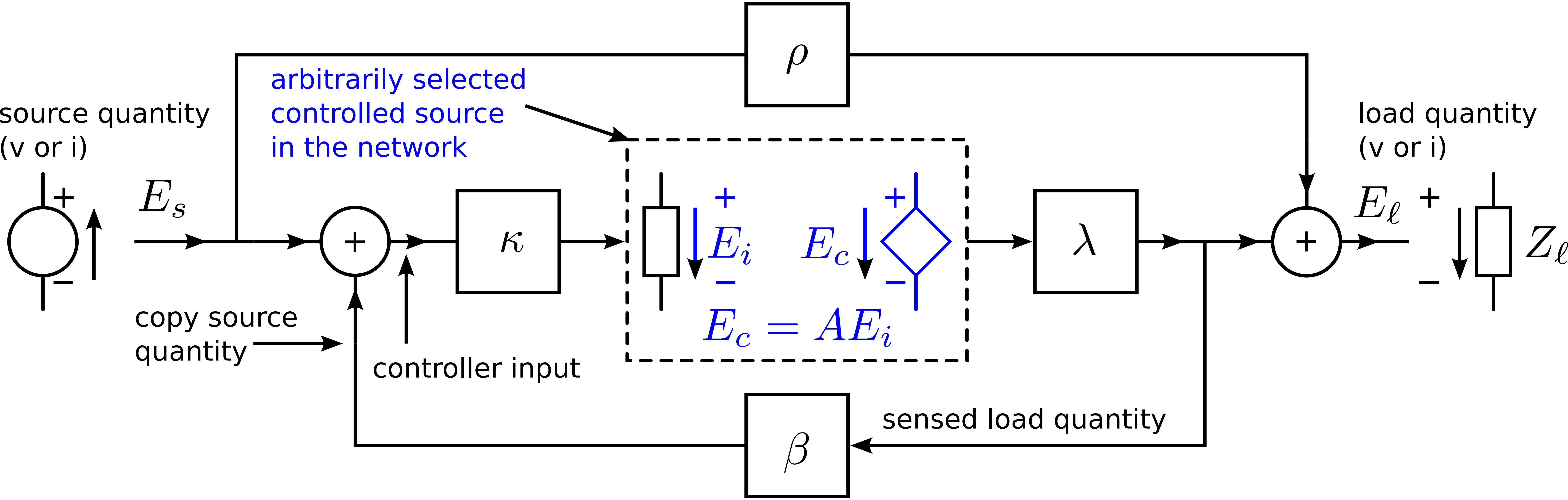
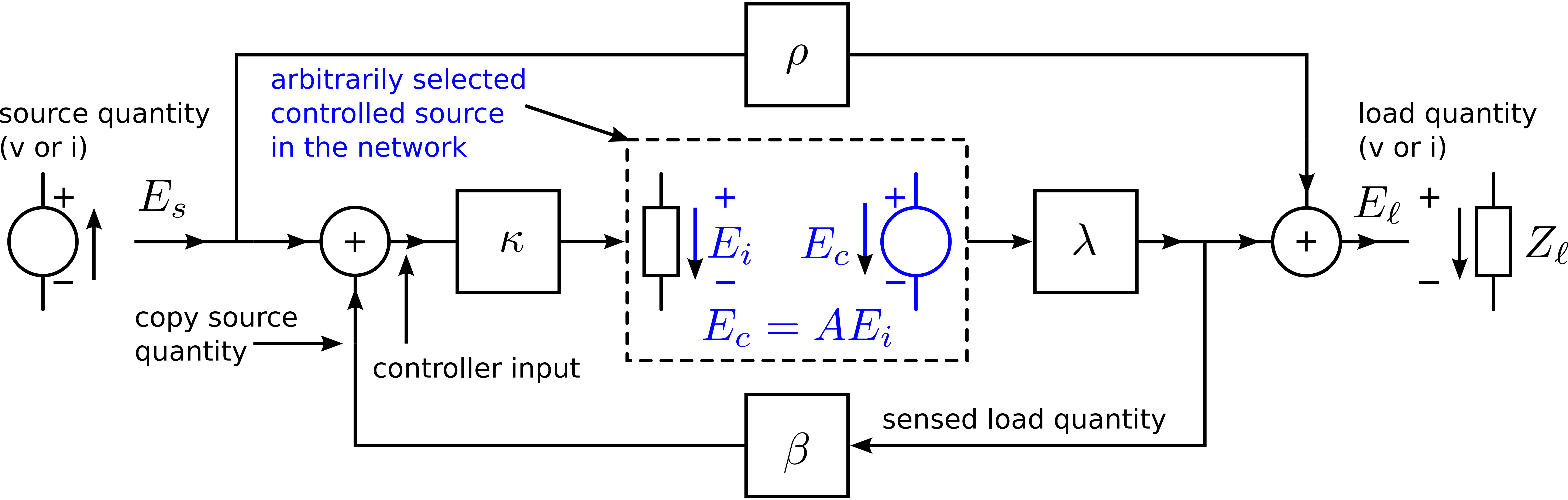
Structured Electronic Design
Asymptotic-gain feedback model

Superposition model



In a network comprising feedback, the gain of an arbitrarily selected controlled source is taken as loop gain reference

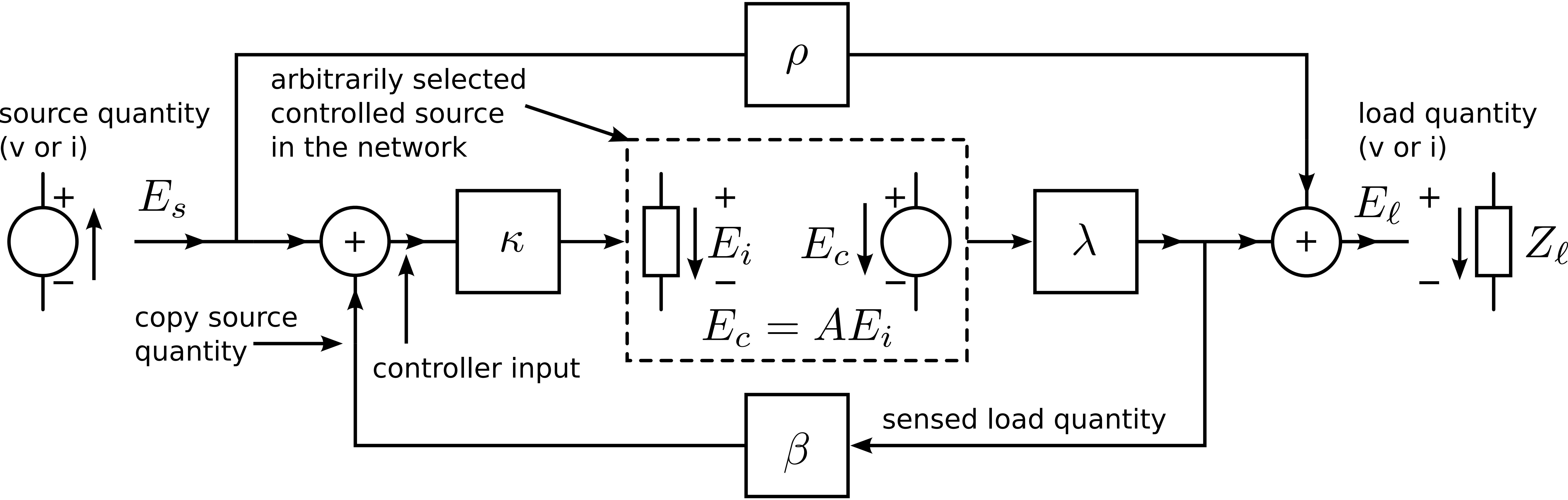
Superposition model



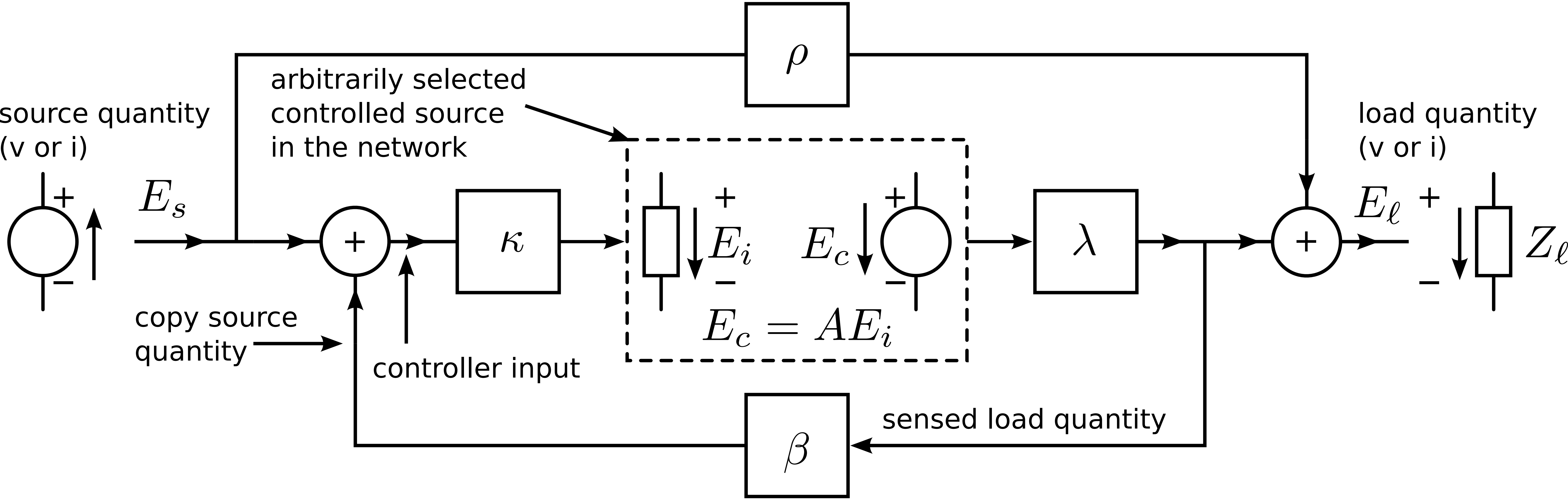
The loop is 'opened' by replacing this controlled source with an independent source, while denoting:

$$E_c = AE_i$$

Superposition model

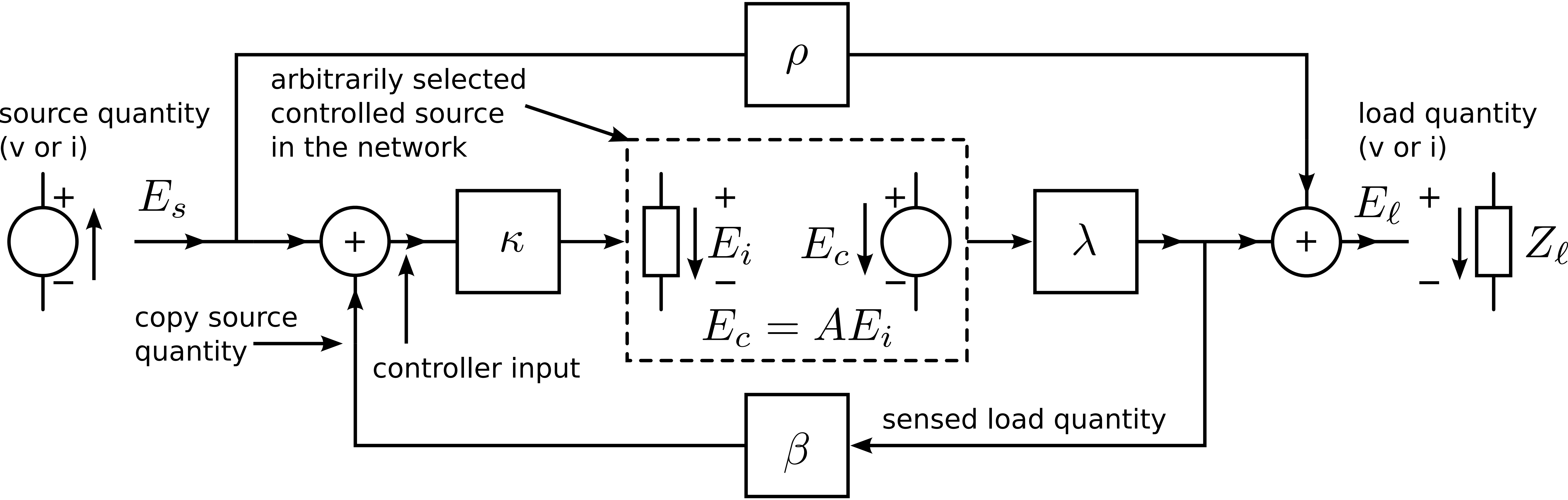


Superposition model



We now have the following equations:

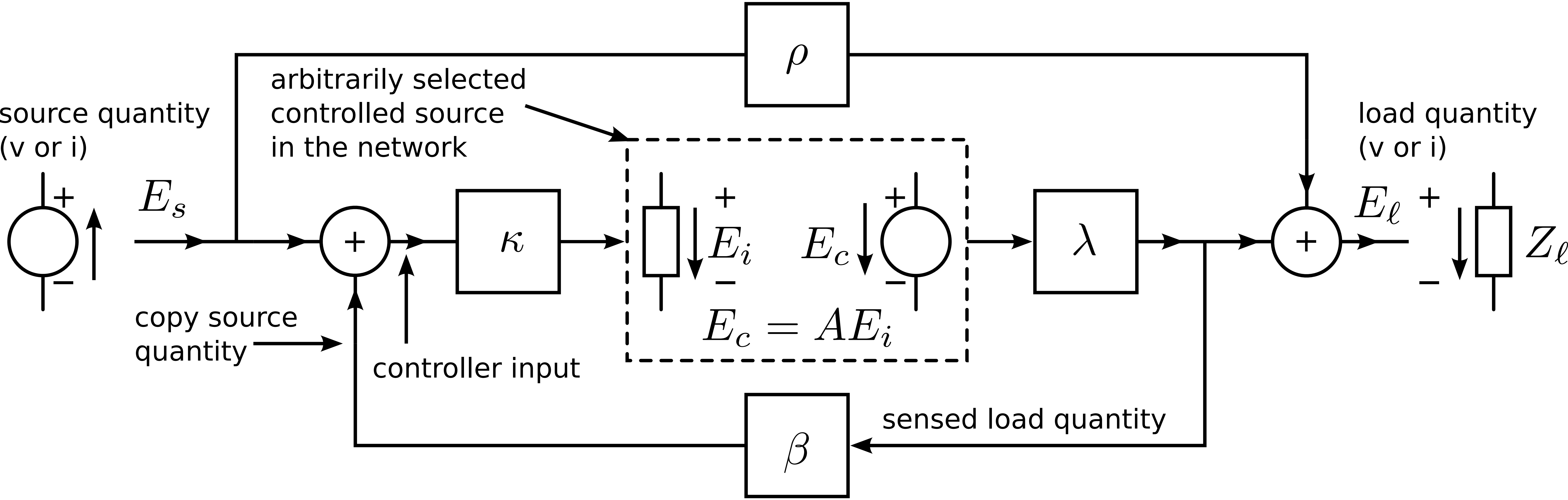
Superposition model



We now have the following equations:

$$\begin{pmatrix} E_\ell \\ E_i \end{pmatrix} = \begin{pmatrix} \rho & \lambda \\ \kappa & \lambda\beta\kappa \end{pmatrix} \begin{pmatrix} E_s \\ E_c \end{pmatrix}$$

Superposition model

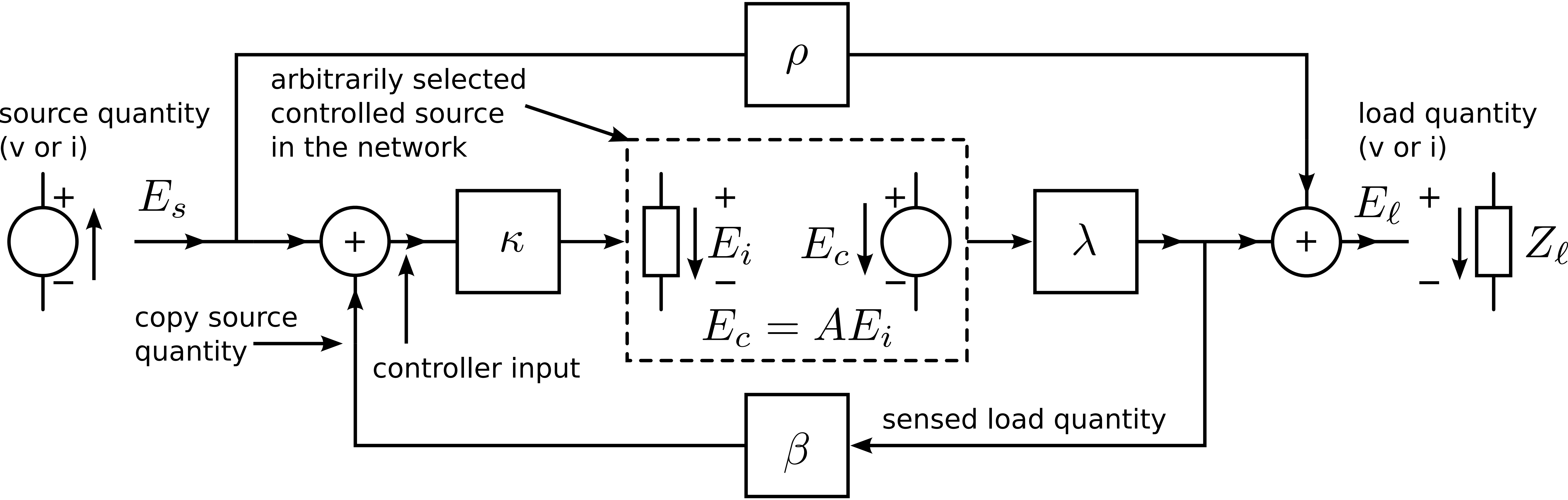


We now have the following equations:

$$\begin{pmatrix} E_\ell \\ E_i \end{pmatrix} = \begin{pmatrix} \rho & \lambda \\ \kappa & \lambda\beta\kappa \end{pmatrix} \begin{pmatrix} E_s \\ E_c \end{pmatrix}$$

loop gain reference $E_c = AE_i$

Superposition model



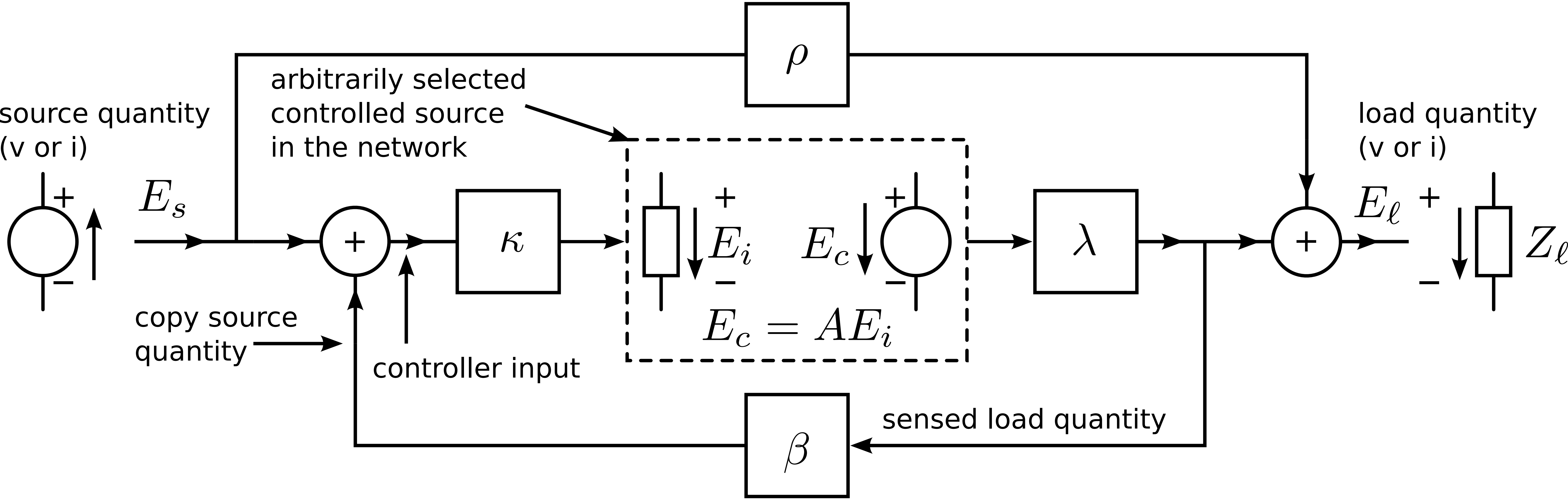
We now have the following equations:

$$\begin{pmatrix} E_\ell \\ E_i \end{pmatrix} = \begin{pmatrix} \rho & \lambda \\ \kappa & \lambda\beta\kappa \end{pmatrix} \begin{pmatrix} E_s \\ E_c \end{pmatrix}$$

$$\rho = \left.\frac{E_\ell}{E_s}\right|_{E_c=0}$$

loop gain reference $E_c = AE_i$

Superposition model



We now have the following equations:

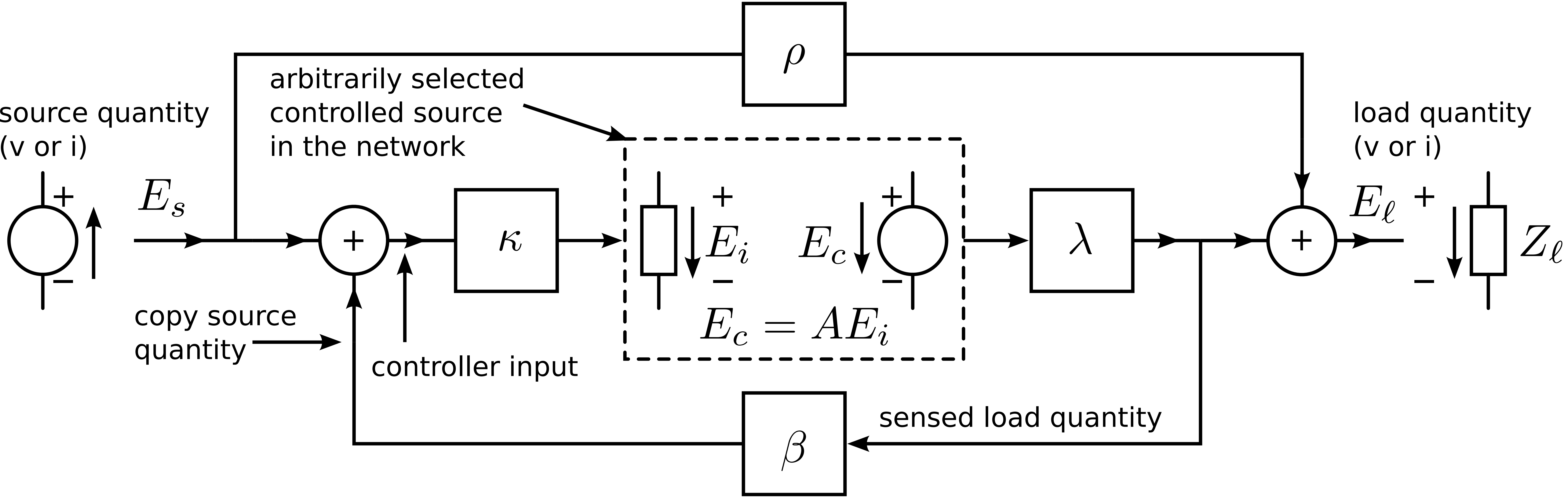
$$\begin{pmatrix} E_\ell \\ E_i \end{pmatrix} = \begin{pmatrix} \rho & \lambda \\ \kappa & \lambda\beta\kappa \end{pmatrix} \begin{pmatrix} E_s \\ E_c \end{pmatrix}$$

$$\rho = \left.\frac{E_\ell}{E_s}\right|_{E_c=0}$$

$$\lambda = \left.\frac{E_\ell}{E_c}\right|_{E_s=0}$$

loop gain reference $E_c = AE_i$

Superposition model



We now have the following equations:

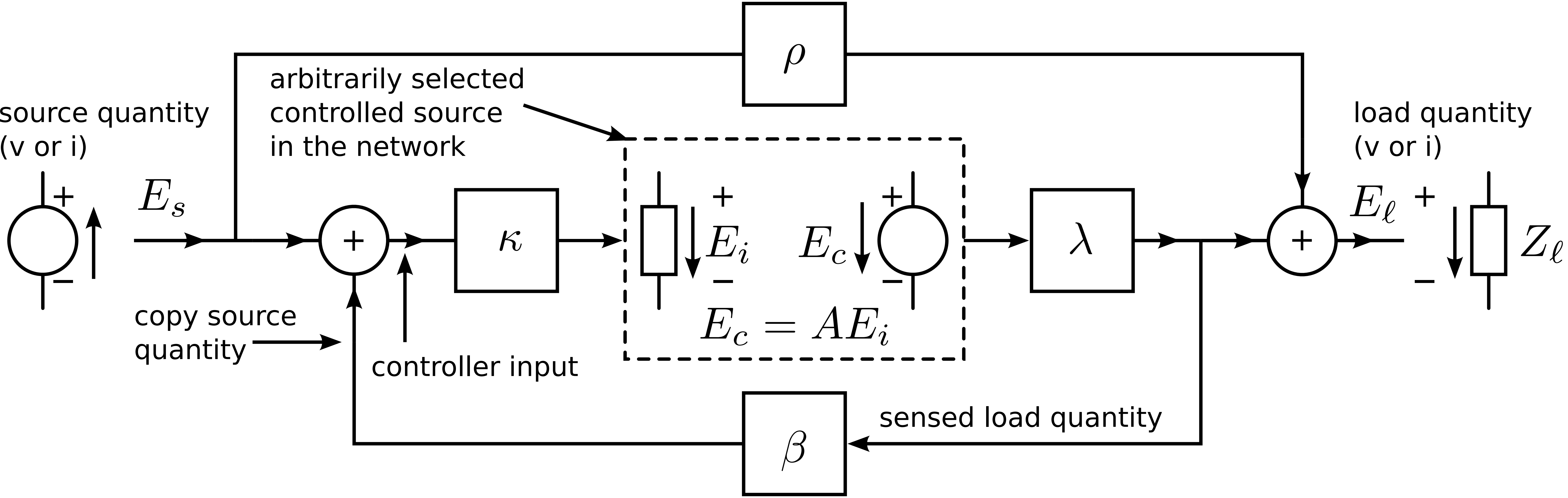
$$\begin{pmatrix} E_\ell \\ E_i \end{pmatrix} = \begin{pmatrix} \rho & \lambda \\ \kappa & \lambda\beta\kappa \end{pmatrix} \begin{pmatrix} E_s \\ E_c \end{pmatrix}$$

$$\rho = \left.\frac{E_\ell}{E_s}\right|_{E_c=0} \qquad \kappa = \left.\frac{E_i}{E_s}\right|_{E_c=0}$$

$$\lambda = \left.\frac{E_\ell}{E_c}\right|_{E_s=0}$$

loop gain reference $E_c = AE_i$

Superposition model



We now have the following equations:

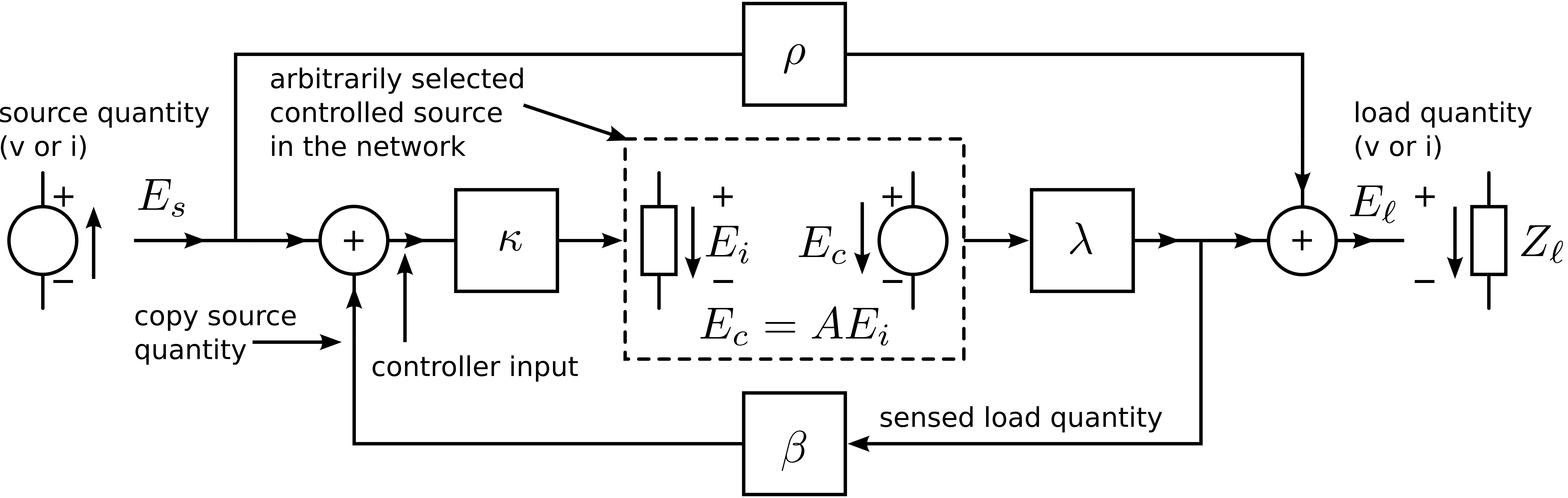
$$\begin{pmatrix} E_\ell \\ E_i \end{pmatrix} = \begin{pmatrix} \rho & \lambda \\ \kappa & \lambda\beta\kappa \end{pmatrix} \begin{pmatrix} E_s \\ E_c \end{pmatrix}$$

$$\rho = \left.\frac{E_\ell}{E_s}\right|_{E_c=0} \qquad \kappa = \left.\frac{E_i}{E_s}\right|_{E_c=0}$$

$$\lambda = \left.\frac{E_\ell}{E_c}\right|_{E_s=0} \qquad \lambda\beta\kappa = \left.\frac{E_i}{E_c}\right|_{E_s=0}$$

loop gain reference $E_c = AE_i$

Superposition model



We now have the following equations:

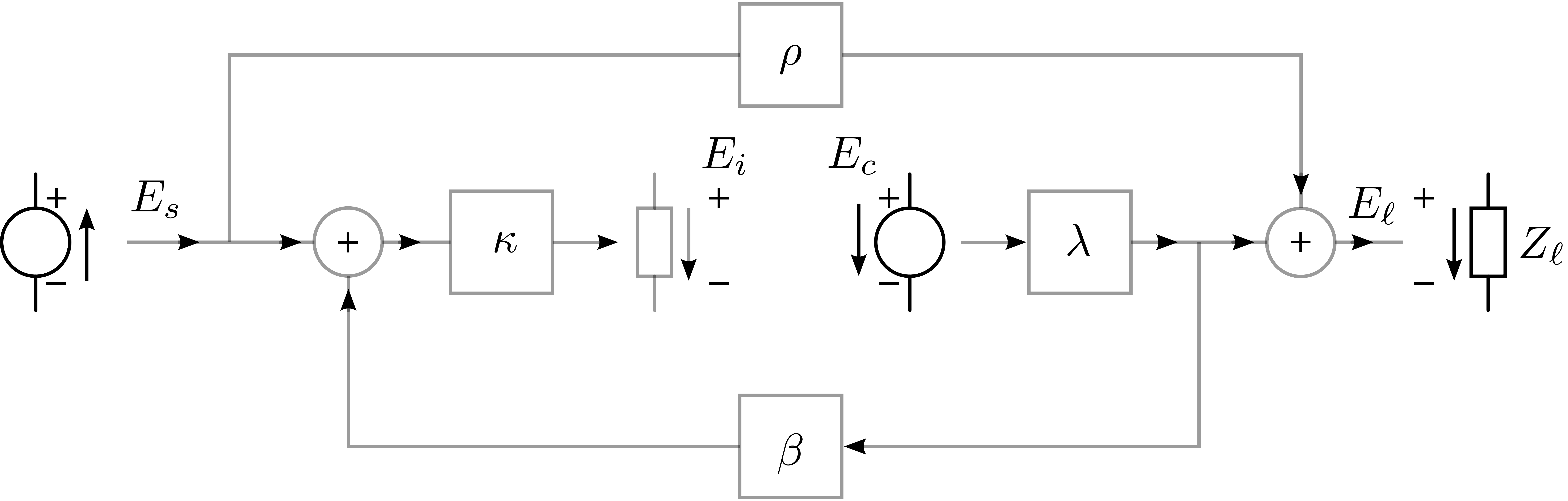
$$\begin{pmatrix} E_\ell \\ E_i \end{pmatrix} = \begin{pmatrix} \rho & \lambda \\ \kappa & \lambda\beta\kappa \end{pmatrix} \begin{pmatrix} E_s \\ E_c \end{pmatrix}$$

$$\rho = \left.\frac{E_\ell}{E_s}\right|_{E_c=0} \qquad \kappa = \left.\frac{E_i}{E_s}\right|_{E_c=0}$$

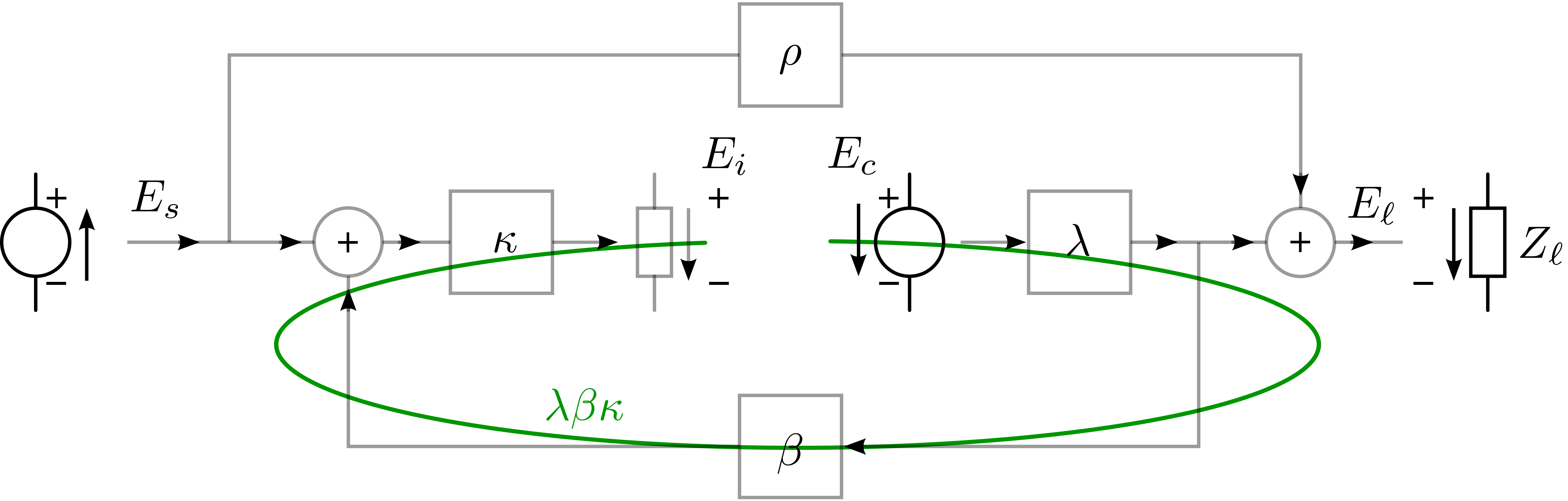
$$\lambda = \left.\frac{E_\ell}{E_c}\right|_{E_s=0} \qquad \lambda\beta\kappa = \left.\frac{E_i}{E_c}\right|_{E_s=0}$$

loop gain reference $E_c = AE_i$

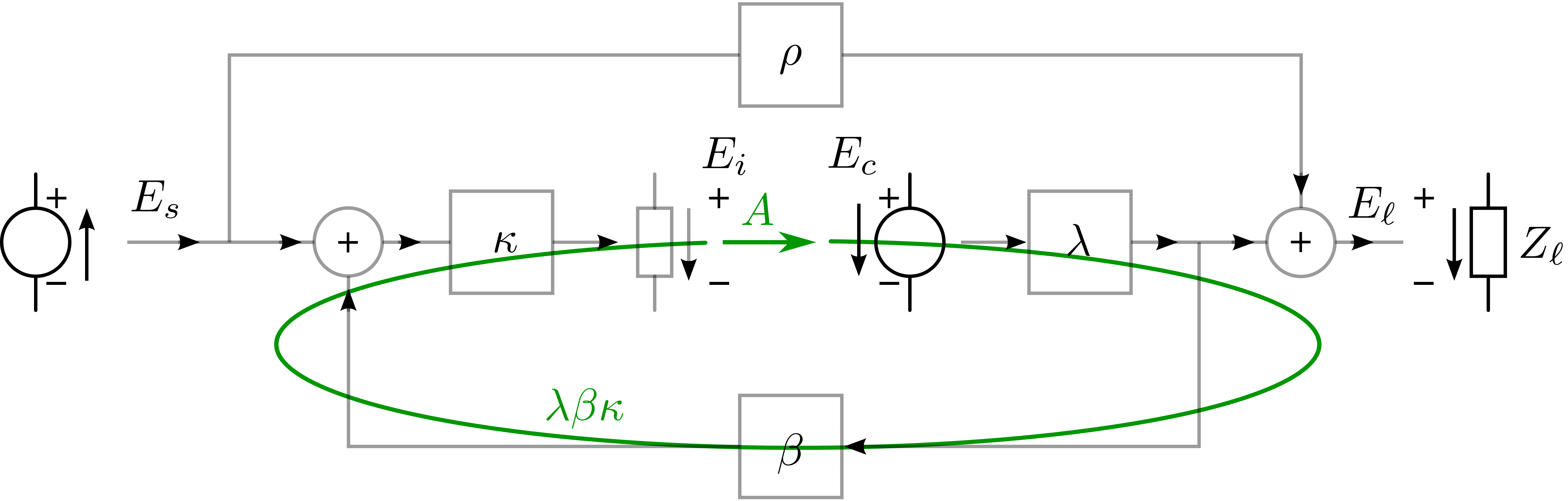
Superposition model: loop gain



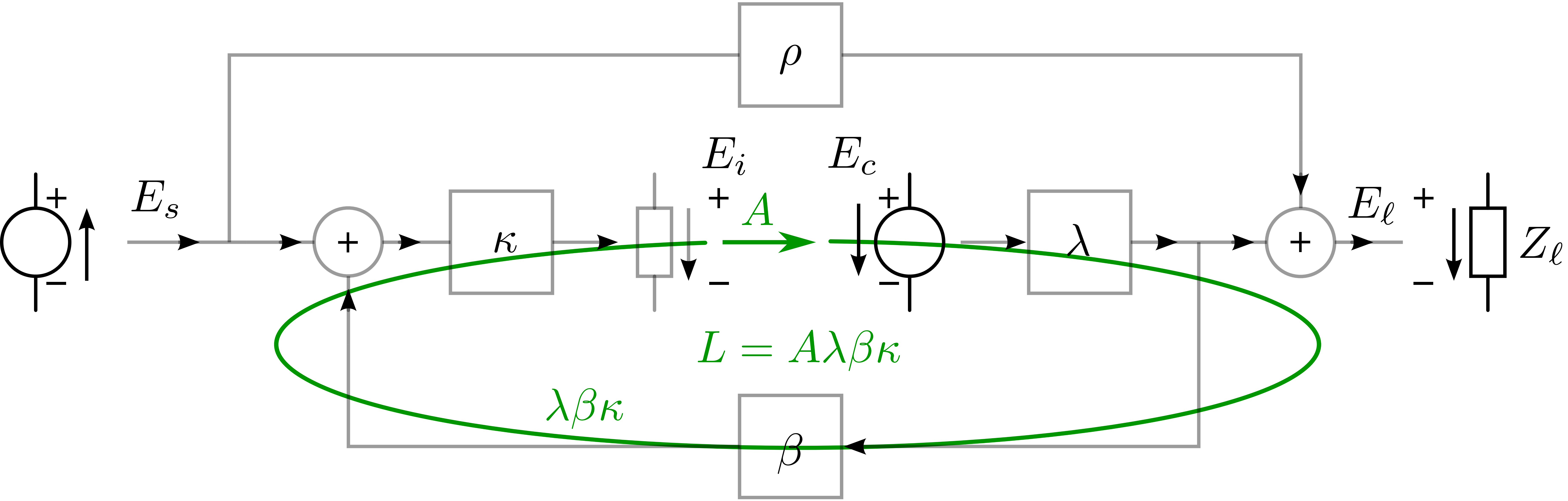
Superposition model: loop gain



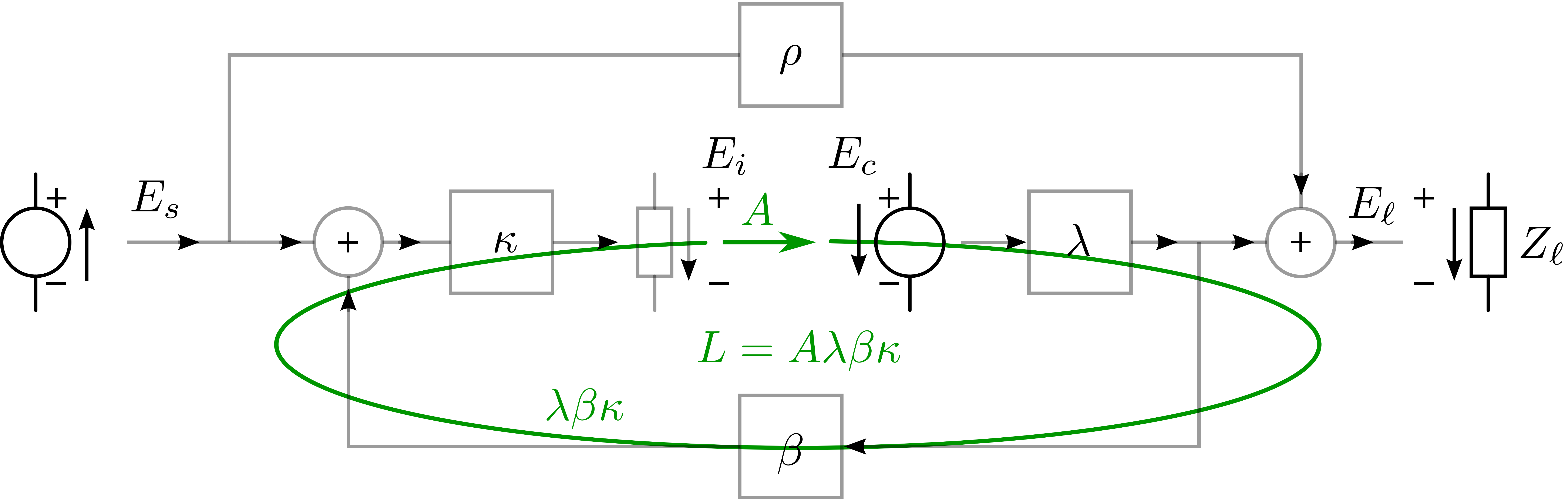
Superposition model: loop gain



Superposition model: loop gain

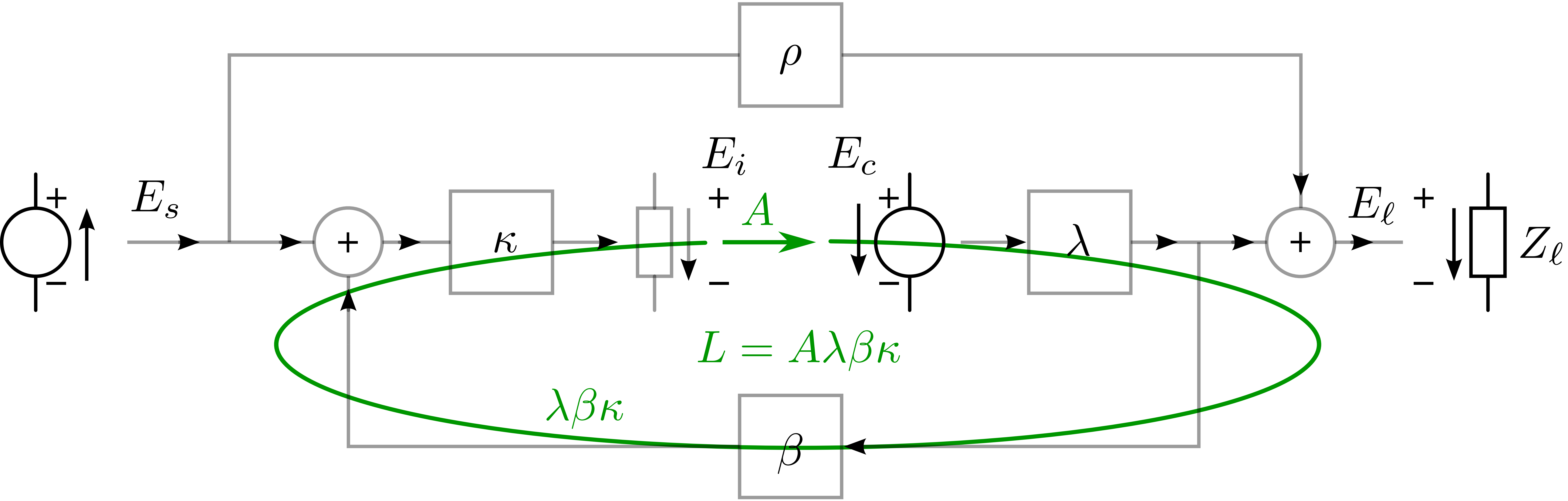


Superposition model: loop gain



$L =$ Loop gain = gain enclosed in the loop $= A\lambda\beta\kappa$

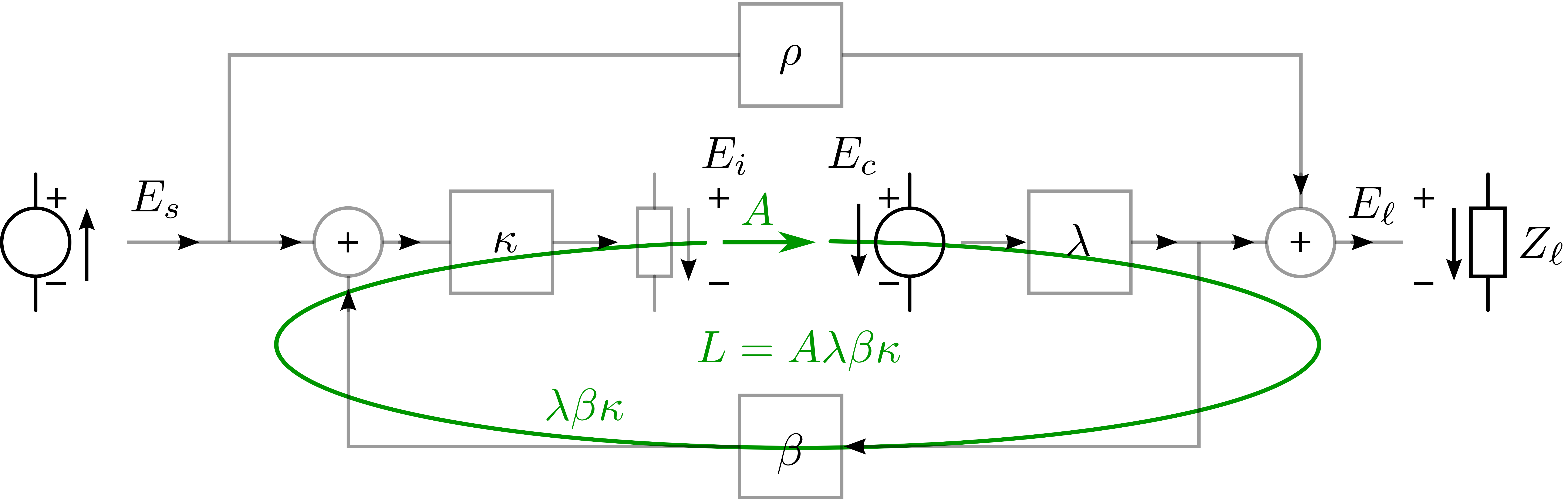
Superposition model: loop gain



$L =$ Loop gain = gain enclosed in the loop $= A\lambda\beta\kappa$

Calculate from product of: A

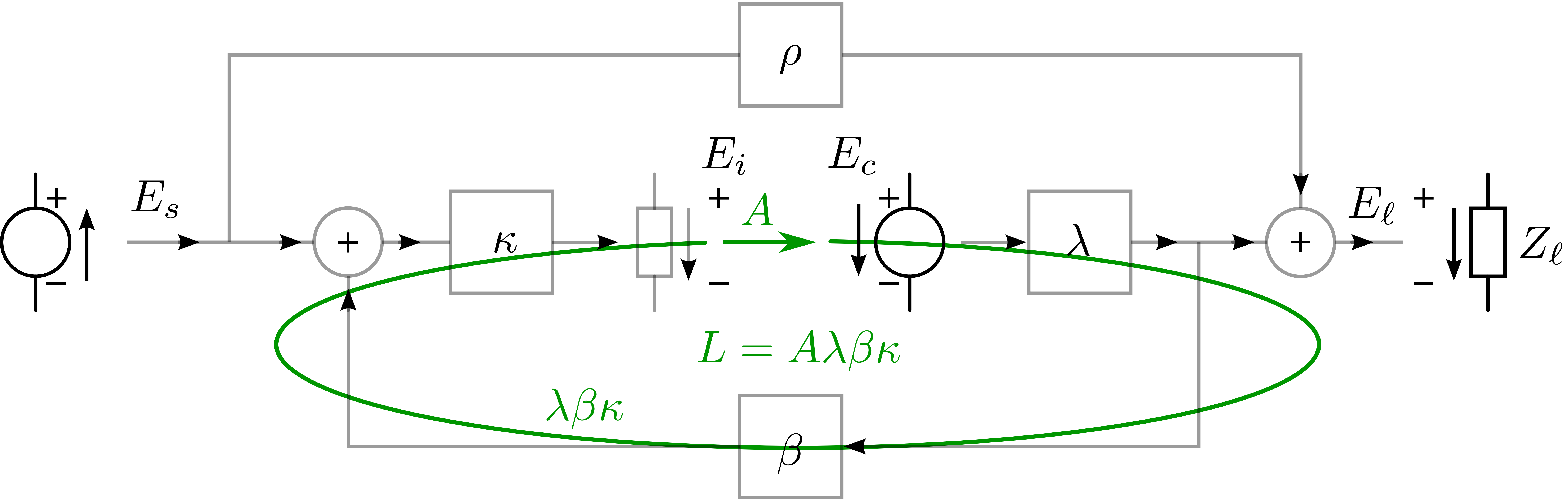
Superposition model: loop gain



$L =$ Loop gain = gain enclosed in the loop $= A\lambda\beta\kappa$

Calculate from product of: A and

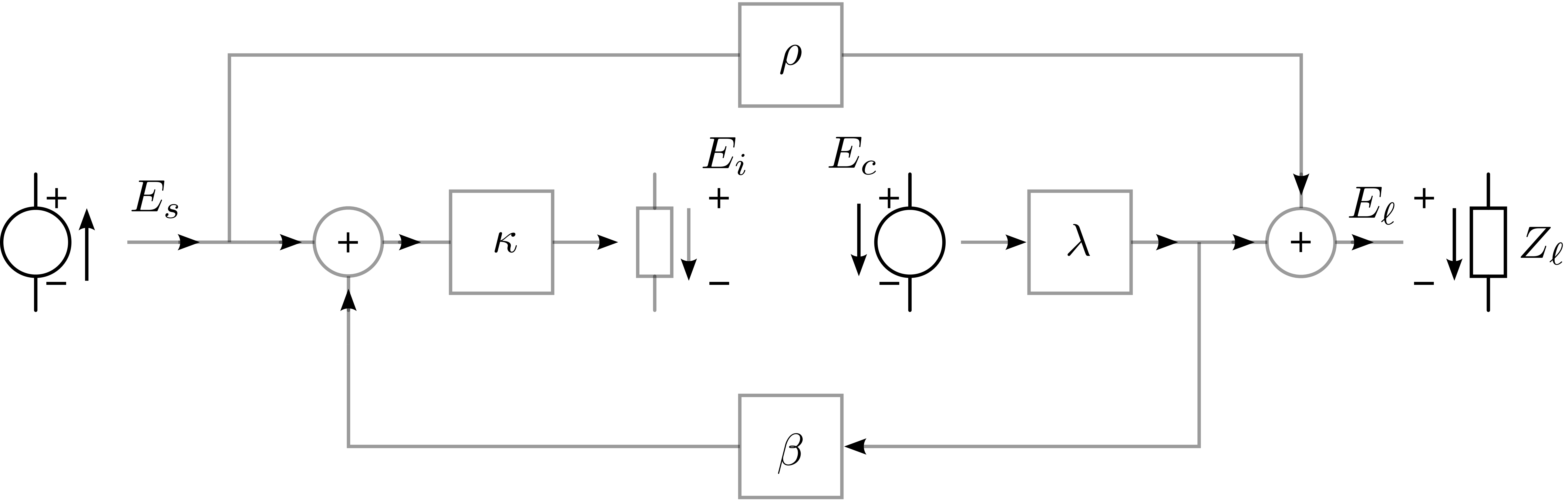
Superposition model: loop gain



$L =$ Loop gain = gain enclosed in the loop $= A\lambda\beta\kappa$

Calculate from product of: A and $\left.\frac{E_i}{E_c}\right|_{E_s=0}$

Superposition model: loop gain

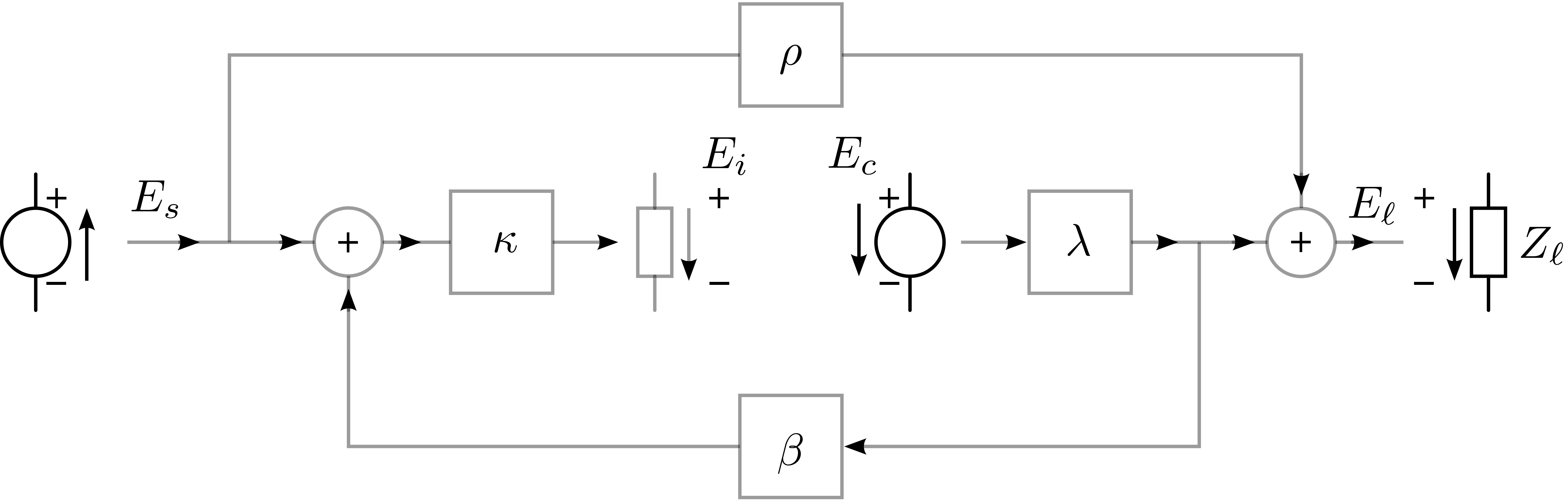


$L =$ Loop gain = gain enclosed in the loop $= A\lambda\beta\kappa$

Calculate from product of: A and $\left.\frac{E_i}{E_c}\right|_{E_s=0}$

Negative feedback:

Superposition model: loop gain

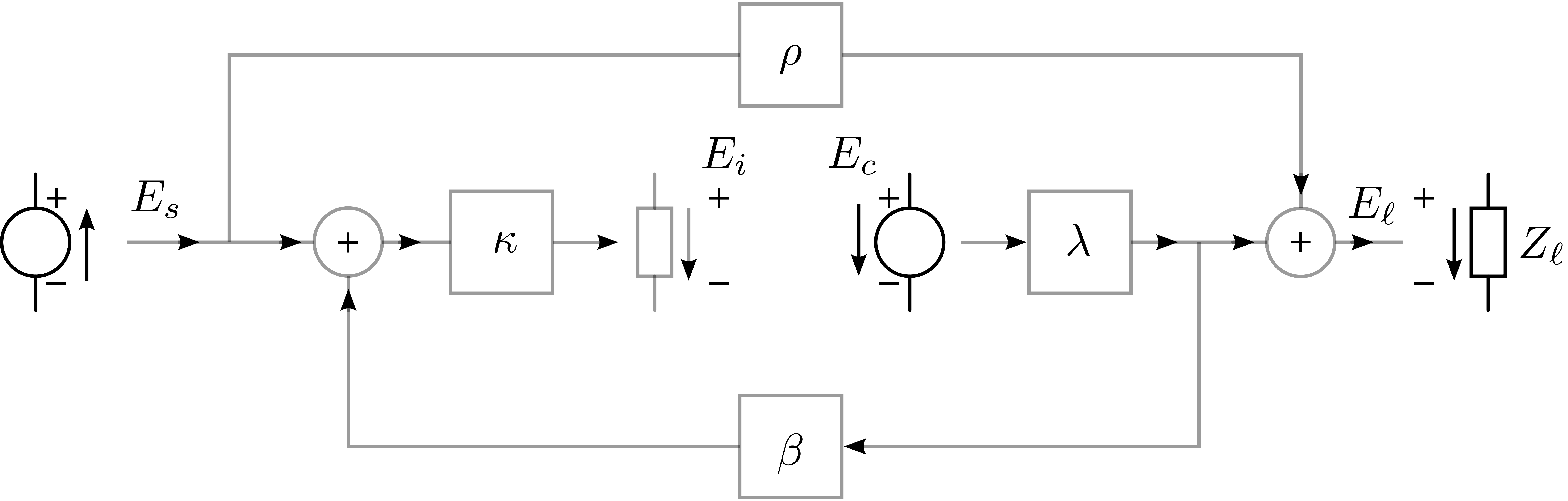


$L =$ Loop gain = gain enclosed in the loop $= A\lambda\beta\kappa$

Calculate from product of: A and $\left.\frac{E_i}{E_c}\right|_{E_s=0}$

Negative feedback: $L < 0$

Superposition model: loop gain

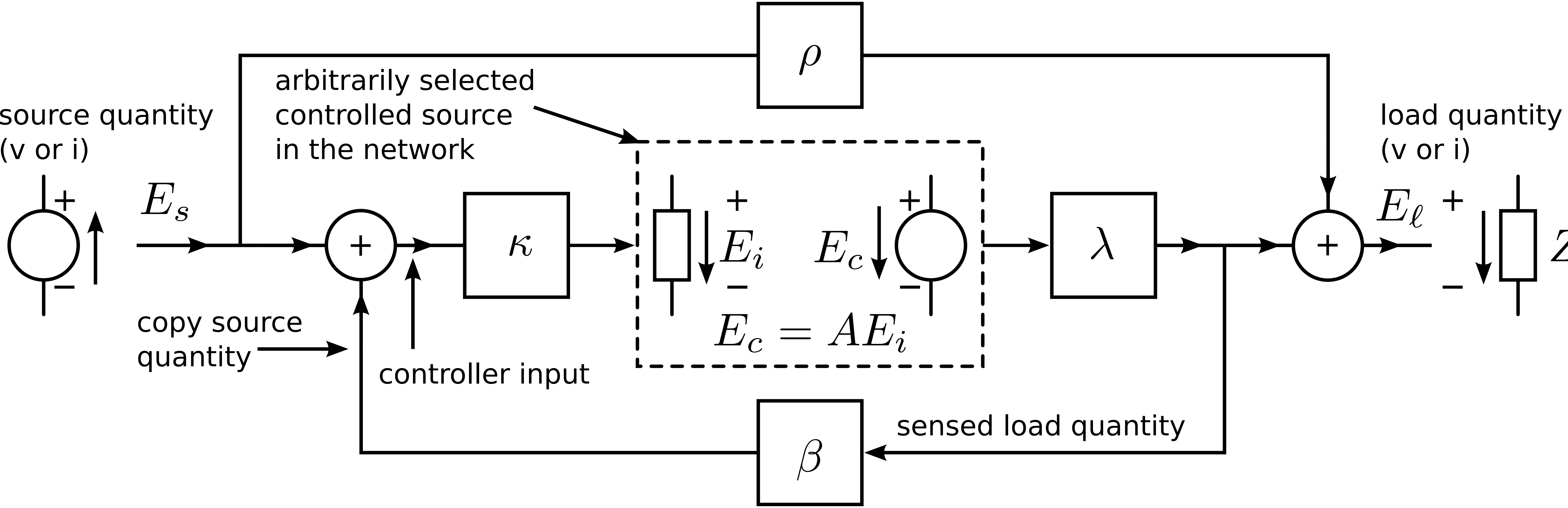


$L =$ Loop gain = gain enclosed in the loop $= A\lambda\beta\kappa$

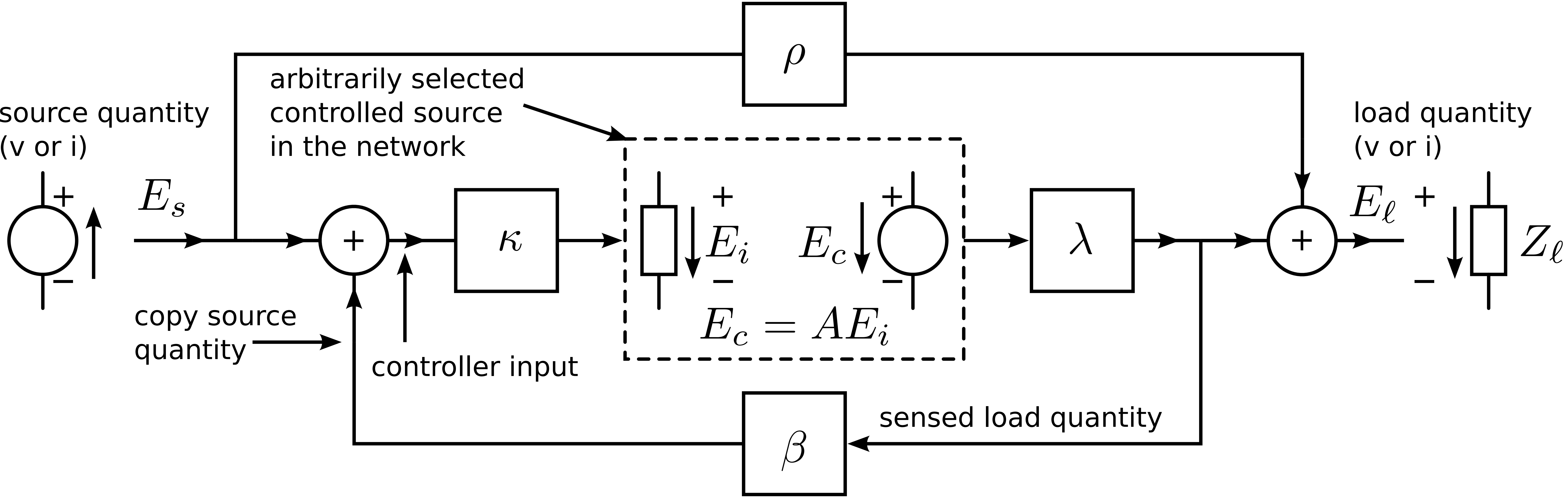
Calculate from product of: A and $\left.\frac{E_i}{E_c}\right|_{E_s=0}$

Negative feedback: $L < 0$

Superposition model

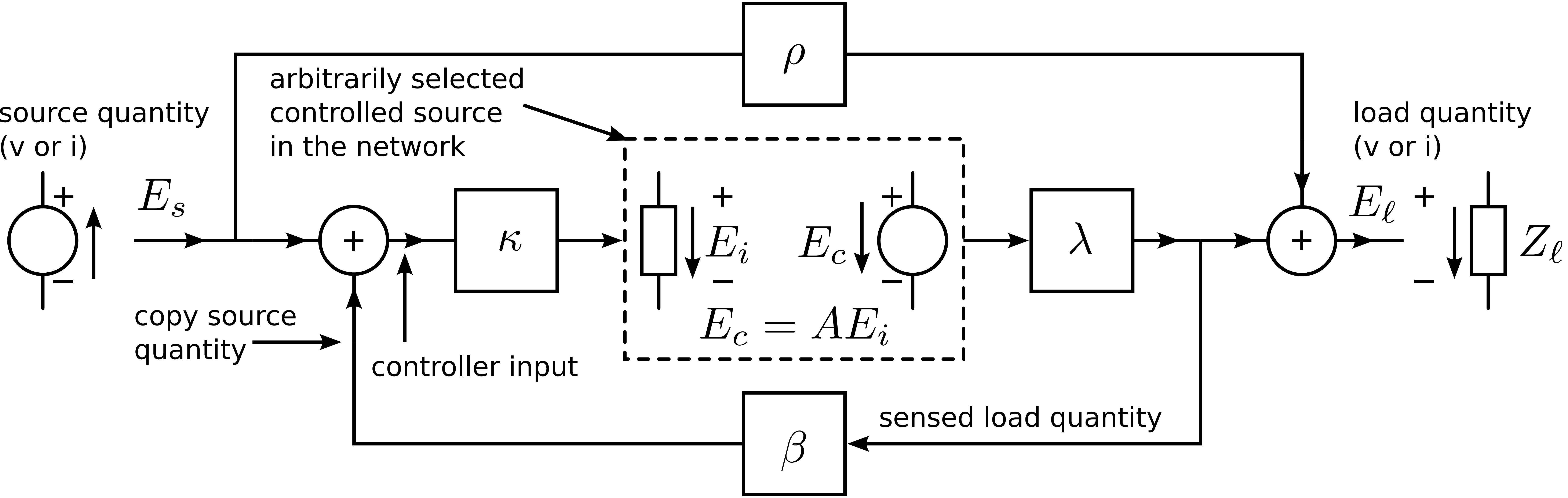


Superposition model



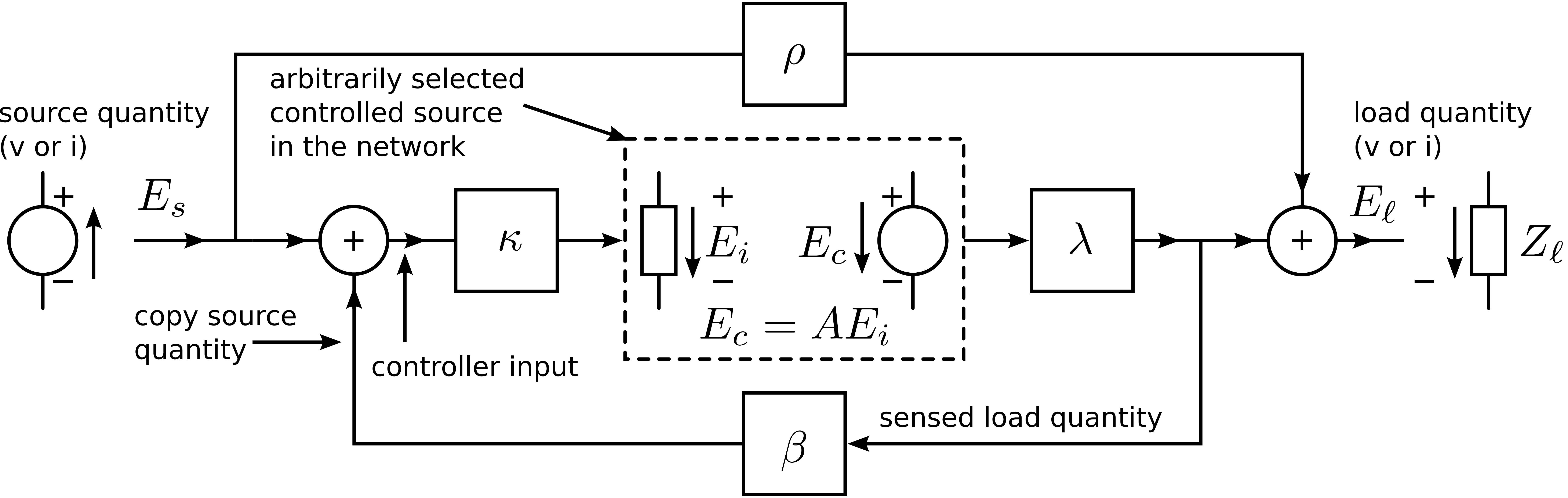
Source-to-load transfer:

Superposition model



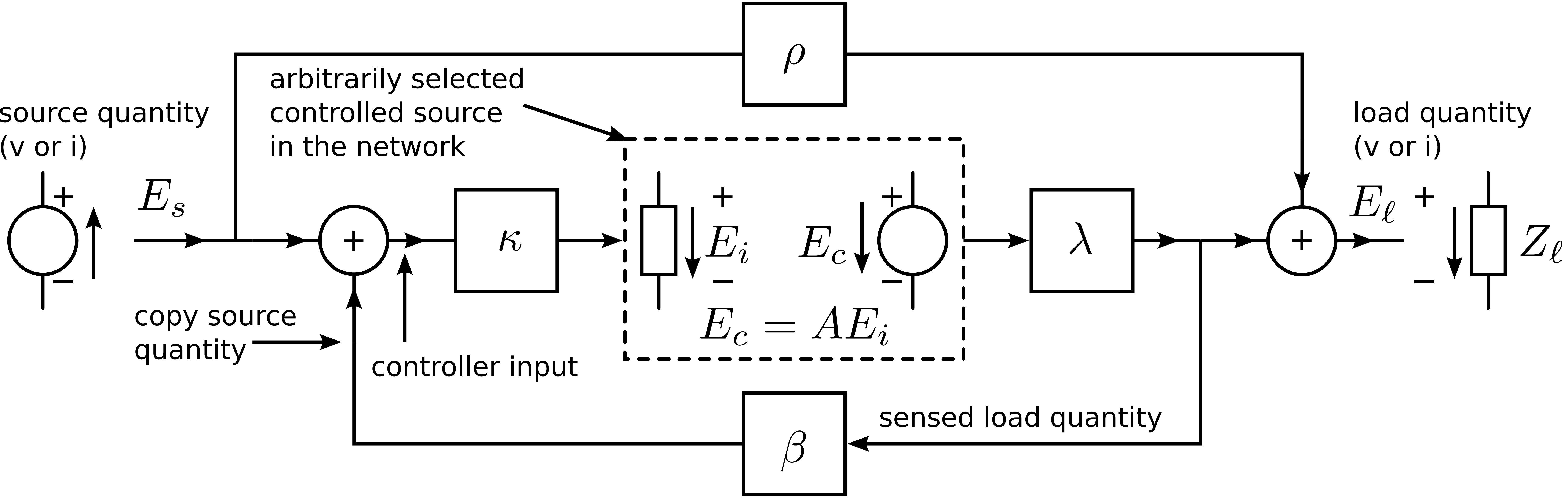
Source-to-load transfer: $A_f = \frac{E_\ell}{E_s}$

Superposition model



Source-to-load transfer: $A_f = \frac{E_\ell}{E_s} = \rho + \frac{A\lambda\kappa}{1 - A\lambda\beta\kappa}$

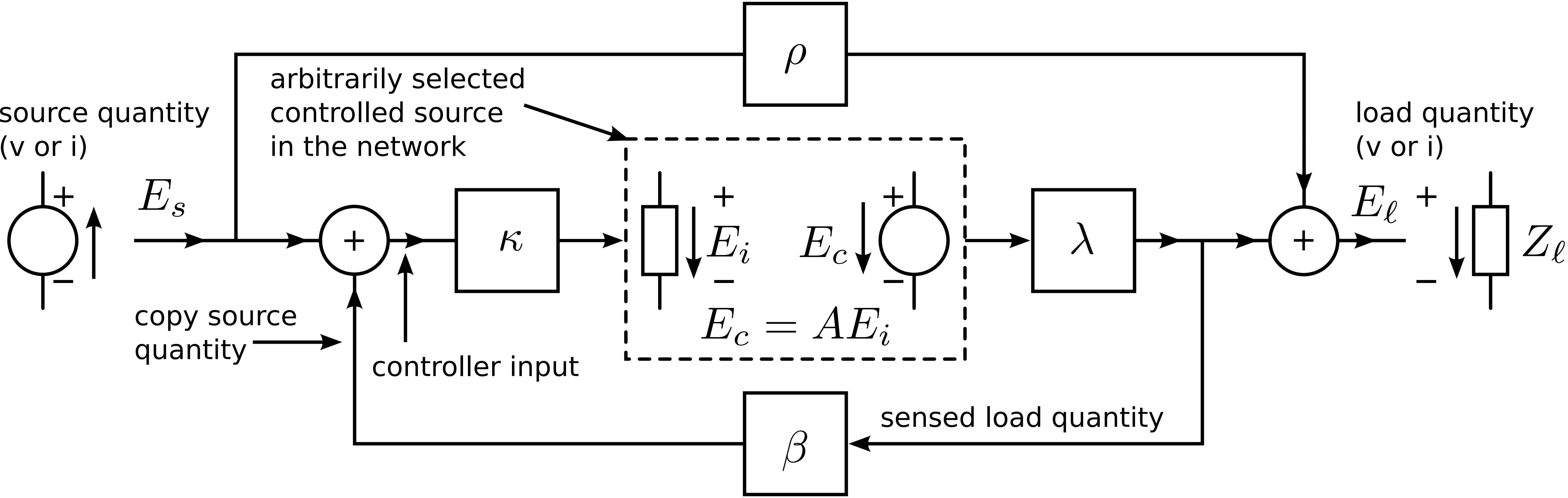
Superposition model



use: $A\lambda\beta\kappa = L$

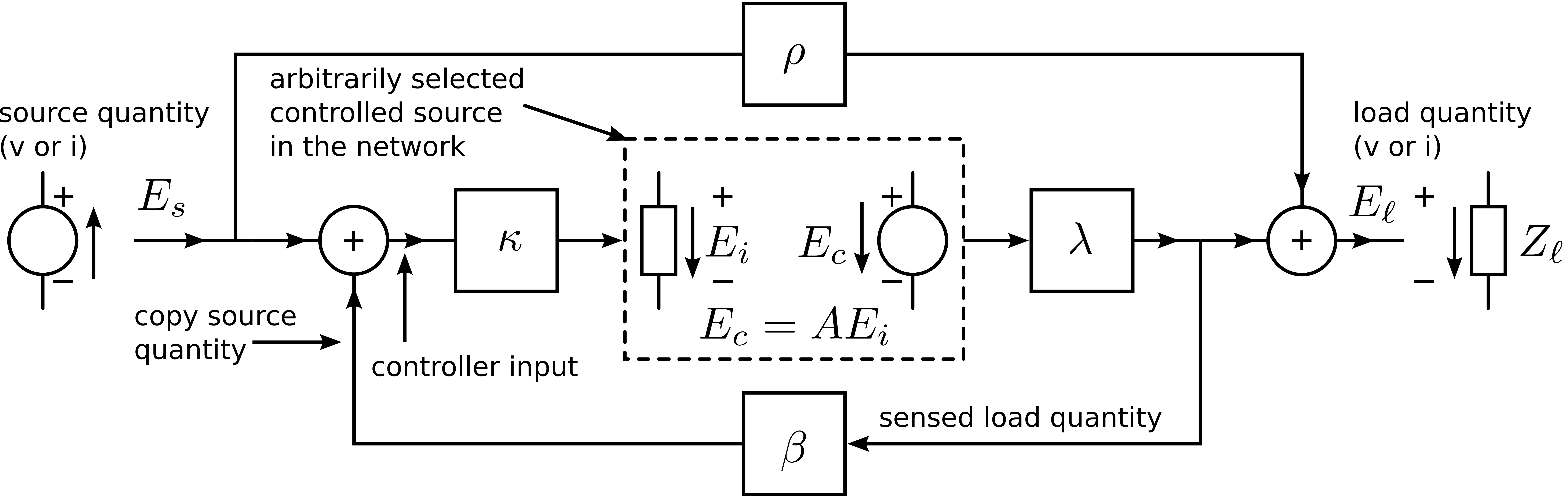
Source-to-load transfer: $A_f = \frac{E_\ell}{E_s} = \rho + \frac{A\lambda\kappa}{1-A\lambda\beta\kappa}$

Superposition model



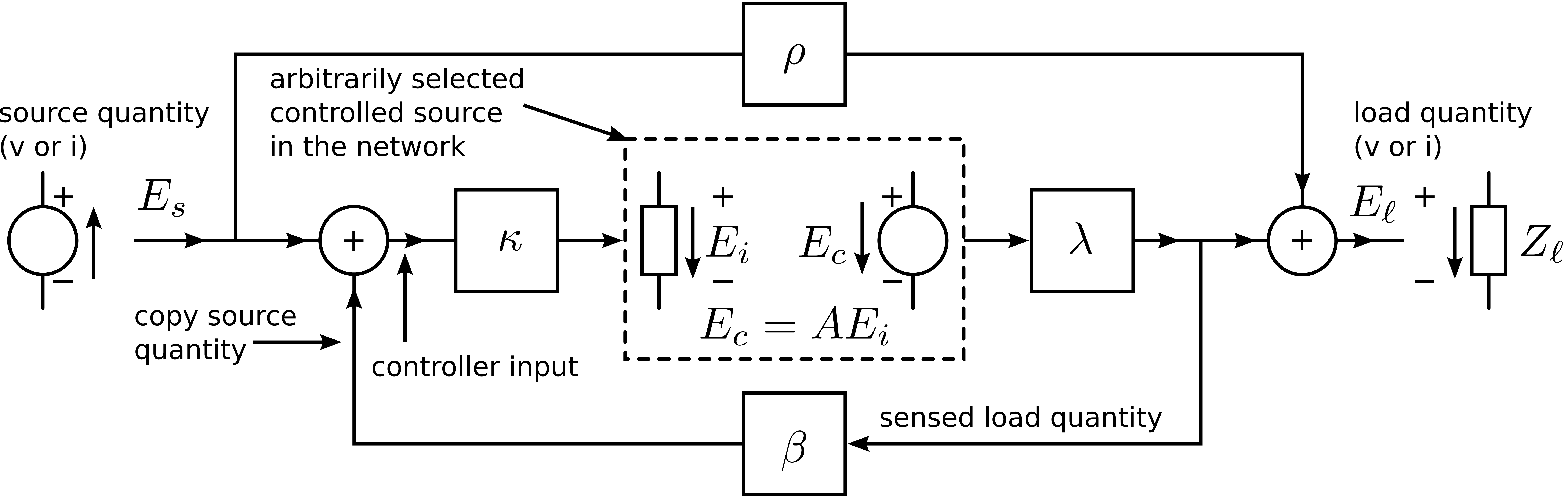
Source-to-load transfer: $A_f = \frac{E_\ell}{E_s} = \rho + \frac{A\lambda\kappa}{1-A\lambda\beta\kappa} = \rho - \frac{1}{\beta}\frac{-L}{1-L}$

Superposition model

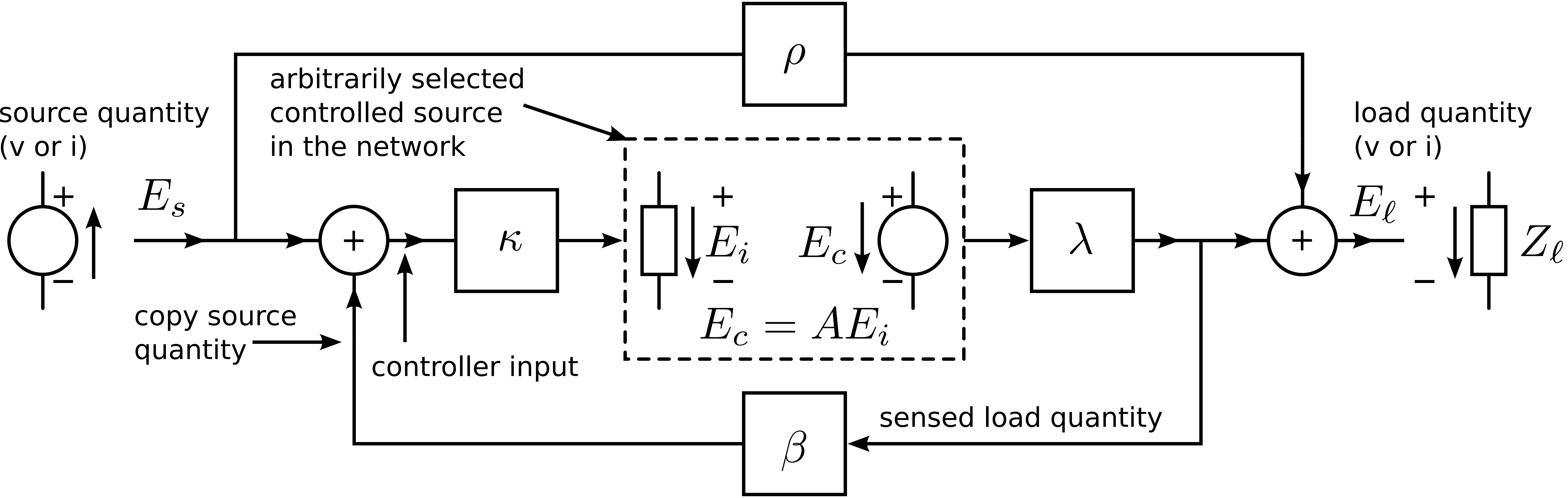


Source-to-load transfer: $A_f = \frac{E_\ell}{E_s} = \rho + \frac{A\lambda\kappa}{1-A\lambda\beta\kappa} = \rho - \frac{1}{\beta}\frac{-L}{1-L}$

Asymptotic-gain model

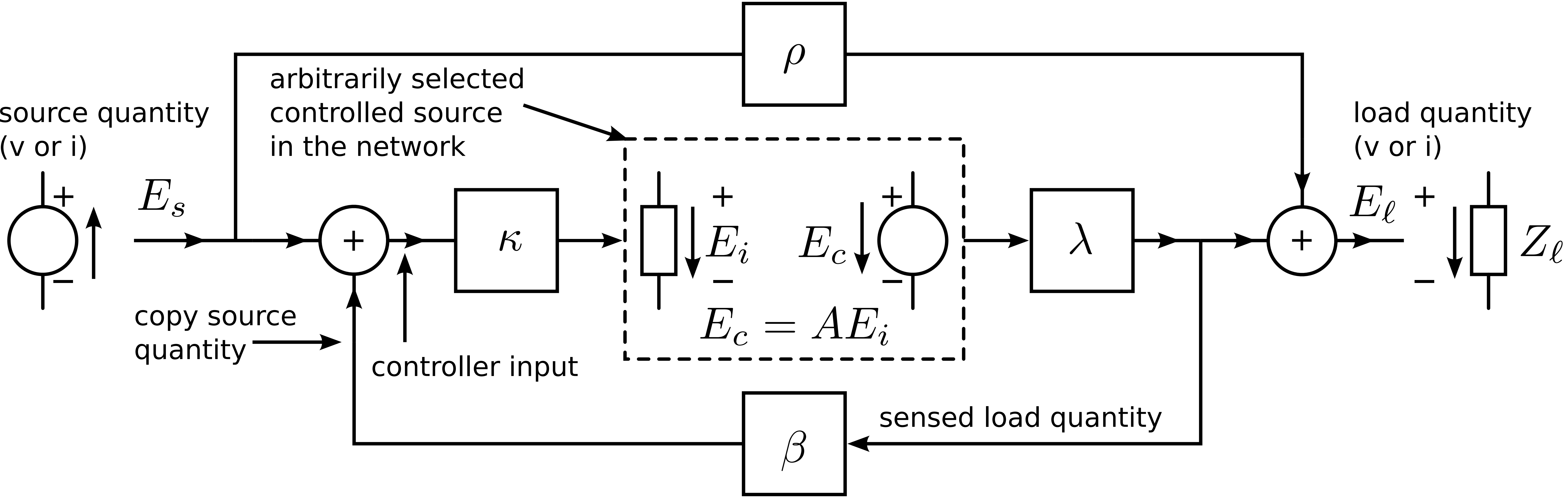


Asymptotic-gain model



Asymptotic-gain:

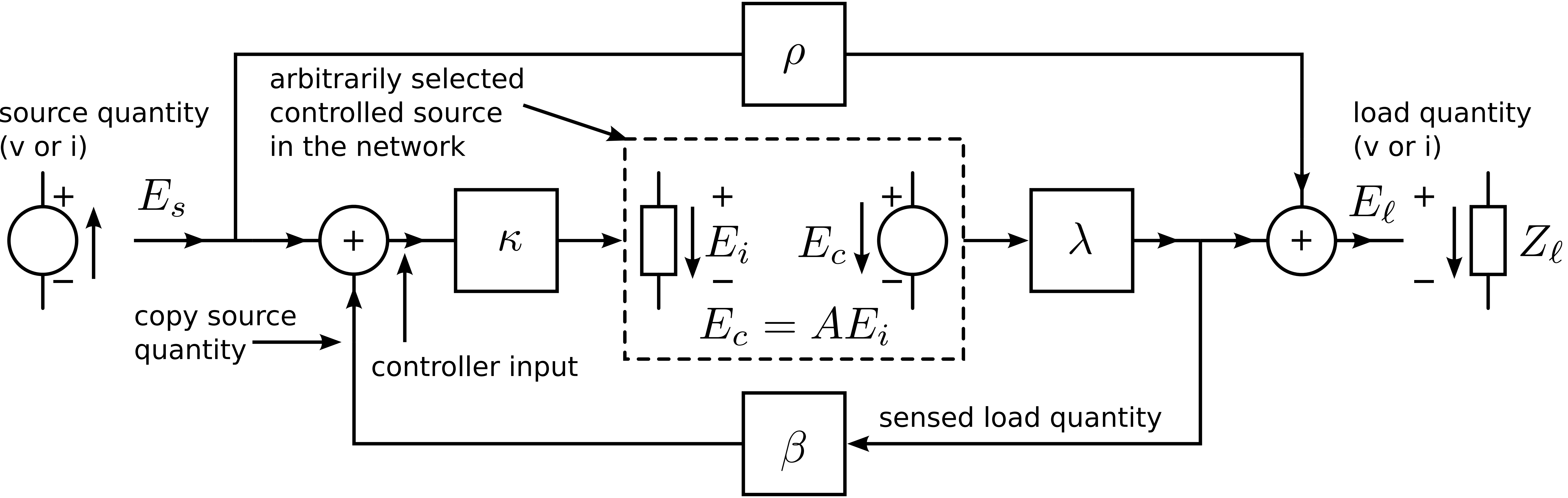
Asymptotic-gain model



Asymptotic-gain:

$A_{f\infty} \triangleq \lim_{A\to\infty} A_f$

Asymptotic-gain model

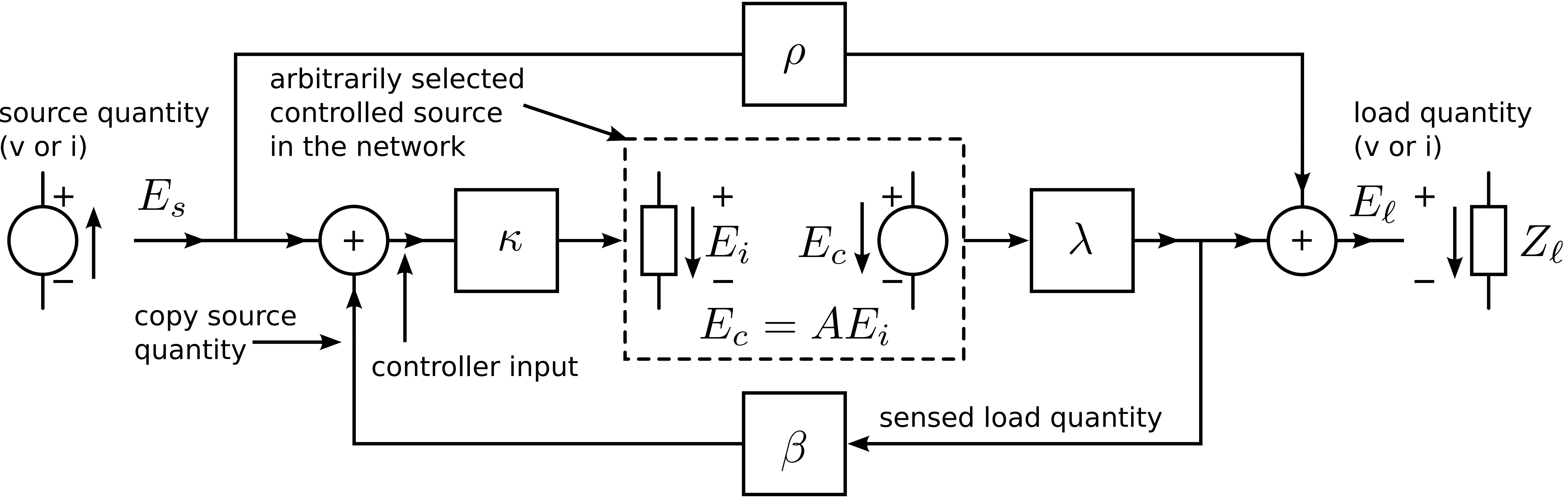


Asymptotic-gain:

$$A_{f\infty} \triangleq \lim_{A\to\infty} A_f$$

$$A_{f\infty} = \rho - \frac{1}{\beta}$$

Asymptotic-gain model



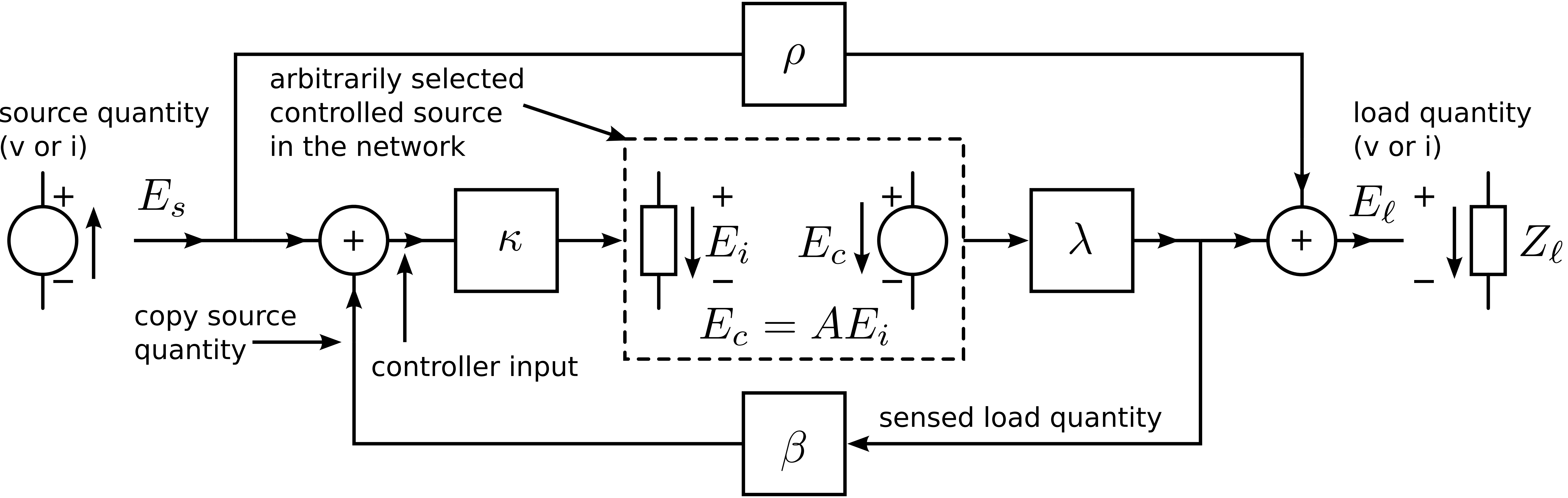
Asymptotic-gain:

$$A_{f\infty} \triangleq \lim_{A\to\infty} A_f$$

$$A_{f\infty} = \rho - \frac{1}{\beta}$$

Source-to-load transfer:

Asymptotic-gain model



Asymptotic-gain:

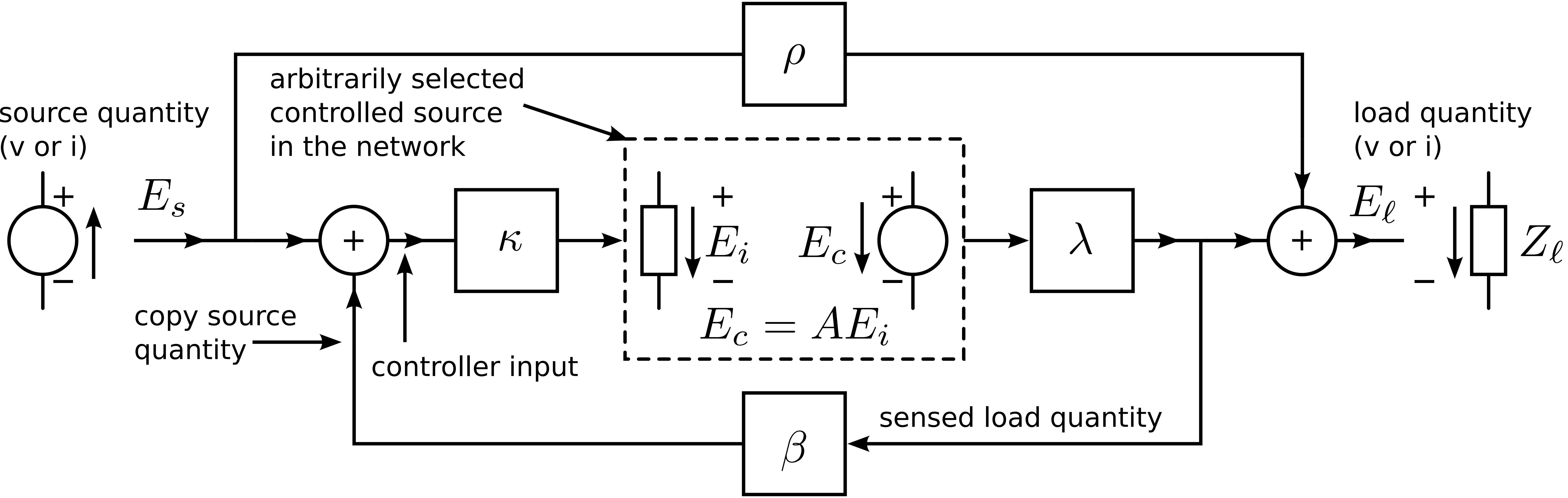
$$A_{f\infty} \triangleq \lim_{A\to\infty} A_f$$

$$A_{f\infty} = \rho - \frac{1}{\beta}$$

Source-to-load transfer:

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

Asymptotic-gain model



Asymptotic-gain:

$$A_{f\infty} \triangleq \lim_{A\to\infty} A_f$$

$$A_{f\infty} = \rho - \frac{1}{\beta}$$

Source-to-load transfer:

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

Asymptotic-gain model

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

If $\frac{\rho}{A_{f\infty}(1-L)} \ll 1$ then: $A_f = A_{f\infty}\frac{-L}{1-L}$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then} \quad A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model,
but no premisses

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model,
but no premisses

Equal to Black's model if:

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

If $\frac{\rho}{A_{f\infty}(1-L)} \ll 1$ then: $A_f = A_{f\infty}\frac{-L}{1-L}$

Looks like Black's model,
but no premisses

Equal to Black's model if:

$$\rho = 0$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

If $\frac{\rho}{A_{f\infty}(1-L)} \ll 1$ then: $A_f = A_{f\infty}\frac{-L}{1-L}$

Looks like Black's model, but no premisses

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

If $\frac{\rho}{A_{f\infty}(1-L)} \ll 1$ then: $A_f = A_{f\infty}\frac{-L}{1-L}$

Looks like Black's model,
but no premisses

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Two-step design if ideal gain (designed in first step) equals asymptotic gain

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Two-step design if ideal gain (designed in first step) equals asymptotic gain

$$A_f \approx A_i\,\frac{-L}{1-L}$$

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$
$$L = \text{Loop gain}$$
$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Two-step design if ideal gain (designed in first step) equals asymptotic gain

Gain

$$A_f \approx A_i\,\frac{-L}{1-L}$$

Equal to Black's model if:

$$\rho = 0$$
$$\kappa = 1$$
$$\lambda = 1$$
$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model,
but no premisses

Two-step design if ideal gain (designed in first step)
equals asymptotic gain

Gain

Ideal gain

$$A_f \approx A_i \frac{-L}{1-L}$$

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Two-step design if ideal gain (designed in first step) equals asymptotic gain

Gain

Ideal gain

Loop gain

$$A_f \approx A_i \frac{-L}{1-L}$$

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$
$$L = \text{Loop gain}$$
$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Two-step design if ideal gain (designed in first step) equals asymptotic gain

$$A_f \approx A_i \frac{-L}{1-L}$$

Gain
Ideal gain
Loop gain
Servo function

Equal to Black's model if:

$$\rho = 0$$
$$\kappa = 1$$
$$\lambda = 1$$
$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Two-step design if ideal gain (designed in first step) equals asymptotic gain

Gain

Ideal gain

Loop gain

Servo function

$$A_f \approx A_i\frac{-L}{1-L}$$

This requires proper selection of the loop gain reference

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

$$\beta = \frac{1}{k}$$

Asymptotic-gain model

$$A_f = A_{f\infty}\frac{-L}{1-L} + \frac{\rho}{1-L}$$

$$A_{f\infty} = \text{Asymptotic-gain}$$

$$L = \text{Loop gain}$$

$$\rho = \text{Direct transfer}$$

$$\text{If } \frac{\rho}{A_{f\infty}(1-L)} \ll 1 \text{ then: } A_f = A_{f\infty}\frac{-L}{1-L}$$

Looks like Black's model, but no premisses

Two-step design if ideal gain (designed in first step) equals asymptotic gain

Gain
Ideal gain
Loop gain
Servo function

$$A_f \approx A_i \frac{-L}{1-L}$$

Equal to Black's model if:

$$\rho = 0$$

$$\kappa = 1$$

$$\lambda = 1$$

$$\beta = \frac{1}{k}$$

This requires proper selection of the loop gain reference