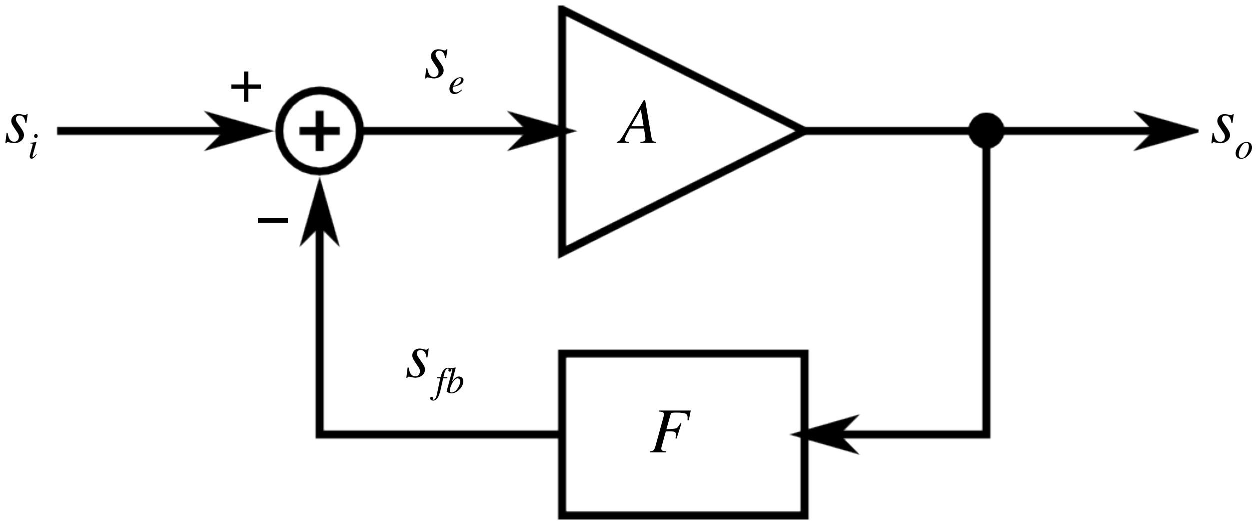
EEE 51: Second Semester 2017 - 2018

Lecture 18

Feedback Basics

Negative Feedback

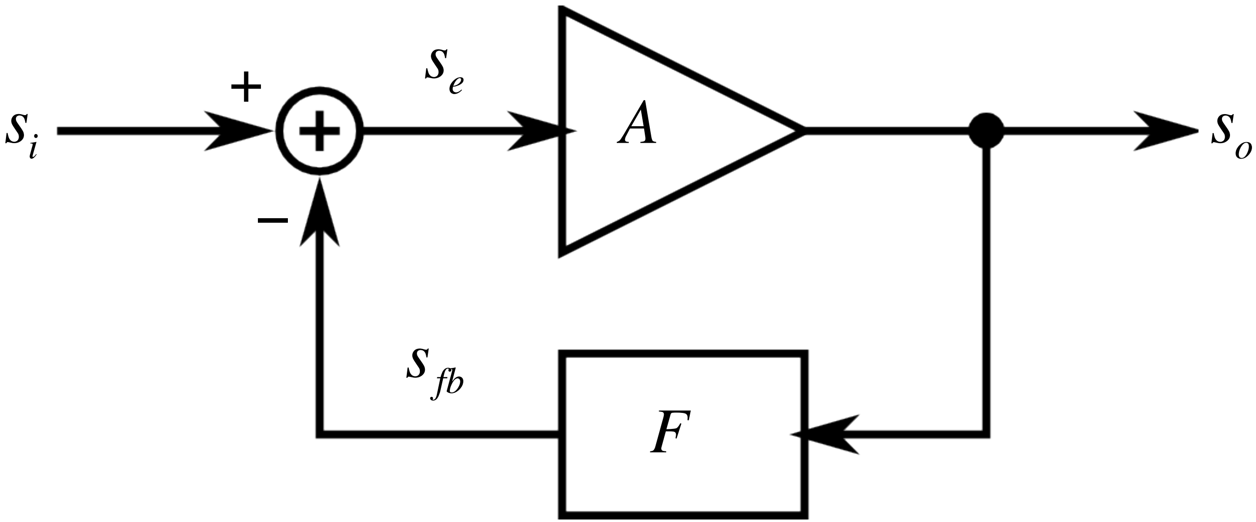


$$s_o = A \cdot s_e$$

$$s_{fb} = F \cdot s_o$$

$$s_e = s_i - s_{fb}$$

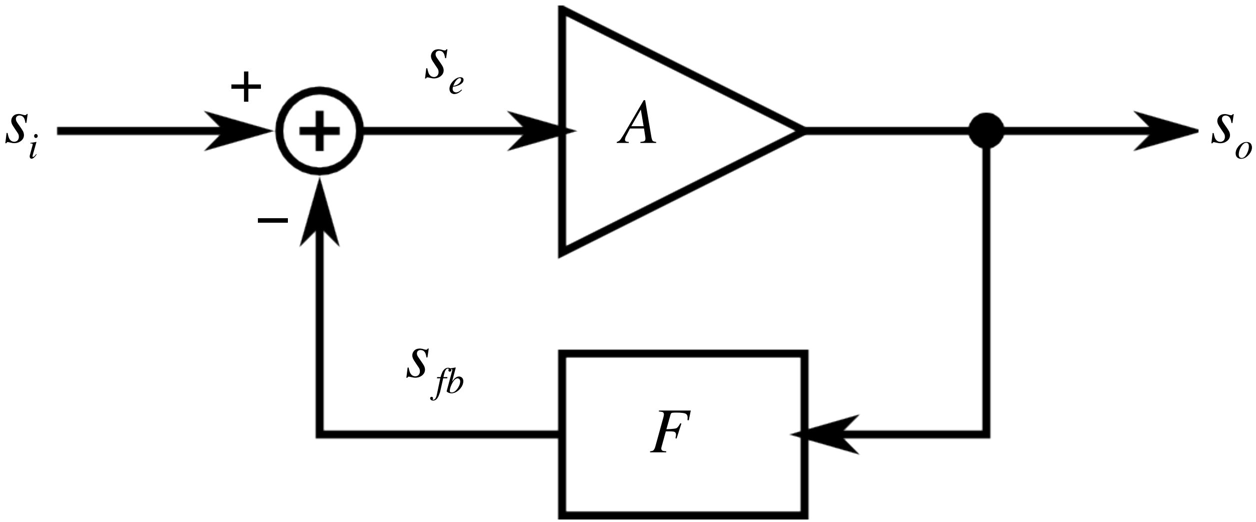
Negative Feedback



$$\frac{s_o}{A} = s_i - F \cdot s_o$$

$$\frac{s_o}{s_i} = \frac{A}{1 + AF} = \frac{1}{F} \cdot \frac{A}{\frac{1}{F} + A} = \frac{1}{F} \cdot \frac{1}{\frac{1}{AF} + 1}$$

Negative Feedback

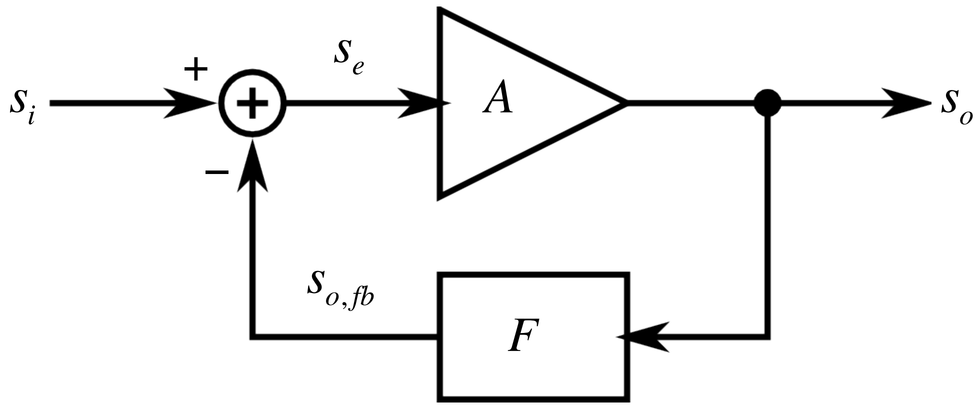


$$\frac{s_o}{s_i} = \frac{A}{1+AF} = \frac{1}{F}\cdot\frac{1}{\underbrace{\frac{1}{T}+1}_{(1+\varepsilon)}}$$

Loop Gain:

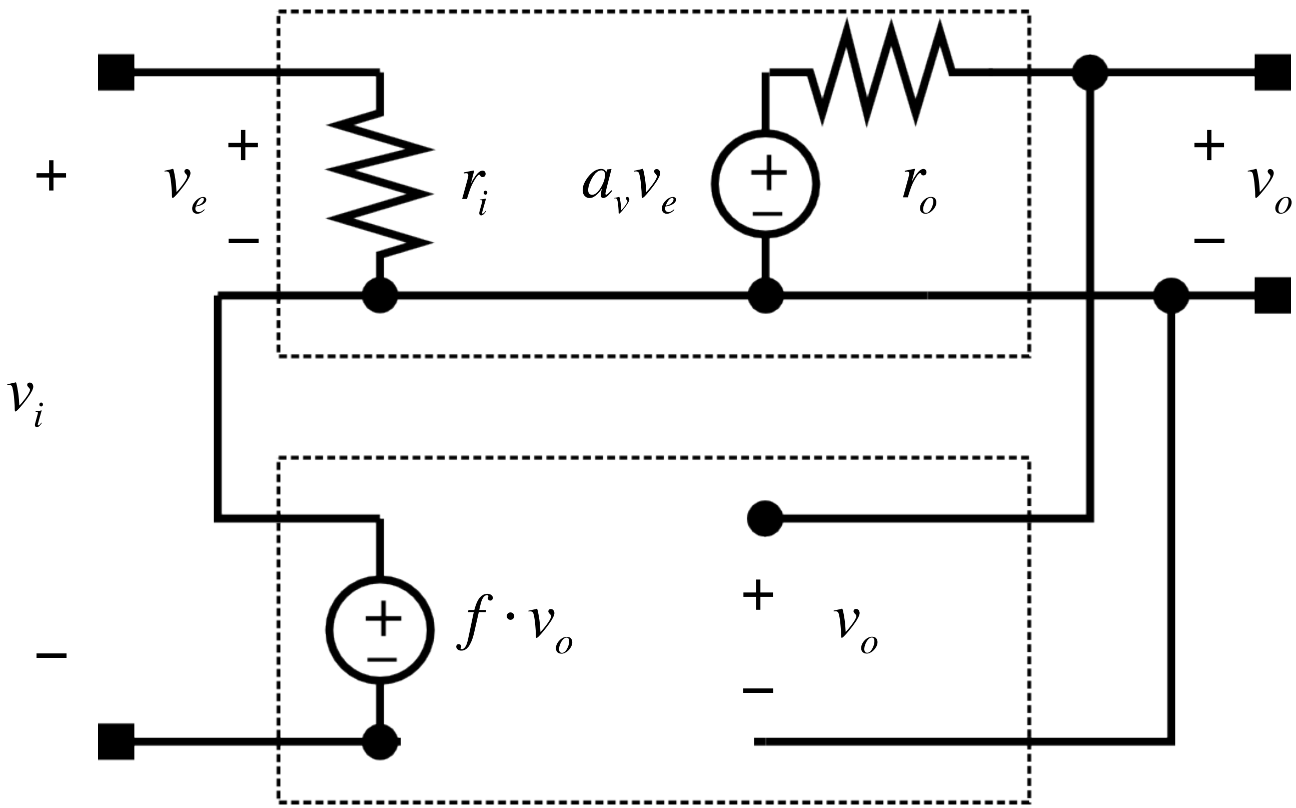
$$T = AF$$

Gain Sensitivity

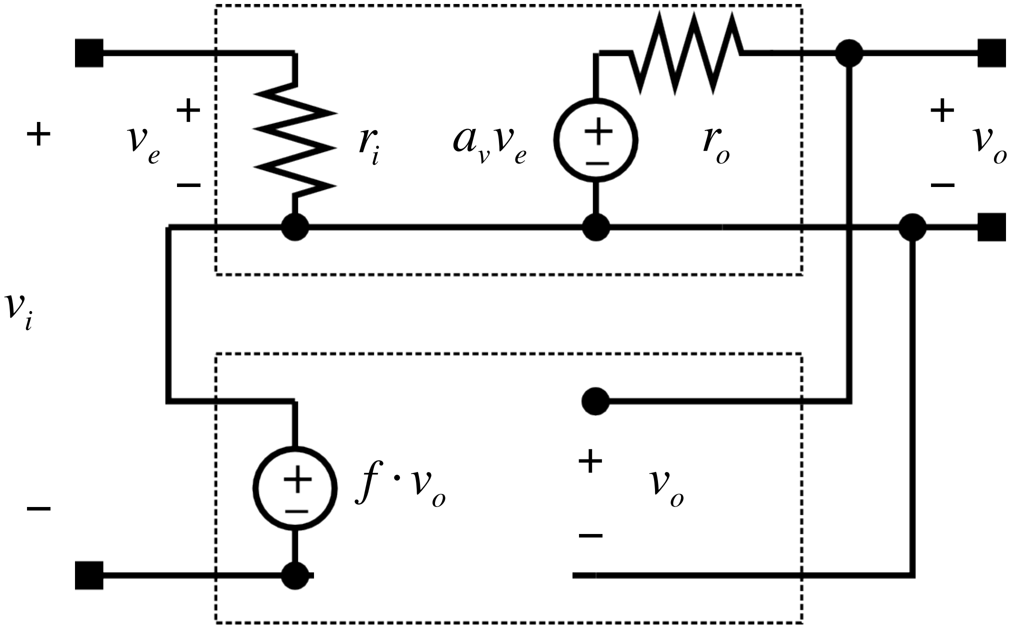


$$\frac{\partial\left(\dfrac{s_o}{s_i}\right)}{\partial A} = \frac{\left(1+AF\right)-AF}{\left(1+AF\right)^2} = \frac{1}{\left(1+AF\right)^2} = \frac{1}{\left(1+T\right)^2}$$

Example: Ideal Series-Shunt Feedback



Ideal Series-Shunt Gain

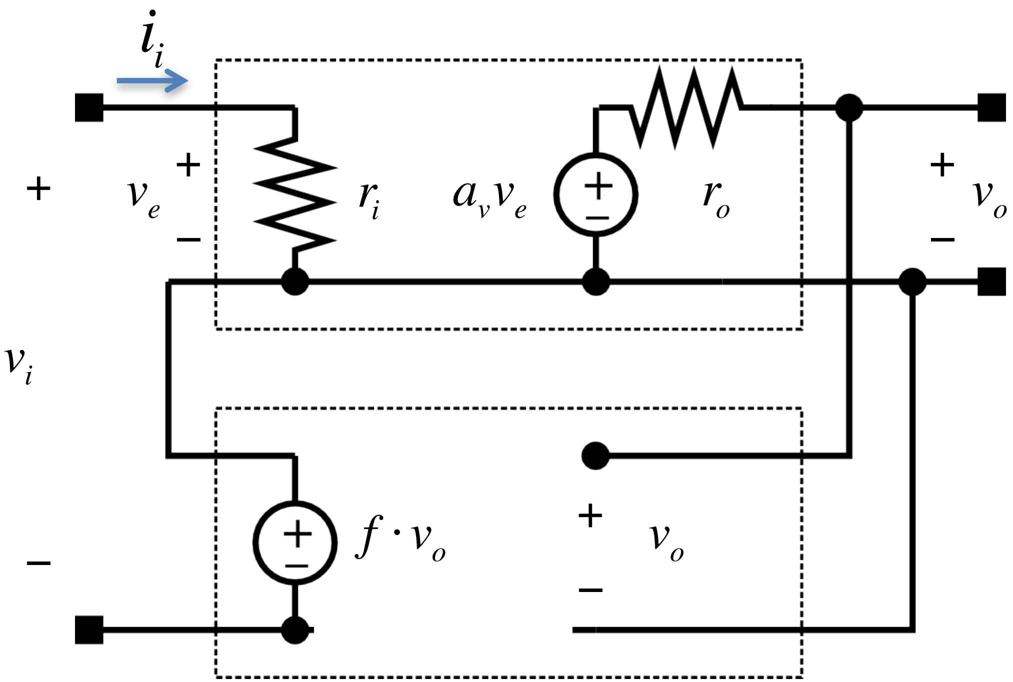


$$A_v = \frac{v_o}{v_e} = a_v$$

$$F = \frac{f \cdot v_o}{v_o} = f$$

$$v_o = a_v v_e = a_v \left(v_i - f \cdot v_o \right) \quad \Rightarrow \quad \frac{v_o}{v_i} = \frac{a_v}{1 + a_v f} = \frac{a_v}{1 + T}$$

Ideal Series-Shunt Input Impedance



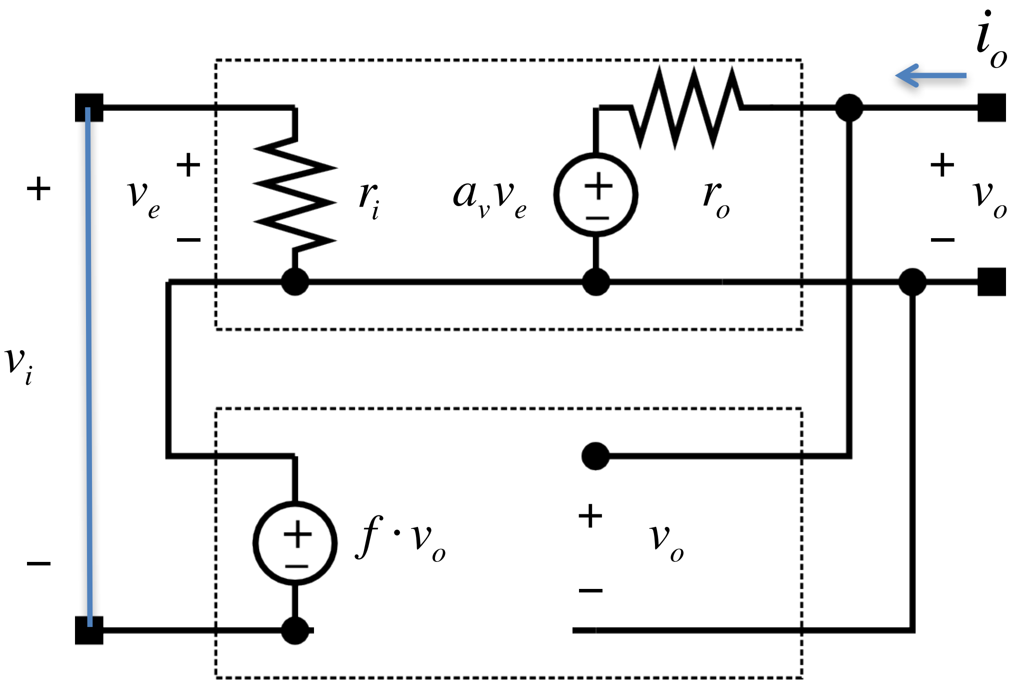
$$A_v = \frac{v_o}{v_e} = a_v$$

$$F = \frac{f \cdot v_o}{v_o} = f$$

$$i_i = \frac{v_e}{r_i} = \frac{v_i - f \cdot v_o}{r_i} = \frac{v_i - f \cdot v_i \dfrac{a_v}{1+T}}{r_i} = \frac{v_i}{r_i\left(1+T\right)}$$

$$\boxed{R_i = r_i\left(1+T\right)}$$

Ideal Series-Shunt Output Impedance



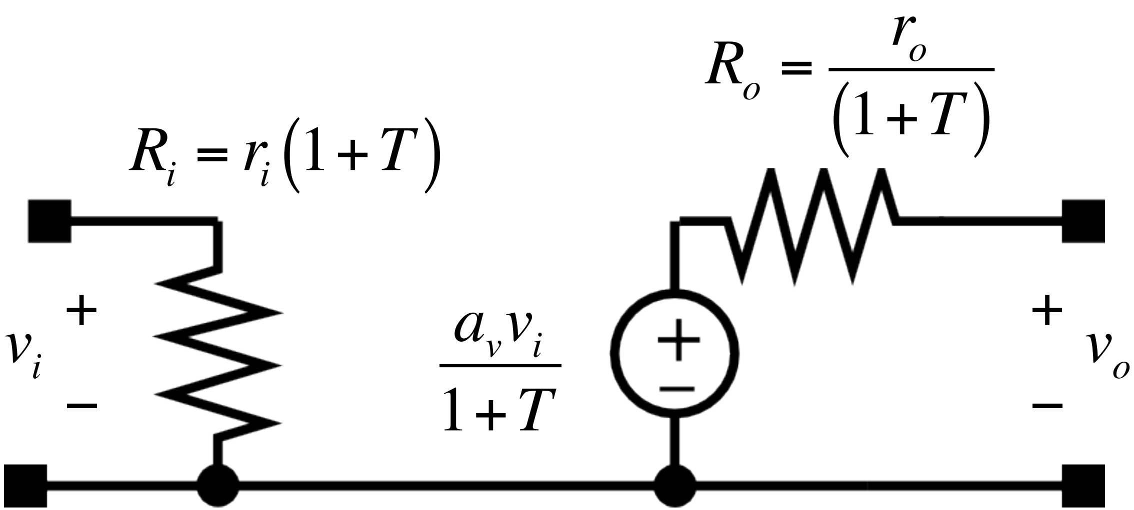
$$A_v = \frac{v_o}{v_e} = a_v$$

$$F = \frac{f \cdot v_o}{v_o} = f$$

$$i_o = \frac{v_o - a_v v_e}{r_o} = \frac{v_o - a_v\left(-f \cdot v_o\right)}{r_o} = \frac{v_o\left(1+T\right)}{r_o}$$

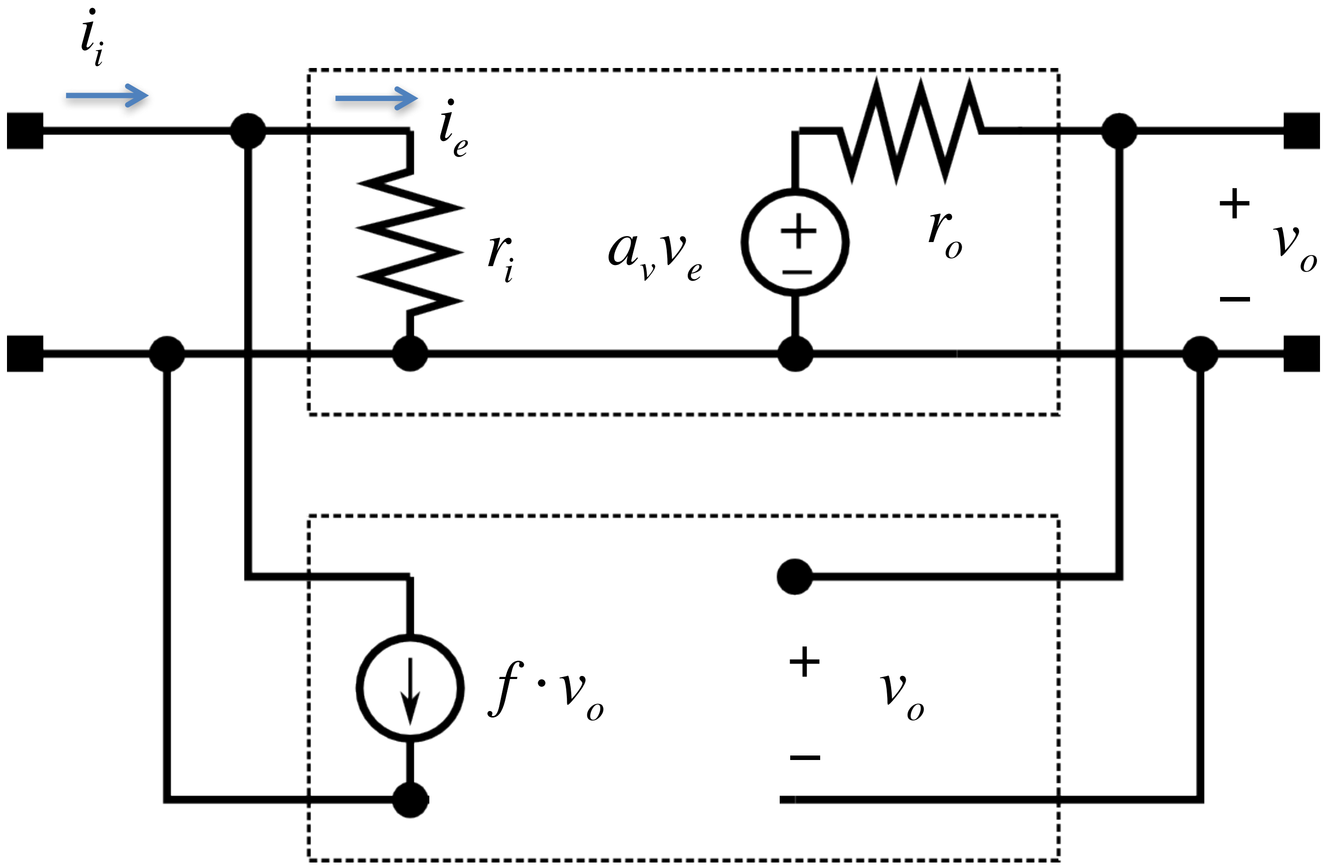
$$\boxed{R_o = \frac{r_o}{\left(1+T\right)}}$$

Effective Series-Shunt Small Signal Model

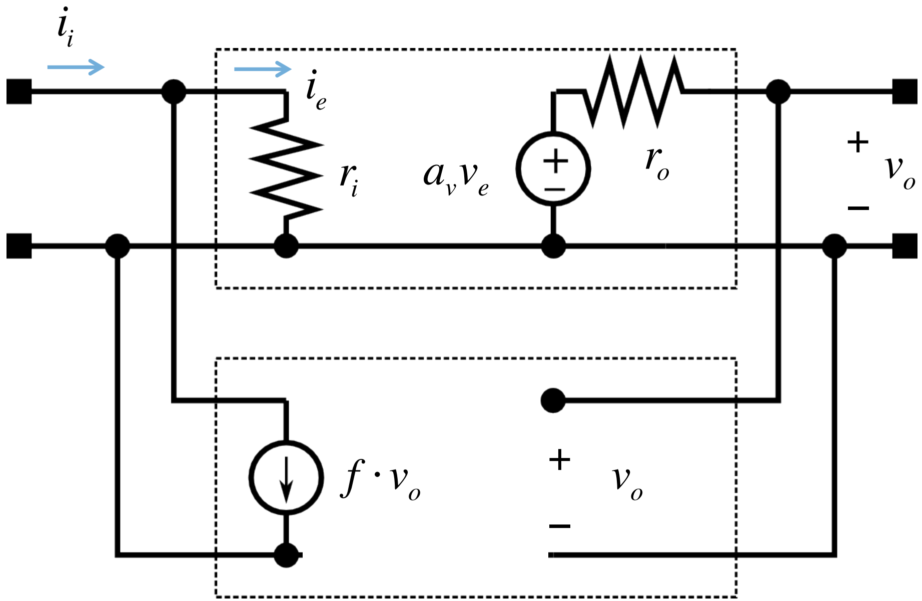


$$A_v = \frac{v_o}{v_e} = a_v \qquad F = \frac{f \cdot v_o}{v_o} = f \qquad T = AF = a_v f$$

Ideal Shunt-Shunt Feedback



Shunt-Shunt Amplifier Gain



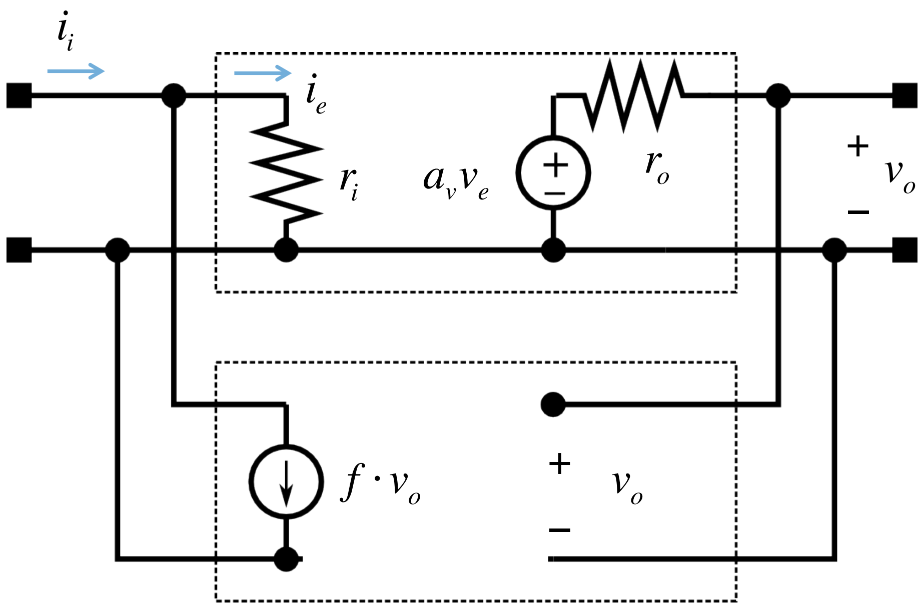
$$R_m = \frac{v_o}{i_e} = a_v r_i$$

$$F = \frac{i_{o,fb}}{v_o} = \frac{f \cdot v_o}{v_o} = f$$

$$T = a_v r_i f$$

$$v_o = a_v r_i \left(i_i - f \cdot v_o\right) \quad \Rightarrow \quad \frac{v_o}{i_i} = \frac{a_v r_i}{1 + a_v r_i f} = \frac{a_v r_i}{1+T}$$

Ideal Shunt-Shunt Input Impedance



$$R_m = \frac{v_o}{i_e} = a_v r_i$$

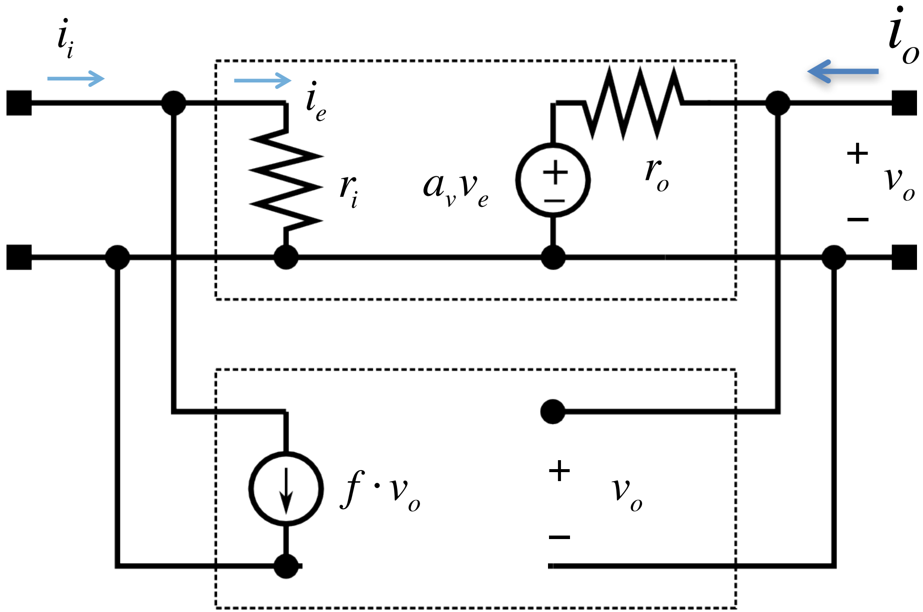
$$F = \frac{i_{o,fb}}{v_o} = \frac{f \cdot v_o}{v_o} = f$$

$$T = a_v r_i f$$

$$v_i = i_e r_i = \left(i_i - f \cdot v_o\right) r_i = \left(i_i - f \frac{a_v r_i}{1+T} i_i\right) r_i = i_i \frac{r_i}{1+T}$$

$$\boxed{R_i = \frac{r_i}{1+T}}$$

Ideal Shunt-Shunt Output Impedance



$$R_m = \frac{v_o}{i_e} = a_v r_i$$

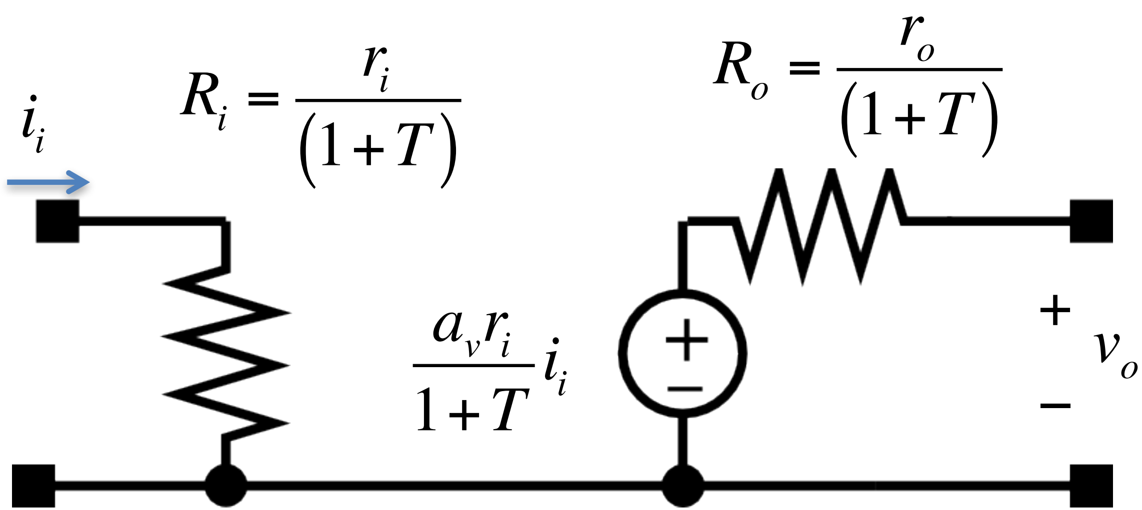
$$F = \frac{i_{o,fb}}{v_o} = \frac{f \cdot v_o}{v_o} = f$$

$$T = a_v r_i f$$

$$i_o = \frac{v_o - a_v v_e}{r_o} = \frac{v_o - a_v r_i \left(-f \cdot v_o\right)}{r_o} = \frac{v_o\left(1+T\right)}{r_o}$$

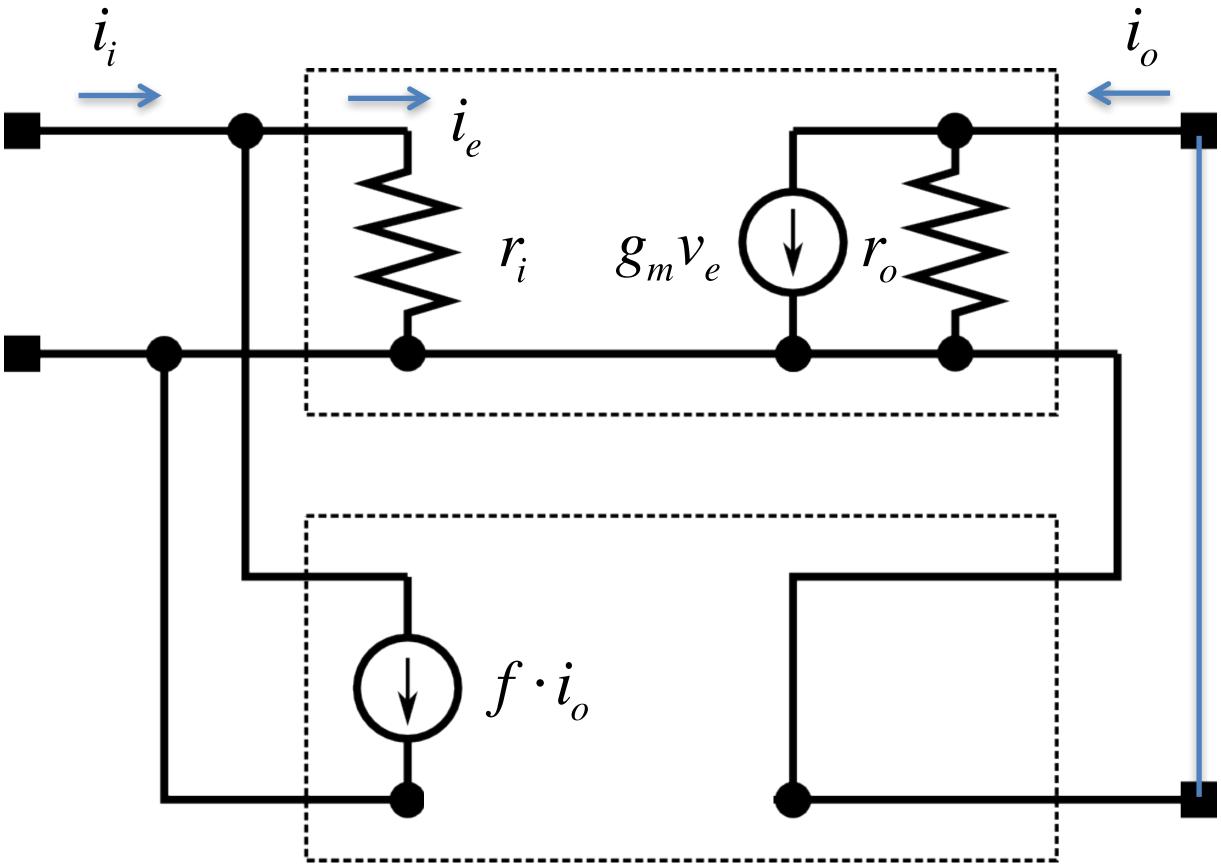
$$\boxed{R_o = \frac{r_o}{1+T}}$$

Effective Shunt-Shunt Small Signal Model

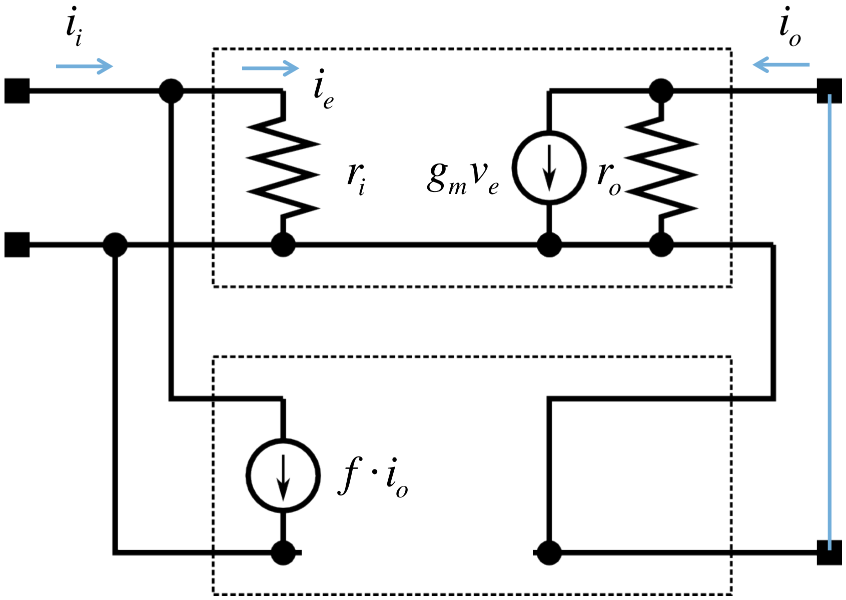


$$R_m = \frac{v_o}{i_e} = a_v r_i \qquad F = \frac{f \cdot v_o}{v_o} = f \qquad T = R_m F = a_v r_i f$$

Ideal Shunt-Series Feedback



Shunt-Series Amplifier Gain



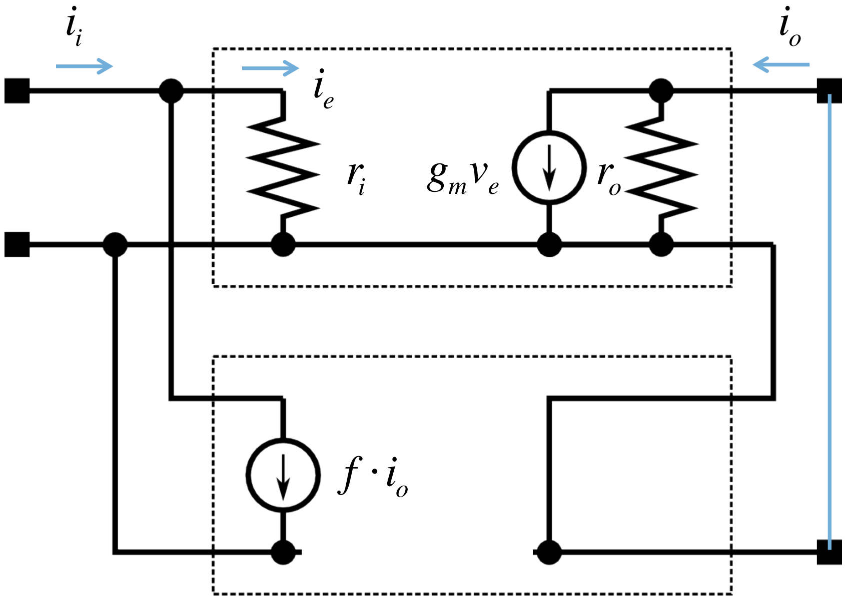
$$A_i = \frac{i_o}{i_e} = g_m r_i$$

$$F = \frac{i_{o,fb}}{i_o} = \frac{f \cdot i_o}{i_o} = f$$

$$T = g_m r_i f$$

$$i_o = g_m r_i \left(i_i - f \cdot i_o \right) \quad \Rightarrow \quad \frac{i_o}{i_i} = \frac{g_m r_i}{1 + g_m r_i f} = \frac{g_m r_i}{1 + T}$$

Shunt-Series Input Impedance



$$A_i = \frac{i_o}{i_e} = g_m r_i$$

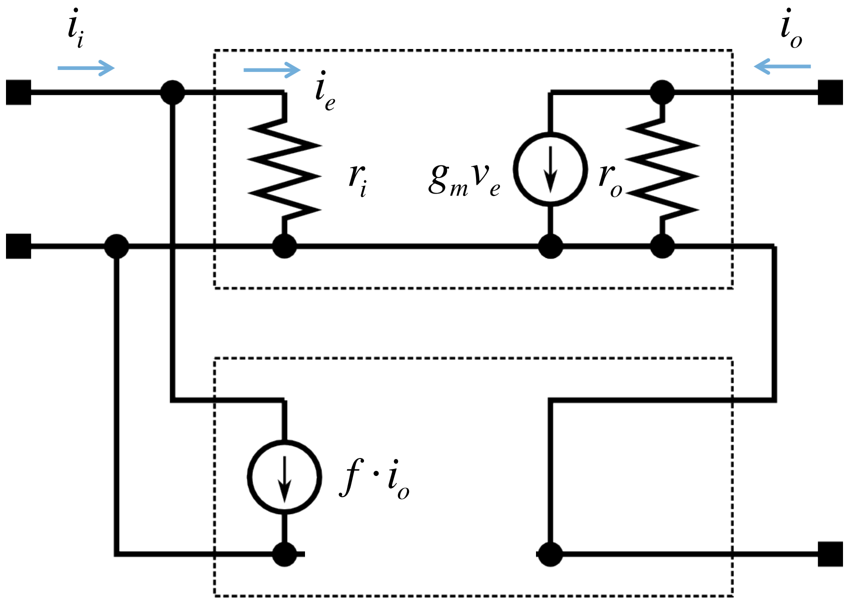
$$F = \frac{i_{o,fb}}{i_o} = \frac{f \cdot i_o}{i_o} = f$$

$$T = g_m r_i f$$

$$v_i = i_e r_i = \left(i_i - f \cdot i_o\right) r_i = \left(i_i - f \frac{g_m r_i}{1+T} i_i\right) r_i = i_i \frac{r_i}{1+T}$$

$$\boxed{R_i = \frac{r_i}{1+T}}$$

Shunt-Series Output Impedance



$$A_i = \frac{i_o}{i_e} = g_m r_i$$

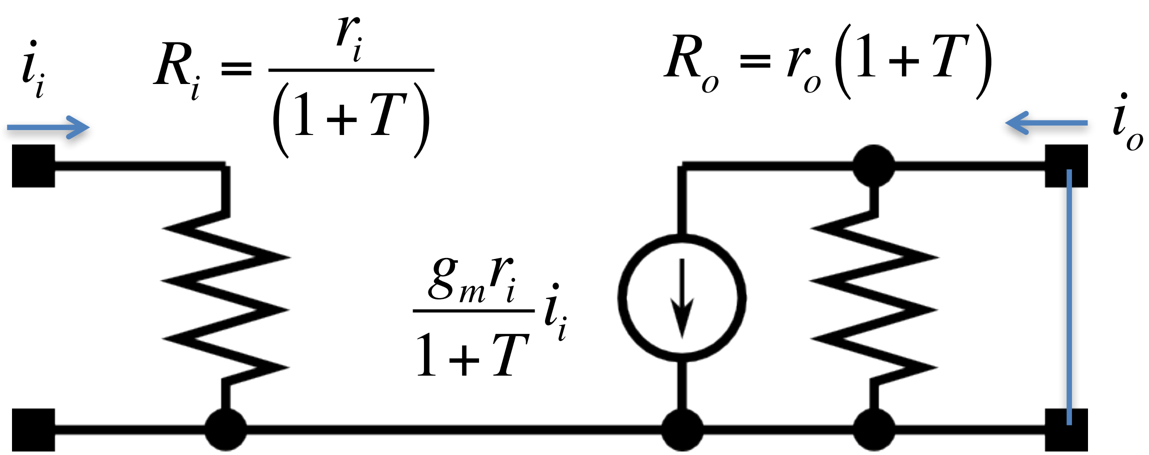
$$F = \frac{i_{o,fb}}{i_o} = \frac{f \cdot i_o}{i_o} = f$$

$$T = g_m r_i f$$

$$v_o = \left(i_o - g_m v_e\right) r_o = \left(i_o - g_m r_i\left[-f \cdot i_o\right]\right) r_o = i_o\left(1+T\right) r_o$$

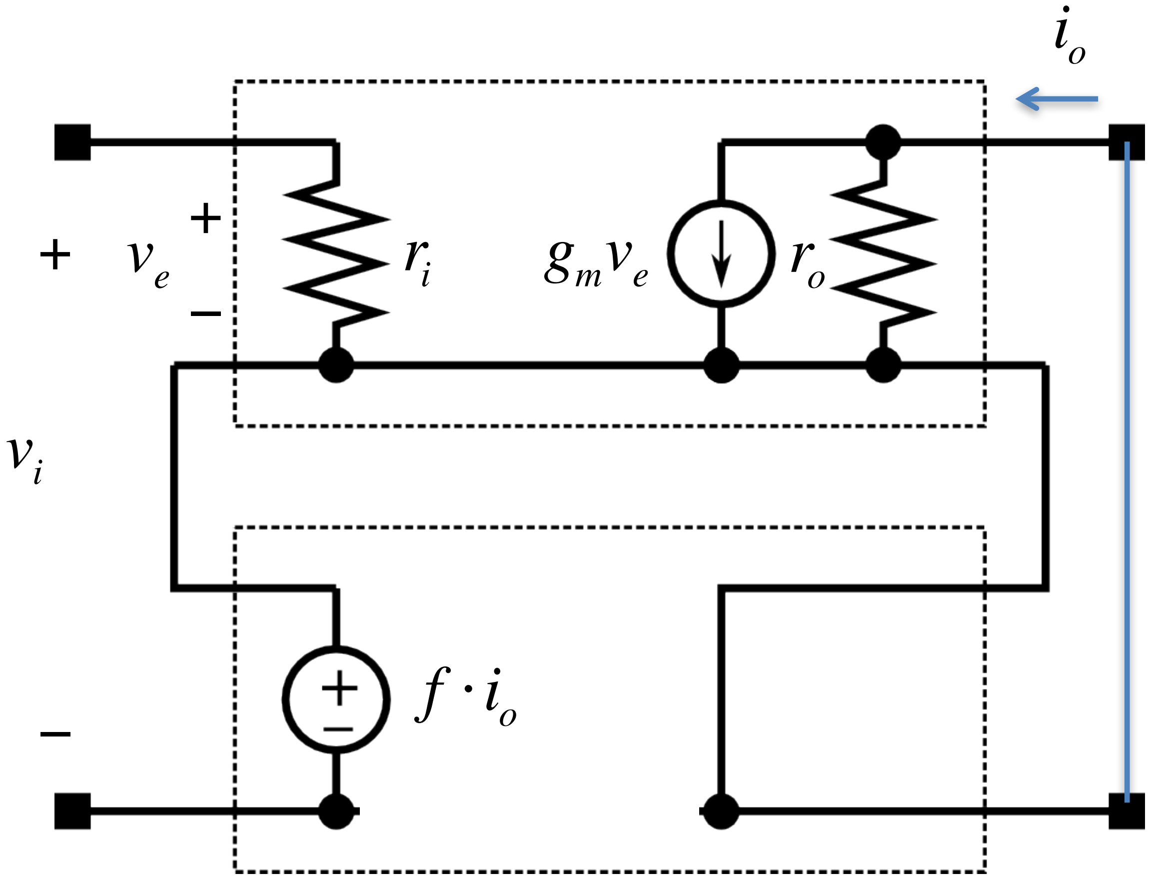
$$\boxed{R_o = r_o\left(1+T\right)}$$

Effective Shunt-Series Small Signal Model

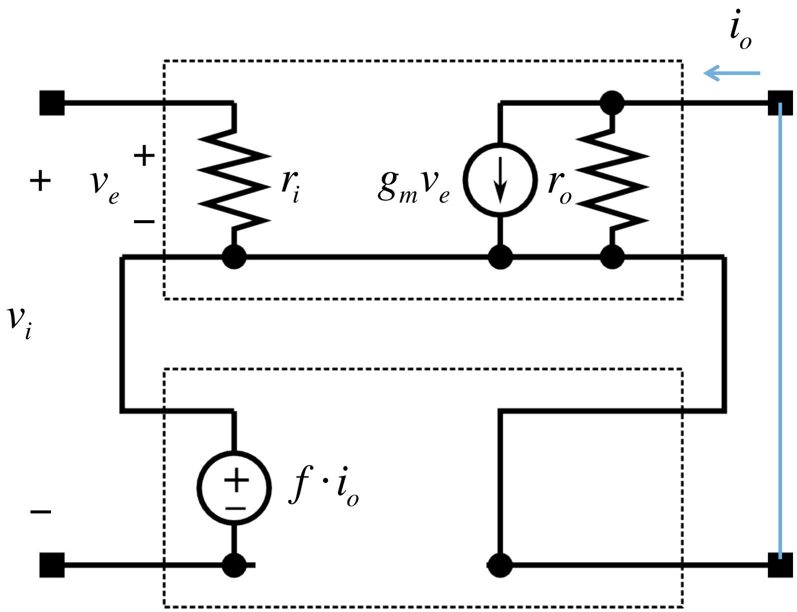


$$A_i = \frac{i_o}{i_e} = g_m r_i \qquad F = \frac{f \cdot i_o}{i_o} = f \qquad T = A_i F = g_m r_i f$$

Ideal Series-Series Feedback



Series-Series Amplifier Gain



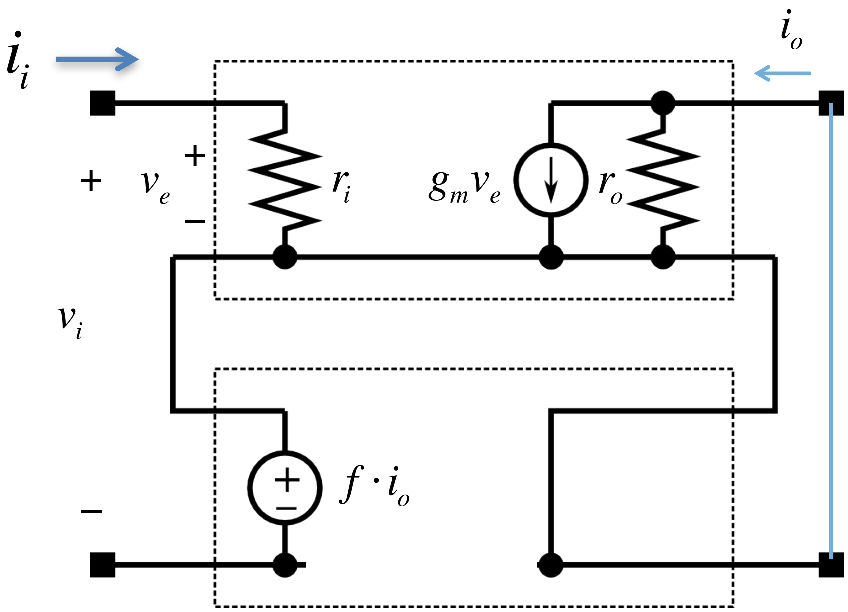
$$G_m = \frac{i_o}{v_e} = g_m$$

$$F = \frac{v_{o,fb}}{i_o} = \frac{f \cdot i_o}{i_o} = f$$

$$T = g_m f$$

$$i_o = g_m \left(v_i - f \cdot i_o\right) \quad \Rightarrow \quad \frac{i_o}{v_i} = \frac{g_m}{1 + g_m f} = \frac{g_m}{1+T}$$

Series-Series Input Impedance



$$G_m = \frac{i_o}{v_e} = g_m$$

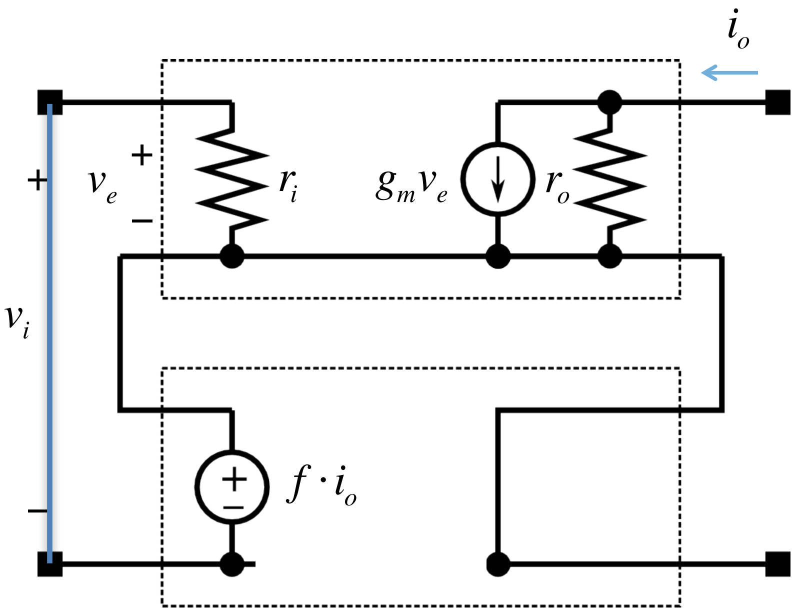
$$F = \frac{v_{o,fb}}{i_o} = \frac{f \cdot i_o}{i_o} = f$$

$$T = g_m f$$

$$i_i = \frac{v_e}{r_i} = \frac{\left(v_i - f \cdot i_o\right)}{r_i} = \left(v_i - f\frac{g_m}{1+T}v_i\right)\frac{1}{r_i} = \frac{v_i}{\left(1+T\right)r_i}$$

$$\boxed{R_i = r_i\left(1+T\right)}$$

Series-Series Output Impedance



$$G_m = \frac{i_o}{v_e} = g_m$$

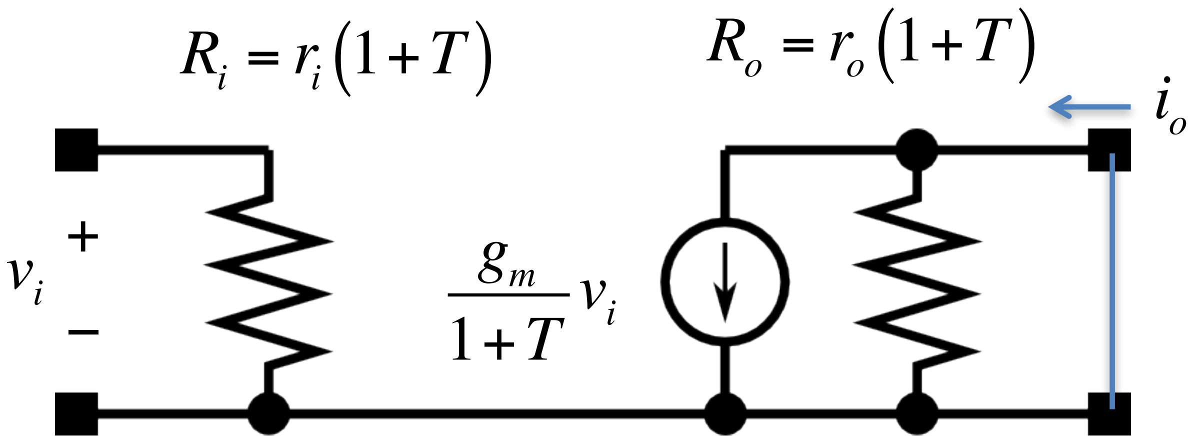
$$F = \frac{v_{o,fb}}{i_o} = \frac{f \cdot i_o}{i_o} = f$$

$$T = g_m f$$

$$v_o = \left[i_o - g_m \left(-f \cdot i_o \right) \right] r_o = i_o \left(1 + T \right) r_o$$

$$\boxed{R_o = r_o \left(1 + T \right)}$$

Effective Series-Series Small Signal Model



$$G_m = \frac{i_o}{v_e} = g_m \qquad F = \frac{f \cdot i_o}{i_o} = f \qquad T = G_m F = g_m f$$

Summary Feedback Configurations

	Input	Output	T
Series-Shunt	Voltage	Voltage	$a_v f$
Shunt-Shunt	Current	Voltage	$a_v r_i f$
Shunt-Series	Current	Current	$g_m r_i f$
Series-Series	Voltage	Current	$g_m f$

Summary Feedback Configurations

	Gain	R_i	R_o
Series-Shunt	$a_v/(1+T)$	$r_i(1+T)$	$r_o/(1+T)$
Shunt-Shunt	$a_v r_i/(1+T)$	$r_i/(1+T)$	$r_o/(1+T)$
Shunt-Series	$g_m r_i/(1+T)$	$r_i/(1+T)$	$r_o(1+T)$
Series-Series	$g_m/(1+T)$	$r_i(1+T)$	$r_o(1+T)$

Next Meeting

- Feedback Amplifiers