5 Operating Point Information from Circuit Simulators

Below is a list of those quantities that should be provided by the circuit simulator to the model user as “operating point information”. The voltages in the expressions are defined as follows:

$$V_{BEi} = V_{B'} - V_{E'}$$
$$V_{BEx} = V_{B*} - V_{E'}$$
$$V_{BCi} = V_{B'} - V_{C'}$$
$$V_{BCx} = V_{B*} - V_{C'}$$
$$V_{SCi} = V_{S'} - V_{C'}$$

Variable	Unit	Description	Definition
IB	A	Base terminal current	as calculated in the model
IC	A	Collector terminal current	as calculated in the model
IS	A	Substrate terminal current	as calculated in the model
VBE	V	External *BE* voltage	as calculated in the model
VBC	V	External *BC* voltage	as calculated in the model
VCE	V	External *CE* voltage	as calculated in the model
VSC	V	External *SC* voltage	as calculated in the model
BETADC		Common emitter forward current gain	$\frac{I_C}{I_B}$
GM	A/V	Transconductance (Same definition as for SGPM)	$\left.\frac{\partial I_T}{\partial V_{BEi}}\right\|_{V_{CEi}} = \left.\frac{\partial I_T}{\partial V_{BEi}}\right\|_{V_{BCi}} + \left.\frac{\partial I_T}{\partial V_{BCi}}\right\|_{V_{BEi}}$
GMAVL	A/V	Transconductance for avalanche current	$\left.\frac{\partial I_{AVL}}{\partial V_{BEi}}\right\|_{V_{BCi}}$
GMS	A/V	Transconductance of the parasitic substrate PNP	$\left.\frac{\partial I_{TS}}{\partial V_{BCx}}\right\|_{V_{SCi}} - \left.\frac{\partial I_{TS}}{\partial V_{SCi}}\right\|_{V_{BCx}}$
RPIi	Ω	Intrinsic input resistance	$\frac{1}{r_{\pi i}} = \frac{\partial I_{BEi}}{\partial V_{BEi}}$

Variable	Unit	Description	Definition
RPIx	Ω	Extrinsic input resistance	$\frac{1}{r_{\pi x}} = \frac{\partial I_{BEp}}{\partial V_{BEx}} - \frac{\partial I_{BEt}}{\partial V_{BEx}}$ (second term is due to tunnelling current)
RMUi	Ω	Intrinsic feedback resistance	$\frac{1}{r_{\mu i}} = \frac{\partial I_{BCi}}{\partial V_{BCi}} - \left.\frac{\partial I_{AVL}}{\partial V_{BCi}}\right\|_{V_{BEi}}$ (second term is due to avalanche current)
RMUx	Ω	Extrinsic feedback resistance	$\frac{1}{r_{\mu x}} = \frac{\partial I_{BCx}}{\partial V_{BCx}}$
RMUs	Ω	Intrinsic substrate feedback resistance	$\frac{1}{r_{\mu s}} = \frac{\partial I_{SC}}{\partial V_{SCi}}$
RO	Ω	Output resistance (same definition as for SGPM)	$\frac{1}{r_o} = -\left.\frac{\partial I_T}{\partial V_{BCi}}\right\|_{V_{BEi}}$
ROs	Ω	Output resistance for the parasitic substrate PNP	$\frac{1}{r_{os}} = -\frac{\partial I_{TS}}{\partial V_{SCi}}$
CPIi	F	Total intrinsic *BE* capacitance	$C_{\pi i} = C_{jEi} + C_{dE}$
CPIx	F	Total extrinsic *BE* capacitance	$C_{\pi x} = C_{iEp} + C_{Epar}$
CMUi	F	Total intrinsic *BC* capacitance	$C_{\mu i} = C_{jCi} + C_{dC}$
CMUx	F	Total extrinsic *BC* capacitance	$C_{\mu x} = C_{jCx} + C_{Cpar} + C_{dS}$
CCS	F	*CS* junction capacitance	C_{jS}
RBI	Ω	Internal base resistance	as calculated in the model
CRBI	F	Shunt capacitance across RBI	as calculated in the model
TF	s	Total forward transit time	as calculated in the model
FT	Hz	Transit frequency (still simplified expression, but improved vs. SGPM)	$\frac{g_m}{C_{BE} + C_{BC} + r\dot{C}_{BC} g_m}$, $C_{BE} = C_{\pi i} + C_{\pi x}$, $C_{BC} = C_{\mu i} + C_{\mu x}$, $r = r_{Cx} + r_E + r_B/\beta_0$

Variable	Unit	Description	Definition
VEF	V	Effective forward Early voltage	$I_T\left(\left.\frac{\partial I_T}{\partial V_{CEi}}\right\|_{V_{BEi}}^{-1}\right) - V_{CEi}$
VER	V	Effective inverse Early voltage	$I_T\left(\left.\frac{\partial I_T}{\partial V_{BEi}}\right\|_{V_{BCi}}\right)^{-1} \qquad -V_{BEi}$