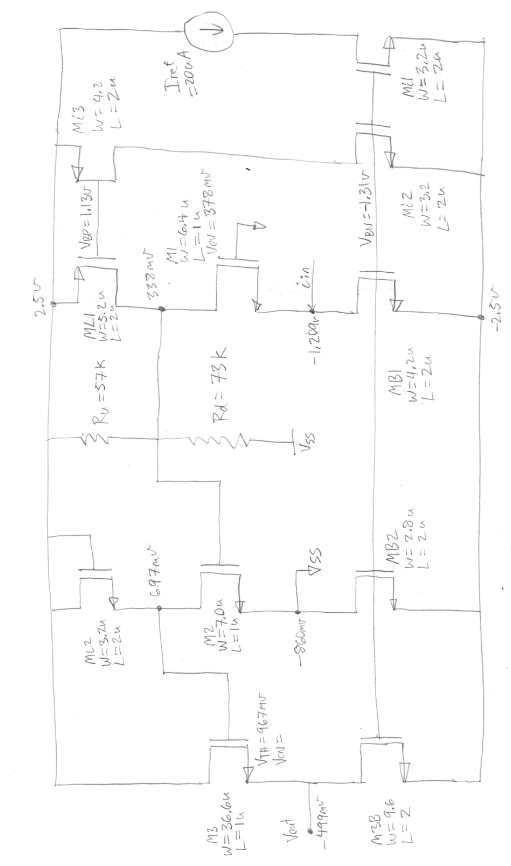
Introduction

|  |  |
| --- | --- |
| **Parameter** | **Specification** |
| Operating temperature | 25 °C |
| VDD / VSS | ±2.5 V |
| RIN half circuit | Inf |
| CIN half-circuit | 100 fF |
| ROUT half circuit | 10 kΩ |
| COUT half-circuit | 500 fF |

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Specification** | **Design Performance** | **agreement** |
| CM output voltage | ±0.5 V | -0.499 V | Meets spec |
| Power dissipation | ≤2 mW | 1.59 mW | Meets spec |
| Small-signal transresistance gain | ≥40 kΩ | 40.07 | Meets spec |
| Freq resp characteristics | 1 domant pole | Some room for improvement | Not quite |
| -3 dB bandwidth | ≥75 MHz | 76.9 MHz | Meets spec |
| Figure of Merit FOM | ≥(40 x 75)/2 = 1,500 kΩ MHz/mW | 1939 | Meets spec |
| **Additional Design Parameters** | **Specification** | **Design performance** | **agreement** |
| L current mirror | ≥ 2 um | L = 2u for current mirrors | Meet spec |
| Vov,min | 150 mV | Vov’s > 0.2v | Meets spec |
| Size increments | 0.2 um | yes | Meets spec |
| Max current mirror ratio | 20 | 3.1 | Meets spec |

|  |  |
| --- | --- |
| Vov\_1 | 0.378 |
| Vov\_2 | 0.297 |
| Vov\_3 | 0.229 |
| Vov\_N | 0.687 |
| Vov\_P | 0.870 |
| Ru | 57 |
| Rd | 73 |
| Id\_1 | 26u |
| Id\_2 | 18u |
| Id\_3 | 62u |
| ratio\_1 | 0.42 |
| ratio\_2 | 0.20 |

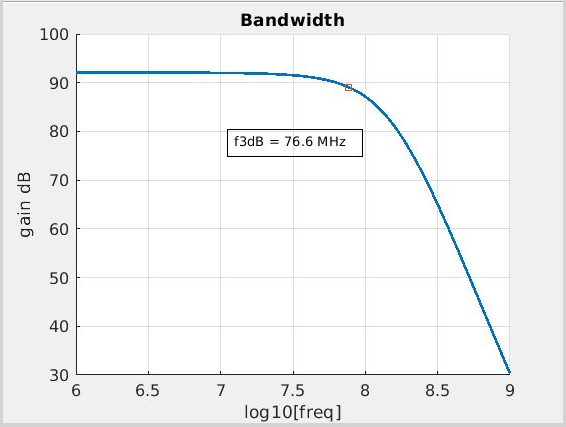


|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **mosfets:** | **M1L** | **M1** | **M1B** | **M2L** | **M2** | **M2B** | **M3** | **M3B** | **Mi1** | **Mi2** | **Mi3** |
| Vov [V] | 0.9 | 0.4 | 0.7 | 0.61 | 0.3 | 0.7 | 0.23 | 0.7 | 0.7 | 0.7 | 0.9 |
| Id [uA] | 25.07 | 25.07 | 25.07 | 21.19 | 21.19 | 21.19 | 59.68 | 59.68 | 10 | 10 | 10 |
| WL | 2.48 | 6.27 | 2.05 | 2.26 | 9.42 | 1.73 | 45.13 | 4.87 | 0.82 | 0.82 | 0.99 |
| W [um] | 4.95 | 6.27 | 4.09 | 4.51 | 9.42 | 3.46 | 45.13 | 9.74 | 1.63 | 1.63 | 1.98 |
| L [um] | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 |
| gm [A/V] | 0.06 | 0.13 | 0.07 | 0.07 | 0.14 | 0.06 | 0.52 | 0.17 | 0.03 | 0.03 | 0.02 |
| gmp [A/V] | 0.07 | 0.15 | 0.09 | 0.08 | 0.17 | 0.07 | 0.62 | 0.2 | 0.03 | 0.03 | 0.03 |
| ro [kohms] | 398.93 | 398.93 | 398.93 | 471.98 | 471.98 | 471.98 | 167.55 | 167.55 | 1000 | 1000 | 1000 |
| cgs [fF] | 17.66 | 12.74 | 14.6 | 16.09 | 19.14 | 12.34 | 91.75 | 34.76 | 5.82 | 5.82 | 7.05 |
| cgd [fF] | 2.52 | 3.16 | 2.08 | 2.3 | 4.76 | 1.76 | 22.79 | 4.96 | 0.83 | 0.83 | 1.01 |
| csb [fF] | 8.29 | 8.01 | 6.27 | 6.61 | 10.53 | 5.77 | 39.1 | 10.8 | 4.31 | 4.31 | 4.57 |
| cdb [fF] | 5.58 | 5.65 | 4.46 | 4.69 | 7.4 | 4.11 | 27.14 | 7.58 | 3.1 | 3.1 | 3.15 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | CG | CS | CD |
| |Gain| | 30.77 [kV/A] | -1.70 [V/V] | 0.71 [V/V] |
| Rin | 7.14 | inf | Inf |
| Rout | 30.77 | 11.47 | 1.36 |
| Cin | 127 | 32 | 23 |
| Cout | 17 | 38 | 552 |

|  |  |
| --- | --- |
| Python simulated bandwidth | Pole freq [MHz] |
| P1 | 175 |
| P2 | 106 |
| P3 | 230 |
| P4 | 212 |
| f3dB | 75.5 |

Hspice simulated bandwidth



|  |  |
| --- | --- |
| **Common Gain** | |
|  |  |
| Common Source | |
| Common Drain | |

|  |  |  |
| --- | --- | --- |
| **stage** | **DC gain** | **units** |
| CG | ro1||RU||RD | V/A |
| CS | -0.84\*Vov2L/Vov2 | V/V |
| CD | gm3 RCD,OUT | V/V |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Req** | | | | | **Approximate** |
| RIN | | R1 | inf |  | |
| CG | RCG,IN | (ro1 + 2RU||RD) / gm1’(ro + RU||RD) | 1 / gm1’ | |
| RCG,OUT | R2 | ro1||RU||RD | RU||RD | |
| CS | RCS,IN | Inf | Inf | |
| RCS,OUT | R3 | 0.5ro2 / (1 + 0.5gm2L’ro2) | 1 / gm2L | |
| CD | RCD,IN | Inf |  | |
| RCD,OUT | R4 | (1 / gm3’) || 0.5 ro3 || ROUT | 1 / gm3’ | |
| ROUT | | 10 kΩ |  | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Ceq** | | | | |
| CIN | | C1 | 100 fF |  |
| CG | CCG,IN | Cgs1 + Csb1 | Cgs1 + Csb1 + Cgd1B + Cdb1B |
| CCG,OUT | C2 | Cgd1 + Cdb1 | Cgd1 + Cdb1 + Cgd1L + Cdb1L |
| CS | CCS,IN | Cgs2 + (1+A1)Cgd2 | Cgs2 + (1+A1)Cgd2 |
| CCS,OUT | C3 | (1+1/A1)Cgd2 + Cdb2 + Csb2L + Cgs2L |  |
| CD | CCD,IN | Cgd3 + (1+A2)Cgs3 |  |
| CCD,OUT | C4 | (1+1/A2)Cgs3+ Csb3 + Cgd3B + Cdb3B + COUT |  |
| COUT | | 500 fF |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **A** | **equation** | **pole location** | **gain** |
| i1/iin | 1 / (1+sR1C1) | P2 = -1 / R1C1 | 1 |
| v1/i1 | RCG,OUT / (1+sR2C2) | P2 = -1 / R2C2 | RCG,OUT |
| v2/v1 | -A1 / (1+sR3C3) | P3 = -1 / R3C3 | 0.84\*Vov2L/Vov2 |
| vo/v2 | -A2 / (1+sR4C4) | P4 = -1 / R4C4 | gm3 R4/(1+gm3 R4) |

|  |  |
| --- | --- |
| **Stage** | **Input variables** |
| CG | Vov1 |
| ID1 |
| RU||RD |
| CS | Vov2 |
| ID2 |
| A1 |
| CD | Vov3 |
| ID3 |

|  |  |
| --- | --- |
| **Power Consumption** | |
| VSUPPLY | VDD - VSS |
| Power I\_ref | I\_ref\*VSUPPLY |
| Power Resistor | 2\*(RU + RD)\*VSUPPLY |
| ID,Total | 2\*(ID1 + ID2 + ID2) |
| ratio\_1 | ID1 / ID3 |
| ratio\_2 | ID2 / ID,Total |
| ID1 | ID,Total [ (ratio\_1)\*(1 - ratio\_2) ] / [ 1 + ratio\_1 ] |
| ID2 | ID,Total ratio\_2 |
| ID3 | ID,Total [ (1 – ratio\_2) / (1 + ratio\_1) ] |
| RL,CG | RU||RD |
| RU | RL,CG ( 5 / (2.5+V1) ) |
| RD | RL,CG ( 5 / (2.5 -V1) ) |

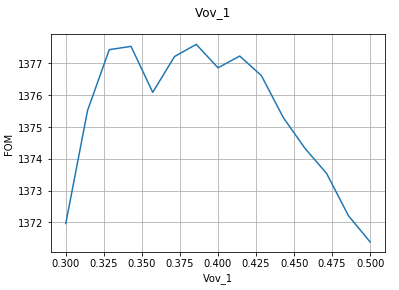
|  |  |
| --- | --- |
| **Pole Locations** | |
| P1 |  |
| Vov1 |  |
| Vov1 |  |
| Id\_1 |  |
| Id\_2 |  |
| Id\_3 |  |
| A2 = (VovL2 / Vov2) |  |
| R = RU||RD |  |

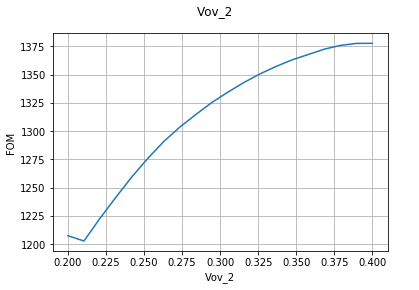
|  |  |  |
| --- | --- | --- |
| **Equations** | | |
| 1/gmL2 | VovL2/(2Id) | (A2\*Vov2)/(2Id) |
| Vov1 |  |  |
| Vov1 |  |  |
| Id\_1 |  |  |
| Id\_2 |  |  |
| Id\_3 |  |  |
| A2 = (VovL2 / Vov2) |  |  |
| R = RU||RD |  |  |

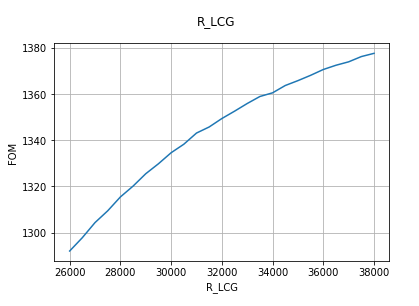
|  |  |
| --- | --- |
| **HSpice .op outputs** | |
| cgs | Cgs |
| cgd | Cgd |
| cgtot | Cgs + Cgd + Cgb |
| cdtot | Cgd + Cdb |
| cstot | Cgs + Csb |
| cbtot | Cgb + Csb +Cdb |
| **Other way** | |
| Cgs | cgs |
| Cgd | cgd |
| Cgb | cgtot – cgs – cgd |
| Csb | cstot – cgs |
| Cdb | cdtot – cgd |
| **Linear equivalences** | |
| Cdb / Cgs | 0.33 |
| Cgd / Cgs | 0.25 |
| gmb /gm | 0.2 |

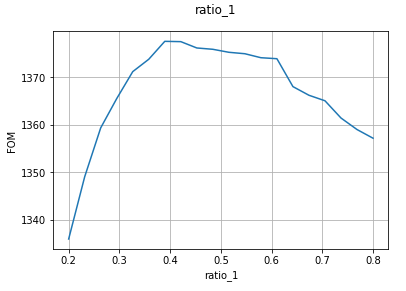
Common Drain:

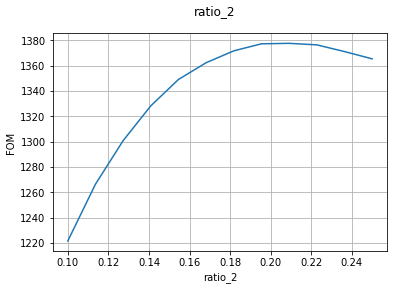
|  |
| --- |
|  |
|  |
|  |

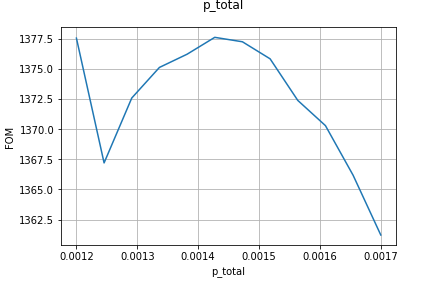












Appendix Caps

Example Hspice code for capacitance characterization of a single mosfet

Hspice netlist for capacitance lookup

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_nmos test netlist:

\* single device characteristics

.include /afs/ir.stanford.edu/class/ee114/hspice/ee114\_hspice.sp

\* MOSFETS

M1 2 1 0 0 nmos114 w=100u l=1u

Vg 1 0 0.9v

Vdd 2 0 5v

.op

.end

pmos test netlist:

\* single device characteristics

.include /afs/ir.stanford.edu/class/ee114/hspice/ee114\_hspice.sp

\* MOSFETS

M1 2 1 0 0 pmos114 w=2u l=1u

Vg 1 0 -0.9v

Vdd 2 0 -0.5v

.op

.end

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Nmos L=1u

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| W [um] | 2 | 5 | 10 | 20 | 50 | 100 |
| cdtot [fF] | 3.45 | 6.18 | 10.72 | 19.80 | 47.04 | 92.45 |
| cgtot [fF] | 5.17 | 12.92 | 25.85 | 51.70 | 129.24 | 258.48 |
| cstot [fF] | 8.67 | 17.17 | 31.33 | 59.67 | 144.67 | 286.33 |
| cbtot [fF] | 7.10 | 10.78 | 16.93 | 29.22 | 66.08 | 127.53 |
| cgs [fF] | 4.07 | 10.17 | 20.33 | 40.67 | 101.67 | 203.33 |
| cgd [fF] | 1.03 | 2.58 | 5.15 | 10.31 | 25.77 | 51.53 |
| cgb [fF] | 0.07 | 0.18 | 0.36 | 0.72 | 1.81 | 3.61 |
| csb [fF] | 4.60 | 7.00 | 11.00 | 19.00 | 43.00 | 83.00 |
| cdb [fF] | 2.42 | 3.60 | 5.57 | 9.49 | 21.28 | 40.92 |
| cgs\_calc | 3.07 | 7.67 | 15.33 | 30.67 | 76.67 | 153.33 |

|  |  |  |
| --- | --- | --- |
|  | x | y |
| cgs | 2.033 | 0 |
| cgd | 0.515 | 0 |
| cgb | 0.036 | 0 |
| csb | 0.8 | 3 |
| cdb | 0.393 | 1.637 |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Nmos L=2u

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| W [um] | 2 | 5 | 10 | 20 | 50 | 100 |
| cdtot [fF] | 3.48 | 6.25 | 10.87 | 20.11 | 47.81 | 93.98 |
| cgtot [fF] | 8.34 | 20.85 | 41.70 | 83.39 | 208.48 | 416.96 |
| cstot [fF] | 11.73 | 24.83 | 46.67 | 90.33 | 221.33 | 439.67 |
| cbtot [fF] | 7.17 | 10.96 | 17.29 | 29.94 | 67.89 | 131.14 |
| cgs [fF] | 7.13 | 17.83 | 35.67 | 71.33 | 178.33 | 356.67 |
| cgd [fF] | 1.06 | 2.65 | 5.31 | 10.61 | 26.53 | 53.07 |
| cgb [fF] | 0.14 | 0.36 | 0.72 | 1.44 | 3.61 | 7.22 |
| csb [fF] | 4.60 | 7.00 | 11.00 | 19.00 | 43.00 | 83.00 |
| cdb [fF] | 2.42 | 3.60 | 5.57 | 9.49 | 21.28 | 40.92 |
| cgs\_calc | 6.13 | 15.33 | 30.67 | 61.33 | 153.33 | 306.67 |

|  |  |  |
| --- | --- | --- |
|  | x | y |
| cgs | 3.567 | 0 |
| cgd | 0.531 | 0 |
| cgb | 0.072 | 0 |
| csb | 0.8 | 3 |
| cdb | 0.393 | 1.638 |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Pmos L=1u

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| W [um] | 2 | 5 | 10 | 20 | 50 | 100 |
| cdtot [fF] | 4.90 | 9.50 | 17.17 | 32.52 | 78.55 | 155.27 |
| cgtot [fF] | 5.12 | 12.81 | 25.62 | 51.25 | 128.12 | 256.24 |
| cstot [fF] | 8.67 | 18.52 | 34.93 | 67.77 | 166.27 | 330.43 |
| cbtot [fF] | 8.55 | 15.48 | 27.03 | 50.13 | 119.45 | 234.97 |
| cgs [fF] | 4.07 | 10.17 | 20.33 | 40.67 | 101.67 | 203.33 |
| cgd [fF] | 1.00 | 2.51 | 5.02 | 10.03 | 25.08 | 50.15 |
| cgb [fF] | 0.05 | 0.14 | 0.28 | 0.55 | 1.38 | 2.75 |
| csb [fF] | 4.60 | 8.35 | 14.60 | 27.10 | 64.60 | 127.10 |
| cdb [fF] | 3.89 | 6.99 | 12.16 | 22.48 | 53.47 | 105.12 |
| cgs\_calc | 3.07 | 7.67 | 15.33 | 30.67 | 76.67 | 153.33 |

|  |  |  |
| --- | --- | --- |
|  | x | y |
| cgs | 2.033 | 0 |
| cgd | 0.502 | 0 |
| cgb | 0.028 | 0 |
| csb | 1.25 | 2.1 |
| cdb | 1.033 | 1.826 |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Pmos L=2u

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| W [um] | 2 | 5 | 10 | 20 | 50 | 100 |
| cdtot [fF] | 4.90 | 9.51 | 17.19 | 32.55 | 78.62 | 155.42 |
| cgtot [fF] | 8.25 | 20.62 | 41.25 | 82.50 | 206.24 | 412.48 |
| cstot [fF] | 11.73 | 26.18 | 50.27 | 98.43 | 242.93 | 483.77 |
| cbtot [fF] | 8.60 | 15.62 | 27.31 | 50.68 | 120.82 | 237.72 |
| cgs [fF] | 7.13 | 17.83 | 35.67 | 71.33 | 178.33 | 356.67 |
| cgd [fF] | 1.01 | 2.52 | 5.03 | 10.06 | 25.15 | 50.31 |
| cgb [fF] | 0.11 | 0.28 | 0.55 | 1.10 | 2.75 | 5.50 |
| csb [fF] | 4.60 | 8.35 | 14.60 | 27.10 | 64.60 | 127.10 |
| cdb [fF] | 3.89 | 6.99 | 12.16 | 22.48 | 53.47 | 105.12 |
| cgs\_calc | 6.13 | 15.33 | 30.67 | 61.33 | 153.33 | 306.67 |

|  |  |  |
| --- | --- | --- |
|  | x | y |
| cgs | 3.567 | 0 |
| cgd | 0.503 | 0 |
| cgb | 0.055 | 0 |
| csb | 1.25 | 2.1 |
| cdb | 1.033 | 1.826 |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Limitations to the parasitic capacitance model:

|  |  |  |  |
| --- | --- | --- | --- |
| Vds | 5.0v | 1.0v | % difference |
| cgs | 66.33 | 66.33 | 0.00 |
| cgd | 5.61 | 5.12 | -9.58 |
| cgb | 1.10 | 1.10 | 0.00 |
| csb | 11.00 | 11.00 | 0.00 |
| cdb | 5.57 | 8.40 | 33.78 |

Cdb as well as Cgd are functions of Vds which is not taken into account in this model.

