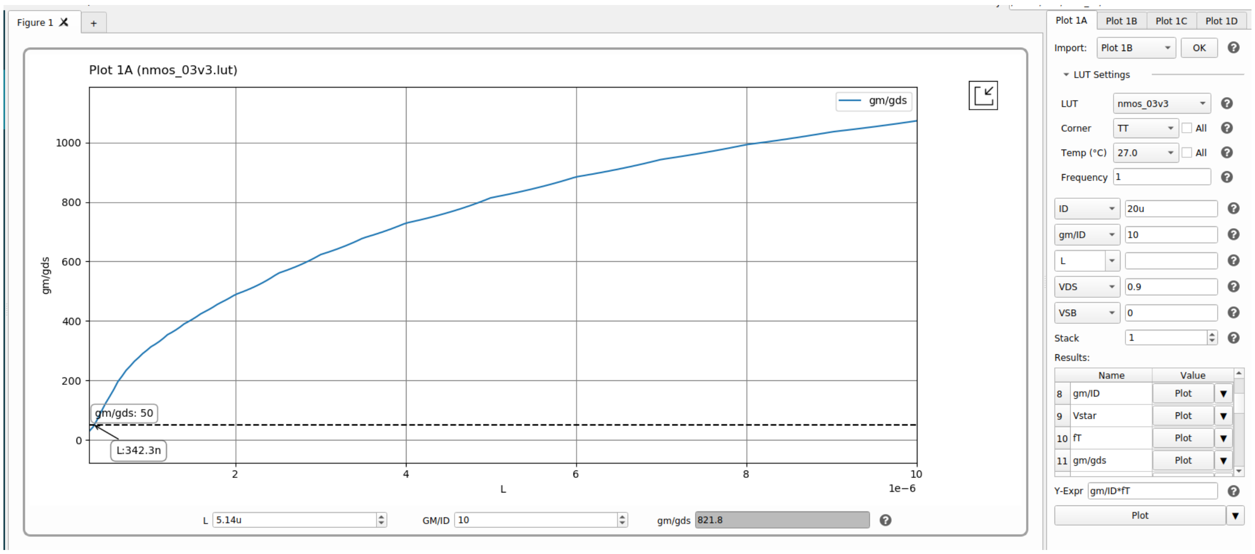
<u>Lab 03</u>

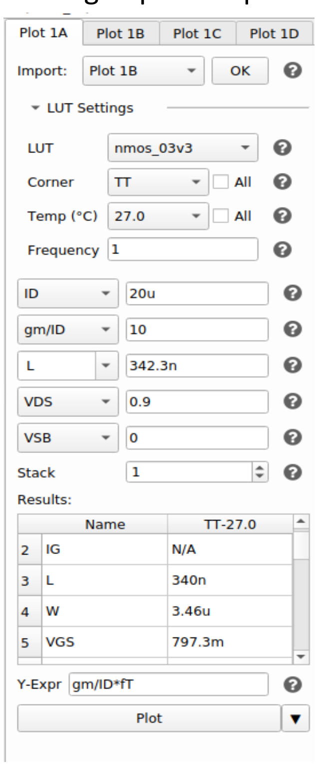
PART 1: Sizing chart:

- **Analysis:**

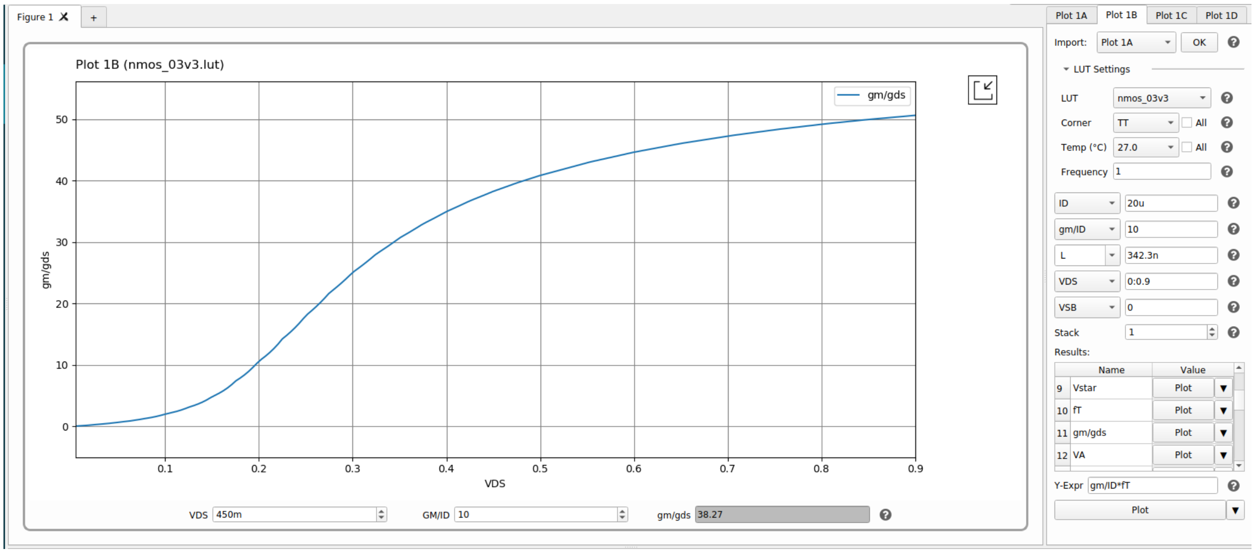
➢ We need to get $\frac{gm}{ID} = 10$ and $\mathrm{ID} = 20\ \mu\mathrm{A}$. First, we will choose L.



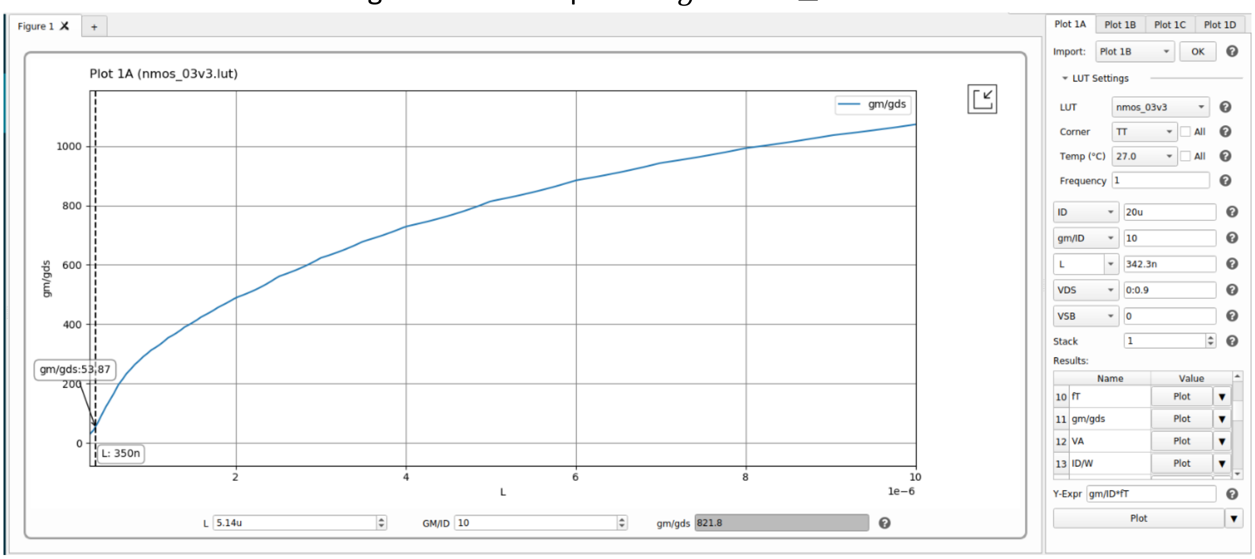
➢ Getting important parameters like W and VGS we get $W = 3.46\mu m$.



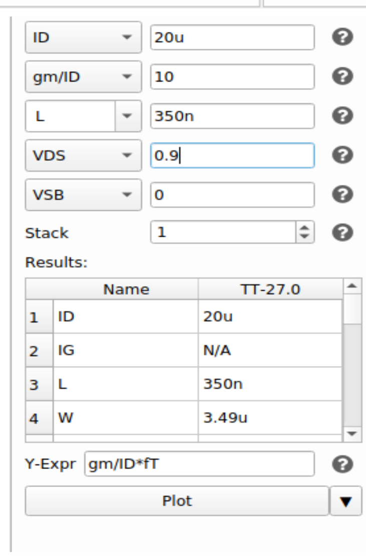
- Notice that gm/gds depends on VDS the graph for L=342nm.



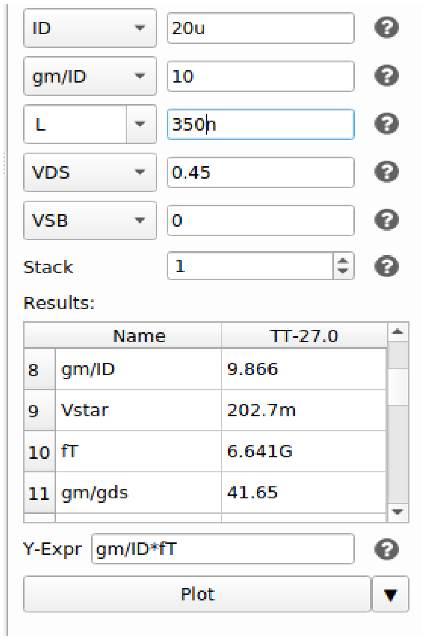
- We will choose L=350nm to guarantee the specs on $gm * ro \geq 50$.



- Getting W for L=350nm we get $W \approx 3.5\ \mu m$



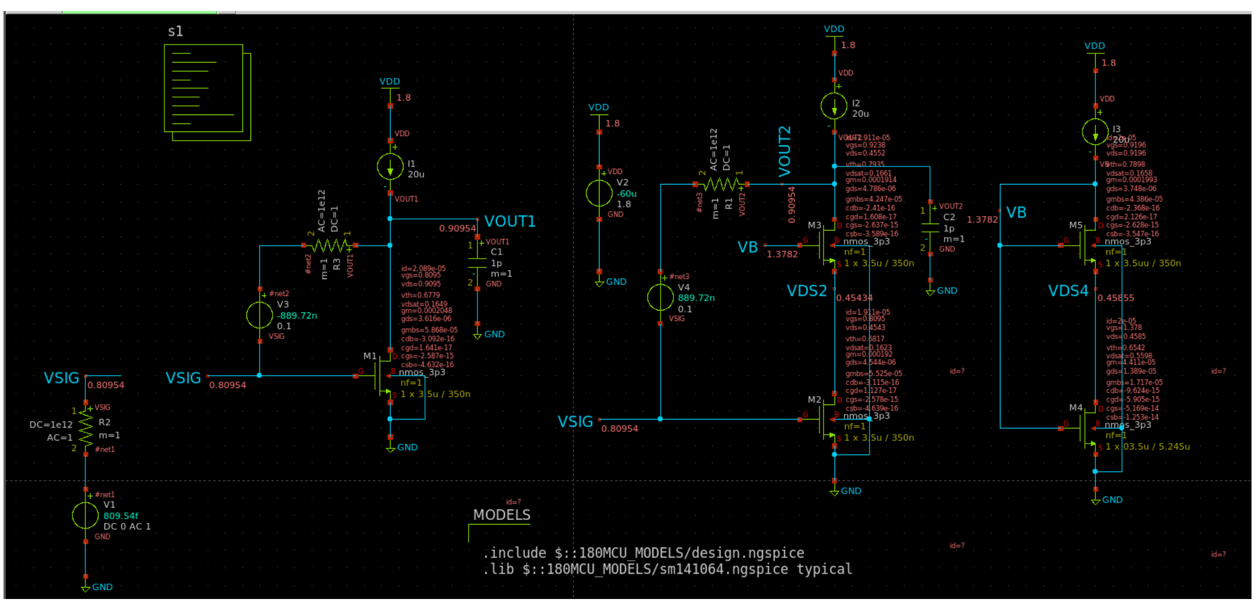
➢ For the cascode amplifier when we use the same sizing VDS will be 0.45v then $\frac{gm}{gds} = 41.65$.



PART 2: Cascode for Gain:

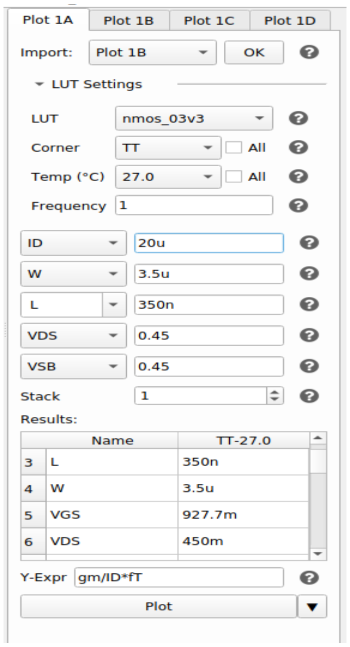
1. OP Analysis:

- **Schematic with DC OP Annotation:**



- **Choosing VB:**

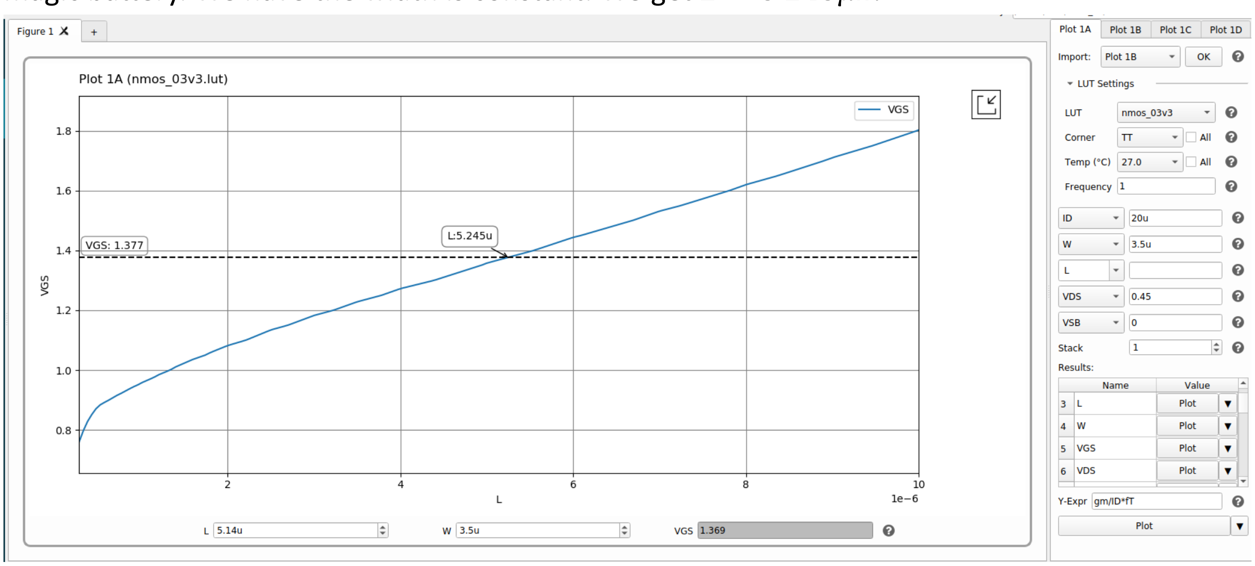
➢ We find that the value of $VB = VGS3 + VDS2$. First, we will get VGS3 from sizing assistant. We found that $VGS3 = 927.7mv$.



➢ We will assume $VDS2 \approx 0.45v$ then $VB = 1.377v$.

➢ Now to get the value of V3 and V4 dc voltages on the schematic above we know that $VDS = 0.9v$ and we got VGS in the first part approximately 0.8v then $V3 = V4 = 0.1v$.

➢ We will use the value of VB we got to calculate the length of the lower device (M4) of the magic battery. We have the width is constant. We get $L = 5.245\mu m$.



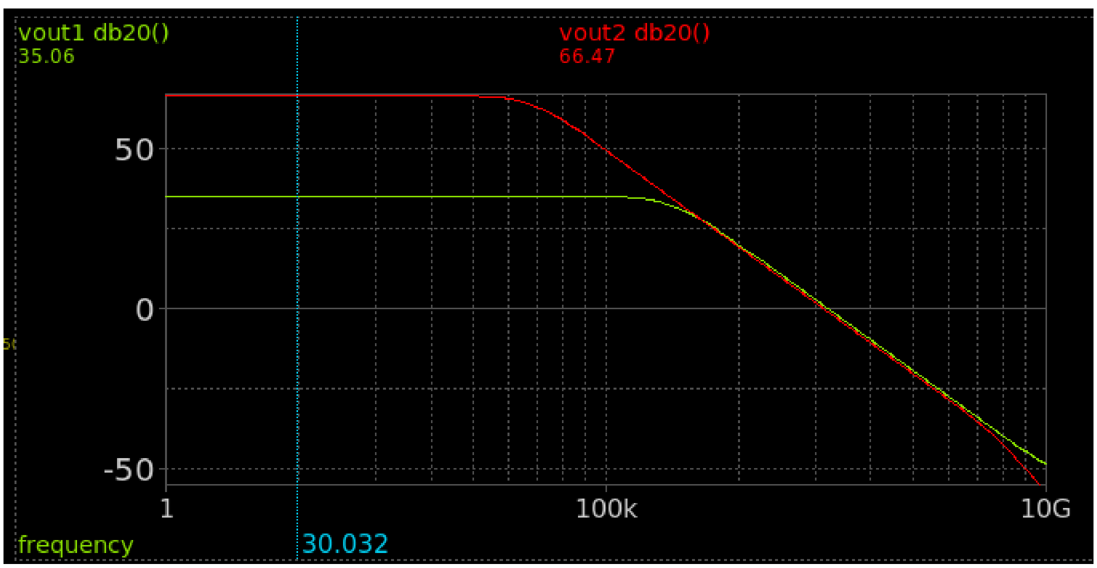
- Note: the DC OP annotations are on the schematic in p.3.
- Check that all transistors operate in saturation:
  All transistors are in saturation except M4 as VDS4=0.4585v < VDSsat4=0.5598v but for the rest of transistors VDS>VDSsat so they are in saturation.
- Not all the transistors have the same Vth. The transistors (M1,M2,M4) almost have the same Vth and (M3,M5) almost have the same Vth. M3 and M5 have higher Vth as they suffer from bulk effect which increses the Vth.
- gm>>gds
- gm>gmb
- cgs>>cgd
- csb>cdb
- For the (M4) which is in triode (gm>gds, gm>gmb, cgs>cgd,csb>cdb)

2. AC Analysis:

- calculate parameters (DC gain, BW, GBW, and UGF) and export them to a text file:

```
max_gain_cs = 5.663693e+01
bw_cs = 5.755274e+05
gbw_cs = 3.259611e+07
ugf_cs = 3.267548e+07
max_gain_casc = 2.107317e+03
bw_casc = 1.423088e+04
gbw_casc = 2.998898e+07
ugf_casc = 3.015883e+07
```

- **Bode plot (magnitude) of CS and cascode in dB:**



- **Hand Analysis:**
  - DC gain: for CS $|A| = \frac{gm}{gds} = 56.6$, and in dB it will be 35.06 dB.

    For cascode $|GM| = gm1 = 192\mu S$

    $Rout = ro2 + ro1 + (gm2 + gmb2)ro1ro2 = 11.158M\Omega$

    $|A| = 2142$, and in dB will be 66.6 dB.
  - Calculating BW we can neglect other capacitances at output node as they are a lot less than CL. The output node is dominant so we will only consider it.

    for CS $BW = \frac{1}{2\pi * ro * CL} = 575.5KHz$

    For cascode BW=$\frac{1}{2\pi * Rout * CL} = 14.26KHZ$
  - GBW: for CS $GBW = A * BW = 32.57\ MHz$

    For cascode $GBW = A * BW = 30.54MHz$
  - UGF: for first order systems $UGF \approx GBW$ and for CS and cascode we can consider them first order as we have a dominant pole.

- **Common Source Results comparison:**

	Analytical	simulation
DC gain	56.6	56.6
BW	$575.5KHz$	$575.5KHz$
GBW	$32.57MHz$	$32.596MHz$
UGF	$32.57MHz$	$32.67MHz$

- **Cascode Results comparison:**

	Analytical	simulation
DC gain	2142	2107
BW	$14.26KHZ$	$14.23KHz$
GBW	$30.54MHz$	$29.98MHz$
UGF	$30.54MHz$	$30.16MHz$

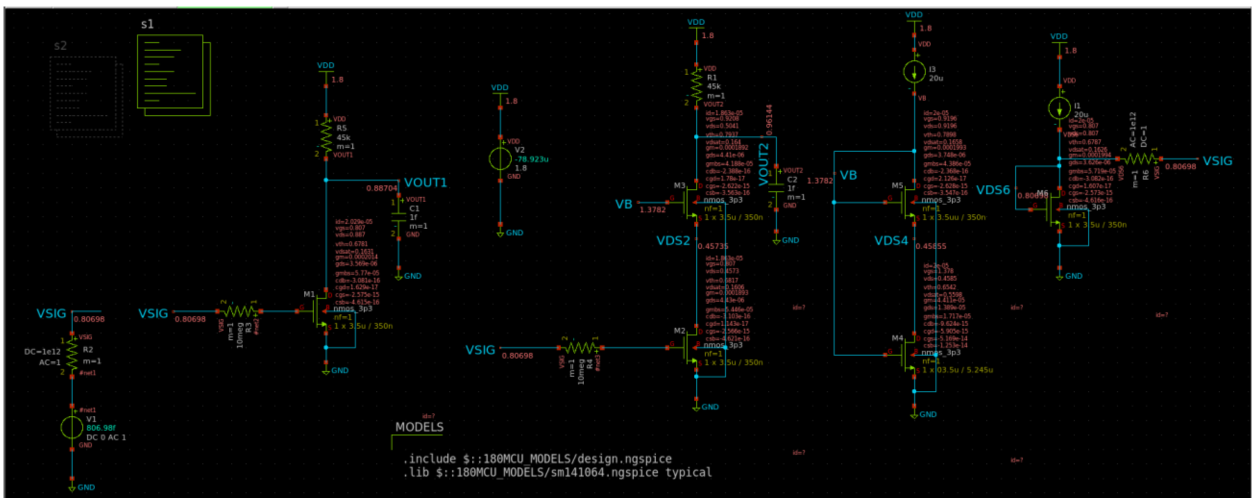
- **Comment on results:**

  The cascode for gain topology gives higher gain than the common source due to increasing the Rout but it decreases the BW (the range of frequency it works properly at) and the GBW which is a measure for speed stays almost constant as the output node is dominant.

PART 3: Cascode for BW:

1. OP Analysis:

- **Schematic and DC OP annotation:**



➢ Calculating RD: We know that $ID \approx 20uA$ as we use replica biasing by M6. If we want VDS=0.9 then $RD = \frac{0.9}{20*10^{-6}} = 45k\Omega$.

➢ All transistors are in saturation except M4 as (VDS4=0.4585) < (VDSsat=0.5598v).

2. AC Analysis:

➢ calculate parameters (DC gain, BW, GBW, and UGF) and export them to a text file:

```
max_gain_cs = 7.806966e+00
bw_cs = 1.695066e+06
gbw_cs = 1.323332e+07
ugf_cs = 1.318210e+07
max_gain_casc = 8.331485e+00
bw_casc = 3.008329e+06
gbw_casc = 2.506385e+07
ugf_casc = 2.486351e+07
```

- **Bode plot (magnitude) of CS and cascode in dB:**

- ➢ We will use the capacitors from ADT values for as xschem values aren't accurate.
  For CS (M1) → CGS=3.239 fF, CGD=605.2 aF.
  For cascode (M2) → CGS=3.255fF, CGD=675 aF.
- ➢ DC gain: for CS $|A| = gm(RD//ro) = 7.82$, and in dB it will be 17.87 dB.
  For cascode $|GM| = gm1 = 192\mu S$
  $Rout' = ro2 + ro1 + (gm2 + gmb2)ro1ro2 = 11.158M\Omega$
  $Rout = RD//Rout' = 44.82K\Omega$
  $|A| = 8.6$, and in dB will be 18.69 dB
- ➢ Calculating BW we know that input node is dominant.
  for CS $BW = \frac{1}{2\pi * Rsig * (Cgs + (1+A) * Cgd)} = 1.855MHz$
  For cascode BW=$\frac{1}{2\pi * Rsig * (Cgs + 2 * Cgd)} = 3.577MHZ$
- ➢ GBW: for CS $GBW = A * BW = 14.5\ MHz$
  For cascode $GBW = A * BW = 30.76MHz$
- ➢ UGF: for first order systems $UGF \approx GBW$ and for CS and cascode we can consider them first order as we have a dominant pole.

- **Common Source Results comparison:**

	Analytical	simulation
DC gain	7.82	7.8
BW	$1.855MHz$	$1.695MHz$
GBW	$14.5MHz$	$13.23MHz$
UGF	$14.5MHz$	$13.18MHz$

- **Cascode Results comparison:**

	Analytical	simulation
DC gain	8.6	8.33
BW	$3.577MHZ$	$3.008MHz$
GBW	$30.76MHz$	$25.06MHz$
UGF	$30.76MHz$	$24.86MHz$

- Note that the results a bit off the capacitor values may be the problem.
- Comment on results:

  Cascode for BW gives almost the same gain (a little higher) and higher BW so it gives higher GBW than the normal common source.