Verification of the validity of BJT lab

(<http://nanohub.org/tools/bjt>)

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**Simulation setup**

 We will validate results obtained from BJT Lab by comparing with analytical model. A *pnp* BJT in Common Base configuration is set up with the following parameters,

Base width, WB = 2µm

Emitter region doping, NE = 1018 /cm3

Base region doping, NB = 1016 /cm3

Collector region doping, NC = 1015 /cm3

Emitter region minority carrier lifetime, τE = 0.1µs

Base region minority carrier lifetime, τB = 1µs

Collector region minority carrier lifetime, τC = 0.1µs

1. **DC current gain, β parameter**

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Figure 1 Beta parameter from BJT (www.nanohub.org/bjt)

 Analytical calculation for β in W<<LB limit.(Diffusion constant values from R.F Pierret, SDF pg 400, Table 11.1)

$$β=\frac{1}{\frac{D\_{E}}{D\_{B}}\frac{N\_{B}}{N\_{E}}\frac{W}{L\_{E}}+\frac{1}{2}\left(\frac{W}{L\_{B}}\right)^{2}}=310$$

Where D=Diffusion constant and L=Diffusion length.

1. **Output Characteristics**

The output characteristics for *pnp* Common Base configuration BJT are calculated using Ebers-Moll model (MATLAB script given at the end).



Figure 2 Comparison of analytical and numerical (BJT Lab) output characteristics of *pnp* BJT in CB mode

MATLAB script for analytical model

% Analytical solution for BJT PNP Common Base output characteristics

% for validation of BJT Lab (www.nanohub.org/tools/bjt)

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% Input Parameters

% Lifetime in s

TauE=1e-7; TauB=1e-6; TauC=1e-7;

% Doping in /cm3

NE=1e18; NB=1e16; NC=1e15;

% Length in cm

WB=2e-4;

% Mobility Parameters (from R.F. Pierret, Semiconductor Device Fundamentals pg. 777)

NDref=1.3e17; NAref=2.35e17;

unmin=92;upmin=54.3;

un0=1268; up0=406.9;

an=0.91;ap=0.88;

uE=unmin+un0./(1+(NE/NDref).^an);

uB=unmin+up0./(1+(NB/NAref).^ap);

uC=unmin+un0./(1+(NC/NDref).^an);

% Universal constants

k=8.617e-5; T=300; kT=k\*T; ni=1e10; q=1.6e-19;

DE=kT\*uE; DB=kT\*uB; DC=kT\*uC;

LE=sqrt(DE\*TauE); LB=sqrt(DB\*TauB); LC=sqrt(DC\*TauC);

nE0=(ni^2)./NE; pB0=(ni^2)./NB; nC0=(ni^2)./NC;

% Ebers-Moll model

W=WB;

fB=(DB/LB)\*pB0\*(cosh(W/LB)/sinh(W/LB));

IF0=q\*((DE/LE)\*nE0+fB);

IR0=q\*((DC/LC)\*nC0+fB);

aF=q\*(DB/LB)\*(pB0/sinh(W/LB))/IF0;

aR=q\*(DB/LB)\*(pB0/sinh(W/LB))/IR0;

% Common Base output characteristics

Vcb=linspace(0,-20,40);

% Emitter injection current

Ie=linspace(5e-6,1e-5,4);

for ii=1:1:4

Ic(ii,:)=aF\*Ie(ii)-(1-aF\*aR)\*IR0\*(exp(Vcb/kT)-1);

end

hold on

plot(Vcb,Ic,'-g')