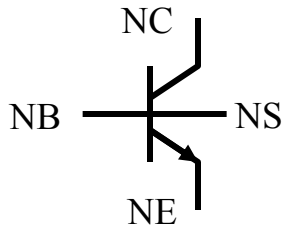
SPICE BJT Declaration

The generic BJT is a 4-terminal device that is specified in the netlist as:

Qname NC NB NE <NS> ModName <Area>



where:

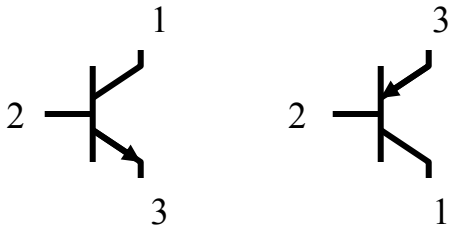
Ns: optional substrate node (assumed to be grounded if omitted)

Area: an optional area factor. Default: 1

If an optional parameter is omitted the default values are used.

Here is an example declaration for the devices at right:

Q1 1 2 3 MyBJT



Additional device parameters, including whether the device is NPN or PNP, are defined in the MODEL declaration for MyBJT (next slide!)

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SPICE BJT Model

The SPICE BJT Model is defined in the netlist as

.MODEL ModName TYPE (parameters) **(TYPE is either NPN or PNP)**

Some key parameters are:

Parameter	Description	Units	Default
BF	ideal maximum forward beta		100.0
VAF (VA)	forward Early voltage	volt	∞
CJC	base-collector zero-bias p-n capacitance	farad	0.0
CJE	base-emitter zero-bias p-n capacitance	farad	0.0
TF	forward transit time (for b-e diffusion capacitance)	sec	0
TR	reverse transit time (for b-c diffusion capacitance)	sec	0
IS	transport saturation current	amp	1E-16
NF	Forward emission coefficient (ideality factor)		1
IKF (IK)	corner for forward-beta high-current roll-off	amp	∞
RB	zero-bias (maximum) base resistance ohm		0.0
RC	collector ohmic resistance	ohm	0.0
RE	emitter ohmic resistance	ohm	0.0

In terms of these parameters some of the basic device characteristics are:

$$I_c \approx \mathrm{IS}\left(e^{V_{be}/\mathrm{NF}\cdot V_T} - 1\right)\left(1 + \frac{V_{ce}}{\mathrm{VAF}}\right) \qquad g_m = \frac{I_c}{V_T} \qquad r_\pi = \frac{\mathrm{BF}}{g_m} \qquad r_o = \frac{\mathrm{VAF}}{I_c}$$

A simple silicon NPN device with no parasitics could be specified as

.MODEL MyBJT NPN (BF=200 VAF=75)

Key Device Capacitances: $C_\pi \approx g_m \mathrm{TF} + 2\,\mathrm{CJE}$ $C_\mu \approx \frac{1}{r_o}\mathrm{TR} + \mathrm{CJC}$

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SPICE BJT Parameters

Model parameters	Description	Units	Default
AF	flicker noise exponent		1.0
BF	ideal maximum forward beta		100.0
BR	ideal maximum reverse beta		1.0
CJC	base-collector zero-bias p-n capacitance	farad	0.0
CJE	base-emitter zero-bias p-n capacitance	farad	0.0
CJS (CCS)	substrate zero-bias p-n capacitance	farad	0.0
CN	quasi-saturation temperature coefficient for hole mobility		2.42NPN, 2.20PNP
D	quasi-saturation temperature coefficient for scattering-limited hole carrier velocity		0.87NPN, 0.52PNP
EG	bandgap voltage (barrier height)	eV	1.11
FC	forward-bias depletion capacitor coefficient		0.5
GAMMA	epitaxial region doping factor		1E-11
IKF (IK)	corner for forward-beta high-current roll-off	amp	∞
IKR	corner for reverse-beta high-current roll-off	amp	∞
IRB	current at which Rb falls halfway to	amp	∞
IS	transport saturation current	amp	1E-16
ISC (C4) †	base-collector leakage saturation current	amp	0.0
ISE (C2) †	base-emitter leakage saturation current	amp	0.0
ISS	substrate p-n saturation current	amp	0.0
ITF	transit time dependency on Ic	amp	0.0
KF	flicker noise coefficient		0.0
MJC (MC)	base-collector p-n grading factor		0.33
MJE (ME)	base-emitter p-n grading factor		0.33
MJS (MS)	substrate p-n grading factor		0.0
NC	base-collector leakage emission coefficient		2.0
NE	base-emitter leakage emission coefficient		1.5
NF	forward current emission coefficient		1.0
NK	high-current roll-off coefficient		0.5
NR	reverse current emission coefficient		1.0
NS	substrate p-n emission coefficient		1.0
PTF	excess phase @ 1/(2π·TF)Hz	degree	0.0
QCO	epitaxial region charge factor	coulomb	0.0
QUASIMOD	quasi-saturation model flag for temp. dependence of GAMMA, RCO, VO if QUASIMOD = 0, then no temp dependence. if QUASIMOD = 1, then include		0
RB	zero-bias (maximum) base resistance ohm		0.0
RBM	minimum base resistance	ohm	RB

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BJT SPICE Parameters (cont..!)

Model parameters	Description	Units	Default
RC	collector ohmic resistance	ohm	0.0
RCO ‡	epitaxial region resistance	ohm	0.0
RE	emitter ohmic resistance	ohm	0.0
TF	ideal forward transit time	sec	0.0
TR	ideal reverse transit time	sec	0.0
TRB1	RB temperature coefficient (linear)	$°C^{-1}$	0.0
TRB2	RB temperature coefficient (quadratic)	$°C^{-2}$	0.0
TRC1	RC temperature coefficient (linear)	$°C^{-1}$	0.0
TRC2	RC temperature coefficient (quadratic)	$°C^{-2}$	0.0
TRE1	RE temperature coefficient (linear)	$°C^{-1}$	0.0
TRE2	RE temperature coefficient (quadratic)	$°C^{-2}$	0.0
TRM1	RBM temperature coefficient (linear)	$°C^{-1}$	0.0
TRM2	RBM temperature coefficient (quadratic)	$°C^{-2}$	0.0
T_ABS	absolute temperature	°C	
T_MEASURED	measured temperature	°C	
T_REL_GLOBAL	relative to current temperature	°C	
T_REL_LOCAL	relative to AKO model temperature	°C	
VAF (VA)	forward Early voltage	volt	∞
VAR (VB)	reverse Early voltage	volt	∞
VG	quasi-saturation extrapolated bandgap voltage at 0° K	volt	1.206
VJC (PC)	base-collector built-in potential	volt	0.75
VJE (PE)	base-emitter built-in potential	volt	0.75
VJS (PS)	substrate p-n built-in potential	volt	0.75
VO	carrier mobility knee voltage	volt	10.0
VTF	transit time dependency on Vbc	volt	∞
XCJC	fraction of CJC connected internally to Rb		1.0
XCJC2	fraction of CJC connected internally to Rb		1.0
XCJS	fraction of CJS connected internally to Rc		
XTB	forward and reverse beta temperature coefficient		0.0
XTF	transit time bias dependence coefficient		0.0
XTI (PT)	IS temperature effect exponent		3.0

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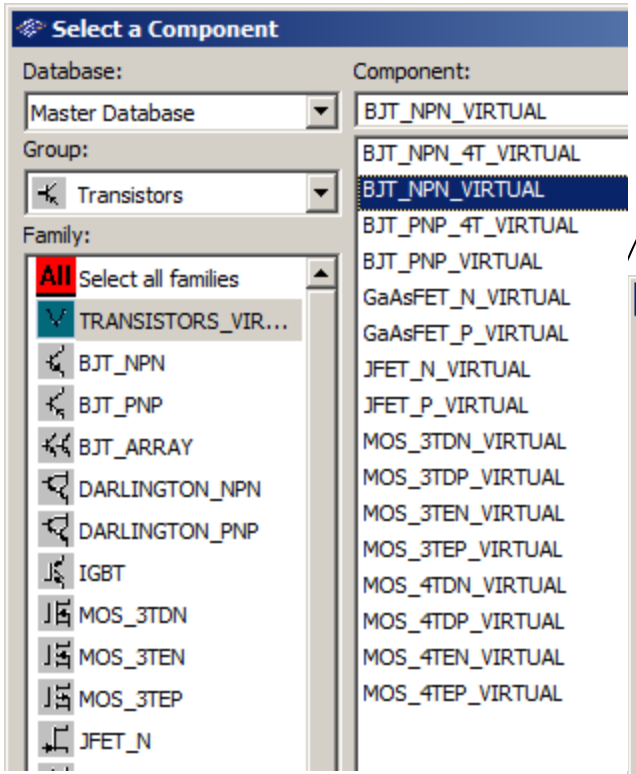
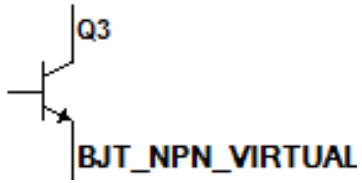
BJT Devices in MultiSim

Select "Place→Component…"

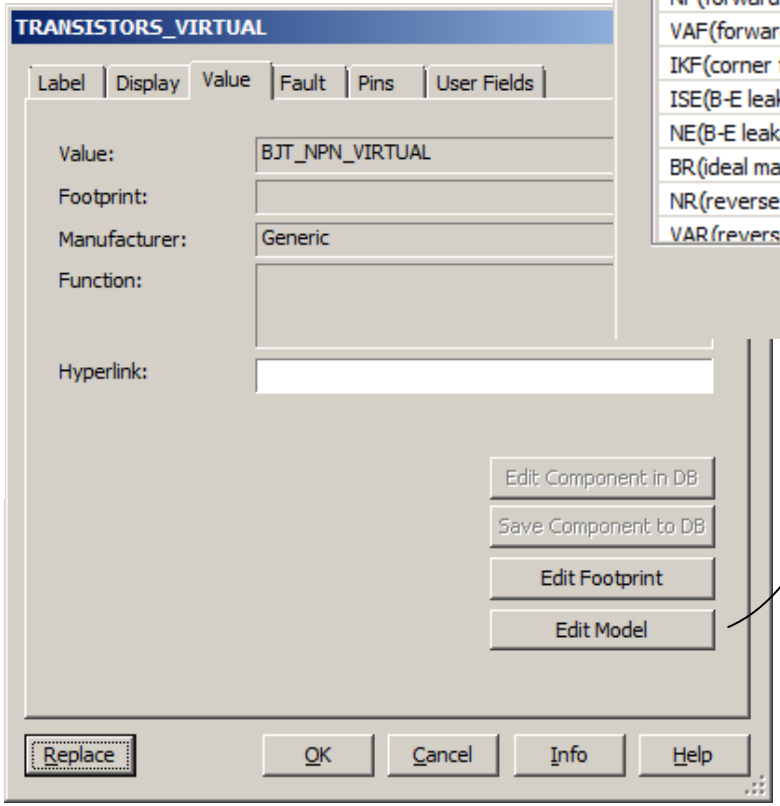


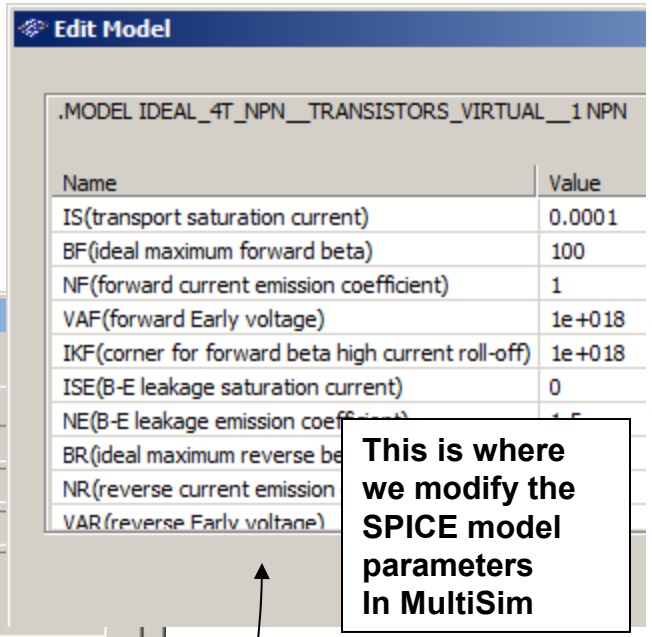
A number of "virtual" devices to choose from, here we select the 3-terminal NPN BJT

This will appear in the circuit schematic



Double-click on the component:





This is where we modify the SPICE model parameters In MultiSim

Click "Edit Model" to see SPICE Model declaration

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Simple NPN/PNP Devices in MultiSim

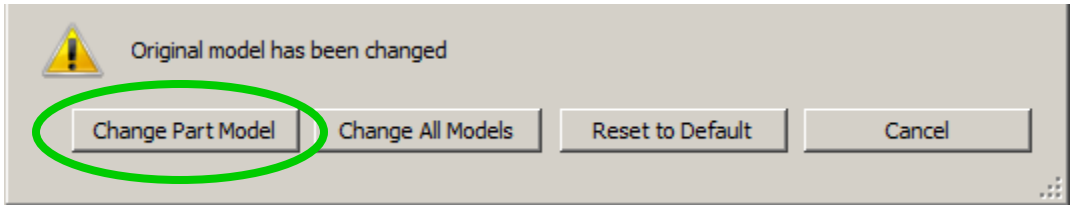
In ECE 2 we will often solve problems assuming a very basic device described by a current gain (β), and output resistance (Early voltage V_A). Set these two parameters in the virtual Model as follows:

Name	Value	Units
IS(transport saturation current)	0.0001	pA
BF(ideal maximum forward beta)	100	
NF(forward current emission coefficient)	1	
VAF(forward Early voltage)	1e+018	TV

Be sure to set the units too!

All other parameters in the ideal (virtual) model can be left to their default values.

After making desired changes in the model, select "Change Part Model". Only use "Change All Models" if you want the same model to apply to all the BJTs in your circuit!



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Example Datasheet SPICE models

2N3904

NPN (Is=6.734f Xti=3 Eg=1.11 Vaf=74.03 Bf=416.4 Ne=1.259
Ise=6.734 Ikf=66.78m Xtb=1.5 Br=.7371 Nc=2
Isc=0 Ikr=0 Rc=1 Cjc=3.638p Mjc=.3085 Vjc=.75 Fc=.5
Cje=4.493p Mje=.2593 Vje=.75 Tr=239.5n Tf=301.2p
Itf=.4 Vtf=4 Xtf=2 Rb=10)

2N3906

PNP (Is=1.41f Xti=3 Eg=1.11 Vaf=18.7 Bf=180.7 Ne=1.5 Ise=0
Ikf=80m Xtb=1.5 Br=4.977 Nc=2 Isc=0 Ikr=0
Rc=2.5 Cjc=9.728p Mjc=.5776 Vjc=.75 Fc=.5 Cje=8.063p
Mje=.3677 Vje=.75 Tr=33.42n Tf=179.3p Itf=.4
Vtf=4 Xtf=6 Rb=10)

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