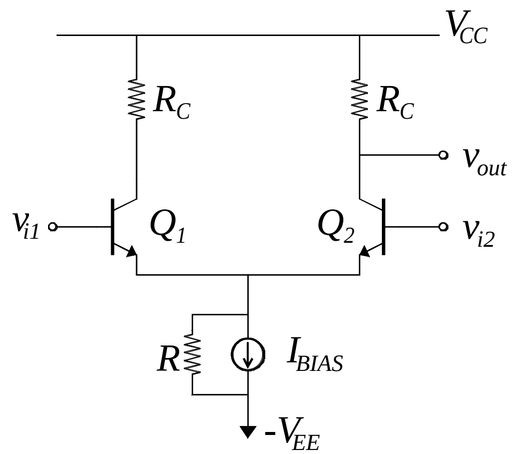
DIFFERENTIAL AMPLIFIER, SINGLE-ENDED OUTPUT

Analysis of a symmetrical differential single-ended output amplifier

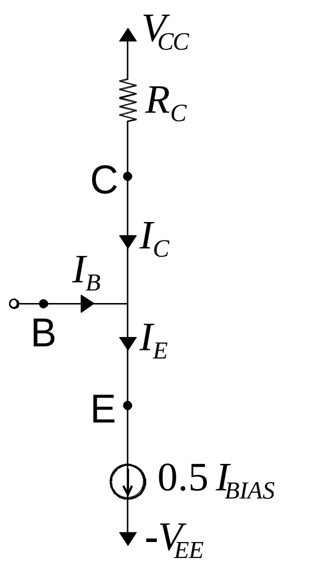
THE CIRCUIT



SINGLE-ENDED OUTPUT AMPLIFIER

Differential amplifiers are used in integrated circuit design. In IC design, large capacitors and large (Ω) resistors are impractical.

DC ANALYSIS



Since the circuit is symmetrical, we are looking at only ½ the circuit, through which ½ the bias current flows. The bias resistance *R* is ignored. We find the value of r_e for our AC circuit model using these formulas:

$$I_C = \frac{\beta}{\beta+1} I_E = 0.5\frac{\beta}{\beta+1} I_{BIAS} \qquad g_m = 40 I_C$$

$$r_\pi = \frac{\beta}{g_m} \qquad r_e = \frac{r_\pi}{\beta+1}$$

AC ANALYSIS

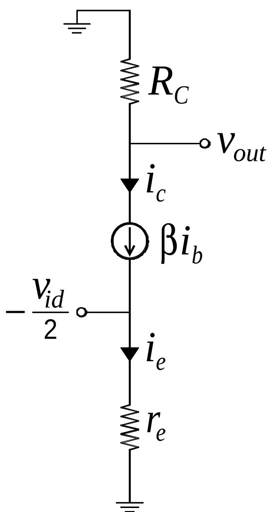
For the AC analysis, we divide the input signals v_{i1} and v_{i2} into differential and common-mode components. The inputs are written as

$v_{i1} = v_{i\,cm} + \frac{v_{id}}{2}$	$v_{i2} = v_{i\,cm} - \frac{v_{id}}{2}$

We solve for the differential output v_d and the common mode output v_{cm} separately using different models and then combine the results.

DIFFERENTIAL MODE ANALYSIS - solving for the differential mode voltage gain A_d

DM MODEL



Since the circuit is symmetrical and the differential mode inputs are 180° out of phase, a ground potential results at the emitters. The two halves of the circuit are isolated. Since there is an output only on the right-hand half, this is the only part of the circuit we include in this analysis.

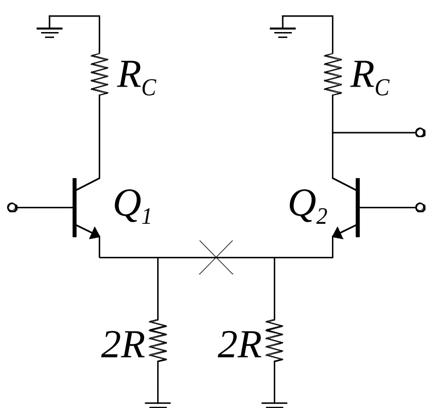
$$i_e = -\frac{v_{i\,d}}{2} \div r_e = -\frac{v_{i\,d}}{2r_e} \qquad i_c = \frac{\beta}{\beta+1}\left(-\frac{v_{i\,d}}{2r_e}\right)$$

$$v_{d\,out} = -i_c R_C = \frac{\beta}{\beta+1}\left(\frac{v_{i\,d}}{2r_e}\right)R_C \qquad A_d = \frac{v_{d\,out}}{v_{i\,d}}$$

A_d is the differential mode gain [*V/V*]

COMMON MODE ANALYSIS - solving for the common mode voltage gain A_{cm}

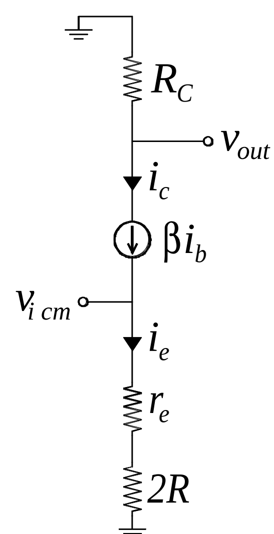
AC ANALYSIS



Because of the symmetry of the circuit, we can write *R* as two parallel 2*R* resistors and observe that no current flows between them. Therefore this connection can be eliminated and we separate the circuit into halves. Once again, we need only look at the right-hand half since that contains the output.

Even though we have looked only at the right-hand side in both phases of the analysis, the presence of the left-hand side does significantly affect the outcome.

CM MODEL



$$i_e = \frac{v_{i\,cm}}{r_e + 2R} \qquad i_c = \frac{\beta}{\beta+1}\left(\frac{v_{i\,cm}}{r_e+2R}\right) \qquad v_{cm\,out} = -i_c R_C = \frac{\beta}{\beta+1}\left(\frac{v_{id}}{2r_e}\right)R_C \qquad A_{cm} = \frac{v_{cm\,out}}{v_{i\,cm}}$$

COMMON MODE REJECTION RATIO (CMRR)

$$\text{CMRR} = \left|\frac{A_d}{A_{cm}}\right| \qquad \text{CMRR}_{\text{dB}} = 20\log_{10}\left|\frac{A_d}{A_{cm}}\right|$$