106010006 黃詩瑜 電機 21

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<tr><td>Transimpedance gain (KΩ)</td><td>> 0.95KΩ</td><td>0.9507807</td><td>0.9517468</td></tr>
<tr><td>core amp size (W/LN, W/LP)</td><td></td><td>NMOS:W=99u L=0.27u M=4
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<tr><td>core amp gm (gmN, gmP)</td><td></td><td>NMOS:38.2993m
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<tr><td>core amp ro (roN, roP)(ohm)</td><td></td><td>NMOS:902
PMOS:2.94k</td><td></td></tr>
<tr><td>Bandwidth (-3dB) (MHz)</td><td>>150MHz#2</td><td>724</td><td>665.91</td></tr>
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<tr><td>Closed-loop input impedance(ohm)</td><td></td><td>48.7320</td><td>47.7753</td></tr>
<tr><td>Closed-loop output impedance(ohm)</td><td></td><td>20.1021</td><td>19.7049</td></tr>
<tr><td>FoM (MHz/μA)</td><td>#2/#1</td><td>0.31396</td><td></td></tr>
</table>

a.

M1 W=99u L=0.27u m=4

M2 W=26u L=0.28u m=4

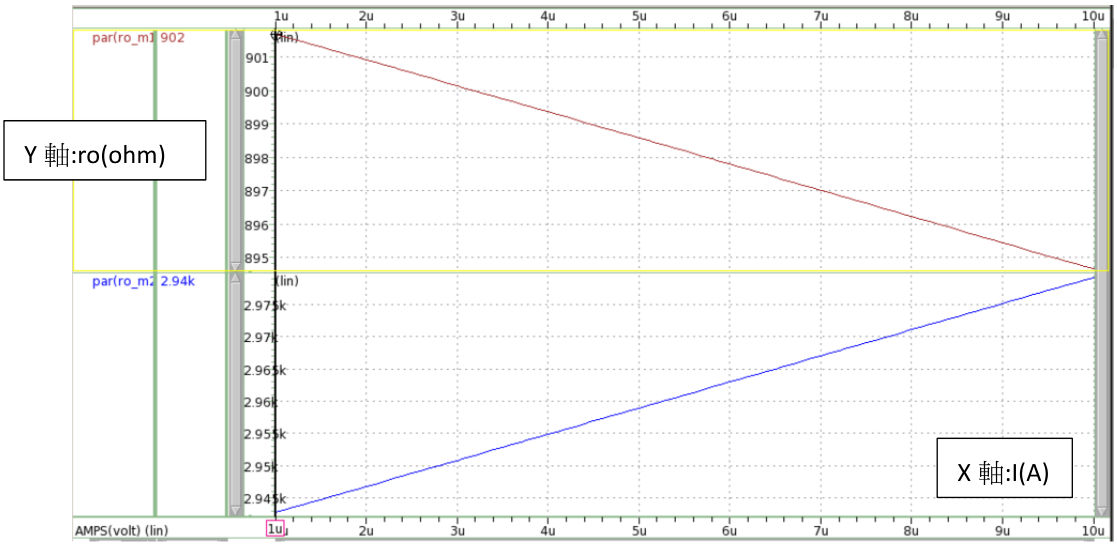
b.

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

     v(out)/iin                              = -950.7807
     input resistance at          iin        =   48.7320
     output resistance at v(out)             =   20.1021
```

c.

```
subckt
element  0:m1n        0:m2p
model    0:n_18.1     0:p_18.1
region      Saturati     Saturati
 id          2.3060m    -2.3106m
 ibs       -3.862e-19  2.468e-19
 ibd       -15.9270f     4.4217f
 vgs       559.8611m  -940.1389m
 vds       564.4597m  -935.5403m
 vbs         0.          0.
 vth       493.2101m  -516.2981m
 vdsat     115.2230m  -402.0517m
 vod        66.6510m  -423.8409m
 beta      502.8922m    28.9122m
 gam eff   507.4463m   557.0843m
 gm         38.9223m     9.8606m
 gds         1.1090m   339.8186u
 gmb         6.4751m     3.1587m
 cdtot     535.9406f   114.1288f
 cgtot     866.0077f   234.3900f
 cstot       1.1591p   312.4927f
 cbtot       1.0054p   231.3879f
 cgs       639.1496f   185.2894f
 cgd       144.6956f    37.3719f
```



Ro: M1:902(ohm) M2:2.94K(ohm)

$$V_{in} = I_{in}\,(R_F\,//\,R_s)$$

$$V_{out} = -(g_{m1} + g_{m2})(r_{o1}\,//\,r_{o2}\,//\,R_F)\,(R_F\,//\,R_s)\,V_{in}$$

$$\text{Gain} = \frac{A}{1+KA}$$

$$\text{K} = -\frac{1}{R_F} = -\frac{1}{1000}$$

$$A = -(g_{m1}+g_{m2}) \times (r_{o1}//r_{o2}//R_F) \times (R_F//R_S)$$
$$= (38.9223\text{m} + 9.8606\text{m})\text{X}(902//2.94\text{K}//1000)\text{X}(1000//100\text{K}) = -19724.0388$$

$$\text{Gain} = \frac{-19724.0388}{1 + \frac{1}{1000} X19724.0388} = -951.746857(ohm)$$

$$Zin = \frac{(R_F//R_S)}{1 + KA} = \frac{(1000//100K)}{1 + \frac{1}{1000} X19724.0388} = 47.7753(ohm)$$

$$\text{Zout} = \frac{(r_{o1}//r_{o2}//R_F)}{1 + KA} = \frac{(902//2.94K//1000)}{1 + \frac{1}{1000} X19724.0388} = 19.7049(ohm)$$

模擬與手算誤差:

$$Gain = \frac{950.7807 - 951.7468}{950.7807} \text{X}100\% = -0.1016\%$$

$$Zin = \frac{47.7753 - 48.7320}{47.7753} \text{X}100\% = -2.002\%$$

$$Zout = \frac{19.7049 - 20.1021}{19.7049} \text{X}100\% = -2.0157\%$$

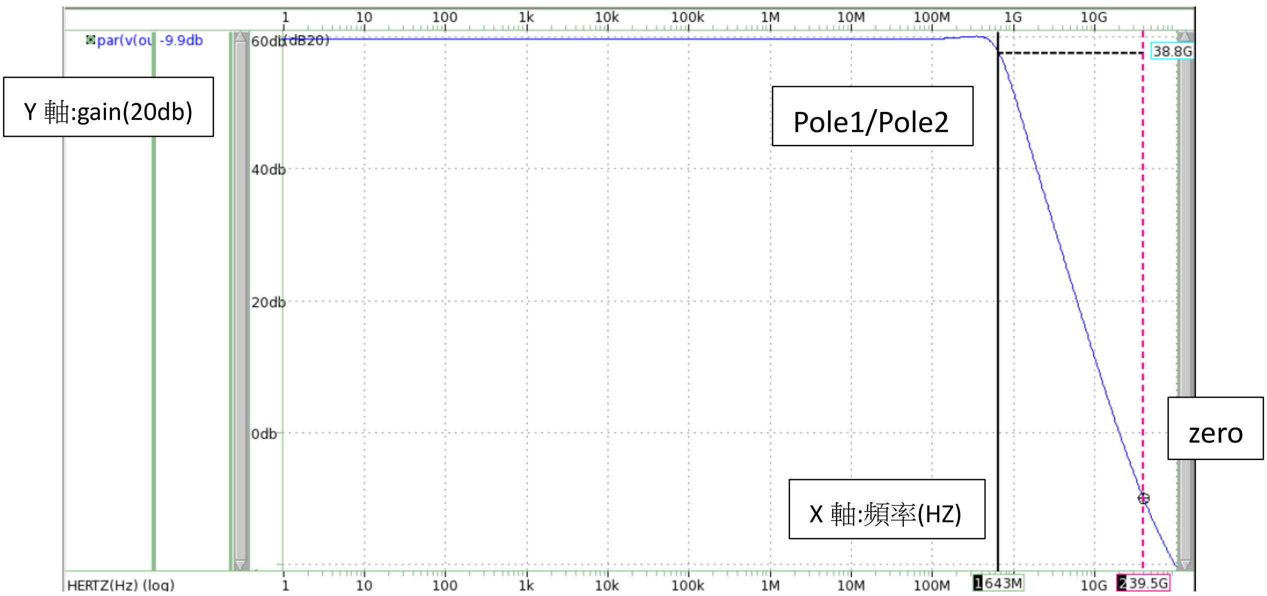
結果都與模擬非常接近

d.

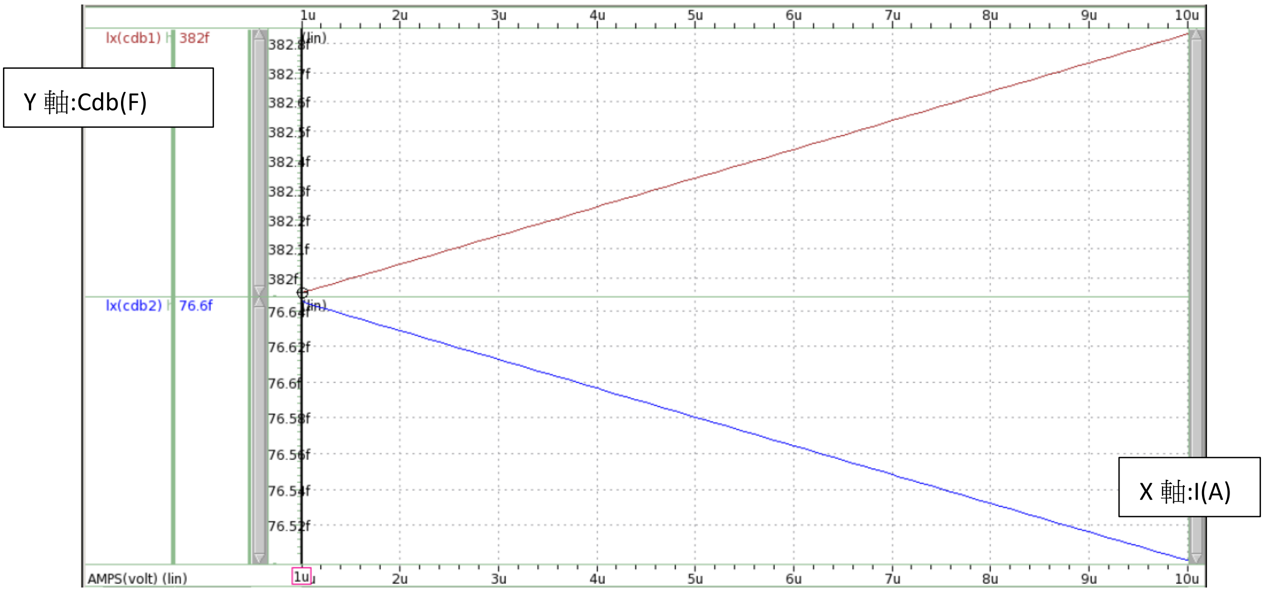
poles (rad/sec) real	imag	poles (hertz) real	imag
-2.23205g	3.10871g	-355.242x	494.767x
-2.23205g	-3.10871g	-355.242x	-494.767x

zeros (rad/sec) real	imag	zeros (hertz) real	imag
248.094g	0.	39.4854g	0.

$$pole1/pole2 = |355.242M + 494.767Mj| = 643.734\text{M}(HZ)$$



e.



Cdb: M1:382fF M2:76.6f

$$C_{GS}' = C_{GS1} + C_{GS2} + C_L = 639.1496f + 185.2894f + 1p = 1.8244X10^{-12}$$
$$C_{GD}' = C_{GD1} + C_{GD2} = 144.6956f + 37.3719f + 1p = 1.182 \times 10^{-12}$$
$$C_{DB}' = C_{DB1} + C_{DB2} + C_L = 382f + 76.6f + 1p = 1.4586 \times 10^{-12}$$

$$\begin{aligned} \mathrm{a} &= (R_F//R_S)(r_{o1}//r_{o2}//R_F)(C_{GS}'C_{GD}' + C_{DB}'C_{GD}' + C_{GS}'C_{DB}') \\ &= (1000//100k)(902//2.94k//1000)(1.8244pX1.182p + 1.4586pX1.182p \\ &\quad + 1.8244pX1.4586p) = 2.6449X10^{-18} \end{aligned}$$

$$\begin{aligned} b &= (1 + (g_{m1} + g_{m2})(r_{o1}//r_{o2}//R_F))C_{GD}'(R_F//R_S) + (R_F//R_S)C_{GS}' + (r_{o1}//r_{o2}//R_F)(C_{DB}' + C_{GD}') \\ &= (1 + (38.9223m + 9.8606m)(902//2.94k//1000))1.182p(1000//100k) \\ &\quad + (1000//100k)1.8244p + (902//2.94k//1000)(1.4586p + 1.182p) = 2.73686X10^{-8} \end{aligned}$$

$$\text{open pole1} = \frac{1}{2\pi \times \mathrm{b}} = \frac{1}{2\pi X2.7368X10^{-8}} = 5.815537 \times 10^{7}$$

$$\text{open pole2} = \frac{b}{2\pi \times \mathrm{a}} = \frac{2.7368X10^{-8}}{2\pi X2.6449X10^{-18}} = 2.6468 \times 10^{9}$$

$$\text{closed loop pole} = \frac{-(\text{ pole1} + \text{pole2}) \pm \sqrt{(\text{pole1} + \text{pole2})^2 - 4(1 + KA)\text{pole1} \times \text{pole2}}}{2}$$
$$= -369.999M \pm 550.862Mj\ (HZ)$$

$$\text{Bandwidth} = |-369.999\text{M} + 550.862\text{Mj}| = 665.91\text{M(HZ)}$$

$$\text{zero} = \frac{(g_{m1} + g_{m2})}{2\pi(C_{GD1} + C_{GD2})} = \frac{(38.9223m + 9.8606m)}{2\pi(144.6956f + 37.3719f)} = 4.2643 \times 10^{10}$$

模擬與手算誤差:

$$Pole = 實部 = \frac{-369.999-(-355.242)}{-369.999}X100\% = 3.9888\%$$

$$虛部 = \frac{550.862-494.767}{550.862}X100\% = 10.1831\%$$

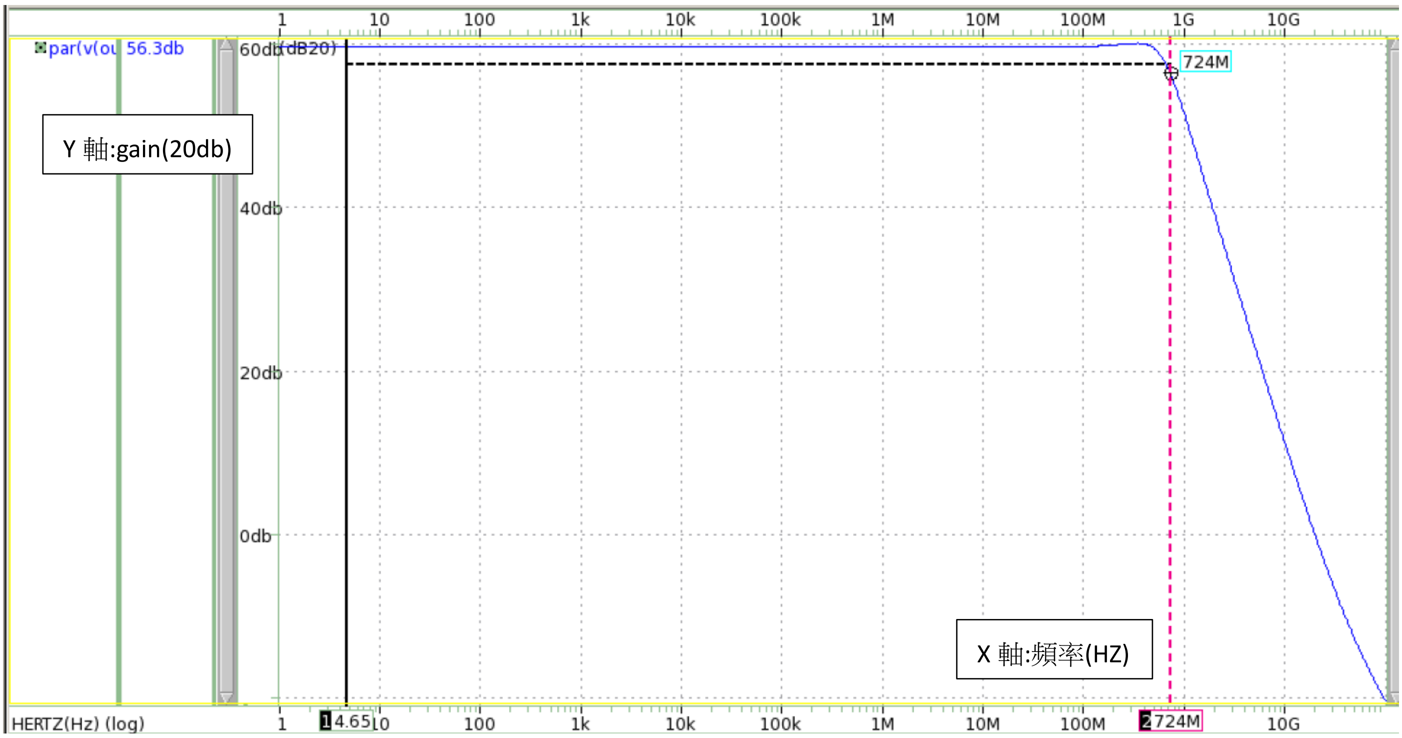
$$Zero = \frac{42.643-39.4854}{42.643}X100\% = 7.1702\%$$

手算結果與模擬有些誤差，推測是因為電路中會有電阻及寄生電容是手算沒辦法算到的。

f.

$$\text{FoM}=\frac{bandwidth(MHZ)}{current(\mu A)}$$

```
subckt
element   0:m1n       0:m2p
model     0:n_18.1    0:p_18.1
region      Saturati    Saturati
 id           2.3060m    -2.3106m
```



-3db 時，頻率為 724M(HZ)

$$\text{FoM} = \frac{724}{2306.0} = 0.31396$$

g.

$$\text{Gain} = \frac{A}{1+KA}$$

$$A = -(g_{m1} + g_{m2}) \times (r_{o1}//r_{o2}//R_F) \times (R_F//R_S)$$
$$FoM = \frac{bandwidth(MHZ)}{current(\mu A)}$$

我一開始先想辦法讓 gain 大於 0.95K，gm1/gm2 越大 A 就越大，gain 就會越大，所以我將 M1 和 M2 的 W/L 的比值調到最大，發現都 gain 沒辦法到達 0.95K，就將 M1 和 M2 都並聯，並聯到達 m=4 時，gain 大約是 0.944K，接著我把 M1 的 L 調高一點點，Vgs-Vth 變大，gain 到達了 0.95K，這時候的 bandwidth 已經遠大於 150M(HZ)了。

接著要讓 FoM 越大越好，這時的電流很大，FoM 就很小，所以我將 M2 的 W 調小一半，電流減小了很多，但還是要讓 gain 維持在 0.95K 以上，這時的 bandwith 還是遠大於 150M(HZ)。

我的 bandwidth 遠大於 150M(HZ)，跟同學的比較後，我認為是我的 gm 相對地比較小，而 gm 越小，pole 越大，所以我的 bandwidth 才很大。

.sp 檔

```
*hw6***
.prot
.lib 'cic018.l' TT
.unprot
.option
+ post=1
+ACCURATE=1
+ runlvl=6
.temp 25

.param
+ wn = 99u
+ ln = 0.27u
+ wp = 26u
+ lp = 0.28u
+ I = 1u


M1N out in gnd gnd N_18 w=wn l=ln m=4
M2P out in Vdd Vdd P_18 w=wp l=lp m=4

RF in out 1k
Rs in gnd 100k
Cin in gnd 1p
Cout out gnd 1p

Vdd Vdd gnd 1.5V
Iin gnd in dc=I ac=1m


.op
.probe DC
+ ro_m1 = par('1/LX8(M1N)')
+ ro_m2 = par('1/LX8(M2P)')
+ Cdb1 =LX29(M1N)
+ Cdb2 =LX29(M2P)
.tf V(out) Iin
.dc Iin 1u 10u 0.1u
.print par('V(out)/I(Iin)')
.pz V(out) Iin
.ac dec 100 1 100g

.probe par('V(out)/I(Iin)')



.end
```