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**Exercise 2**

1. The circuit shown in Fig.2.1 illustrates a single-channel MOS resistor with a W/L of 2μm/2μm. Using Table.2.1 model parameters calculate the small-signal on resistance of the MOS transistor at various values for VS and fill in the table below. (Note that the transistor was in linear region, VB=0, IDS=0)

|  |  |
| --- | --- |
| VS(V) | R(Ω) |
| 0.0 |  |
| 1.0 |  |
| 2.0 |  |
| 3.0 |  |
| 4.0 |  |
| 5.0 |  |



Fig.2. 1

***Answer***

The equation for threshold voltage is represented with absolute values so that it can be applied to n-channel or p-channel transistors without confusion.

For n-channel device

1. When ,and
2. When ,and
3. When ,and
4. When ,and
5. When ,and

The device is cutoff, so

1. When ,and

The device is cutoff, so

|  |  |
| --- | --- |
| VS(V) | R(Ω) |
| 0.0 | 1.736K |
| 1.0 | 2.402K |
| 2.0 | 3.806K |
| 3.0 | 8.905K |
| 4.0 | infinity |
| 5.0 | infinity |

1. An NMOS with W=50μm and L=0.5μm operates in the saturated region and its layout is folded shown as Fig2.2. Calculate the all capacitances by using the parameters in Table2.2 and *C*ox=3.8×10-3 F/m, VR=0.6V. Assume that the minimum size (lateral) of S/D region is 1.5μm



Fig.2. 2

***Answer:***

=

1. There is an N-type current source, *I*D is 0.5mA, and the drain-source voltage *V*DS must more than 0.4V when it works as a current source. If the minimum output resistance is 20 KΩ, determine the length and width of the device by using the parameters in Table.2.2.

***Answer:***



From the table2.2, L can be determined as L=0.5um.(

Calculating W



1. A “ring” MOS structure is shown in Fig.2.3. Explain how the device operations and estimate its equivalent aspect ratio. Calculate the drain junction capacitance of the structure. (use Cj and Cjsw)



Fig.2. 3

***Answer:***

Width/length ratio is 4W/L



1. Find the small-signal model (*gm, gmb, gds*) for an n-channel transistor with the drain at 4 V, gate at 4 V, source at 2 V, and the bulk at 0 V. Assume the model parameters from Table.2.1, and *W/L* = 10 μm/1 μm.

**Answer:**

Table.2. 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Typical Parameter Value | | | | |
| Parameter Symbol | Parameter Description | n-Channel | p-Channel | Units |
| VT0 | Threshold voltage(VBS=0) | 0.7 | -0.8 | V |
| K | Transconductance parameter(in saturation) | 134 | 50 | μA/V2 |
| γ | Bulk threshold parameter | 0.45 | 0.4 | V1/2 |
| λ | Channel length modulation parameter | 0.1 | 0.2 | V-1 |
| 2|ϕF| | Surface potential at strong inversion | 0.9 | 0.8 | V |

\*

Table.2.2

|  |  |  |  |
| --- | --- | --- | --- |
| NMOS Model | | | |
| LEVEL=1 | VTO=0.7 | GAMMA=0.45 | PHI=0.9 |
| PSUB=9e+14 | LD=0.08e-6 | UO=350 | LAMBDA=0.1 |
| TOX=9e-9 | PB=0.9 | CJ=0.56e-3 | CJSW=0.35e-11 |
| MJ=0.45 | MJSW=0.2 | CGDO=0.4e-9 | JS=1.0e-8 |
| PMOS Model | | | |
| LEVEL=1 | VTO=-0.8 | GAMMA=0.4 | PHI=0.8 |
| PSUB=5e+14 | LD=0.09e-6 | UO=100 | LAMBDA=0.2 |
| TOX=9e-9 | PB=0.9 | CJ=0.94e-3 | CJSW=0.32e-11 |
| MJ=0.5 | MJSW=0.3 | CGDO=0.3e-9 | JS=0.5e-8 |

上表给出的是0.5μm工艺level 1 MOS SPICE 模型参数的典型值，其中的参数定义如下：

VTO: VSB=0时的阈值电压 （单位：V）

GAMMA: 体效应系数 （单位：V1/2）

PHI: 2ФF （单位：V）

TOX: 栅氧厚度 （单位：m）

NSUB: 衬底掺杂浓度 （单位：cm-3）

LD: 源/漏侧扩散长度 （单位：m）

UO: 沟道迁移率 （单位：cm2/(v/s)）

LAMBDA: 沟道长度调制系数 （单位：V-1）

CJ: 单位面积的源/漏结电容 （单位：F/m2）

CJSW: 单位长度的源/漏侧壁结电容 （单位：F/m）

PB: 源/漏结内建电势 （单位：V）

MJ: CJ公式中的幂指数 （无单位）

MJSW: CJSW等式中的幂指数 （无单位）

CGDO: 单位宽度的栅/漏交叠电容 （单位：F/m）

CGSO: 单位宽度的栅/源交叠电容 （单位：F/m）

JS: 源/漏结单位面积的漏电流 （单位：A/m2）