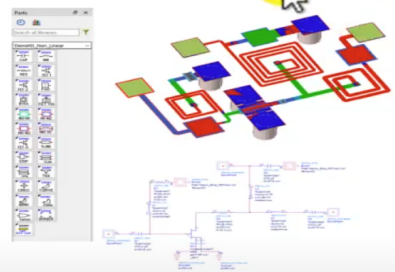


Noise Figure $\mathrm{NF} = 10\log_{10}(F) = 10\log_{10}\left(\frac{\mathrm{SNR_i}}{\mathrm{SNR_o}}\right) = \mathrm{SNR_{i,\,dB}} - \mathrm{SNR_{o,\,dB}}$

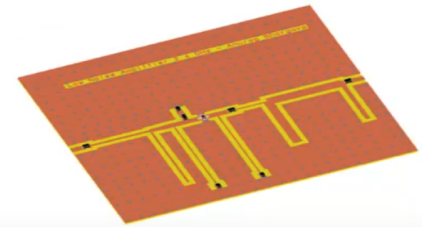
https://en.wikipedia.org/wiki/Friis_formulas_for_noise

LNA Design Process - Options

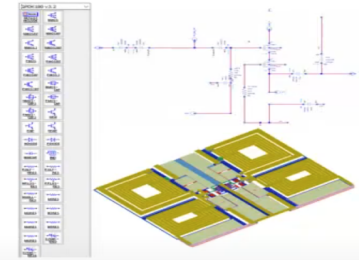
MMIC (GaAs pHEMT process)



PCB / MIC / RF Board



RFIC (Silicon / CMOS)



Pros & Cons

1. Good performance & Mass Production friendly
2. Less Size (few microns)
3. Can be designed up to very high frequencies (>30 GHz)
4. Octave bandwidth possible
5. Cost is prohibitive if large quantities are not needed
6. Performance tuning not possible after fabrication

Pros & Cons

1. Good performance & Low cost
2. Decent performance up to Ku-band (~18 GHz)
3. Easy tuning after fabrication
4. Octave bandwidth matching - very difficult
5. Large Physical Size (compared to MMIC/RFIC)

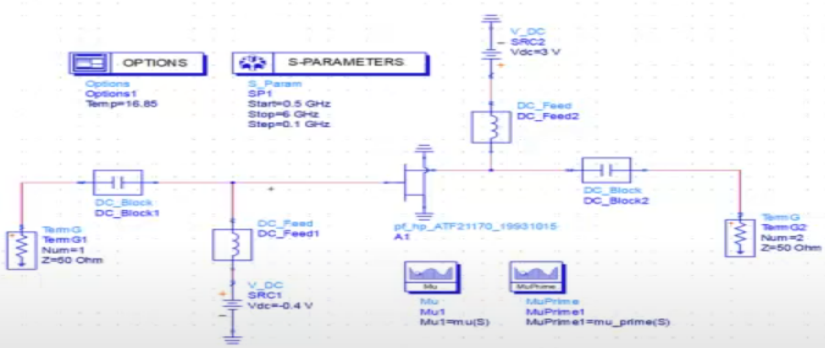
Pros & Cons

1. Decent performance & Mass Production friendly
2. Less Size (few microns) and can be integrated into SoCs
3. Usually limited to sub – 6 GHz applications
4. Inferior Noise Figure compared to GaAs due to Silicon
5. Cost is prohibitive if large quantities are not needed
6. Performance tuning nor possible after fabrication

Transistor Models for LNA Designs

Freq. Range	2.35 GHz – 2.45 GHz
Gain	> 14 dB
I/P Return Loss (S11)	< -15 dB
O/P Return Loss (S22)	< -15 dB
Noise Figure	<= 1.4 dB
~~P1dB~~	~~> 10 dBm~~
~~OIP3~~	~~> 20 dBm~~

With Non-Linear Model



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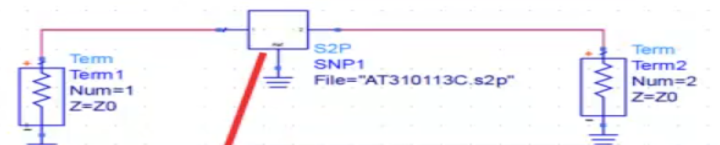
Noise Figure	<= 1.4 dB
P1dB	> 10 dBm
OIP3	> 20 dBm

S2P File with Noise Data

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!AT-31011
!S and NOISE PARAMETERS at Vce=2.7V Ic=1mA. LAST UPDATED 06-23-94
# ghz s ma r 50
0.1    0.96    -7     3.59    174    0.01    86    0.999    -2
0.5    0.93    -32    3.41    152    0.05    69    0.95     -13
0.9    0.83    -56    3.13    132    0.08    55    0.91     -22
1.0    0.81    -61    2.99    128    0.08    53    0.9      -24
1.5    0.68    -89    2.61    107    0.1     40    0.84     -32
1.8    0.62    -104   2.38    96     0.11    34    0.8      -36
2.0    0.58    -113   2.28    90     0.11    31    0.78     -38
2.4    0.52    -133   1.99    77     0.11    27    0.75     -42
3.0    0.45    -160   1.71    61     0.11    25    0.72     -46
4.0    0.43    158    1.37    39     0.1     29    0.69     -56
5.0    0.46    123    1.14    20     0.12    41    0.68     -66

0.5    0.5     0.92   13      0.85
0.9    0.6     0.85   29      0.73
1.8    1.1     0.68   67      0.46
2.4    1.6     0.55   98      0.28
```