Name: Email: ID#

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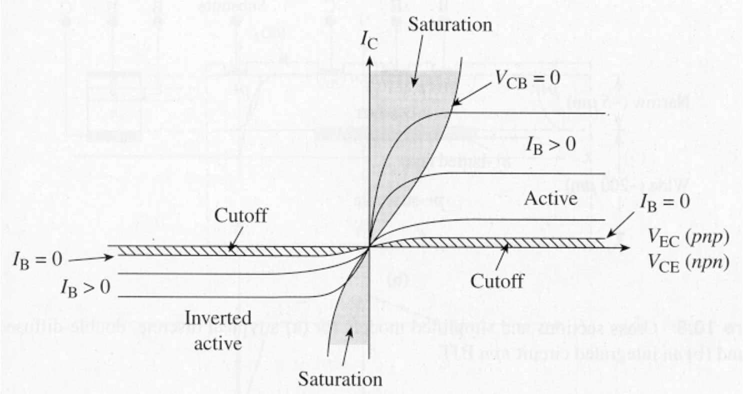
Test #3

1) Compared to forward active mode, inverted active mode typically results in degraded device performance, as shown in the figure below. Assume that each device region is uniformly doped, and assume that the doping is optimized to maximize gain in amplifier applications.



a) To understand why this is true, compare the following parameters for the two modes of operation, giving reasons for the differences.

i) α_T : *should be similar in both, to first order, since recombination in base should stay unchanged.*

3 pts

ii) γ: *Should be degraded in inverted mode, since EB junction now has heavier base doping that emitter doping, which increases emitter minority current.*

iii) β: *Should be degraded due to the degradation in emitter injection efficiency, as above.*

b) Which mode would you expect to have a higher V_{CB} limit, assuming the limit is imposed by (give reasons):

2 pts

i) Alavanche breakdown: *FW active should have a higher limit, since the heavily doped collector in the inverted mode will increase the peak electric field in the CB depletion region.*

ii) Punchthrough: *FW active should have a higher limit, since the depletion region in the inverted mode with stretch further into the base due to the high C-doping.*

c) Which mode would you expect to have a higher f_T? Why? *FW mode should have a higher f_T, due to the improved gain. This should generally outweigh any other effects.*

2 pts

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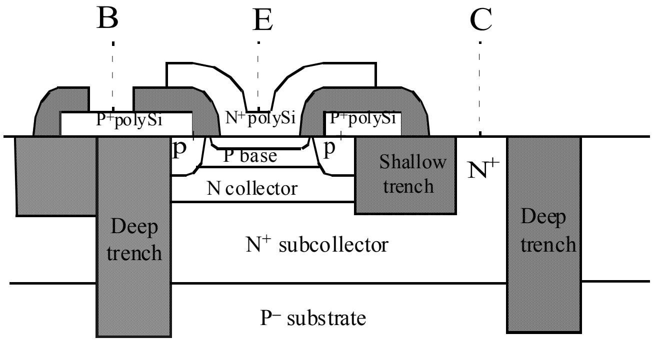
2) Consider the typical BJT structure shown below:



a) Why do we use the following parts of the device? Give you answer in terms of the specific device parameters that are improved through the use of the same.

i) Subcollector: *Reduces collector resistance, improving* f_T.

5 pts

ii) Polysilicon emitter: *Improved emitter injection efficiency.*

iii) P- substrate: *Provides isolation by ensuring a reverse-biased bottom region.*

iv) Trench isolation regions: *Provides isolation by eliminating lateral current paths between devices.*

v) P+ contacts to base: *Reduces base resistance, improving* f_T.

b) Suppose, due to a processing mistake, the subcollector is made unintentionally shallow, such that the collector quasi-neutral region thickness is reduced to only 100nm, as opposed to the intended thickness of 500nm. What will be the impact on the following device parameters (give reasons).

i) r_o, measured at edge of saturation: *shouldn't change, since the subcollector will remain well below the CB depletion region at EOS.*

4 pts

ii) r_o, measured at a high enough voltage that the C-B depletion region is >300nm thick. *Will likely be degraded, since, now, the heavier SC doping will cause the BC depletion region to modulate the base-width more strongly.*

iii) V_{PT}, assuming V_{PT} occurs at some voltage greater that (ii) above.: *Will be degraded, for the same reason as (ii).*

iv) f_T, measured at edge of saturation: *Will likely be higher, due to reduced collector resistance.*

3) SiGe is often used as the base material in modern NPN BJTs.

   a) What is the impact of the use of a SiGe base on the following device parameters, relative to a purely silicon-based device (give reasons):

      i) γ: *improved, since minority carrier concentration in the base is increased, increasing emitter majority current relative to emitter minority current.*

4 pts

      ii) α_T (assume the recombination lifetime in SiGe is the same as that in Si): *Will likely increase, since diffusion coefficient in SiGe is larger than in Si due to higher mobility. This will incrase diffusion length, thus enhancing base transport factor.*

      iii) $V_{CB,\ \text{avalanche breakdown}}$: *Will likely be degraded, since reduced bandgap of SiGe will result in more impact ionization in BC depletion region.*

      iv) f_T: *Will increase, due to improved gain.*

   b) Suppose, instead of using a SiGe base, I used a SiGe collector. Discuss (with reasons) the impact on the following device parameters, again with respect to a purely silicon-based device.

      i) γ: *Should have no impact, since the collector region has no effect on this parameter.*

3 pts

      ii) $V_{CB,\ \text{avalanche breakdown}}$: *Will degrade, as in (iii) above.*

      iii) f_T: *Will likely improve slightly, due to reduced collector resistance. This is caused by improved mobility in SiGe over Si.*

4) As you know, BJTs are essentially two PN diodes placed back-to-back, such that minority carriers from one device are able to diffuse into the depletion region of the other device. Suppose I were to implement a similar structure using Schottky diodes such that the device was an NMN device rather than an NPN device. Would you expect this device to function as a transistor? Give reasons for your answer (HINT: Focus on the role of minority carriers).

2 pts

This won't work, since no minority current can exist in the metal base region. Thus, this device will act like two back-to-back schottky diodes rather than a transistor (Note: By using a perforated metal plate instead of a continuous base region, some minority carriers are allowed through, enabling transistor action… this device is called a "permeable base transistor". Unfortunately, in practice, the performance of these devices isn't very good.)