ECE Tutorials

Electronics and control Systems

Description of Early effect or Base width modulation

Consider a transistor in common base configuration biased in active region of operation. As you increase collector to base voltage that is if you more reverse bias base collector junction the depletion layer width increases as depletion layer width is proportional to reverse bias voltage (depletion layer width is proportional to square root of reverse bias voltage in abrupt junctions in which P-type to n-type semiconductor transition or vice verse is abrupt and proportional to cube root of reverse bias voltage in gradual junction or linear junction in which transition of semiconductors from n-type to p-type is gradual almost linearly with distance).

This depletion layer protrudes more in to the base than collector because base is lightly doped compared to collector. The inverse relationship of depletion layer width on doping concentration can be explained as follows, as depletion region is a region of uncovered charge carriers due to conservation of charge total charge in base is equal to the total charge in collector. Total uncovered charge in base is equal to product of base depletion layer volume and doping concentration, similarly in collector. Hence

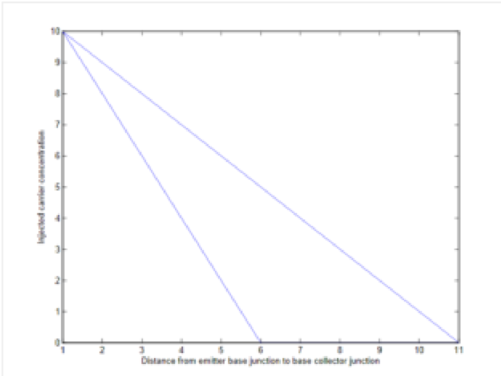
$$\mathbf{W_B*N_B*A_B=W_C*N_C*A_C}$$

as lateral area is same for base and collector so

$$\mathbf{W_B*N_B=W_C*N_C}$$

Since $\mathbf{N_C>N_B}$, $\mathbf{W_B>W_C}$ where **W** stands for depletion layer widths, **A** stands for areas, **N** stands for doping concentrations of respective regions **B** for base, **C** for collector.

As we increase base to collector voltage depletion layer width increases this in turn decreases effective base width. According to law of junction injected carrier(hole) concentration form emitter in to base should reduce to zero at the onset of depletion layer in base. In the graph shown below the left side is plotted for higher reverse bias compared to graph on right side with less slope compared to the one on the right.This is termed as Early effect.



— Illustrating early effect (Variation of charge gradient with reverse bias of CB junction)

consequences of Early effect

Early effect has three main consequences

- The emitter current entering the collector through the base is mainly diffusion current. The diffusion current $I_{diffusion}$ will be directly proportional to the concentration gradient which is the slope of curve drawn for free concentration v/s distance from high concentration(emitter) to low concentration(base) region.Now as collector base reverse bias increases hole concentration gradient increases, this leads to more emitter current (I_E α $\Delta P/\Delta X$). The increase in emitter current in turn causes a increase in the collector current.
- Also as effective base width decreases there is less chance for recombination and base current decreases as reverse bias increases. The base current is recombination current. Hence beta current gain of common emitter transistor increases. This increase in beta will increase the collector current.
- As we increase further the reverse bias voltage at some point effective base width approaches zero and transistor will breakdown.This phenomenon is called reach through or punch through.

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