Lab. 07

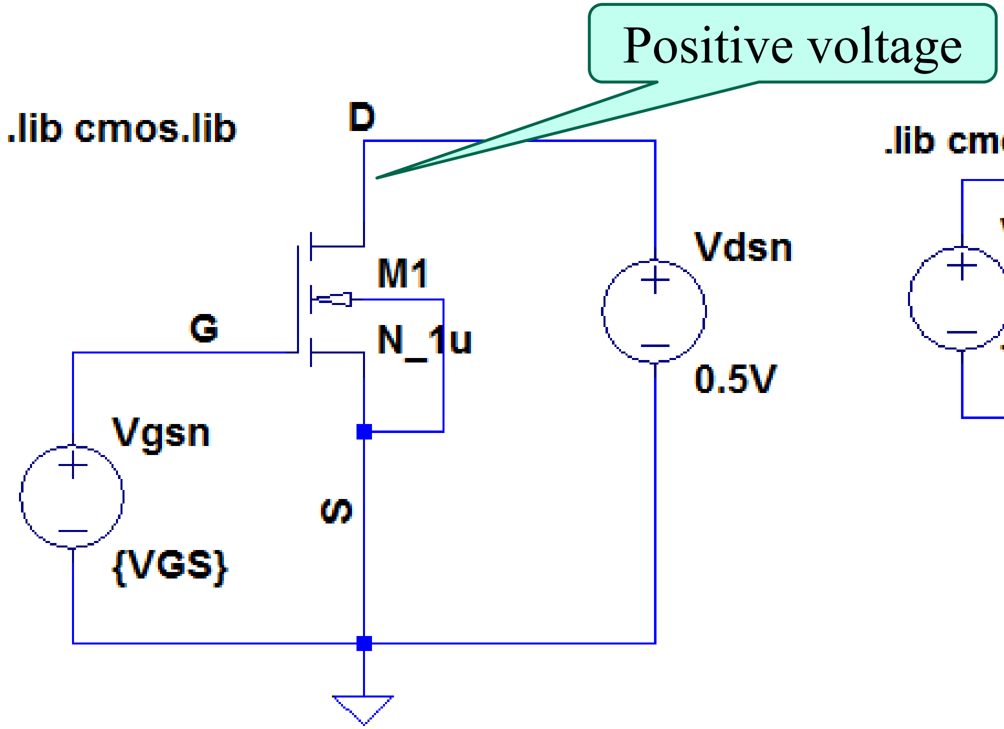
SUMMARY OF MOSFET CHARACTERISTICS

1. DC parameters of MOSFET

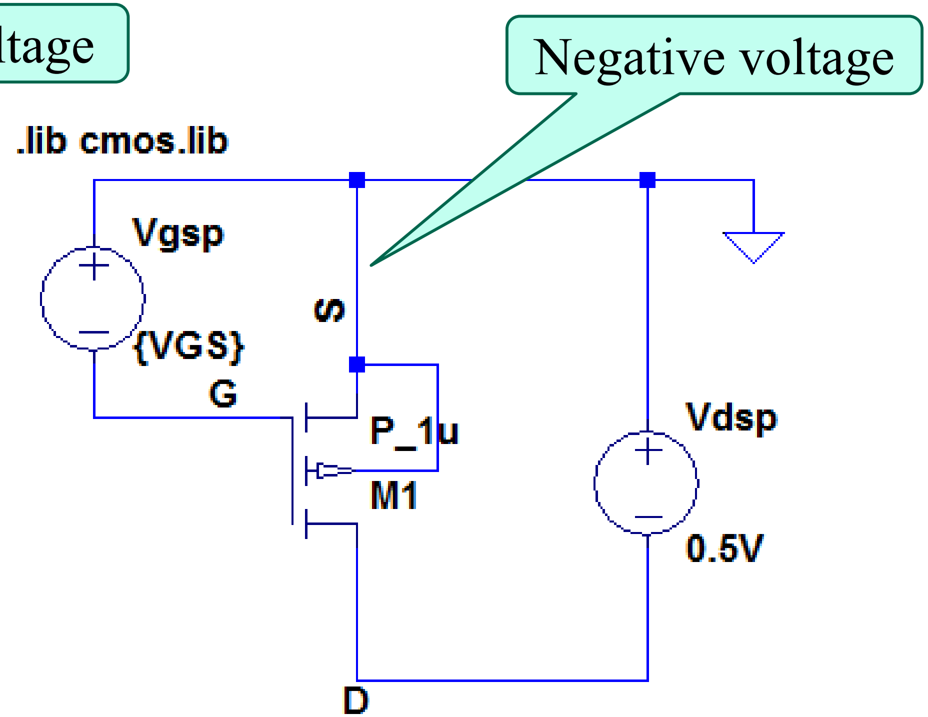
1. Estimate the DC parameters of MOSFET N_1u, P_1u by the circuit simulation.

MOSFET model	*N_1u*	*P_1u*	*Remarks*
L [m]	2u	2u	Gate length
W/L	10	10	Gate width/L
AD [m²]	60p	60p	Area of drain
AS [m²]	60p	60p	Area of source
PD [m]	26u	26u	Periphery of drain
PS [m]	26u	26u	Periphery of source
Multiplier	1	1	Number of fingers
V_{DS} [V]	0 – 5.0	0 – 5.0	
V_{GS} [V]	0 – 5.0	0 – 5.0	
V_T [V]			
$Kp=\mu C_{OX}$ [A/V²]			@ $\Delta_{OV} = 0.2$ [V]
			@ $\Delta_{OV} = 0.4$ [V]
λ [V^{-1}]			@ $\Delta_{OV} = 0.2$ [V]
			@ $\Delta_{OV} = 0.4$ [V]

Measuring circuits

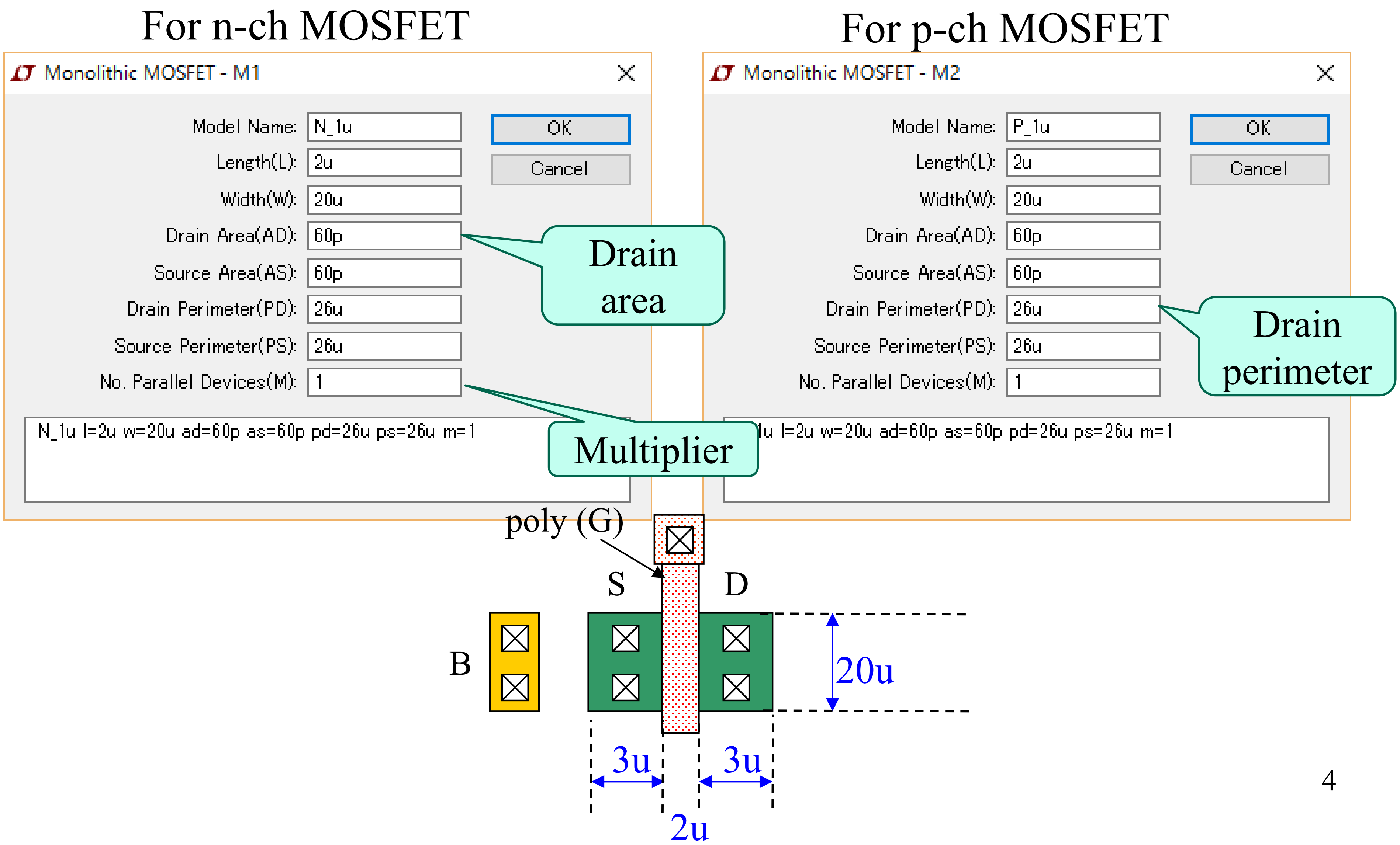


For n-ch MOSFET

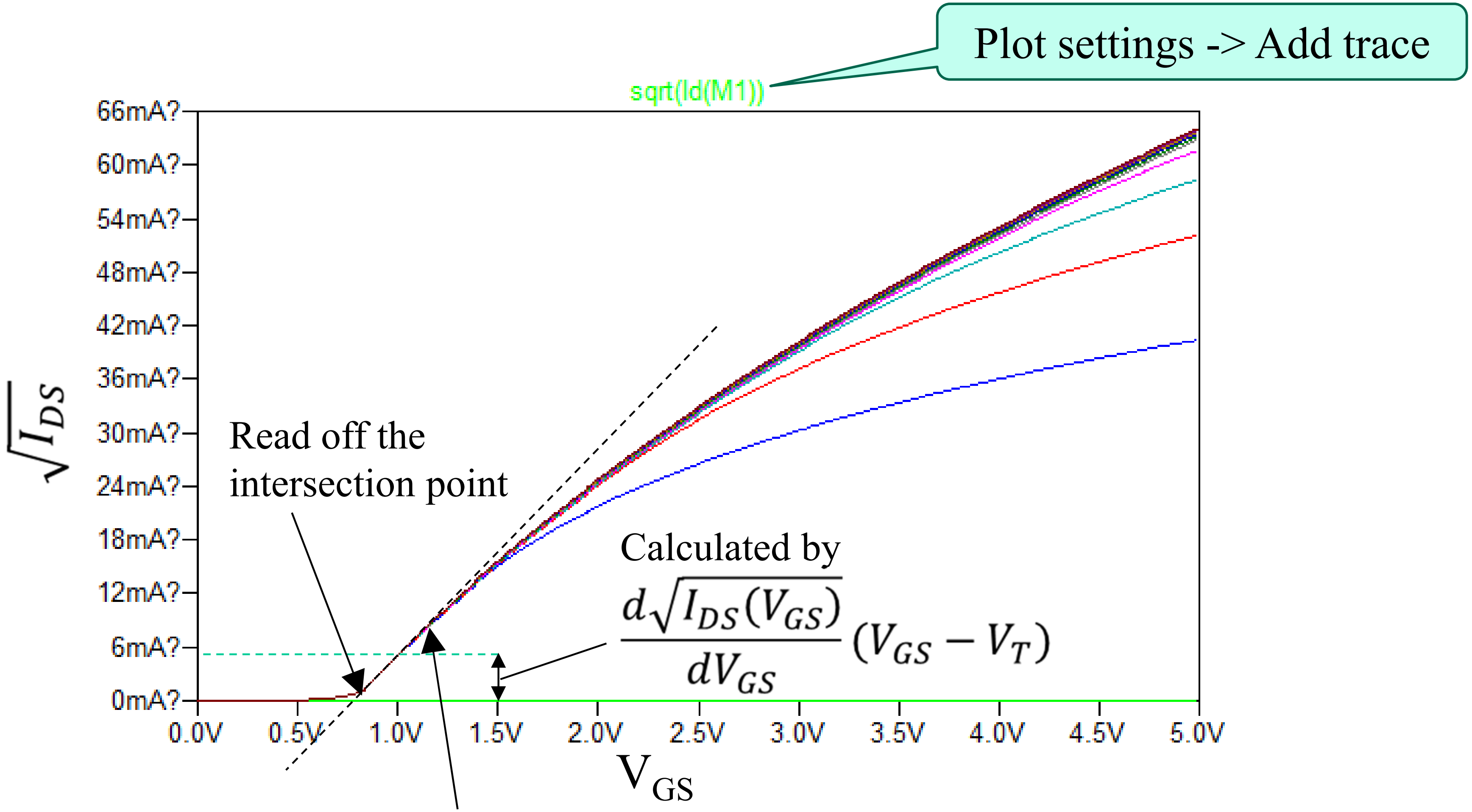


For p-ch MOSFET

MOSFET properties



Estimation of V_T from the plot



Find the linear region in neighborhood of the threshold.

[Note] You can estimate from the VT for $g_m - V_{GS}$ characteristic too.

Estimation of V_T by .meas directive

```
.param VGS=0V

.dc Vgsn 0V 5V 0.001V

.meas dc VTN find V(G)-sqrt(Id(M1))/(d(sqrt(Id(M1)))/d(V(G))) when Vgsn=1.0V
```

- dc: Type of analysis
- VTN: Label of the result
- find: Read command for the expression
- V(G)-sqrt(Id(M1))/(d(sqrt(Id(M1)))/d(V(G))): Expression of V_T (See last slide)
- when Vgsn=1.0V: Measurement condition

- Procedure to read the results
  1. Click the graph window
  2. Menu bar : View – SPICE Error Log
  3. Read the calculation result of VT (V_{dsn} = 0.5V in saturation region)

Estimation of Kp(μC_{OX}) by .meas

```
.param VGS=0V
.param VTN=0.777V
.step param VOV list 0.2V 0.4V
.dc Vgsn 0V 5V 0.001V
.meas dc KP find 2*Id(M1)/10/VOV**2 when Vgsn=VTN+VOV
```

- `.param VTN=0.777V`: Set the parameter V_T at the estimated value
- `.step param VOV list 0.2V 0.4V`: Step the parameter Δ_{ov} at 0.2V and 0.4V
- `2*Id(M1)/10/VOV**2`: Expression of μC_{OX} (See Ch.3)
- `when Vgsn=VTN+VOV`: Measurement condition

Estimation of λ by .meas

```
.param VTN=0.777V

.step param VOV list 0.2V 0.4V

.param VGS=VTN+VOV

.dc Vdsn 0V 5V 0.001V

.meas dc LAMBDA find 1/(Id(M1))*d(Id(M1))/d(V(D)) when Vdsn=VOV
```

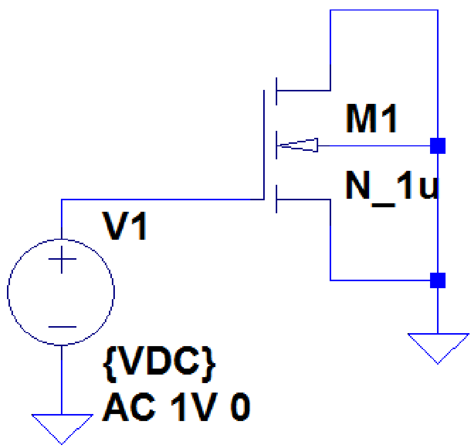
Set the parameter of V_{GS}

Set the measurement condition of $VDS = \Delta_{OV}$

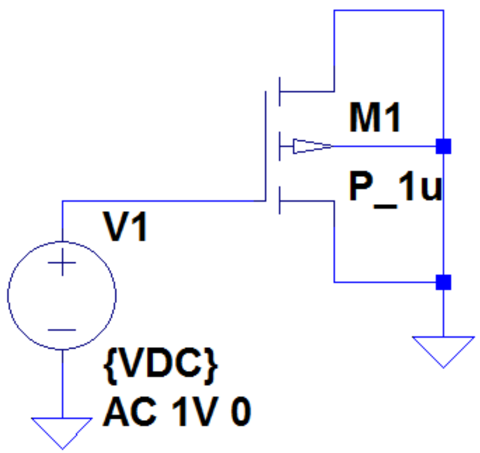
Expression of LAMBDA parameter (See Ch.3)

2. AC parameters of MOSFET

1. Simulate the C-V characteristics of MOSFET N_1u, P_1u with the circuit simulator. Take account of the serial resistance in the C-V measurement circuits. The MOSFET properties are same as the circuit of I-V characteristic (Slide 4).

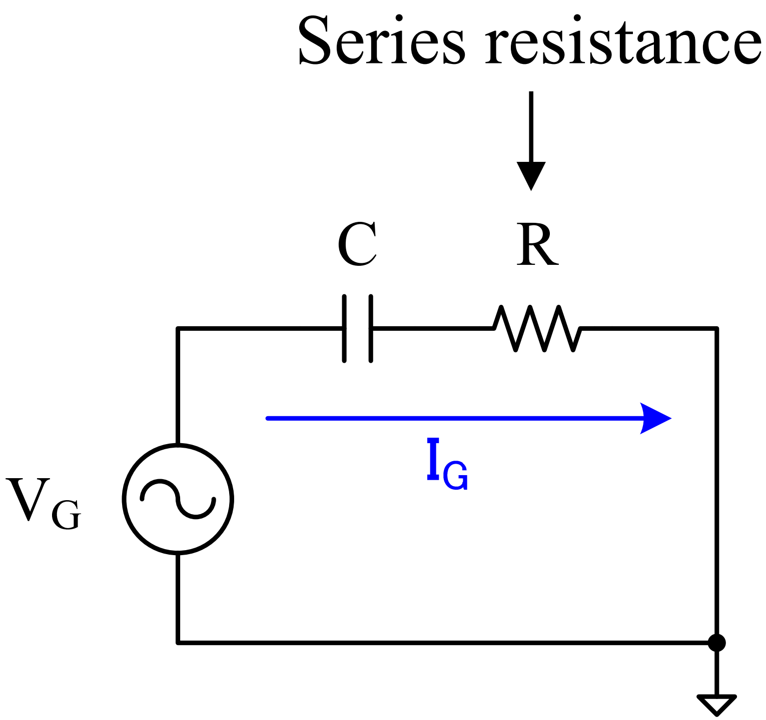


For n-ch MOSFET



For p-ch MOSFET

Cancelation technique of the series resistance



$$V_G = \left(\frac{1}{j\omega C} + R\right)[\mathrm{Re}(I_G) + \mathrm{Im}(I_G)]$$

$$\mathrm{Im}(V_G) = R \cdot \mathrm{Im}(I_G) - \frac{\mathrm{Re}(I_G)}{\omega C} = 0 \quad (1)$$

$$\mathrm{Re}(V_G) = R \cdot \mathrm{Re}(I_G) + \frac{\mathrm{Im}(I_G)}{\omega C} = 1 \quad (2)$$

From Eq.(1), $R = \frac{\mathrm{Re}(I_G)}{\mathrm{Im}(I_G)} \frac{1}{\omega C}$

From Eq.(2), $C = \frac{\mathrm{Im}(I_G)}{\omega}\left(1 + \frac{\mathrm{Re}(I_G)^2}{\mathrm{Im}(I_G)^2}\right)$

Example of .meas directive for the C-V measurement

```
.ac dec 101 1 100MEG
.lib cmos.lib
.step param VDC -1.5V 1.5V 0.01V
.meas ac CGS find
Im(Ig(M1))/(2*pi*frequency)*(1+Re(Ig(M1))**2/Im(Ig(M1))**2)  at 1MEG
```

A small-signal capacitance in semiconductors is defined as an AC property.

Built-in constant of π.

Don't insert a linefeed in the .meas directive.

Measurement frequency. The capacitance in the semiconductor depends on the measurement frequency.