|  |  |  |
| --- | --- | --- |
| 浙江大学电气工程学院 | **模拟与数模混合集成电路** | 吴晓波，赵梦恋 |
| 2018-2019学年夏学期 | 2019年5月 |

Table 3.1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | 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 |

1. The circuit shown in Figure 3.1 illustrates a single-channel MOS resistor with a W/L of 2μm/2μm. Using Table 3.1 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)

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



Figure 3.1

**Solution:**

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. Suppose the common-source stage of Fig 3.2 is to provide an output swing from 1V to 2.5V. Assume that (W/L)1 = 50/0.5, RD = 2kΩ, VDD = 3V and λ = 0. Use model parameters in Table 3.1.
   1. Calculate the input voltages that yield Vout = 1V and Vout = 2.5V.
   2. Calculate the drain current and the transconductance of M1 for both cases.
   3. How much does the small-signal gain, gmRD, vary as the output goes from 1V to 2.5V?



Figure 3.2

解：

a), b):

Vout=1V时：

Vout=2.5V时：

c)：

1. Consider the circuit of Fig 3.3 with (W/L)1 = 50/0.5 and (W/L)2 = 10/0.5. Assume that λ = γ = 0, VDD = 3V.
   1. At what input voltage is M1 at the edge of the triode region? What is the small-signal gain under this condition?
   2. What input voltage drives M1 into the triode region by 50mV? What is the small-signal gain under this condition?



Figure 3.3

解：

a)

M1在临界点：

解得，此时

b)

由于Vout=0.66V＜0.71V，所以M1工作在三极管区

解得

1. In the circuit of Fig 3.4, (W/L)1 = 20/0.5, I1 = 1mA, and IS = 0.75mA. Assuming λ = 0, VDD = 3V, calculate (W/L)2 such that M1 is at the edge of triode region. What is the small-signal voltage gain under this condition? Use model parameters in Table 3.1.



Figure 3.4

且：

解得：，

所以：

1. Consider the circuit of Fig 3.5 with (W/L)1 = 50/0.5, RD = 2kΩ, and RS = 200Ω, VDD = 3V. Use model parameters in Table 3.1.

(a) Calculatethe small-signal voltage gain if ID = 0.5mA.

(b) Assuming that λ = γ = 0, calculate the input voltage that places M1 at the edge of the triode region. What is the gain under this condition?



Figure 3.5

解：

a)：

b):

M1在临界点，所以

所以

解得（此时VGS＜VTH，舍去），