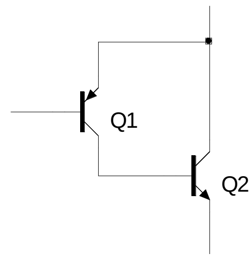
Complementary BJT Configuration

by Dennis L Feucht

A commonly-used circuit in the output stages of power amplifiers is the "complementary" two-BJT configuration, shown below.



npn BJTs are preferred power devices (just as n-channel MOSFETs are). The complementary pnp configuration is, like the Darlington or compound configuration, a two-transistor combination that has three terminals like a single BJT. Consequently, the complementary pnp behaves like a pnp while using a npn to implement the output.

The base of the equivalent pnp is the base of Q1, the Q1 emitter and Q2 collector node is the equivalent emitter, and the Q2 emitter is the equivalent collector. Apply KCL at the equivalent emitter to express the currents in terms of I_{E2}:

$$I_E' = I_{E1} + I_{C2} = I_{E2} \cdot \left(\frac{1}{\alpha_1 \cdot (\beta_2 + 1)} + \alpha_2 \right)$$

The first term:

$$I_{E2} \cdot \frac{1}{\alpha_1 \cdot (\beta_2 + 1)}$$

is I_{E1}; $I_{C1} = I_{B2} = I_{E2}/(\beta_2 + 1)$. Then:

$$I_{E1} = \frac{I_{C1}}{\alpha_1} = \frac{I_{E2}}{\alpha_1 \cdot (\beta_2 + 1)}$$

This can be rearranged to become:

$$I_E' = I_{E1} + I_{C2} = I_{E2} \cdot \left(\frac{1}{\alpha_1 \cdot (\beta_2 + 1)} + \alpha_2 \right) = I_{E2} \cdot \left(1 + \frac{1}{\beta_1 \cdot (\beta_2 + 1)} \right)$$

where the second term:

$$I_{E2} \cdot \frac{1}{\beta_1 \cdot (\beta_2 + 1)} = I_{B1}$$

An equivalent β, or β' is then:

$$\beta' = \frac{I_C'}{I_B'} = \frac{I_{E2}}{I_{B1}} = \frac{I_{E2}}{I_{E2} \cdot \left(\frac{1}{\beta_1 \cdot (\beta_2 + 1)} \right)} = \beta_1 \cdot (\beta_2 + 1)$$

An equivalent α can also be solved for:

$$\alpha' = \frac{I_C'}{I_E'} = \frac{I_{E2}}{I_{E2} \cdot \left(1 + \frac{1}{\beta_1 \cdot (\beta_2 + 1)}\right)} = \frac{\beta_1 \cdot (\beta_2 + 1)}{\beta_1 \cdot (\beta_2 + 1) + 1} = \frac{\beta'}{\beta' + 1}$$

Thus, the formulas for β and α are consistent with each other relative to a single BJT. We consequently have some assurance in regarding the complementary pnp as having at least quasistatic functional equivalency to a single pnp with the designated terminals corresponding to a single pnp.

Dynamically, the situation is somewhat more complicated in that the two BJTs form a tight feedback loop with a loop gain dependent upon external impedances. If the pnp is a smaller, faster transistor than the more powerful npn, then the npn places a dominant pole in the loop and this usually stabilizes the pair.