3. Noise Reduction

Negative feedback reduces the noise or interference in an amplifier, more precisely, by increasing the ratio of signal to noise, which is possible only under certain conditions.

The improvement in signal to noise ratio is acheived by connecting a noise-free amplifier before the noisy stage, with the application of negative feedback.

4. Reduction in Non-linear Distortion

The transfer characteristics can be considerably linearized by applying negative feedback to the amplifier. It is known that, negative feedback reduces the dependence of the overall closed loop gain on the open loop gain of the basic amplifier. Thus, large changes in open loop gain results in much smaller changes in closed-loop gain.

Due to introduction of negative feedback, with the feedback ratio (β), the distortion (D) is reduced by a factor of $(1+A\beta)$ and the distortion with feedback (D_f) is given by,

$$D_f = \frac{D}{1+A\beta}$$

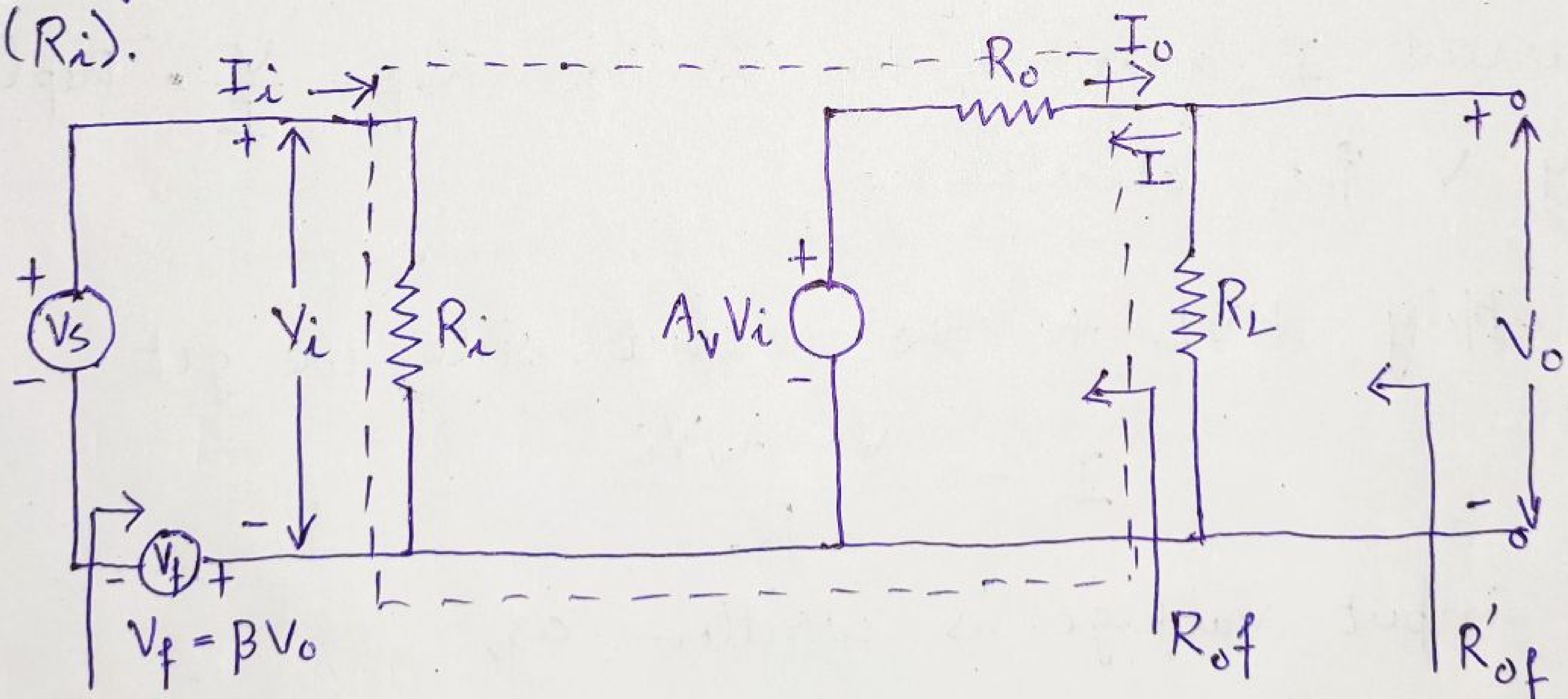
* * * * * * *

Effect of Negative Feedback on Input Resistance and Output Resistance

1. Voltage - Series Feedback

The voltage series feedback topology is shown below with the amplifier input and output circuit replaced by its Thevenin's model. We have considered R_s to be part of the amplifier througout the discussion.

When the negative feedback signal is feed back to the input in series with the applied voltage, the input resistance is increased. Since the feedback voltage V_f opposes V_s, the input current I_i becomes less and the input resistance with feedback (R_{if}) is greater than the input resistance without feedback (R_i).



$$R_{if} = \frac{V_s}{I_i}$$

Applying KVL to the input side, we get

$$V_s = I_i R_i + V_f = I_i R_i + \beta V_o$$

The output voltage is written as

$$V_o = \frac{A_v V_i R_L}{R_o + R_L} = A'_v V_i$$

where $A_v' = \frac{V_o}{V_i} = \frac{A_v R_L}{R_o + R_L}$

Substituting the value of V_o in the above KVL equation, we get

$$V_s = I_i R_i + \beta A_v' I_i R_i$$

Therefore, $\boxed{R_{if} = \frac{V_s}{I_i} = R_i (1 + \beta A_v')}$

where $A_v = \lim_{R_L \to \infty} A_v'$

Now, the resistance with feedback R_{of} looking into the output terminals is obtained by disconnecting R_L (i.e $R_L = \infty$) and by making the external source signal to zero (i.e set $V_s = 0$). To find R_{of}, impress a voltage V across the output terminals and calculate the current I delivered by V. Then $R_{of} = \frac{V}{I}$. Replace V_o by V for calculations.

So, apply KVL to the output side, we get

$$I = \frac{V - A_v V_i}{R_o}$$

The input voltage is written as,

$$V_i = -V_f = -\beta V \quad (\text{with } V_s = 0)$$

Substituting V_i in the above KVL equation, we get

$$I = \frac{V + A_v \beta V}{R_o} = \frac{V(1 + \beta A_v)}{R_o}$$

The output resistance with feedback is given as,

$$R_{of} = \frac{V}{I} = \frac{R_o}{1+\beta A_v}$$

where A_v represents the open circuit voltage gain without taking the load R_L into account.

The output resistance with feedback R_{of}' including R_L as part of the amplifier is given by

$$R_{of}' = R_{of} \parallel R_L$$

Therefore, $$R_{of}' = \frac{R_{of} R_L}{R_{of} + R_L} = \frac{\left(\frac{R_o}{1+\beta A_v}\right) \cdot R_L}{\left(\frac{R_o}{1+\beta A_v}\right) + R_L}$$

$$R_{of}' = \frac{R_o R_L}{(1+\beta A_v)\left[\frac{R_o}{1+\beta A_v} + R_L\right]}$$

$$R_{of}' = \frac{R_o R_L}{R_o + R_L + \beta A_v R_L}$$

Dividing numerator and denominator by $(R_o + R_L)$

$$R_{of}' = \frac{R_o R_L / R_o + R_L}{1 + [\beta A_v R_L / R_o + R_L]}$$

where $R_o' = \frac{R_o R_L}{R_o + R_L}$ and $A_v' = \frac{A_v R_L}{R_o + R_L}$

$$\therefore R_{of}' = \frac{R_o'}{1+\beta A_v'}$$

where A_v' indicates the open circuit voltage gain taking load R_L into account.

2. Current Series Feedback

The current series feedback topology is shown in Figure blow with amplifier input circuit represented by Thevenin's model and the output circuit by Norton's equivalent circuit. Here the input impedance with feedback is given by $R_{if} = \frac{V_s}{I_i}$.

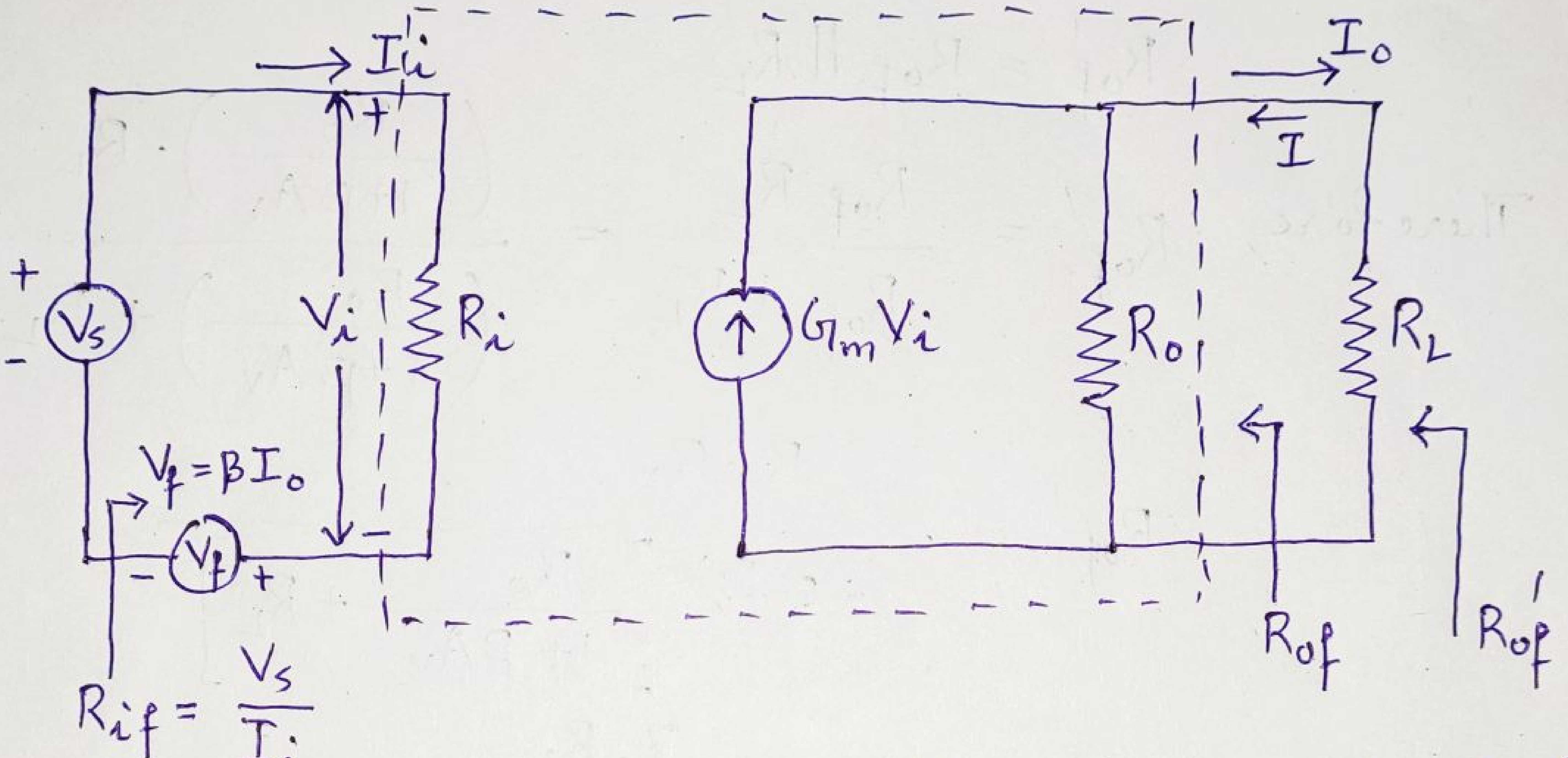


Fig. Equivalent circuit for Current series feedback circuit.

Apply KVL to the input side, we get

$$V_s = I_i R_i + V_f = I_i R_i + \beta I_o$$

The output current is written as

$$I_o = \frac{G_m V_i R_o}{R_o + R_L} = G_M V_i$$

$$\text{where } G_M = \frac{I_o}{V_i} = \frac{G_m R_o}{R_o + R_L}$$

Substituting the value of I_o in the above KVL equation, we get

$$V_s = I_i R_i + \beta G_M I_i R_i$$

$$\boxed{R_{if} = \frac{V_s}{I_i} = R_i (1 + \beta G_M)}$$

where $G_m \rightarrow$ short circuit transconductance without feedback

$G_M \rightarrow$ transconductance without feedback taking the load R_L into account.

$$\therefore \quad G_m = \lim_{R_L \to 0} G_M$$

For finding R_{of}, R_L is disconnected (i.e $R_L = \infty$), the external source signal is made zero (i.e set $V_s = 0$) and V_o is replaced with V.

Applying KCL to the output node, we get

$$I = \frac{V}{R_o} - G_m V_i$$

The input voltage is written as

$$V_i = V_f = -\beta I_o = \beta I \quad (\text{with } V_s = 0 \text{ and } I = -I_o)$$

Substituting V_i in the above KCL equation, we get

$$I = \frac{V}{R_o} - \beta G_m I$$

$$I(1 + \beta G_m) = \frac{V}{R_o}$$

The output resistance with feedback is given as

$$\boxed{R_{of} = \frac{V}{I} = R_o(1 + \beta G_m)}$$

The output resistance with feedback R_{of}' including R_L as part of the amplifier is given by

$$R_{of}' = R_{of} \parallel R_L$$

$$\therefore \quad R_{of}' = \frac{R_{of} \cdot R_L}{R_{of} + R_L} = \frac{R_o(1 + \beta G_m) R_L}{R_o(1 + \beta G_m) + R_L}$$

$$= \frac{R_o R_L (1 + \beta G_m)}{R_o + R_L + \beta G_m R_o}$$

Dividing numerator and denominator by $(R_o + R_L)$, we get

$$R'_{of} = \frac{\dfrac{R_o R_L (1 + \beta G_m)}{R_o + R_L}}{1 + \dfrac{\beta G_m R_o}{R_o + R_L}} = R_o' \cdot \frac{1 + \beta G_m}{1 + \beta G_M}$$

where $R_o' = \dfrac{R_o R_L}{R_o + R_L}$ and $G_M = \dfrac{G_m R_o}{R_o + R_L}$