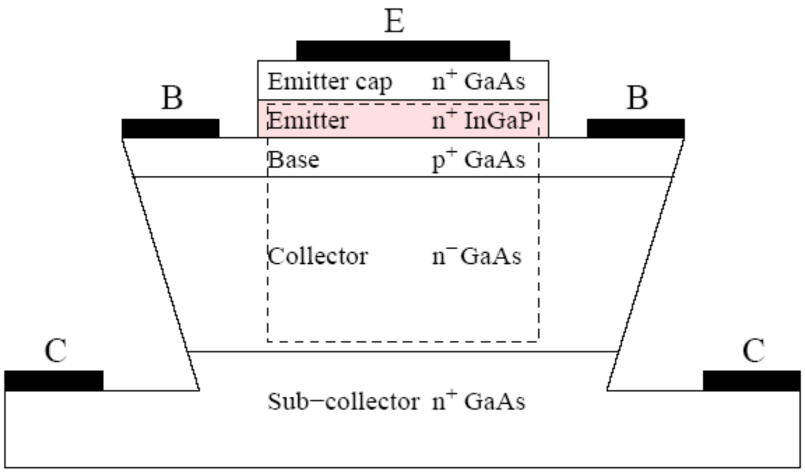
HBT basics

LECTURE 15

- Applications
- Structure
- Energy band diagram
- Collector current

HBTs enable portable wireless products



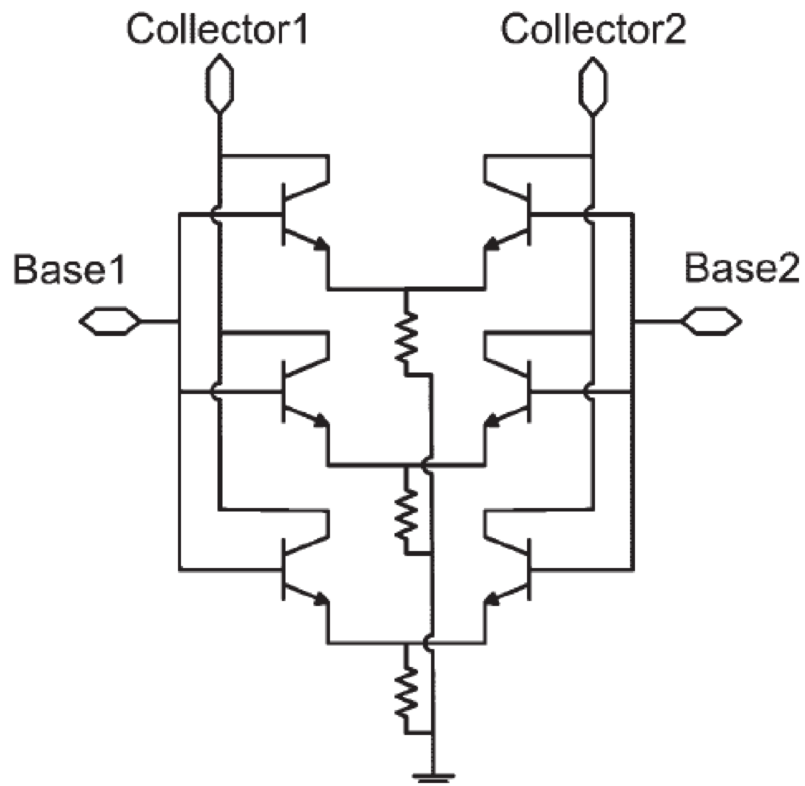
Why does this PDA need HBTs?

A DIFFERENTIAL HBT POWER CELL AND ITS MODEL

Dong Ho Lee,[1] Yue Chen,[2] Kyung-Ai Lee,[3] and Songcheol Hong[3]
[1] School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA; Corresponding author: dlee96@mail.gatech.edu
[2]Department of Electrical and Computer Engineering, North Carolina State University, Raleigh, NC
[3]Department of Electrical Engineering and Computer Science, Korea Advanced Institute of Science and Technology, Korea

Received 12 January 2008

ABSTRACT: *A differential heterojunction bipolar transistor (HBT) power cell has been designed and modeled with additional model extraction patterns. The differential power cell, which is composed of a unit differential amplifier with a common emitter ballast resistor, has no gain degradation by the ballast resistors and has been implemented in InGaP/GaAs HBT technology. DC and AC characteristics are extracted from a half circuit of the differential power cell and thermal characteristics are extracted from a common-mode circuit of that. Using the extracted model, a 5-GHz differential power amplifier has been designed and fabricated with on-chip output networks. The 5-GHz differential power amplifier delivers 26 dBm of* P_{1dB} *with 30% collector efficiency.* Microwave Opt Technol Lett 50: 2262–2268, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23684



A 1.4-dB-NF Variable-Gain LNA with Continuous Control for 2-GHz-band Mobile Phones Using InGaP Emitter HBTs

Yuuichi Aoki, Masahiro Fujii, Satoru Ohkubo*, Sadayoshi Yoshida*, Takaki Niwa*,
Yosuke Miyoshi*, Hideaki Dodo, Norio Goto*, and Hikaru Hida

System Devices and Fundamental Research, NEC Corporation
34 Miyukigaoka, Tsukuba, Ibaraki 305-8501, Japan
* Compound Semiconductor Device Division, NEC Corporation
1753 Shimonumabe, Nakahara, Kawasaki, Kanagawa 211-8666, Japan

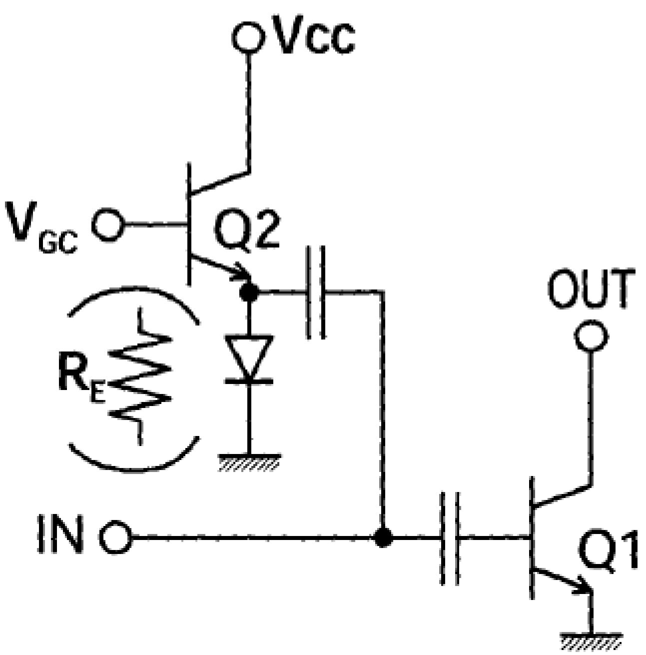


Fig. 1. VG-LNA circuit with input-bypassing by using a diode-loaded emitter follower.

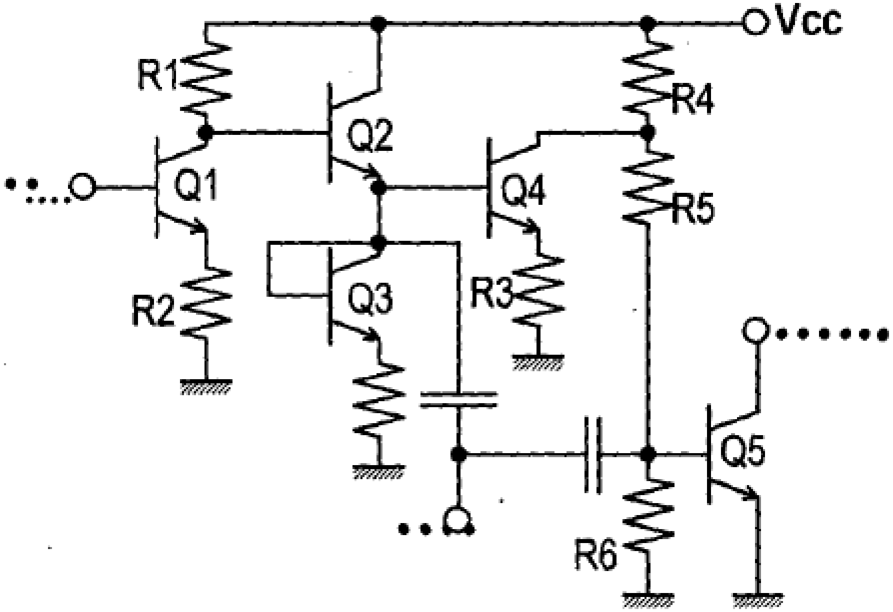
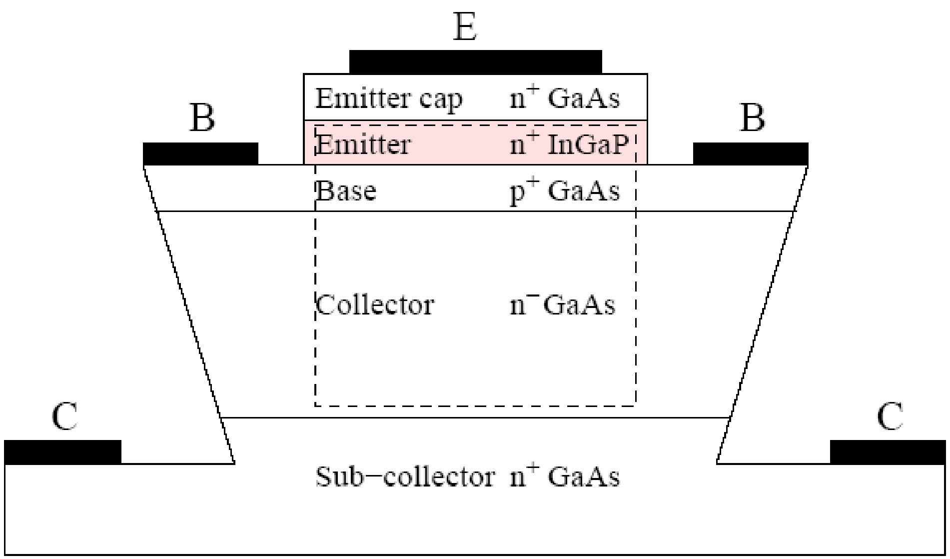


Fig. 3. Circuit schematic of a variable-gain LNA.

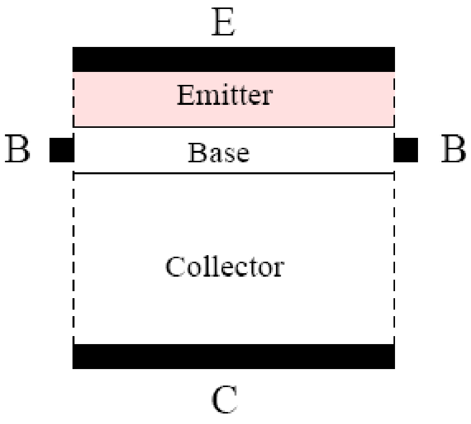
IEEE RF IC Symposium, pp. 231-234, 2002

HBT structure



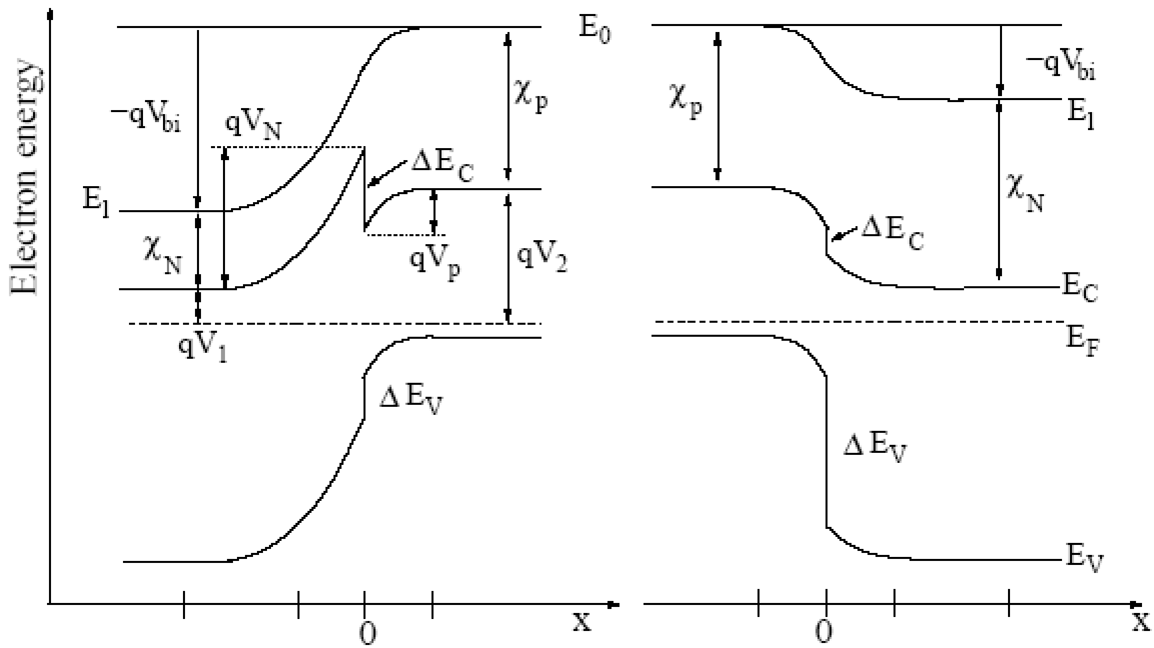
Note:

- Epitaxial structure
- Dissimilar emitter and base materials
- Highly doped base.



Simplified 1-D structure

Energy band diagrams for HBTs



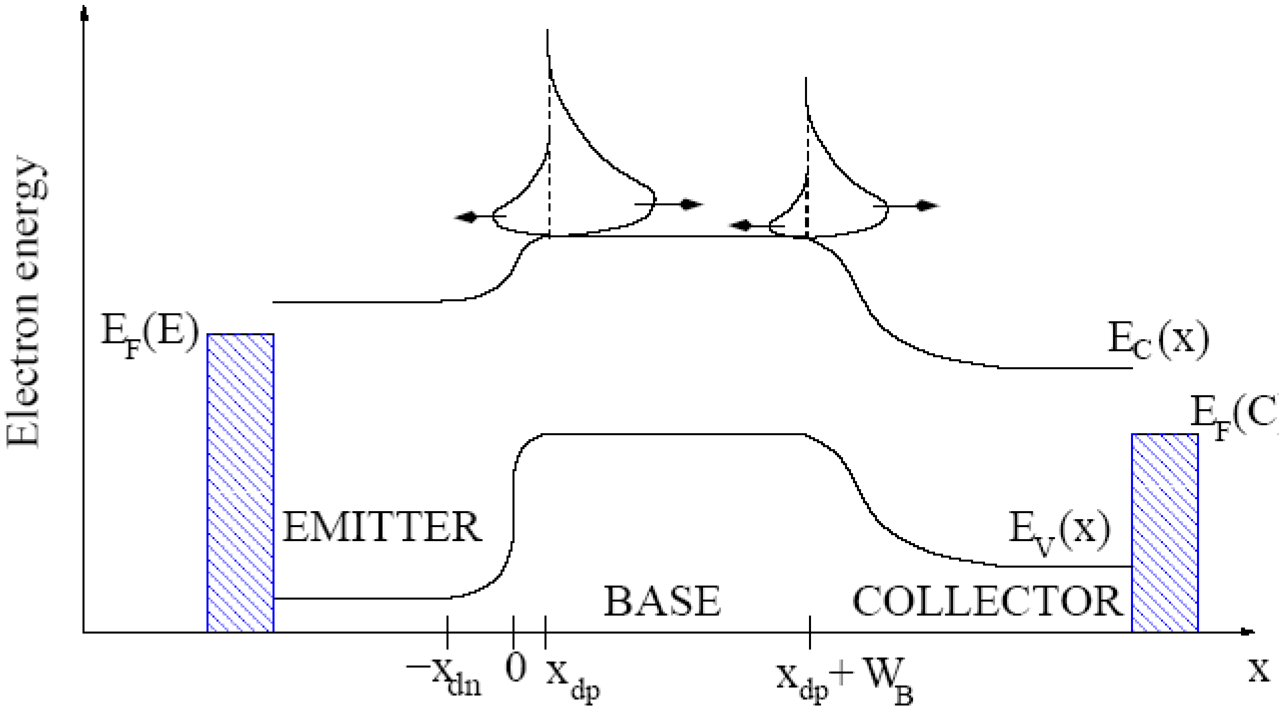
Construct in usual way, but note the band-edge discontinuities:

$\Delta E_C =$

$\Delta E_C + \Delta E_V =$

What materials are represented in the above band diagrams?

Preparing to predict I_C



Go to the toolbox and select the equations needed

$$-\nabla^2\psi = \frac{q}{\epsilon}[p - n + N_D - N_A]$$

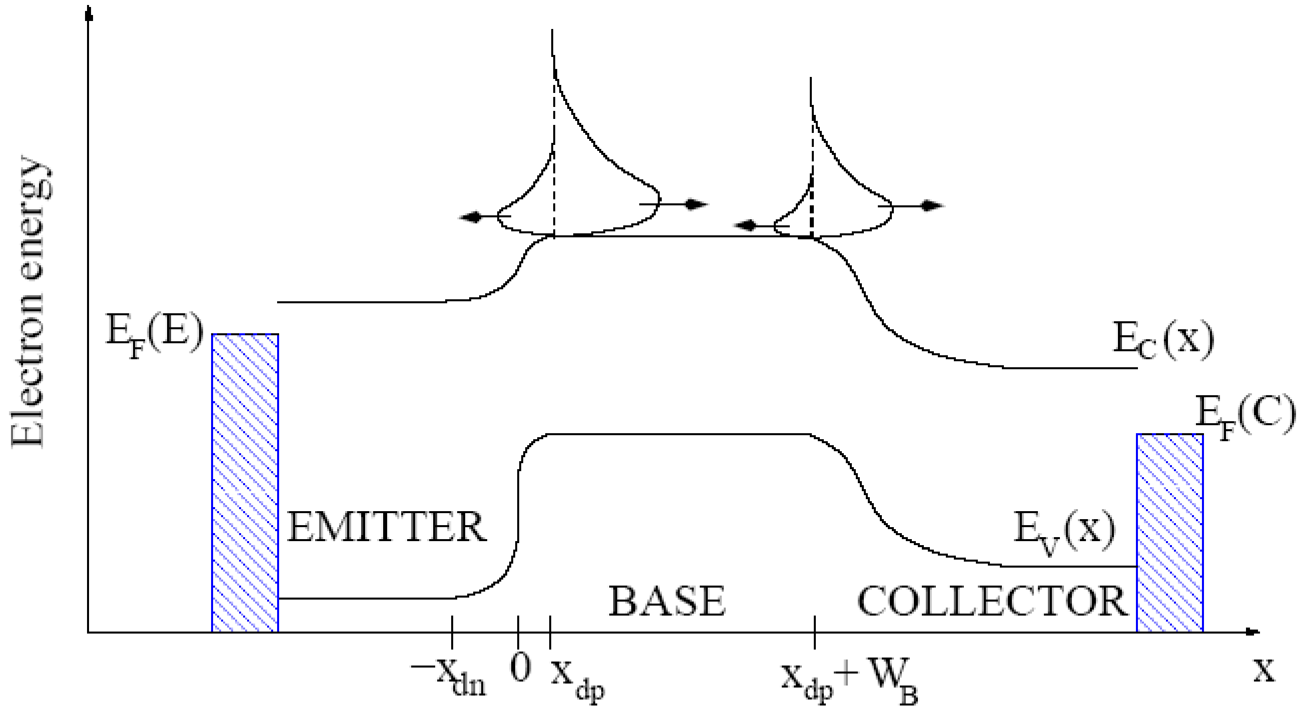
$$J_e = -qn\mu_e\nabla\psi + qD_e\nabla n$$

$$J_h = -qp\mu_h\nabla\psi - qD_h\nabla p$$

$$\frac{\partial n}{\partial t} = \frac{1}{q}\nabla\cdot J_e - \frac{n-n_0}{\tau_e} + G_{op}$$

$$\frac{\partial p}{\partial t} = -\frac{1}{q}\nabla\cdot J_h - \frac{p-p_0}{\tau_h} + G_{op}$$

Setting up for the I_C derivation



W_B can be as small as 30nm.

N_B can be as high as 1E19-1E20 cm^{-3}

What is W_B/L_e ?

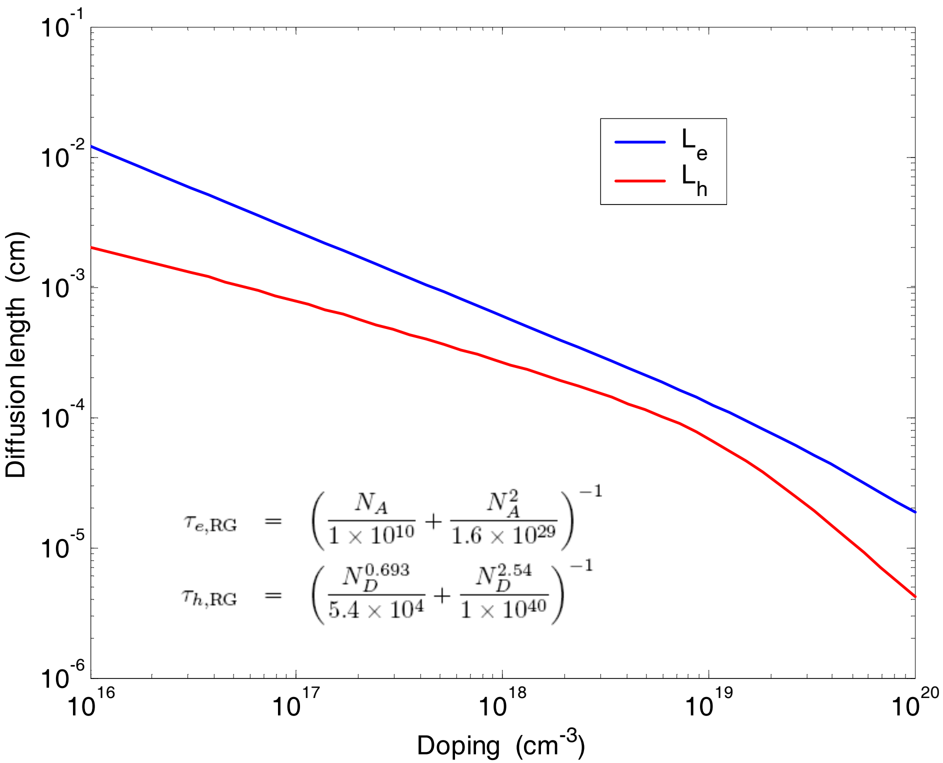
What is the minority carrier profile in the base?

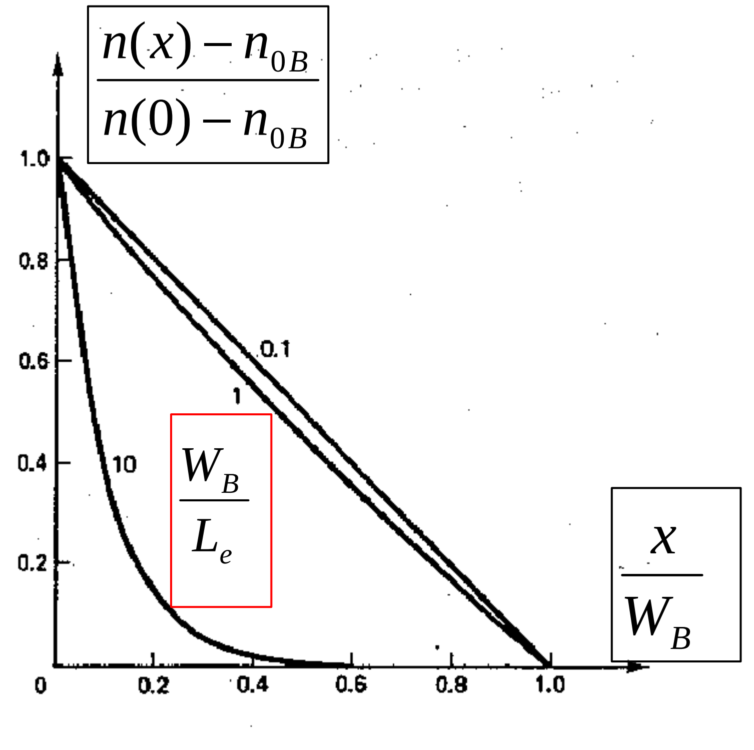
What is the expression for the electron current in the base?

What are the boundary conditions?

Sec. 9.2

Answering the questions from the previous slide





In modern HBTs
$W_B/L_e << 1$ ∴

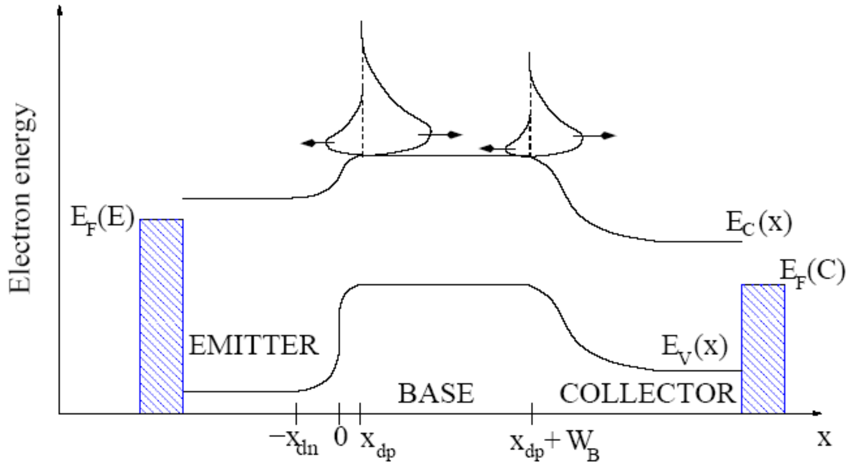
$$\frac{d^2n}{dx^2} = \square \quad \text{and} \quad J_e = \square$$

is constant

Now we just need the boundary conditions

Sec. 9.2

BC's for I_C derivation



New boundary conditions

$$n(x_{dp}) = \frac{n_E^*}{2} + n_L$$

$$J_e(x_{dp}) = -q\frac{n_E^*}{2}2v_R - (-qn_L2v_R)$$

$$n(x_{dp}) = n_E^* + \square$$

What is n_E*?

Why do we need a new BC?

What is the BC at the other end of the QNB?

This is a modified Shockley BC

Sec. 9.2

Collector current: controlling velocities

Substitute for the carrier concentrations at the boundaries

$$J_e = -qn_{0B}\left[e^{qV_{BE}/kT} - e^{qV_{BC}/kT}\right]\left[\frac{W_B}{D_e} + \frac{1}{v_R}\right]^{-1}$$

Note:
- the reciprocal velocities
- estimate typical values
- inclusion of v_R necessary in modern HBTs