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# APPENDIX D: Binning BSIM3v3 Parameters

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Below is a list of all BSIM3v3 model parameters which can or cannot be binned. All model parameters which can be binned follow the following implementation:

$$P = P_0 + \frac{P_L}{L_{eff}} + \frac{P_W}{W_{eff}} + \frac{P_p}{L_{eff} \times W_{eff}}$$

For example, for the parameter k1:  $P_0=k1$ ,  $P_L=lk1$ ,  $P_W=wk1$ ,  $P_p=pk1$ . Binunit is a bin unit selector. If binunit=1, the units of  $L_{eff}$  and  $W_{eff}$  used in the binning equation above have the units of microns. Otherwise, they are in meters.

For example, for a device with  $L_{eff}=0.5\mu\text{m}$  and  $W_{eff}=10\mu\text{m}$ . If binunit = 1, the parameter values for vsat are 1e5, 1e4, 2e4, and 3e4 for vsat, lvsat, wvsat, and pvsat, respectively. Therefore, the effective value of vsat for this device is:

$$vsat = 1e5 + 1e4/0.5 + 2e4/10 + 3e4/(0.5*10) = 1.28e5$$

To get the same effective value of vsat for binunit = 0, the values of vsat, lvsat, wvsat, and pvsat would be 1e5, 1e-2, 2e-2, 3e-8, respectively. Thus,

$$vsat = 1e5 + 1e-2/0.5e6 + 2e-2/10e-6 + 3e-8/(0.5e-6 * 10e-6) = 1.28e5$$

As a final note: although BSIM3v3 supports binning as an option for model extraction, it is not strongly recommended.

## D.1 BSIM3v3 Model Control Parameters

| Symbols used in equation | Symbols used in SPICE | Description                                  | Can Be Binned? |
|--------------------------|-----------------------|--|----------------|
| none                     | level                 | BSIMv3 model selector                        | NO             |
| Mobmod                   | mobmod                | Mobility model selector                      | NO             |
| Capmod                   | capmod                | Flag for the short channel capacitance model | NO             |
| Nqsmod                   | nqsmod                | Flag for NQS model                           | NO             |
| Noimod                   | noimod                | Flag for Noise model                         | NO             |

## D.2 DC Parameters

| Symbols used in equation | Symbols used in SPICE | Description                           | Can Be Binned? |
|--------------------------|-----------------------|---------------------------------------|----------------|
| Vth0                     | vth0                  | Threshold voltage @Vbs=0 for Large L. | YES            |
| K1                       | k1                    | First order body effect coefficient   | YES            |
| K2                       | k2                    | Second order body effect coefficient  | YES            |
| K3                       | k3                    | Narrow width coefficient              | YES            |
| K3b                      | k3b                   | Body effect coefficient of k3         | YES            |
| W0                       | w0                    | Narrow width parameter                | YES            |
| Nlx                      | nlx                   | Lateral non-uniform doping parameter  | YES            |

## DC Parameters

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| Symbols used in equation | Symbols used in SPICE | Description  | Can Be Binned? |
|--------------------------|-----------------------|--|----------------|
| Dvt0                     | dvt0                  | first coefficient of short-channel effect on $V_{th}$                          | YES            |
| Dvt1                     | dvt1                  | Second coefficient of short-channel effect on $V_{th}$                         | YES            |
| Dvt2                     | dvt2                  | Body-bias coefficient of short-channel effect on $V_{th}$                      | YES            |
| Dvt0w                    | dvt0w                 | First coefficient of narrow width effect on $V_{th}$ for small channel length  | YES            |
| Dvt1w                    | dvt1w                 | Second coefficient of narrow width effect on $V_{th}$ for small channel length | YES            |
| Dvt2w                    | dvt2w                 | Body-bias coefficient of narrow width effect for small channel length          | YES            |
| $\mu_0$                  | u0                    | Mobility at Temp = $T_{nom}$<br>NMOSFET<br>PMOSFET                             | YES            |
| Ua                       | ua                    | First-order mobility degradation coefficient                                   | YES            |
| Ub                       | ub                    | Second-order mobility degradation coefficient                                  | YES            |
| Uc                       | uc                    | Body-effect of mobility degradation coefficient                                | YES            |
| vsat                     | vsat                  | Saturation velocity at Temp = $T_{nom}$  | YES            |
| A0                       | a0                    | Bulk charge effect coefficient for channel length                              | YES            |

## DC Parameters

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| Symbols used in equation | Symbols used in SPICE | Description   | Can Be Binned? |
|--------------------------|-----------------------|---|----------------|
| Ags                      | ags                   | gate bias coefficient of Abulk                              | YES            |
| B0                       | b0                    | Bulk charge effect coefficient for channel width            | YES            |
| B1                       | b1                    | Bulk charge effect width offset                             | YES            |
| Keta                     | keta                  | Body-bias coefficient of bulk charge effect                 | YES            |
| A1                       | a1                    | First non0saturation effect parameter                       | YES            |
| A2                       | a2                    | Second non-saturation factor                                | YES            |
| Rdsw                     | rdsw                  | Parasitic resistance per unit width                         | YES            |
| Prwb                     | prwb                  | Body effect coefficient of Rdsw                             | YES            |
| Prwg                     | prwg                  | Gate bias effect coefficient of Rdsw                        | YES            |
| Wr                       | wr                    | Width Offset from Weff for Rds calculation                  | YES            |
| Wint                     | wint                  | Width offset fitting parameter from I-V without bias        | NO             |
| Lint                     | lint                  | Length offset fitting parameter from I-V without bias       | NO             |
| dWg                      | dwg                   | Coefficient of Weff's gate dependence                       | YES            |
| dWb                      | dwb                   | Coefficient of Weff's substrate body bias dependence        | YES            |
| Voff                     | voff                  | Offset voltage in the subthreshold region for large W and L | Yes            |
| Nfactor                  | nfactor               | Subthreshold swing factor                                   | YES            |

## DC Parameters

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| Symbols used in equation | Symbols used in SPICE | Description   | Can Be Binned? |
|--------------------------|-----------------------|---|----------------|
| Eta0                     | eta0                  | DIBL coefficient in subthreshold region                           | YES            |
| Etab                     | etab                  | Body-bias coefficient for the subthreshold DIBL effect            | YES            |
| Dsub                     | dsub                  | DIBL coefficient exponent in subthreshold region                  | YES            |
| Cit                      | cit                   | Interface trap capacitance  | YES            |
| Cdsc                     | cdsc                  | Drain/Source to channel coupling capacitance                      | YES            |
| Cdscb                    | cdscb                 | Body-bias sensitivity of Cdsc                                     | YES            |
| Cdscd                    | cdscd                 | Drain-bias sensitivity of Cdsc                                    | YES            |
| Pclm                     | pclm                  | Channel length modulation parameter                               | YES            |
| Pdiblc1                  | pdiblc1               | First output resistance DIBL effect correction parameter          | YES            |
| Pdiblc2                  | pdiblc2               | Second output resistance DIBL effect correction parameter         | YES            |
| Pdiblcb                  | pdiblcb               | Body effect coefficient of DIBL correction parameters             | YES            |
| Drout                    | drout                 | L dependence coefficient of the DIBL correction parameter in Rout | YES            |
| Pscbe1                   | pscbe1                | First substrate current body-effect parameter                     | YES            |
| Pscbe2                   | pscbe2                | Second substrate current body-effect parameter                    | YES            |

## AC and Capacitance Parameters

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| Symbols used in equation | Symbols used in SPICE | Description  | Can Be Binned? |
|--------------------------|-----------------------|--|----------------|
| Pvag                     | pvag                  | Gate dependence of Early voltage                       | YES            |
| $\delta$                 | delta                 | Effective Vds parameter                                | YES            |
| Ngate                    | ngate                 | poly gate doping concentration                         | YES            |
| $\alpha 0$               | alpha0                | The first parameter of impact ionization current       | YES            |
| $\beta 0$                | beta0                 | The second parameter of impact ionization current      | YES            |
| Rsh                      | rsh                   | Source drain sheet resistance in ohm per square        | NO             |
| Jso                      | js                    | Source drain junction saturation current per unit area | NO             |

## D.3 AC and Capacitance Parameters

| Symbols used in equation | Symbols used in SPICE | Description   | Can Be Binned? |
|--------------------------|-----------------------|---|----------------|
| Xpart                    | xpart                 | Charge partitioning rate flag                                     | NO             |
| CGS0                     | cgso                  | Non LDD region source-gate overlap capacitance per channel length | NO             |

## AC and Capacitance Parameters

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| Symbols used in equation | Symbols used in SPICE | Description   | Can Be Binned? |
|--------------------------|-----------------------|---|----------------|
| CGD0                     | cgdo                  | Non LDD region drain-gate overlap capacitance per channel length                    | NO             |
| CGB0                     | cgbo                  | Gate bulk overlap capacitance per unit channel length                               | NO             |
| Cj                       | cj                    | Bottom junction per unit area   | NO             |
| Mj                       | mj                    | Bottom junction capacitance grading coefficient                                     | NO             |
| Mjsw                     | mjsw                  | Source/Drain side junction capacitance grading coefficient                          | NO             |
| Cjsw                     | cjsw                  | Source/Drain side junction capacitance per unit area                                | NO             |
| Pb                       | pb                    | Bottom built-in potential   | NO             |
| Pbsw                     | pbsw                  | Source/Drain side junction built-in potential                                       | NO             |
| CGS1                     | cgs1                  | Light doped source-gate region overlap capacitance                                  | YES            |
| CGD1                     | cgd1                  | Light doped drain-gate region overlap capacitance                                   | YES            |
| CKAPPA                   | ckappa                | Coefficient for lightly doped region overlap capacitance Fringing field capacitance | YES            |
| Cf                       | cf                    | fringing field capacitance  | YES            |
| CLC                      | clc                   | Constant term for the short channel model   | YES            |
| CLE                      | cle                   | Exponential term for the short channel model  | YES            |

## NQS Parameters

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| Symbols used in equation | Symbols used in SPICE | Description                                     | Can Be Binned? |
|--------------------------|-----------------------|---|----------------|
| DLC                      | dlc                   | Length offset fitting parameter from C-V        | YES            |
| DWC                      | dwc                   | Width offset fitting parameter from C-V         | YES            |
| Vfb                      | vfb                   | Flat-band voltage parameter (for capmod=0 only) | YES            |

## D.4 NQS Parameters

| Symbols used in equation | Symbols used in SPICE | Description                    | Can Be Binned? |
|--------------------------|-----------------------|--------------------------------|----------------|
| Elm                      | elm                   | Elmore constant of the channel | YES            |

## D.5 dW and dL Parameters

| Symbols used in equation | Symbols used in SPICE | Description  | Can Be Binned? |
|--------------------------|-----------------------|--|----------------|
| Wl                       | wl                    | Coefficient of length dependence for width offset            | NO             |
| Wln                      | wln                   | Power of length dependence of width offset                   | NO             |
| Ww                       | ww                    | Coefficient of width dependence for width offset             | NO             |
| Wwn                      | wnw                   | Power of width dependence of width offset                    | NO             |
| Wwl                      | wwl                   | Coefficient of length and width cross term for width offset  | NO             |
| Ll                       | ll                    | Coefficient of length dependence for length offset           | NO             |
| Lln                      | lln                   | Power of length dependence for length offset                 | NO             |
| Lw                       | lw                    | Coefficient of width dependence for length offset            | NO             |
| Lwn                      | lwn                   | Power of width dependence for length offset                  | NO             |
| Lwl                      | lwl                   | Coefficient of length and width cross term for length offset | NO             |

## D.6 Temperature Parameters

| Symbols used in equation | Symbols used in SPICE | Description  | Can Be Binned? |
|--------------------------|-----------------------|--|----------------|
| Tnom                     | tnom                  | Temperature at which parameters are extracted                                  | NO             |
| $\mu_{te}$               | ute                   | Mobility temperature exponent  | YES            |
| Kt1                      | kt1                   | Temperature coefficient for threshold voltage                                  | YES            |
| Kt11                     | kt11                  | Channel length dependence of the temperature coefficient for threshold voltage | YES            |
| Kt2                      | kt2                   | Body-bias coefficient of Vth temperature effect                                | YES            |
| Ua1                      | ua1                   | Temperature coefficient for Ua   | YES            |
| Ub1                      | ub1                   | Temperature coefficient for Ub   | YES            |
| Uc1                      | uc1                   | Temperature coefficient for Uc   | YES            |
| At                       | at                    | Temperature coefficient for saturation velocity                                | YES            |
| Prt                      | prt                   | Temperature coefficient for Rdsw   | YES            |
| nj                       | nj                    | Emission coefficient   | YES            |
| XTI                      | xti                   | Junction current temperature exponent coefficient                              | YES            |

## D.7 Flicker Noise Model Parameters

| Symbols used in equation | Symbols used in SPICE | Description             | Can Be Binned? |
|--------------------------|-----------------------|-------------------------|----------------|
| Noia                     | noia                  | Noise parameter A       | NO             |
| Noib                     | noib                  | Noise parameter B       | NO             |
| Noic                     | noic                  | Noise parameter C       | NO             |
| Em                       | em                    | Saturation field        | NO             |
| Af                       | af                    | Frequency exponent      | NO             |
| Ef                       | ef                    | Frequency exponent      | NO             |
| Kf                       | kf                    | Flicker noise parameter | NO             |

## D.8 Process Parameters

| Symbols used in equation | Symbols used in SPICE | Description                              | Can Be Binned? |
|--------------------------|-----------------------|--|----------------|
| Tox                      | tox                   | Gate oxide thickness                     | NO             |
| Xj                       | xj                    | Junction Depth                           | YES            |
| $\gamma_1$               | gamma1                | Body-effect coefficient near the surface | YES            |

## Bin Description Parameters

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| Symbols used in equation | Symbols used in SPICE | Description                                       | Can Be Binned? |
|--------------------------|-----------------------|---|----------------|
| $\gamma_2$               | gamma2                | Body-effect coefficient in the bulk               | YES            |
| Nch                      | nch                   | Channel doping concentration                      | YES            |
| Nsub                     | nsub                  | Substrate doping concentration                    | YES            |
| Vbx                      | vbx                   | Vbs at which the depletion region width equals xt | YES            |
| Vbm                      | vbm                   | Maximum applied body bias in Vth calculation      | YES            |
| Xt                       | xt                    | Doping depth                                      | YES            |

## D.9 Bin Description Parameters

| Symbols used in equation | Symbols used in SPICE | Description            | Can Be Binned? |
|--------------------------|-----------------------|------------------------|----------------|
| Lmin                     | lmin                  | Minimum channel length | NO             |
| Lmax                     | lmax                  | Maximum channel length | NO             |
| Wmin                     | wmin                  | Minimum channel width  | NO             |
| Wmax                     | wmax                  | Maximum channel width  | NO             |
| binunit                  | binunit               | Bin unit selector      | NO             |

## Bin Description Parameters

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