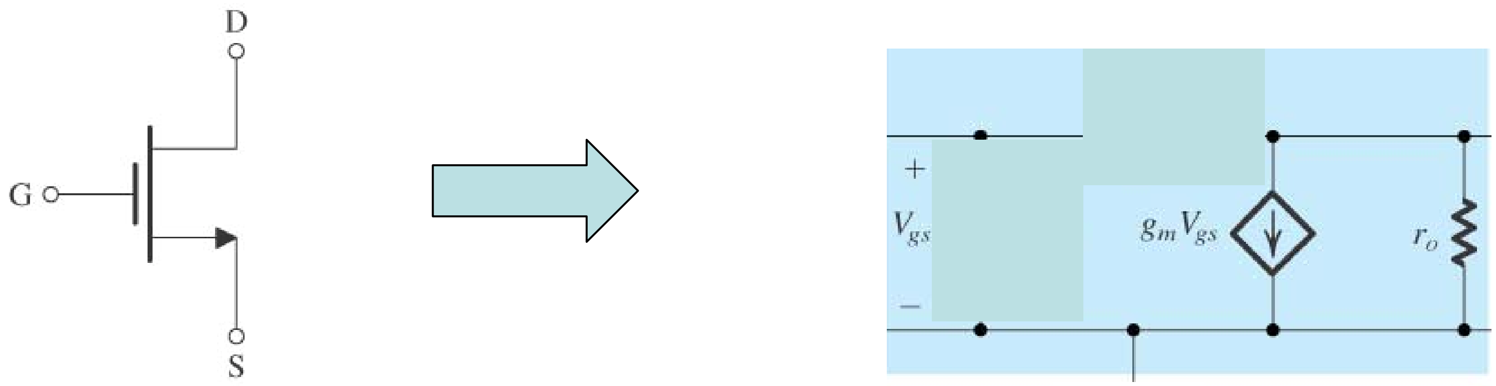
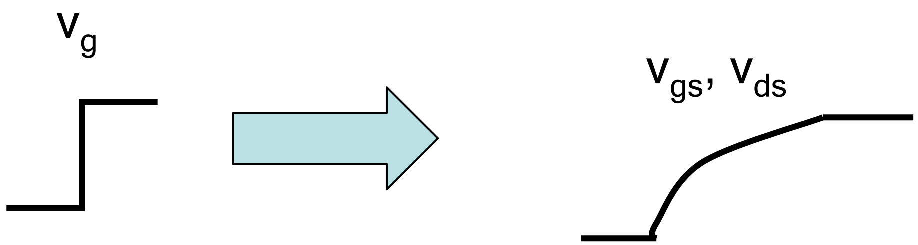
Lect. 4: MOSFET Frequency Response

Frequency Model for MOSFET



(c)



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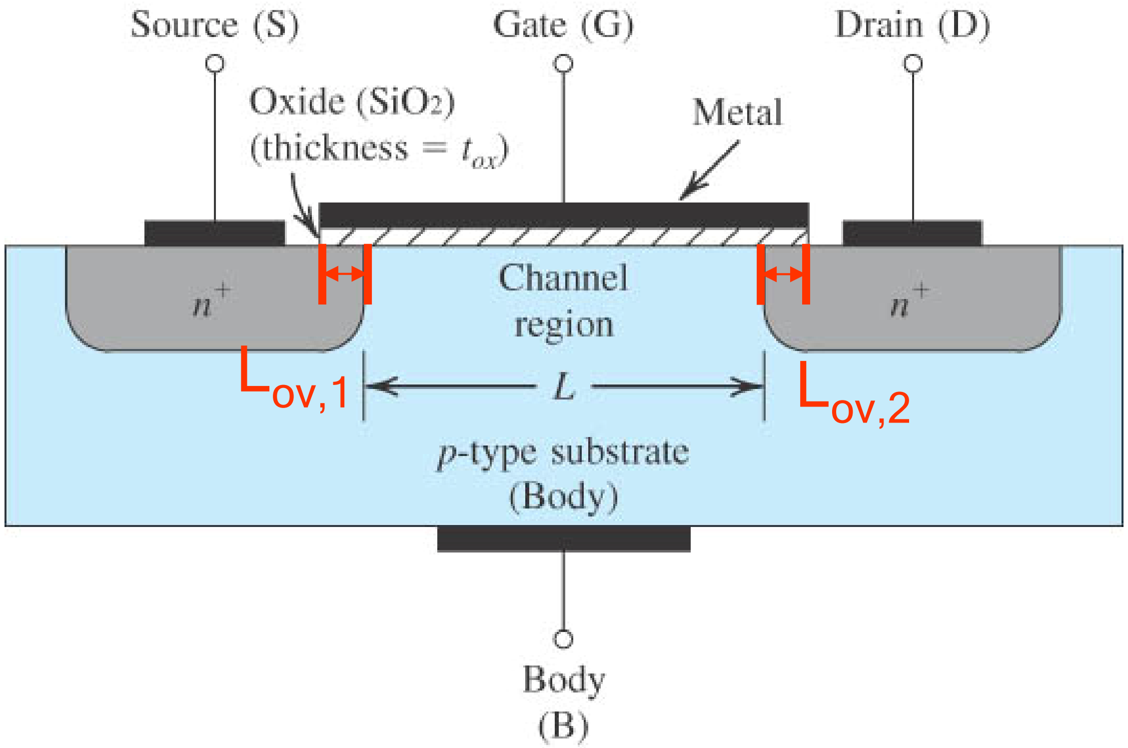


$L_{ov} = L_{ov,1} + L_{ov,2}$

In saturation,

$C_{GS} = 2/3\ WLC_{ox} + WL_{ov}C_{ox}$
$C_{GD} = WL_{ov}C_{ox}$

$C_{GS} > C_{GD}$

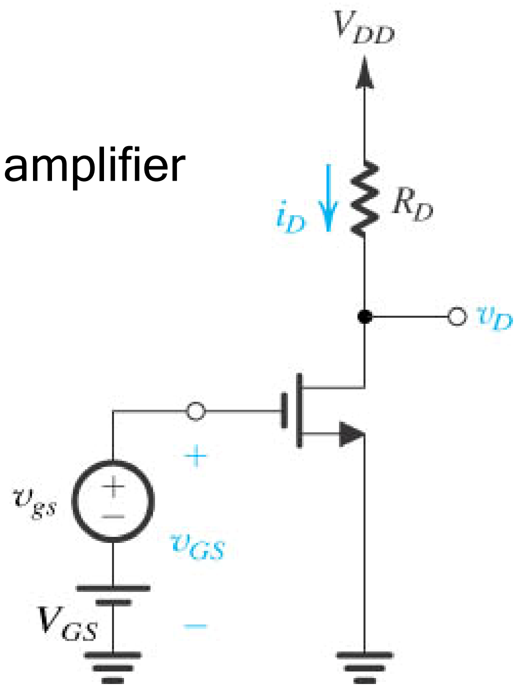
Lect. 4: MOSFET Frequency Response

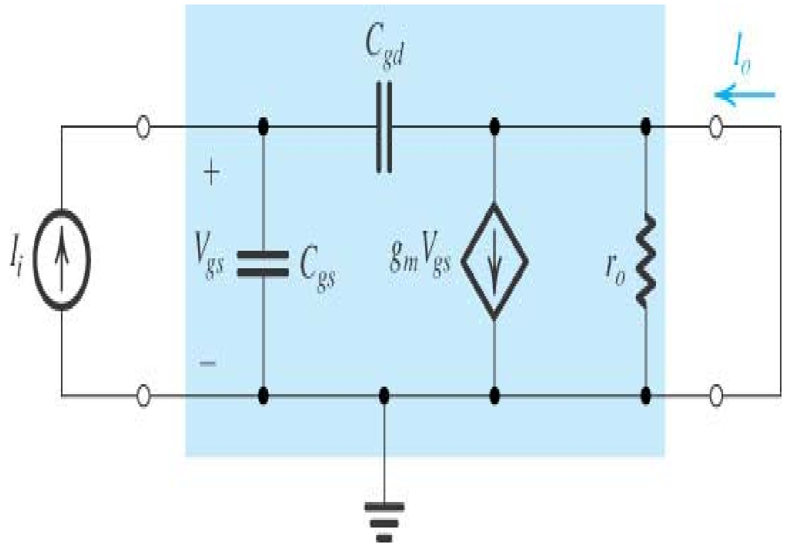
How fast can a MOSFET transistor operate?

➔Unit-Gain Frequency (f_t):

Frequency at which magnitude of the short-circuit current gain of CS configuration becomes 1

CS amplifier





$\frac{I_0}{I_i}$ in frequency (ω) domain?

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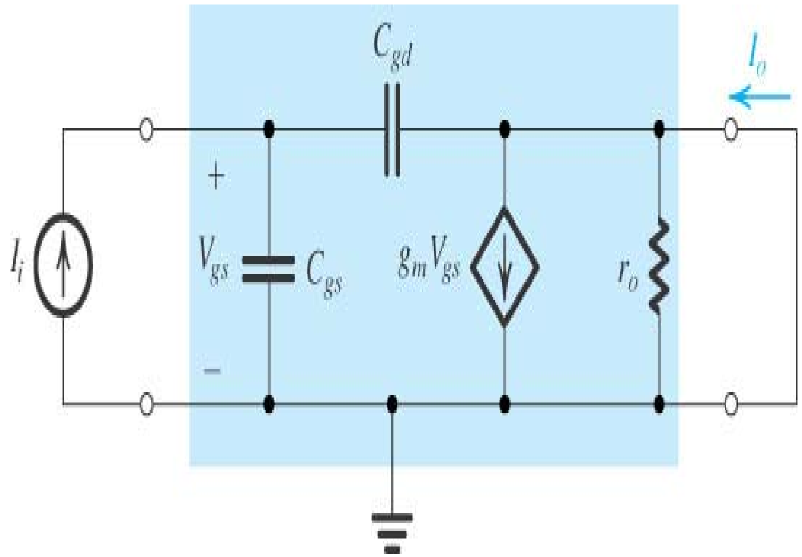

$$I_0 = g_m V_{gs} - \frac{V_{gs}}{1/j\omega C_{gd}} = g_m V_{gs} - j\omega C_{gd} V_{gs}$$

$$\simeq g_m V_{gs} \quad (\because g_m >> \omega C_{gd})$$

$$V_{gs} = I_i \cdot \left(\frac{1}{j\omega C_{gd}} \| \frac{1}{j\omega C_{gS}} \right) = I_i \cdot \frac{1}{j\omega(C_{gd} + C_{gs})}$$

$$\therefore \frac{I_0}{I_i} = \frac{g_m}{j\omega(C_{gd} + C_{gs})}$$

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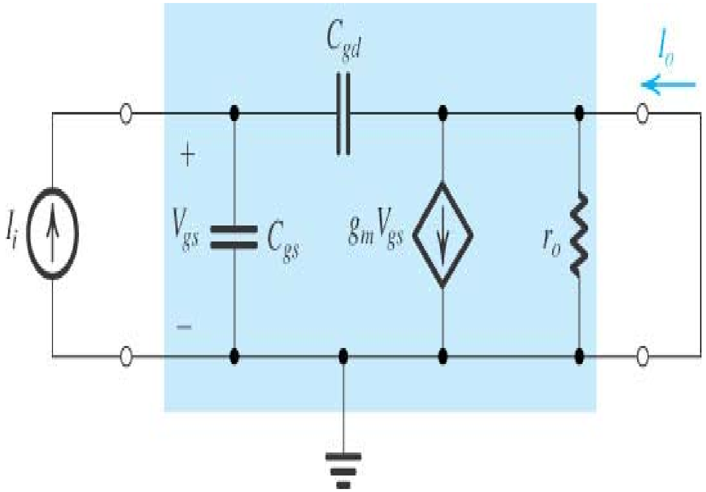
Unit-Gain Frequency (f_t):

Frequency at which magnitude of the short-circuit current gain of CS configuration becomes 1



$$\frac{I_0}{I_i} = \frac{g_m}{j\omega(C_{gd} + C_{gs})}$$

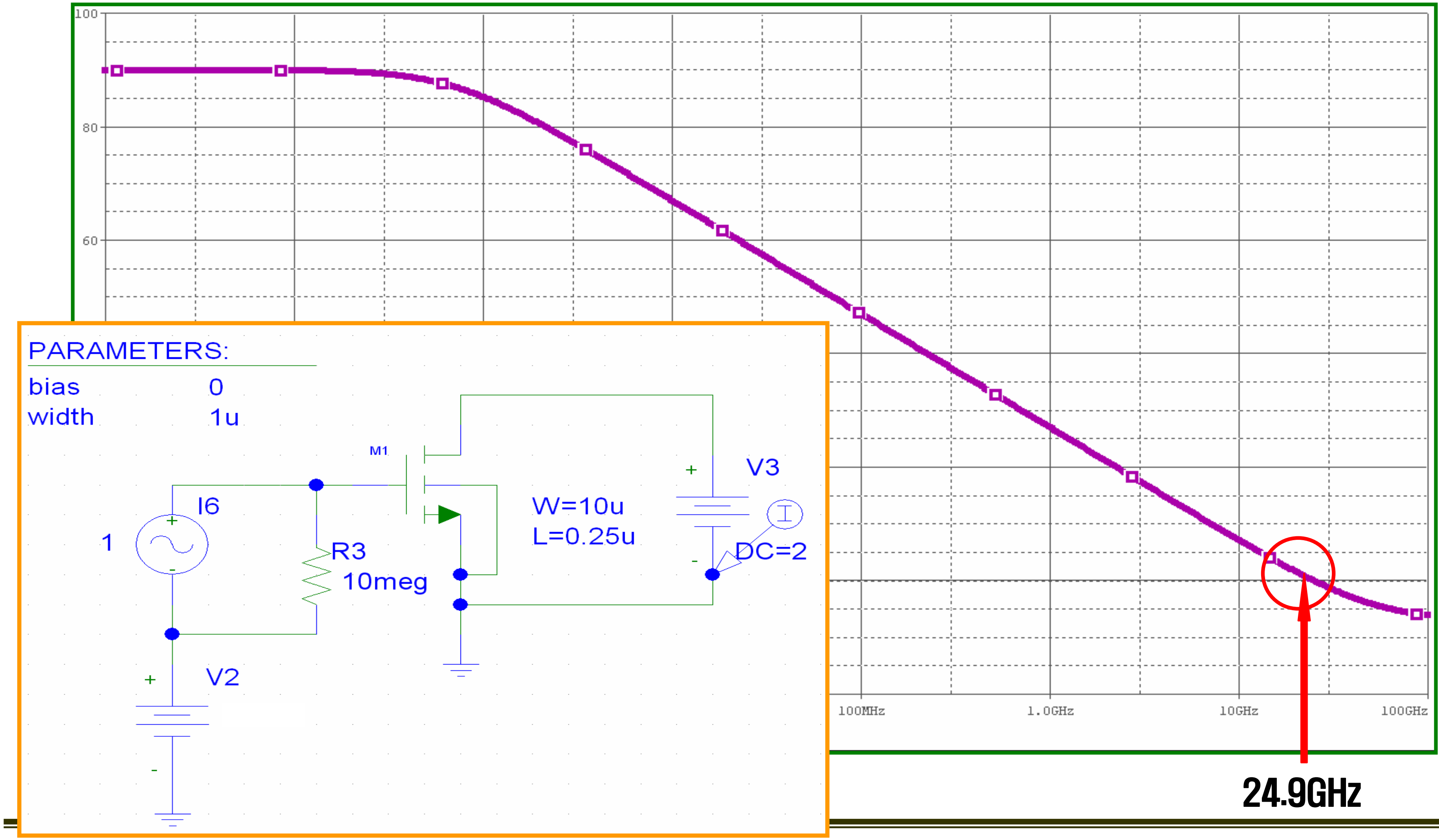
For $\left|\frac{I_0}{I_i}\right| = 1, \ \omega = \frac{g_m}{C_{gd} + C_{gs}}$

$$f_T = \frac{g_m}{2\pi(C_{gd} + C_{gs})} \quad \text{(Unit-gain Frequency)}$$

How to make MOSFET faster?

Which is faster, NMOS or PMOS?

L=0.25㎛ , W=10 ㎛ , V_{DS}=2V, V_{GS}=1.5V



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Lect. 4: MOSFET Frequency Response

L=0.25㎛ , W=10 ㎛ , V_{DS}=2V, V_{GS}=1.5V

$$C_{gd} = C_{ox} \cdot W \cdot L_{ov}$$

$$C_{gs} = \frac{2}{3} \cdot C_{ox} \cdot W \cdot L + C_{ox} \cdot W \cdot L_{ov}$$

$$f_T = \frac{g_m}{2\pi * (C_{gd} + C_{gs})}$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.97 * 8.85 * 10^{-12}[F/m]}{5.6 * 10^{-9}[m]}$$

$$= 0.0063[F/m^2]$$

$$L_{ov} = \frac{C_{GDO}, C_{GSO}}{C_{OX}}$$

$$= \frac{4.59 * 10^{-10}[F/m]}{0.0063[F/m^2]} = 7.28 * 10^{-8} m$$

```
MODEL orbit2L2N NMOS (                              LEVEL   = 7
+TNOM     = 27            TOX      = 5.6E-9
+XJ       = 1E-7          NCH      = 2.3549E17      VTH0    = 0.3654765
+K1       = 0.4732214     K2       = 7.994532E-4    K3      = 1E-3
+K3B      = 3.0713494     W0       = 1E-7           NLX     = 1.617898E-7
+DVT0W    = 0             DVT1W    = 0              DVT2W   = 0
+DVT0     = 0.455178      DVT1     = 0.6258687      DVT2    = -0.5
+U0       = 280.4589023   UA       = -1.607126E-9   UB      = 2.806549E-18
+UC       = 3.290051E-11  VSAT     = 1.07496E5      A0      = 1.8770435
+AGS      = 0.3310181     B0       = -3.173524E-8   B1      = -1E-7
+KETA     = -8.69841E-3   A1       = 8.317145E-5    A2      = 0.6592347
+RDSW     = 200           PRWG     = 0.4477477      PRWB    = 0.0208175
+WR       = 1             WINT     = 0              LINT    = 1.392558E-10
+DWG      = -2.28419E-8
+DWB      = -6.95781E-10  VOFF     = -0.0910963     NFACTOR = 1.202941
+CIT      = 0             CDSC     = 2.4E-4         CDSCD   = 0
+CDSCB    = 0             ETA0     = 5.0732E-3      ETAB    = 6.262008E-5
+DSUB     = 0.0310034     PCLM     = 1.5101091      PDIBLC1 = 0.897659
+PDIBLC2  = 2.924029E-3   PDIBLCB  = 0.0651312      DROUT   = 1
+PSCBE1   = 7.017738E8    PSCBE2   = 2.271109E-4    PVAG    = 8.531511E-3
+DELTA    = 0.01          RSH      = 4.6            MOBMOD  = 1
+PRT      = 0             UTE      = -1.5           KT1     = -0.11
+KT1L     = 0             KT2      = 0.022          UA1     = 4.31E-9
+UB1      = -7.61E-18     UC1      = -5.6E-11       AT      = 3.3E4
+WL       = 0             WLN      = 1              WW      = 0
+WWN      = 1             WWL      = 0              LL      = 0
+LLN      = 1             LW       = 0              LWN     = 1
+LWL      = 0             CAPMOD   = 2              XPART   = 0.5
+CGDO     = 4.59E-10      CGSO     = 4.59E-10       CGBO    = 5E-10
+CJ       = 1.78338E-3    PB       = 0.99           MJ      = 0.4661295
+CJSW     = 4.154041E-10  PBSW     = 0.9563049      MJSW    = 0.3162462
+CF       = 0             PVTH0    = -9.648921E-3   PRDSW   = -10
+PK2      = 3.534961E-3   WKETA    = 0.0120981      LKETA   = -3.31688E-3    )
```

Lect. 4: MOSFET Frequency Response

L=0.25 μm , W=10 μm , V_{DS}=2V, V_{GS}=1.5V

$$C_{gd} = C_{ox} \cdot W \cdot L_{ov}$$

$$C_{gs} = \frac{2}{3} \cdot C_{ox} \cdot W \cdot L + C_{ox} \cdot W \cdot L_{ov}$$

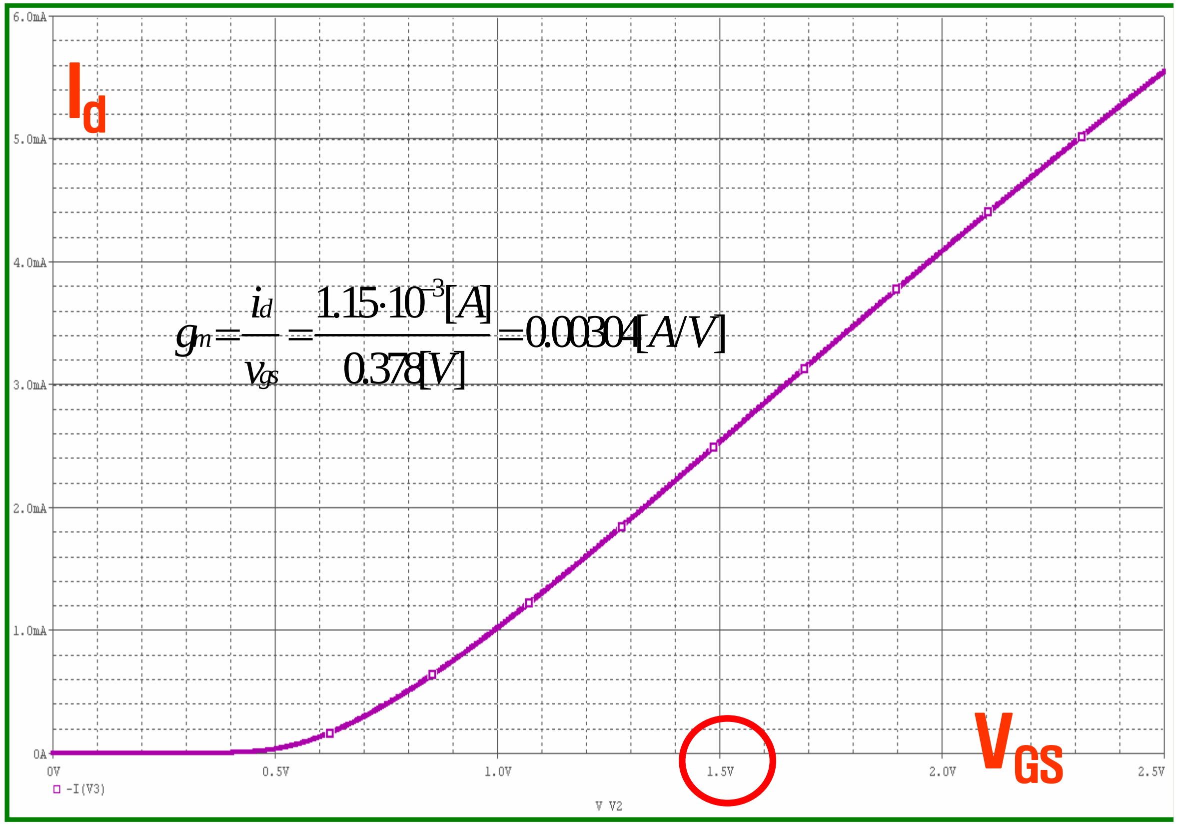
$$C_{ox} = 0.0063 [F/m^2]$$

$$L_{ov} = 7.28 * 10^{-8} m$$

$$C_{gd} = 4.59 * 10^{-15} [F]$$

$$C_{gs} = 1.51 * 10^{-14} [F]$$

$$C_{gd} + C_{gs} = 1.968 * 10^{-14} [F]$$



$$f_T = \frac{g_m}{2\pi * (C_{gd} + C_{gs})} = \frac{0.00304}{2\pi * (1.968 * 10^{-14})} = 24.5 GHz$$