5.4.4. Base spreading resistance and emitter current crowding

Large area bipolar transistors can have a very non-uniform current distribution due to the resistance of the base layer. Since the base current is applied through the thin base layer, there can be a significant series resistance in large devices. This resistance causes a voltage variation across the base region. This voltage variation in turn causes a variation of the emitter current density, especially since the emitter current density depends exponentially on the local base-emitter voltage. This effect is minimal in the center of the emitter-base diode and strongly increases toward the edges. In extreme cases, this effect causes the emitter current to occur only at the very edges of the emitter-base diode. The parameters involved include the sheet resistance of the base layer, the emitter current density and the current gain in the device. The characteristic length, $l_{spreading}$, can be obtained from a distributed model similar to that of a metal contact to a thin semiconductor layer as described in Section 3.9.

$$l_{spreading} = \sqrt{\frac{r_E Area}{R_{s,B}}} = \sqrt{\frac{V_t}{J_E R_{s,B}}} \tag{5.4.11}$$

Where r_E is the small signal emitter resistance, $R_{s,B}$ is the sheet resistance of the base and J_E is the emitter current density. This analysis is only valid if the emitter current density is close to uniform. The emitter current density in a BJT can only be consider close to uniform is the emitter stripe width is less that the characteristic length in the case of a one-sided base contact or less that twice the characteristics length in the case of a double sided base contact or:

$$W_{s,E} \leq 2\, l_{spreading} \tag{5.4.12}$$

The corresponding value of the base resistance for a uniform emitter current distribution equals:

$$R_B = \frac{1}{3} R_s \frac{W_{s,E}}{L_{s,E}} \tag{5.4.13}$$

for a one-sided base contact and

$$R_B = \frac{1}{12} R_s \frac{W_{s,E}}{L_{s,E}} \tag{5.4.14}$$

for a double-sided base contact, which effectively has the resistance of two sections with half the emitter stripe width connected in parallel. A series of narrow emitter fingers with alternating base contacts is therefore typically used in large area power device, resulting in the characteristic interdigitated structure.