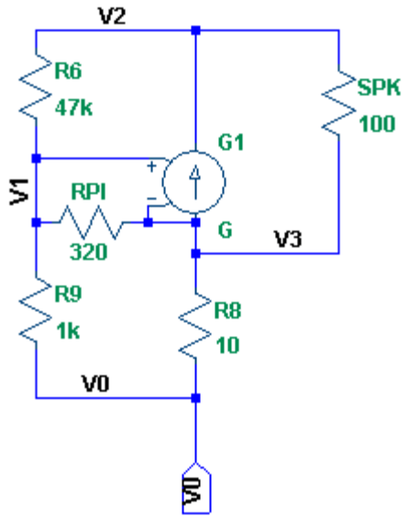
Circuit derivation for upper half of Totem Pole. January 18th 2010, Joe Sousa



Node voltage equations:

$$\frac{V2 - V1}{R6} - \frac{V1 - V3}{RPI}\cdot BETA + \frac{V2 - V3}{SPK} = 0$$

$$\frac{V1 - V2}{R6} + \frac{V1 - V3}{RPI} + \frac{V1 - V0}{R9} = 0$$

$$\frac{V3 - V0}{R8} + \frac{V3 - V1}{RPI} + \frac{V3 - V2}{SPK} - \frac{V1 - V3}{RPI}\cdot BETA = 0$$

Ground V0 and force a unit voltage at V2

$V0 := 0$

$$\frac{(V1 - V2)}{R6} + \frac{(V1 - V3)}{RPI} + \frac{V1}{R9} = 0$$

$$\frac{V3}{R8} + \frac{(V3 - V1)}{RPI} + \frac{(V3 - V2)}{SPK} - \frac{(V1 - V3)}{RPI}\cdot BETA = 0$$

$V2 := 1$

$$\frac{(V1 - 1)}{R6} + \frac{(V1 - V3)}{RPI} + \frac{V1}{R9} = 0$$

$$\frac{V3}{R8} + \frac{(V3 - V1)}{RPI} + \frac{(V3 - 1)}{SPK} - \frac{(V1 - V3)}{RPI}\cdot BETA = 0$$

Solve for V1

$$V1 = \frac{-\left(\frac{-1}{R6} - \frac{1}{RPI}\cdot V3\right)}{\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)}$$

$$V3 = \frac{-\left(\frac{-1}{RPI}\cdot V1 - \frac{1}{SPK} - \frac{1}{RPI}\cdot BETA\cdot V1\right)}{\left(\frac{1}{R8} + \frac{1}{RPI} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\right)}$$

Substitute V1 as a function of V3

$$V3 = \frac{\left[\frac{1}{RPI}\cdot\frac{\left(\frac{1}{R6} + \frac{1}{RPI}\cdot V3\right)}{\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\cdot\frac{\left(\frac{1}{R6} + \frac{1}{RPI}\cdot V3\right)}{\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)}\right]}{\left(\frac{1}{R8} + \frac{1}{RPI} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\right)}$$

Solve for output voltage V3

$$V3 = \frac{-\left[\frac{-1}{\left[\left(\frac{1}{R8} + \frac{1}{RPI} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\right)\cdot\left[RPI\cdot\left[\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)\cdot R6\right]\right]\right]} - \frac{1}{\left[\left(\frac{1}{R8} + \frac{1}{RPI} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\right)\cdot SPK\right]} - \frac{1}{\left[\left(\frac{1}{R8} + \frac{1}{RPI} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\right)\cdot RPI\right]}\cdot\frac{BETA}{\left[\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)\cdot R6\right]}\right]}{\left[1 - \frac{1}{\left[\left(\frac{1}{R8} + \frac{1}{RPI} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\right)\cdot\left[RPI^2\cdot\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)\right]\right]} - \frac{1}{\left[\left(\frac{1}{R8} + \frac{1}{RPI} + \frac{1}{SPK} + \frac{1}{RPI}\cdot BETA\right)\cdot RPI^2\right]}\cdot\frac{BETA}{\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)}\right]}$$

Simplify and apply values from NPN example

$R6 := 47000 \quad R8 := 10 \quad R9 := 1000 \quad RPI := 320 \quad BETA := 200 \quad SPK := 100$

$$V3 := (SPK \cdot R9 + RPI \cdot R9 + R6 \cdot R9 + R6 \cdot RPI + SPK \cdot BETA \cdot R9) \cdot \frac{R8}{(RPI \cdot SPK \cdot R9 + SPK \cdot R6 \cdot R9 + RPI \cdot SPK \cdot R6 + R8 \cdot SPK \cdot R9 + R8 \cdot SPK \cdot R6 + R8 \cdot RPI \cdot R9 + R8 \cdot R6 \cdot R9 + R8 \cdot RPI \cdot R6 + BETA \cdot R8 \cdot SPK \cdot R9 + BETA \cdot R8 \cdot SPK \cdot R}$$

$V3 = 0.049953$ R8=10R drops 5% of the total voltage drop across the upper half of the Totem pole.

$$V1 := \frac{-\left(\frac{-1}{R6} - \frac{1}{RPI} \cdot V3\right)}{\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)}$$

$V1 = 0.04278$

$$Iin := \frac{V1}{R9} + \frac{V3}{R8} \qquad Iin = 5.038 \cdot 10^{-3}$$

$$Rin := \frac{V2}{Iin} \qquad Rin = 198$$

Total end-to-end impedance is 200R.
The Emitter of Q3 modelled by G1 shields half of the 100R Speaker impedance from Q2.

Try a 20 Ohm speaker load: $SPK := 20$

$$V3 := (SPK \cdot R9 + RPI \cdot R9 + R6 \cdot R9 + R6 \cdot RPI + SPK \cdot BETA \cdot R9) \cdot \frac{R8}{(RPI \cdot SPK \cdot R9 + SPK \cdot R6 \cdot R9 + RPI \cdot SPK \cdot R6 + R8 \cdot SPK \cdot R9 + R8 \cdot SPK \cdot R6 + R8 \cdot RPI \cdot R9 + R8 \cdot R6 \cdot R9 + R8 \cdot RPI \cdot R6 + BETA \cdot R8 \cdot SPK \cdot R9 + BETA \cdot R8 \cdot SPK \cdot R}$$

$V3 = 0.174666$ R8=10R drops 17% of the total voltage drop across the upper half of the Totem pole.

$$V1 := \frac{-\left(\frac{-1}{R6} - \frac{1}{RPI} \cdot V3\right)}{\left(\frac{1}{R6} + \frac{1}{RPI} + \frac{1}{R9}\right)}$$

$V1 = 0.136775$

$$Iin := \frac{V1}{R9} + \frac{V3}{R8} \qquad Iin = 0.018$$

$$Rin := \frac{V2}{Iin} \qquad Rin = 57$$

Total end-to-end impedance is 57R.
The Emitter of Q3 modelled by G1 shields more than half of the 20R Speaker impedance from Q2.