

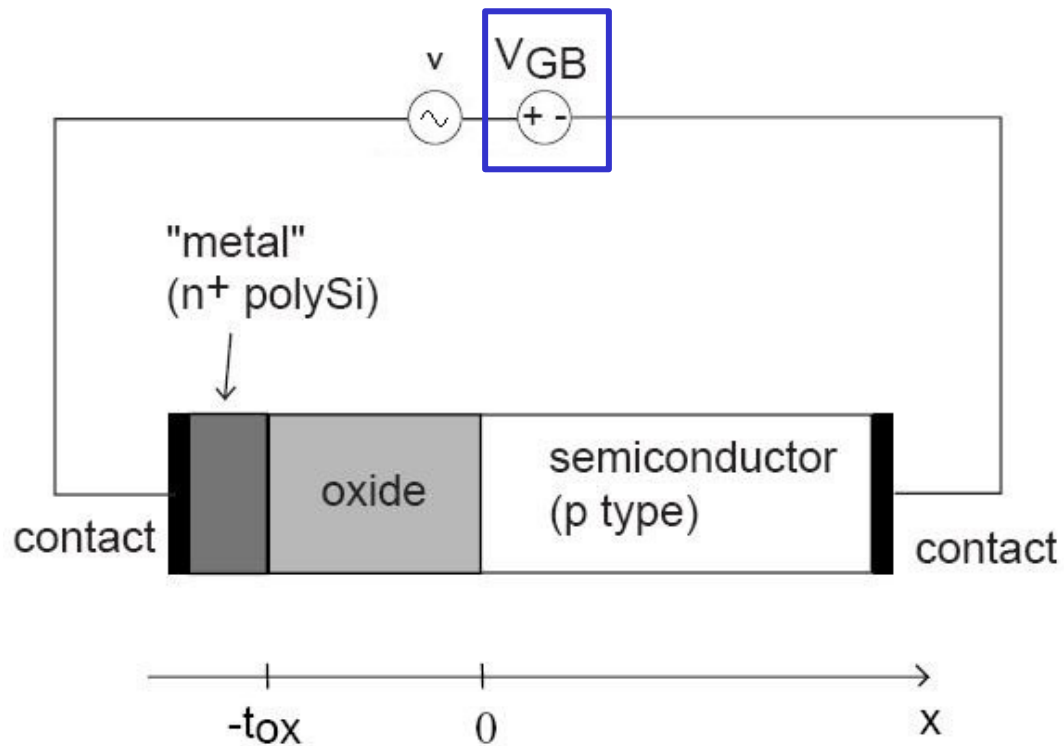
[86.03/66.25] Dispositivos Semiconductores

# Juntura MOS

Curva Capacidad-Tensión

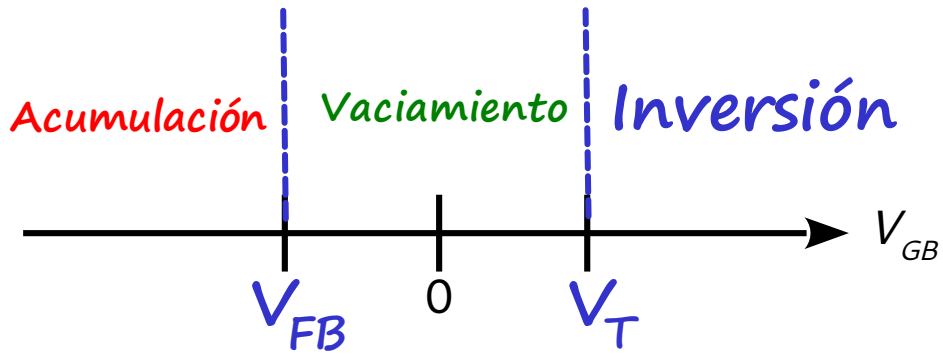
Una estructura MOS con *Gate* de Polisilicio N<sup>++</sup> y sustrato tipo P con densidad de dopantes  $N_A = 10^{17} \text{ cm}^{-3}$  y parámetros  $V_T = 0.547 \text{ V}$ ,  $\Upsilon^2 = 0.545 \text{ V}$  y  $C'_{ox} = 246 \text{ nF/cm}^2$ .

- Hallar la curva de capacidad tensión del dispositivo indicando todos sus valores característicos.



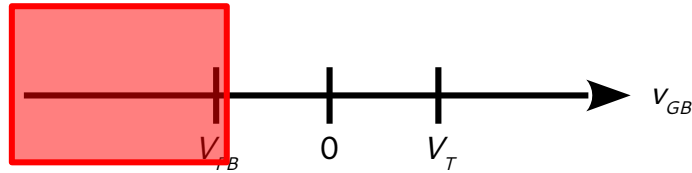
$$C'_{GB} = \left. \frac{\partial Q'(v_{GB})}{\partial v_{GB}} \right|_{v_{GB}}$$

$Q'(v_{GB}) = ??$  *Depende del régimen*



# Acumulación

$$V_{GB} < V_{FB}$$



$$x_d = 0$$

$$Q'_{Bulk} = 0$$

$$Q'_{acum} = -C'_{ox} (V_{GB} - V_{FB}) \longrightarrow C' = C'_{ox}$$



## Datos

Poly-N<sup>++</sup>; Sust-P  
 $N_A = 10^{17} \text{ cm}^{-3}$   
 $V_T = 0.547 \text{ V}$   
 $\gamma^2 = 0.545 \text{ V}$   
 $C'_{ox} = 246 \text{ nF/cm}^2$

## Del ejercicio anterior:

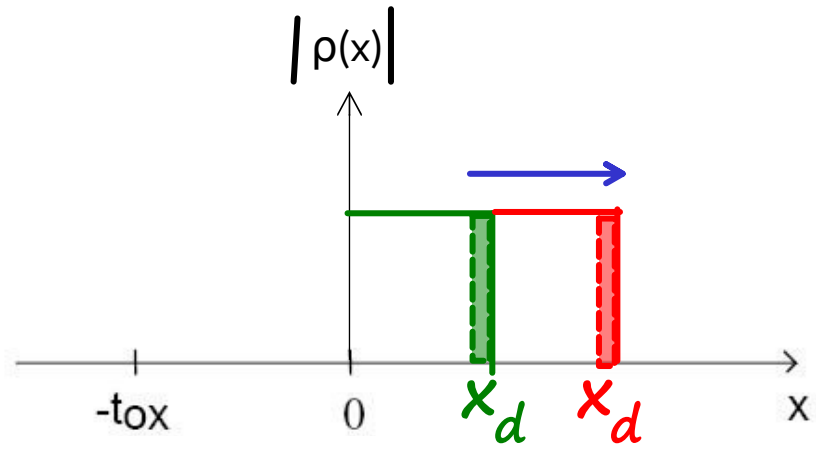
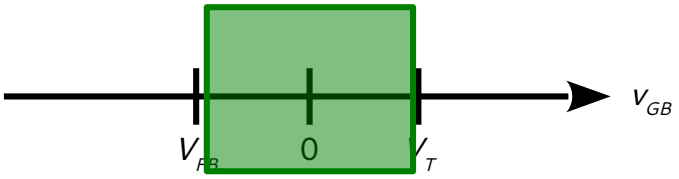
$\phi_{Gate} = -0.42 \text{ V}$   
 $\phi_{Bulk} = -0.42 \text{ V}$   
 $V_{FB} = -0.97 \text{ V}$

# Vaciamiento

**Datos**  
 Poly-N<sup>++</sup>; Sust-P  
 $N_A = 10^{17} \text{ cm}^{-3}$   
 $V_T = 0.547 \text{ V}$   
 $\gamma^2 = 0.545 \text{ V}$   
 $C'_{OX} = 246 \text{ nF/cm}^2$ .

**Del ejercicio anterior:**  
 $\phi_{Gate} = -0.42 \text{ V}$   
 $\phi_{Bulk} = -0.42 \text{ V}$   
 $V_{FB} = -0.97 \text{ V}$

$$V_{FB} < V_{GB} < V_T$$



$$x_d = \frac{\epsilon_{Si}}{C'_{OX}} \left[ \sqrt{1 + \frac{4(\phi_B + V_{GB})}{\gamma^2}} - 1 \right]$$

$$Q'_{Bulk} = -q N_A x_d(V_{GB})$$

$$C'(V_{GB}) = q N_A \frac{\partial x_d}{\partial V_{GB}} = \frac{C'_{OX}}{\sqrt{1 + \frac{4(\phi_B + V_{GB})}{\gamma^2}}}$$

$$C'(V_{GB} = V_{FB}) = C'_{OX}$$

$$C'_0(V_{GB} = 0) = 87.6 \text{ nF/cm}^2$$

$$C'_{min}(V_{GB} = V_T) = 70.9 \text{ nF/cm}^2$$

# Cuentas auxiliares

$$V_{FB} = -\phi_B$$

$$\frac{\partial x_d}{\partial v_{GB}} = \frac{\partial}{\partial v_{GB}} \left[ \frac{\epsilon_{Si}}{C'_{OX}} \left( 1 + \frac{4(\phi_B + v_{GB})^{1/2}}{\gamma^2} \right) \right]$$

$$\frac{\partial x_d}{\partial v_{GB}} = \frac{\epsilon_{Si}}{C'_{OX}} \frac{1}{2} \frac{1}{\left( 1 + \frac{4(\phi_B + v_{GB})^{1/2}}{\gamma^2} \right)^{1/2}} \frac{4}{\gamma^2}$$

$$C'(V_{GB}) = q N_A \frac{\partial x_d}{\partial v_{GB}} = q N_A \frac{\epsilon_{Si}}{C'_{OX}} \frac{2}{\gamma^2} \frac{1}{\left( 1 + \frac{4(\phi_B + v_{GB})^{1/2}}{\gamma^2} \right)^{1/2}}$$

*gamma* 2

$$C'(V_{GB}) = \frac{C'_{OX}}{\sqrt{1 + \frac{4(\phi_B + v_{GB})}{\gamma^2}}}$$

$$C'(V_{GB} = V_{FB}) = \frac{C'_{OX}}{\sqrt{1 + \frac{4(\phi_B + V_{FB})}{\gamma^2}}} = C'_{OX}$$

$$C'_0(V_{GB} = 0) = \frac{C'_{OX}}{\sqrt{1 + \frac{4\phi_B}{\gamma^2}}} = 87.6 \text{ nF/cm}^2$$

$$C'_{min}(V_{GB} = V_T) = \frac{C'_{OX}}{\sqrt{1 + \frac{4(\phi_B + V_T)}{\gamma^2}}} = 70.9 \text{ nF/cm}^2$$

# Cuentas auxiliares

¡¡Otra forma de calcular  $C'_{min}$ !!

$$C'_{Bulk, min} = \frac{\epsilon_{Si}}{x_{d, max}}$$

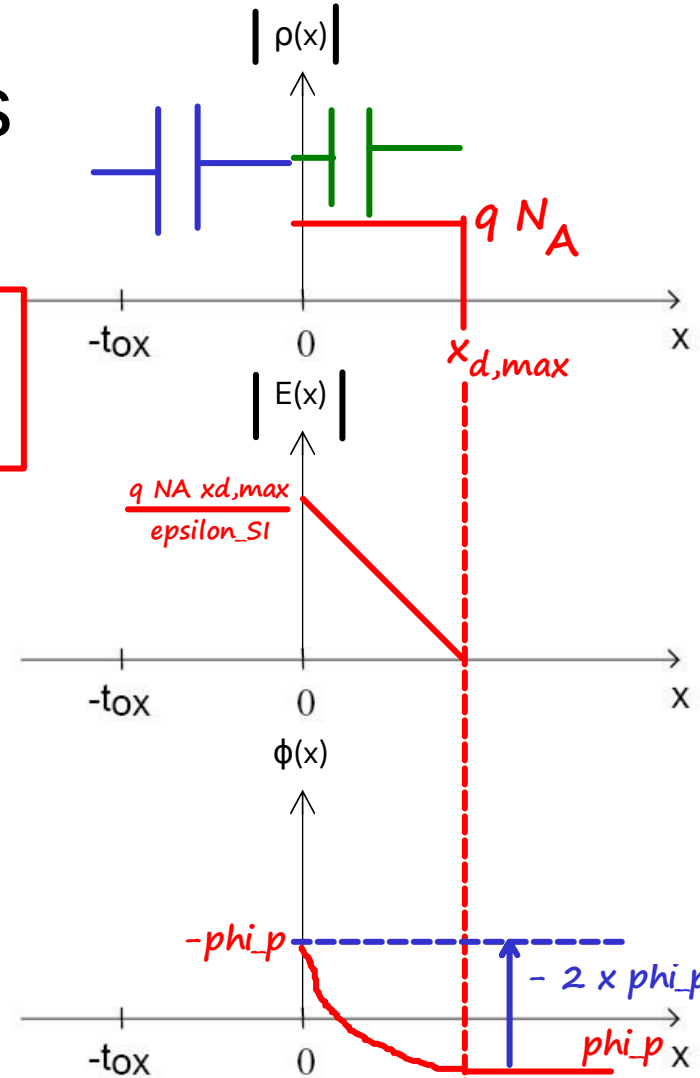
$$-2\phi_{Bulk} = \frac{q N_A x_{d, max}^2}{2 \epsilon_{Si}}$$

$$x_{d, max} = \frac{\epsilon_{Si}}{C'_{OX}} \left[ \sqrt{1 + \frac{4(\phi_B + V_T)}{\gamma^2}} - 1 \right] = 104 \text{ nm}$$

$$x_{d, max} = \sqrt{\frac{-4\phi - B \epsilon_{Si}}{q N_A}}$$

$$C'_{min} = C'_{OX} \text{ en serie } C'_{Bulk, min}$$

$$C'_{min} = \frac{C'_{OX} C'_{Bulk, min}}{C'_{OX} + C'_{Bulk, min}} = 70.9 \text{ nF/cm}^2$$

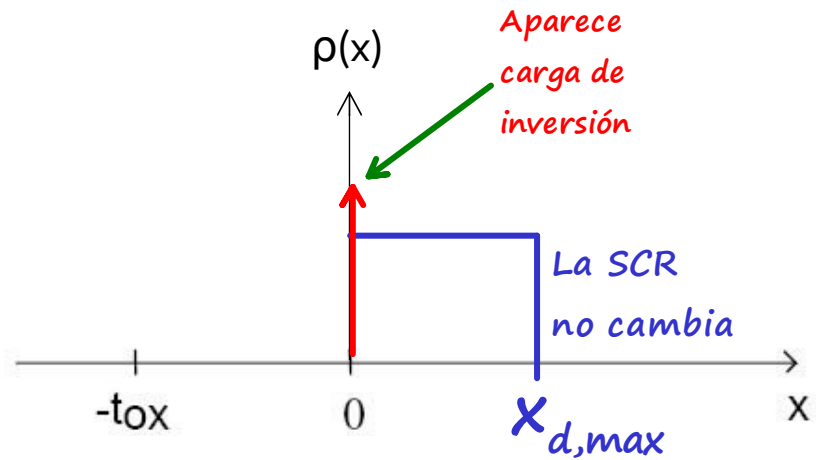
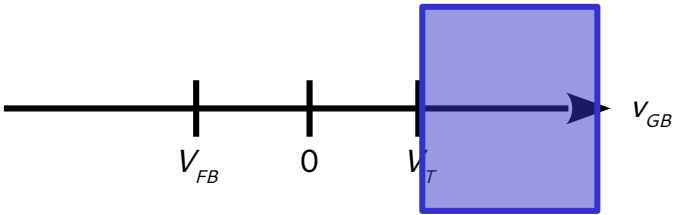


# Inversión

**Datos**  
 Poly-N<sup>++</sup>; Sust-P  
 $N_A = 10^{17} \text{ cm}^{-3}$   
 $V_T = 0.547 \text{ V}$   
 $\gamma^2 = 0.545 \text{ V}$   
 $C_{ox} = 246 \text{ nF/cm}^2$

**Del ejercicio anterior:**  
 $\phi_{Gate} = -0.42 \text{ V}$   
 $\phi_{Bulk} = -0.42 \text{ V}$   
 $V_{FB} = -0.97 \text{ V}$   
 $x_{dmax} = 104 \text{ nm}$

$$V_T < V_{GB}$$



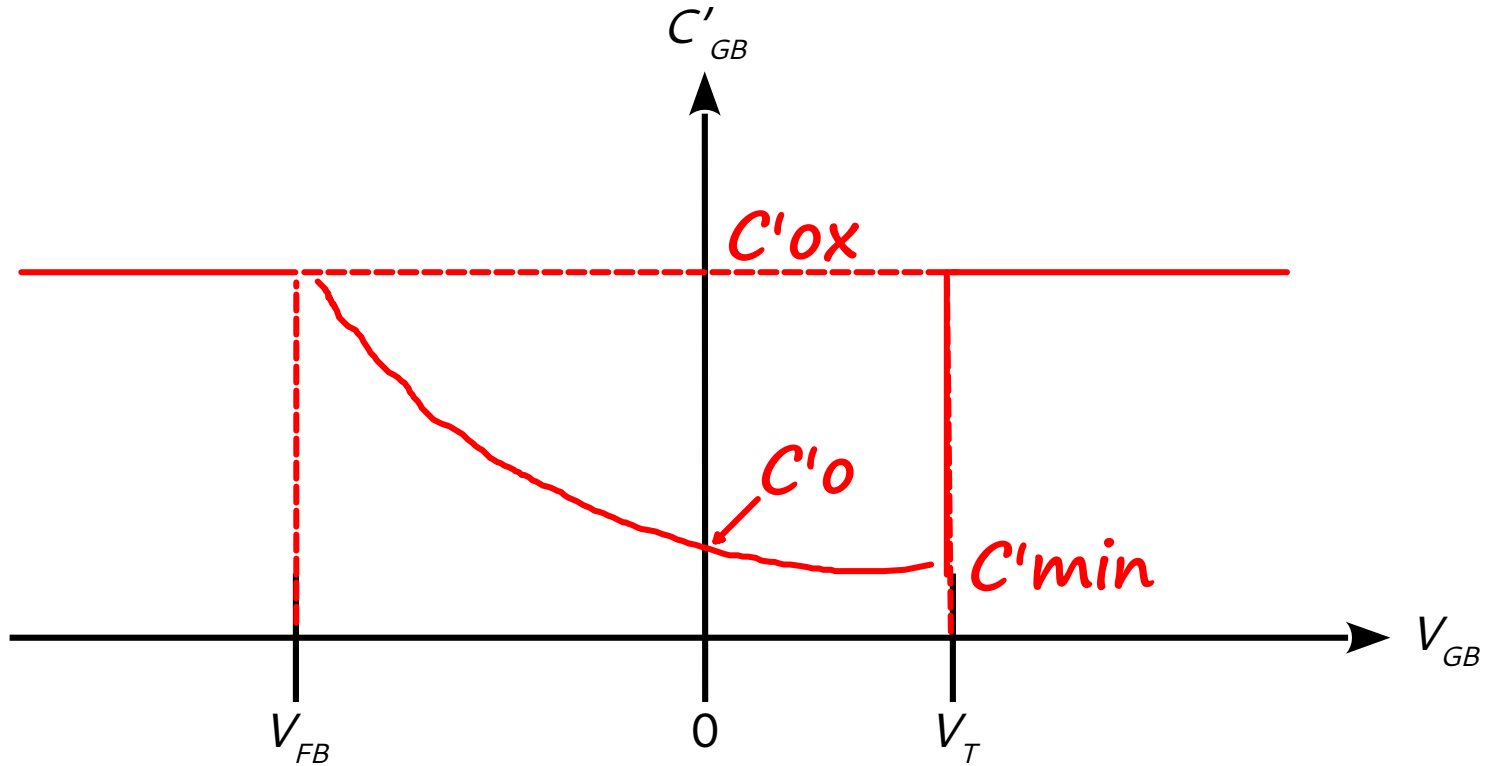
$$x_d = x_{d,max}$$

$$Q'_{Bulk} = -q N_A x_{d,max}$$

$$Q'_{inv} = -C'_{ox} (V_{GB} - V_T)$$

$$C'(V_{GB}) = \frac{\partial Q'_{Bulk}}{\partial V_{GB}} + \frac{\partial Q'_{inv}}{\partial V_{GB}} = C'_{ox}$$

# Gráfico

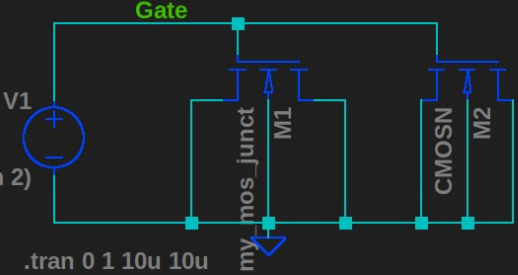




## Bonus: ¿Cómo puedo simular/medir la curva CV?

$$i_C(t) = C \frac{\partial v_C(t)}{\partial t}$$
$$v_C(t) = m t \Rightarrow \frac{\partial v_C(t)}{\partial t} = m = \frac{\Delta V}{\Delta t} \quad [m] = V/s$$
$$\Rightarrow C' = \frac{C}{Area} = \frac{i_C(t) \Delta t}{\Delta V Area}$$

# Bonus: ¿Cómo puedo simular/medir la curva CV?



The circuit diagram shows a pulse source V1 connected to the gate of a MOSFET M1. The drain of M1 is connected to the gate of another MOSFET M2. The source of M2 is connected to ground. A current measurement point 'mv' is placed at the drain of M1. The pulse source is defined as PULSE(-2 1.5 0 1 1 0m 2). The simulation command is .tran 0 1 10u 10u.

```
.MODEL CMOSN NMOS (
+VERSION = 3.1
+XJ = 1.5E-7
+K1 = 0.881737
+K3B = -10.2937044
+DVT0W = 0
+DVT0 = 0.8124251
+U0 = 458.5224758
+UC = 1.084146E-11
+AGS = 0.1183138
+KETA = -4.652199E-3
+RDSW = 1.104981E3
+WR = 1
+XL = 1E-7
+DWB = 9.087096E-9
+CIT = 0
+CDSCB = 0
+DSUB = 0.0630125
+PDIBLC2 = 1.253255E-3
+PSCBE1 = 2.238678E10
+DELTA = 0.01
+PRT = 0
+KT1L = 0
+UB1 = -7.61E-18
+WL = 0
+WWN = 1
+LLN = 1
+LWL = 0
+CF = 0
+PK2 = -0.0630964
+CGDO = 1.83E-10
+CGSO = 1.83E-10
+CGBO = 1E-9
+;+CJ = 4.170522E-4
+;+CJSW = 3.372812E-10
+;+CJSWG = 1.64E-10
+LEVEL = 49
+TNOM = 27
+TOX = 1.403E-8
+NCH = 1E17
+VTH0 = 0.547
+W0 = 1.007228E-8
+W1 = 0.0922905
+W2 = 19.3395825
+NLX = 1.696375E-9
+DVT1W = 0
+DVT1 = 0.3944604
+DVT2 = -0.5
+UA = 5.602831E-13
+UB = 1.485139E-18
+VSAT = 2E5
+A0 = 0.5988247
+B0 = 1.692756E-6
+B1 = 5E-6
+A1 = 0
+A2 = 0.3
+PRWG = 0.0903309
+PRWB = 5.636526E-3
+WINT = 2.336465E-7
+LINT = 8.783866E-8
+DWG = -4.637848E-9
+VOFF = -6.588716E-6
+NFACTOR = 1.2362851
+CDSC = 2.4E-4
+CDSCD = 0
+ETA0 = 3.527811E-3
+ETAB = 4.30528E-3
+PCLM = 2.0164981
+PDIBLC1 = 4.650923E-4
+PDIBLCB = -0.2378438
+DROUT = 5.736575E-4
+PSCBE2 = 4.451843E-9
+PVAG = 9.695046E-3
+RSH = 84.4
+MOBMOD = 1
+UTE = -1.5
+KT1 = -0.11
+UA1 = 4.31E-9
+UC1 = -5.6E-11
+AT = 3.3E4
+WLN = 1
+WW = 0
+WWL = 0
+LL = 0
+LW = 0
+LWN = 1
+CAPMOD = 2
+XPART = 0.5
+PVTH0 = 5.036341E-3
+PRDSW = 356.1146847
+WKETA = -8.454434E-3
+LKETA = -6.040731E-3
+CGDO = 1.83E-10
+CGSO = 1.83E-10
+CGBO = 1E-9
+;+CJ = 4.170522E-4
+;+CJSW = 3.372812E-10
+;+CJSWG = 1.64E-10
+PB = 0.8389423
+MJ = 0.4323873
+PBSW = 0.8
+MJSW = 0.2104244
+PBSWG = 0.8
+MJSWG = 0.2104244
)
```

```
.model my_mos_junct nmos ( level=49
+tox = {3.9*88.5E-15/2.46E-7/100}
+Nch = 1E17
+VTH0 = 0.547
+CAPMOD = 0)
```