Hspice Homework3

As the amplifier circuits shown in the following Figs. (a), (b), and (c), please perform HSPICE simulations with the device parameters of U18 0.18μm CMOS technology. Simulate at TT corner with temperature 25°.

From your simulation results,

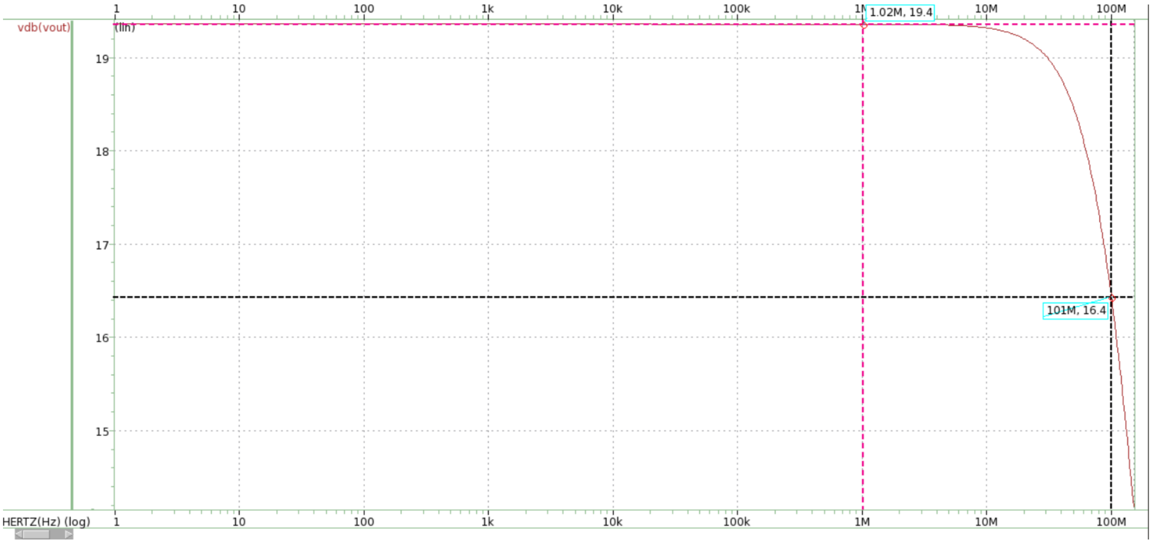
(1) Find the low-frequency voltage gain Av=Vout/Vin and the 3-dB bandwidth by using AC analysis for the amplifiers in Figs. (a), (b), and (c), respectively.

Figure a:

```
Hw3
.option post
.option probe
.temp 25
*source
vdd vdd gnd 1.8
vin 1 gnd 0.6 ac 1
*circuit
mn vout vb gnd gnd n_18_mm w=11u l=1.1u
rs 1 vb 10k
cout vout gnd 0.02p
rd vdd vout 20k
*sim
.meas AC gainmax max vdb(vout)
.meas AC f3db WHEN vdb(vout)="gainmax-3"
.tf V(vout) vin
.tran 10n 1m
.ac dec 100 1 150x

.lib "/RAID2/COURSE/AICIntro/AICIntro071/U18_model/U18_Spice_model/mm180_reg18_v124.lib" tt
.end
```

```
gm        549.5003u

 ****      small-signal transfer characteristics

     v(vout)/vin                                      =   -9.2867
     input resistance at               vin            =  1.000e+20
     output resistance at v(vout)                     =   16.9024k
```

```
****** ac analysis tnom=  25.000 temp=  25.000 ******
gainmax=  19.3572     at=    1.6982
               from=    1.0000      to= 151.3561x
f3db= 102.3077x
```



Gain=-9.2867

f-3db=101MHz

Figure b:

```
Hw3
.option post
.option probe
.temp 25
*source
vdd vdd gnd 1.8
vin vin gnd 0.3 ac 1
vb vb gnd 0.9
*circuit
mn vout vb 1 gnd n_18_mm w=11u l=1.1u
rs 1 vin 10k
cout vout gnd 0.02p
rd vdd vout 20k
*sim
.meas AC gainmax max vdb(vout)
.meas AC f3db WHEN vdb(vout)="gainmax-3"
.tf V(vout) vin
.tran 10n 1m
.ac dec 100 1 2G

.lib "/RAID2/COURSE/AICIntro/AICIntro071/U18_model/U18_Spice_model/mm180_reg18_v124.lib" tt
.end
```

```
gm          173.0438u
****        small-signal transfer characteristics

      v(vout)/vin                                  =     1.3229
      input resistance at              vin         =    15.1180k
      output resistance at v(vout)                 =    19.7362k

 ****** ac analysis tnom=  25.000 temp=  25.000 ******
gainmax=    2.4307      at=    5.7544
              from=    1.0000      to=    2.0417g
f3db= 214.4215x
```

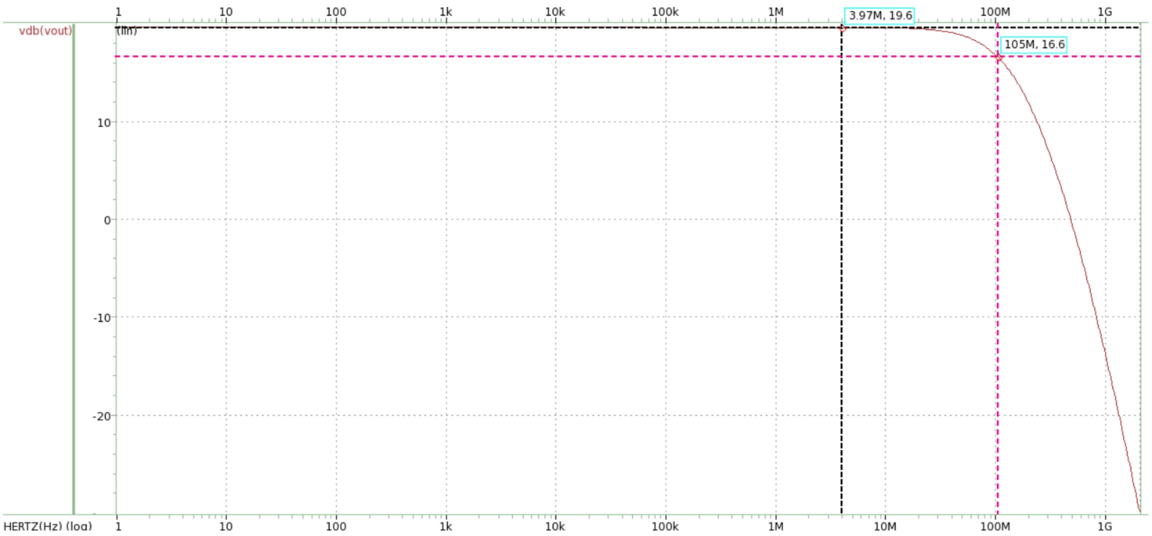
Gain=1.3229

f-3db=214MHz

Figure c:

```
Hw3
.option post
.option probe
.temp 25
*source
vdd vdd gnd 1.8
vin vin gnd 0.6 ac 1
vb2 vb2 gnd 0.9
*circuit
mn1 vx vb1 gnd gnd n_18_mm w=11u l=1.1u
mn2 vout vb2 vx vx n_18_mm w=11u l=1.1u
rs vb1 vin 10k
cout vout gnd 0.02p
rd vdd vout 20k
*sim
.meas AC gainmax max vdb(vout)
.meas AC f3db WHEN vdb(vout)="gainmax-3"
.tf V(vout) vin
.tran 10n 1m
.ac dec 100 1 2G
.lib "/RAID2/COURSE/AICIntro/AICIntro071/U18_model/U18_Spice_model/mm180_reg18_v124.lib" tt
.end
```

```
****     small-signal transfer characteristics

     v(vout)/vin                                = -9.5777
     input resistance at            vin         = 1.000e+20
     output resistance at v(vout)               = 18.6101k

****** ac analysis tnom=  25.000 temp=  25.000 ******
gainmax=  19.6252     at=   1.7783
              from=   1.0000      to=   2.0417g
f3db= 104.2644x
```



Gain=-9.577

f-3db=105MHz

	Figure a	Figure b	Figure c
Av gain	-9.2867	1.3229	-9.577
f-3db	101MHz	214MHz	105MHz

(2) Compare both low-frequency voltage gain Av and 3-dB bandwidth between these two amplifiers in Figs. (a) and (b). Please explain the reasons why they are larger or smaller.

	Av gain	f-3db	Gm
Figure a	-9.2867	101MHz	549u
Figure b	1.3229	214MHz	173u

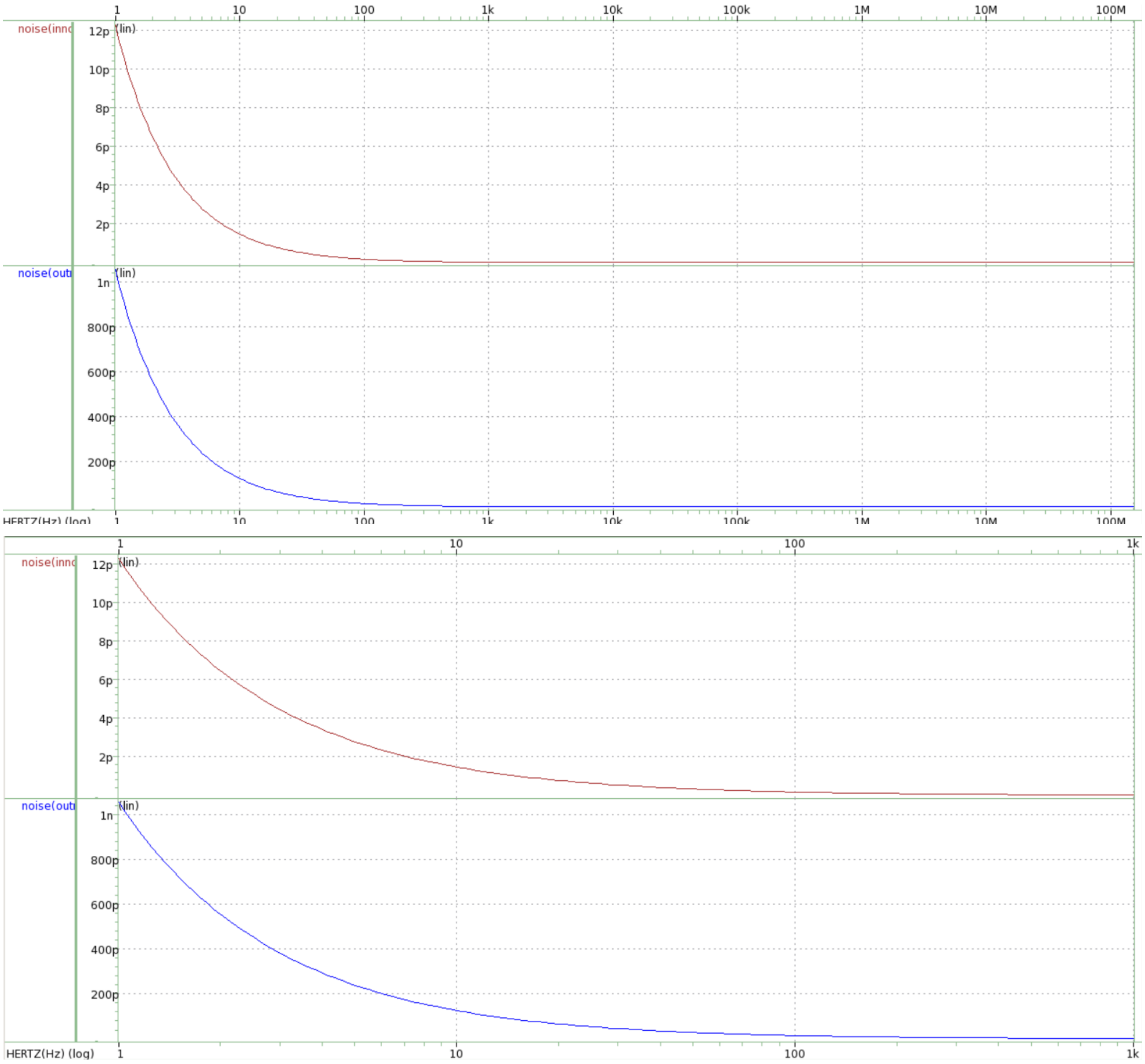
Answer:

The reason that the Av gain of Figure(a) is smaller than Figure(b) is because the output resistance of both figure(a) and figure(b) is approximately the same. However, the transconductance Gm of figure(a), which is equal to 549uS, is much larger than that of figure(b), which is equal to 173uS. The Av gain formula is -GmRout. Thus, the result shows that the magnitude of gain of figure(a) is larger than figure(b).

How about the f-3db point? Generally, The cutoff frequency can be approximately calculated by using the formula f-3db= $\frac{1}{2\pi * RC}$. Figure(a) is dominated by the input node, which is equal to 179MHz. The result of the spice and the calculation is both at the 1xxMHz level. This is acceptable. Figure(b) is dominated by the output node. The result is equal to 252MHz, which is close to the spice result. The error between them is because the calculated result is just an approximate way. Figure(a)'s RC multiply is larger than figure(b). Thus, it causes a larger -3db point at figure(b).

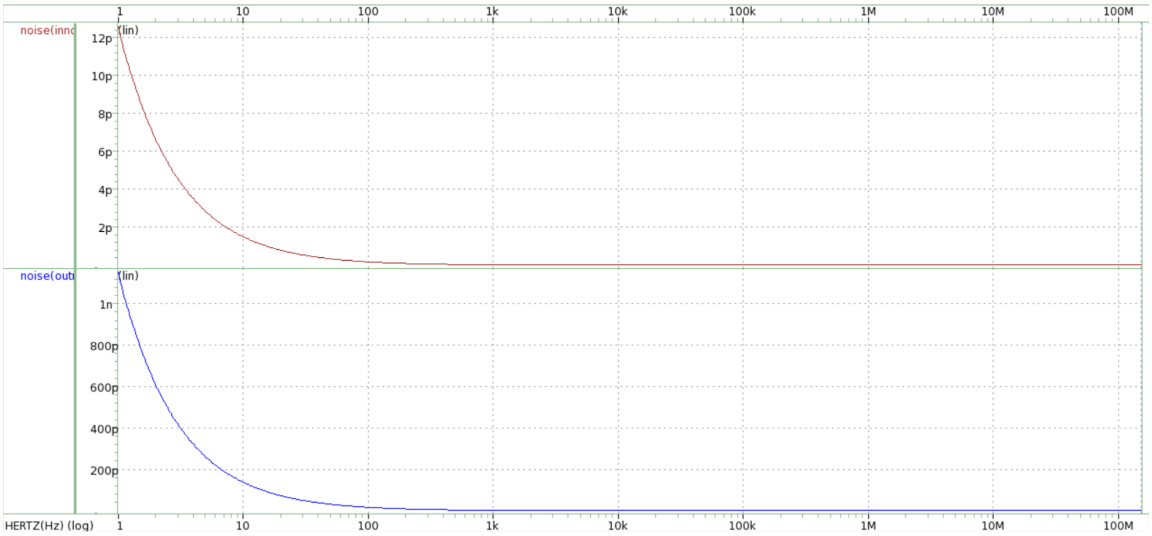
(3) Compare both output noise voltage and input-referred noise between these two amplifiers in Figs. (a) and (c). Please explain the reasons why they are larger or smaller.

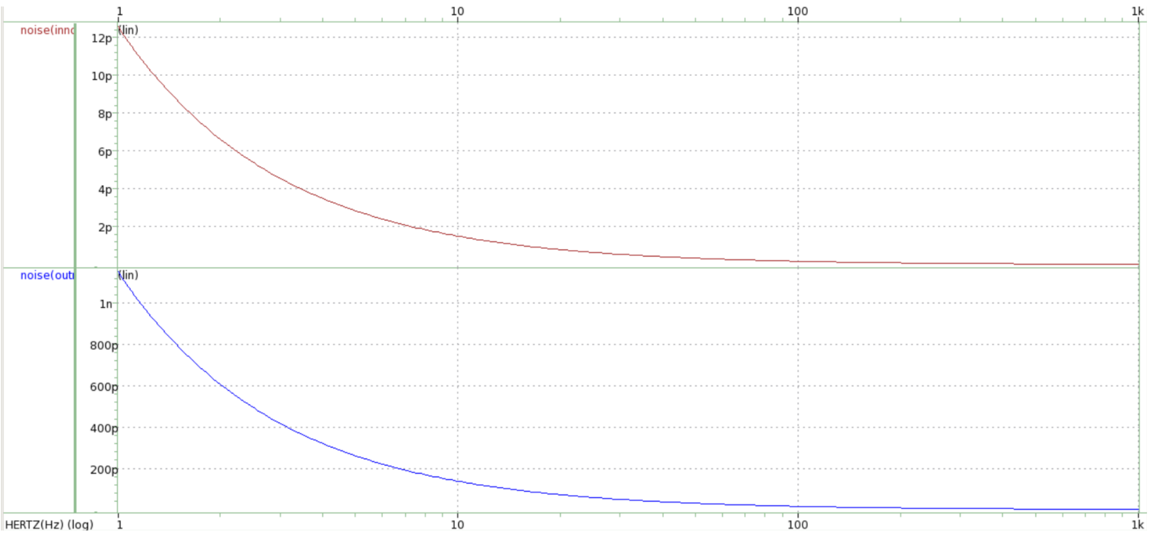
Figure(a).




```
**** the results of the sqrt of integral (V^2 / freq)
     from fstart upto   151.3561x        Hz. using more freq points
     results in more accurate total noise values.

**** total output noise voltage    =     1.3143m       V

 **** total equivalent input noise =   174.1271u       V
```

Figure(c).






```
**** the results of the sqrt of integral (V^2 / freq)
     from fstart upto  151.3561x       Hz. using more freq points
     results in more accurate total noise values.

**** total output noise voltage    =    1.3736m      V

 **** total equivalent input noise =  175.5700u      V
```

Answer:

From the result above, it is found that both the input and output noise of figure(c) are larger than that of figure(a), but just a little bit of difference between them. One of the main reasons is a larger bandwidth will generally cause a larger noise. From the results in part(a), the bandwidth of figure(a) is 101MHz, which is smaller than 105MHz, the bandwidth of figure(c). Thus, the noise of figure (c) in the output and input are larger than the noise of figure(a). This also explains why we need a filter to have a smaller bandwidth and reduce the noise.

Noise in electronics refers to the transmission of signals that are interfered with by signals generated by some external energy (such as stray electromagnetic fields), which are noise. Noise usually causes distortion of the signal. In addition to coming from outside the system, its source may also be generated by the receiving system itself. The intensity of noise is usually proportional to the signal bandwidth, so the wider the signal bandwidth, the greater the noise interference. Therefore, the data that evaluates the noise intensity or the system's ability to resist noise is based on the ratio of signal strength to noise intensity, which is the signal-to-noise ratio.

Referenced from the Wikipedia.

The second possible reason is that figure(c) passes through a longer distance to reach the final output. We all know that the wires exist parasitic resistance and inductance. Thus, it may have more noise if the elements of the circuit are more.

(4) Please explain why the noise of MN2 contributes negligibly to the total output noise in Fig. (c)

Answer:

First, if it is assumed that there's a noise signal from the gate of MN2, the output of this noise signal will be very small, which can be neglected. This is because of the cascode circuit. The Gm of MN2 will be much smaller than the Gm of MN1, which is due to a large resistance looking below. Then the noise output of MN2 will also be much smaller than MN1. Thus, we can neglect the noise from MN2.