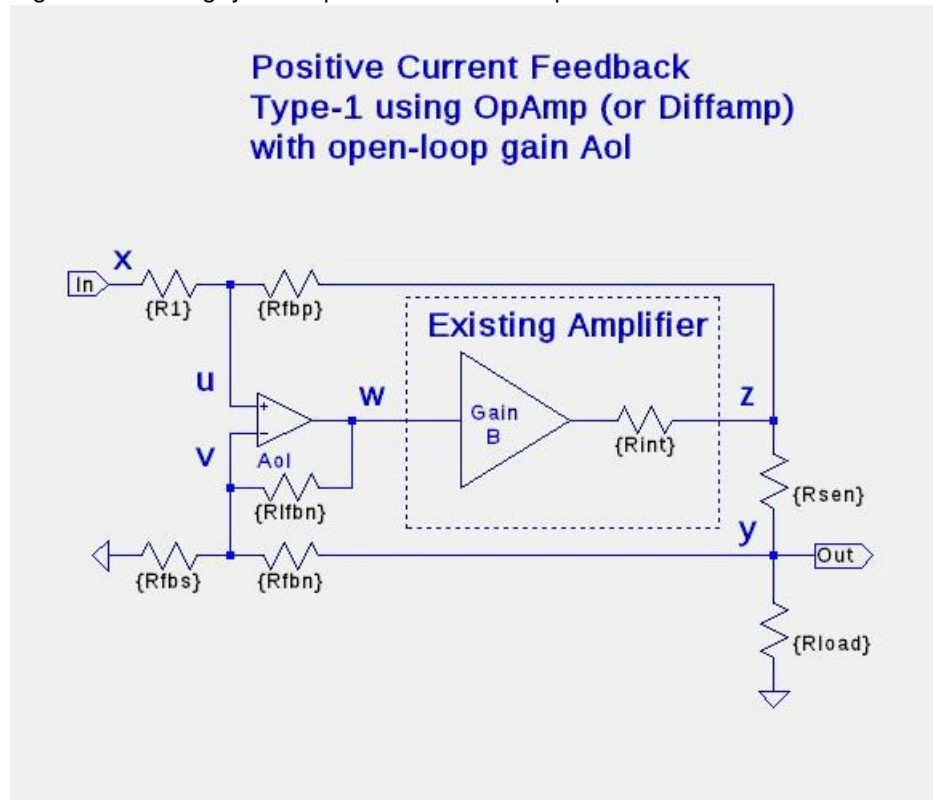


Positive Current Feedback using an opamp around an existing amplifier.

Figure 1: /m/m-rugby/rom1/quam/audio/circuits/spice/F7/DIYAudio-forum/PCF-T1-opamp-3.asc.jpg



Here is a Positive Current Feedback (PCF) circuit that can be used with an existing power amplifier to obtain an arbitrary closed loop gain (CLG), output resistance (R_{out}) and negative feedback factor K around the existing amplifier.

Circuit Equations:

$$0 = (x-u)/R1 + (z-u)/Rfbp$$

$$0 = (0-v)/Rfbs + (y-v)/Rfbn + (w-v)/Rlfbn$$

$$w = Aol \cdot (u-v)$$

$$I_{load} = (B \cdot w - z)/R_{int}$$

$$I_{load} = y/R_{load}$$

(Note: These circuit equations ignore the (minor) effects of currents through the feedback resistors on nodes y and z).

Parameters of the Existing Amplifier:

B : closed loop gain

R_{int} : internal resistance

Parameters of OpAmp:

Aol : open loop gain

Arbitrary parameters of the Circuit:

R_{fbs} , $R1$, R_{sen}

Circuit Unknowns:

R_{lfbn} , R_{fbn} , and R_{fbp}

Resistor Ratios:

$$R_{In} = R_{lfbn}/R_{fbs}$$

$$R_n = R_{fbn}/R_{fbs}$$

$$R_p = R_{fbp}/R1$$

$$R_i = R_{int}/R_{sen}$$

$$R_o = R_{out}/R_{sen}$$

$$V_s = I_{load} \cdot R_{sen}$$

Circuit Equations using Resistor Ratios:

$$0 = (x-u) + (z-u)/R_p$$

$$0 = (0-v) + (y-v)/R_n + (w-v)/R_{in}$$

$$w = A_{ol} \cdot (u-v)$$

$$V_s = (B \cdot w - z)/R_i$$

$$V_s = z - y$$

$$V_s = y/R_l$$

Parameters to obtain:

CLG: closed loop gain of the resulting amplifier
 Rout: output resistance of the resulting amplifier
 K: negative feedback factor around existing amplifier

The above conditions produce a system of 3 equations for CLG, Rout, and K in 3 the unknowns R_{lfbn} , R_{fbn} , and R_{fbp} .

When expressed using resistor ratios we get the following general result:

$$(\%050) \quad R_{ln} = \frac{1 + R_i + (CLG - R_o)K + A_{ol}((CLG - 1)K - B + 1)}{(R_o - CLG)K + A_{ol}B - R_i - 1}$$

$$(\%051) \quad R_n = \frac{-1 - R_i + R_oK - CLGK - A_{ol}(1 - B - K + CLGK)}{A_{ol}(R_oK - K - R_i)}$$

$$(\%052) \quad R_p = \frac{CLGK}{-R_oK + R_i + 1}$$

Special Cases:

When the OpAmp has infinite Aol we get:

$$(\%023) \quad R_{ln} = \frac{1 - B + (CLG - 1)K}{B}$$

$$(\%024) \quad R_n = \frac{1 - B + (CLG - 1)K}{(1 - R_o)K + R_i}$$

$$(\%025) \quad R_p = \frac{CLGK}{-R_oK + R_i + 1}$$

When the OpAmp has infinite Aol and B=1 we get the following:

(This is a desirable result when using an OpAmp with high Aol and a follower output stage)

$$(\%044) \quad R_{ln} = (CLG - 1)K$$

$$(\%045) \quad R_n = \frac{(CLG - 1)K}{(1 - R_o)K + R_i}$$

$$(\%046) \quad R_p = \frac{CLGK}{-R_oK + R_i + 1}$$

When the OpAmp has infinite Aol, B=1, and Rout=0 we get:

$$(\%035) \quad R_{ln} = (CLG - 1)K$$

$$(\%036) \quad R_n = \frac{(CLG - 1)K}{K + R_i}$$

$$(\%037) \quad R_p = \frac{CLGK}{R_i + 1}$$

No local negative feedback case:

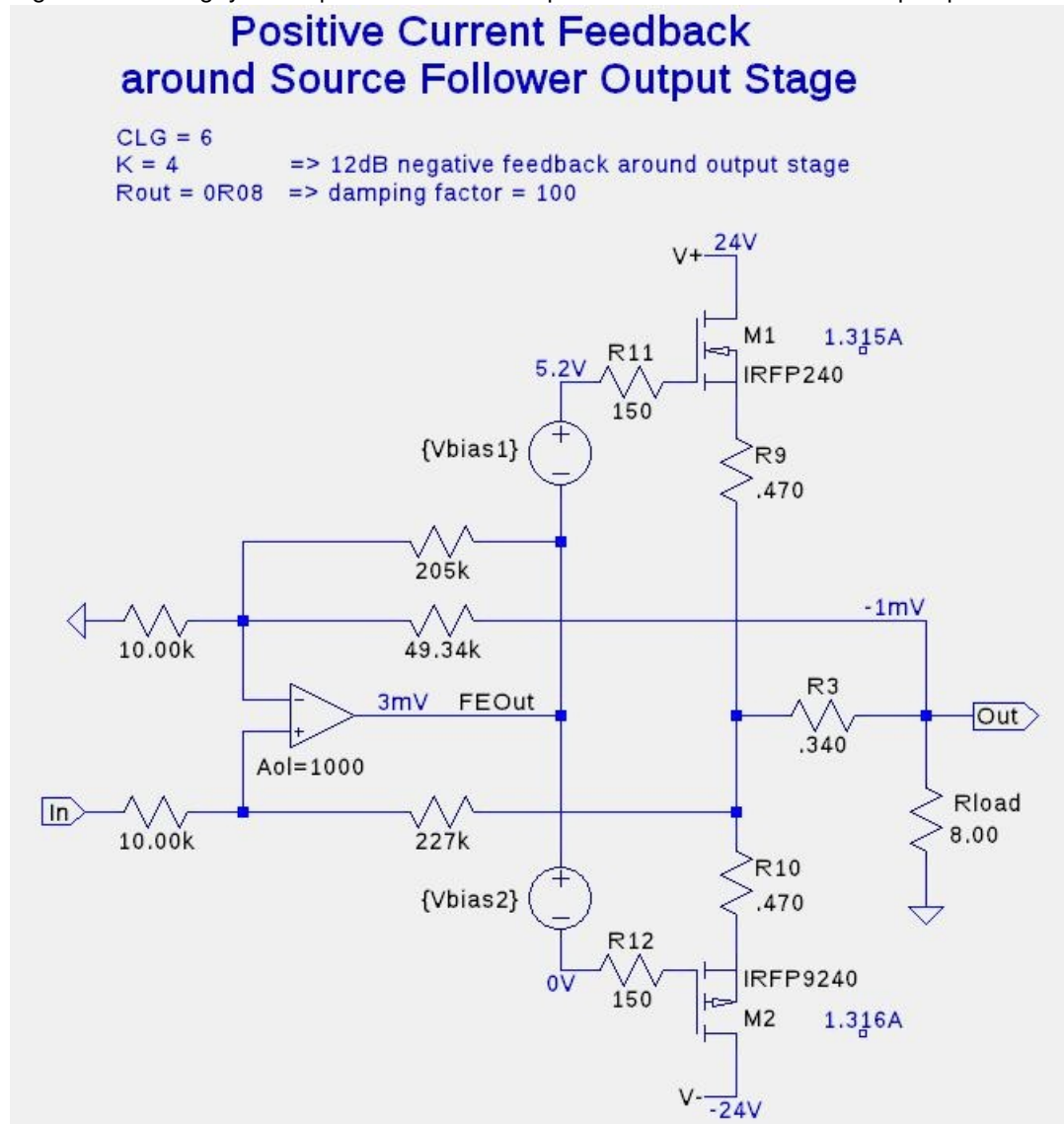
The local negative feedback resistor (R_{lfbn}) can be omitted when the demoninator of R_{ln} in the general case is zero thus making R_{ln} infinite. Thus we can solve for any of Aol, CLG, K, or Ro which zeros the demoninator of R_{ln} .

Examples:

$$\begin{aligned}
 (\%053) \quad Aol &= \frac{1+Ri+(CLG-Ro)K}{B} \\
 (\%054) \quad CLG &= \frac{-1-Ri+Aol B+Ro K}{K} \\
 (\%055) \quad K &= \frac{-1-Ri+Aol B}{CLG-Ro} \\
 (\%056) \quad Ro &= \frac{1+Ri-Aol B+CLG K}{K}
 \end{aligned}$$

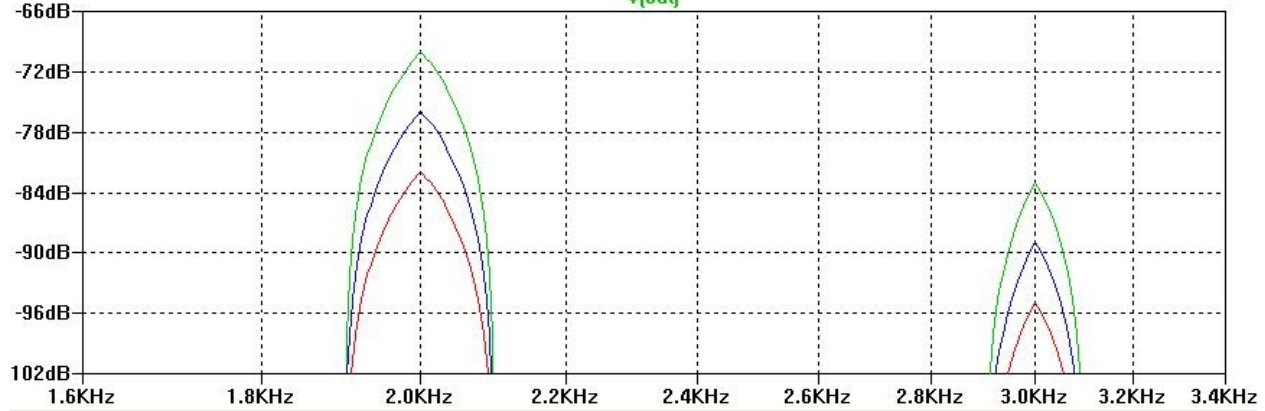
Simulation Results

Figure 2: /m/m-rugby/rom1/quam/audio/circuits/spice/F7/DIYAudio-forum/PCF-opamp-1b-XXX-cleaned.asc.jpg



The plot below shows the 2nd and 3rd harmonics for the circuit at 1kHz and 1 Watt into 8R at 3 values of the negative feedback factor K. Green is K=1 (0dB), Blue is K=2 (6dB), and Red is K=4 (12dB).

Figure 3: /m/m-rugby/rom1/quam/audio/circuits/spice/F7/DIYAudio-forum/PCF-T1-opamp-posting-harm-vs-K.jpg



The plot below shows the 2nd and 3rd harmonics for the circuit at 1kHz and 1 Watt into 8R at 5 different values of Rout. This shows that the harmonic spectrum is not affected by the choice of Rout (damping factor).

Figure 4: /m/m-rugby/rom1/quam/audio/circuits/spice/F7/DIYAudio-forum/PCF-T1-opamp-posting-harm-vs-Rout.jpg

