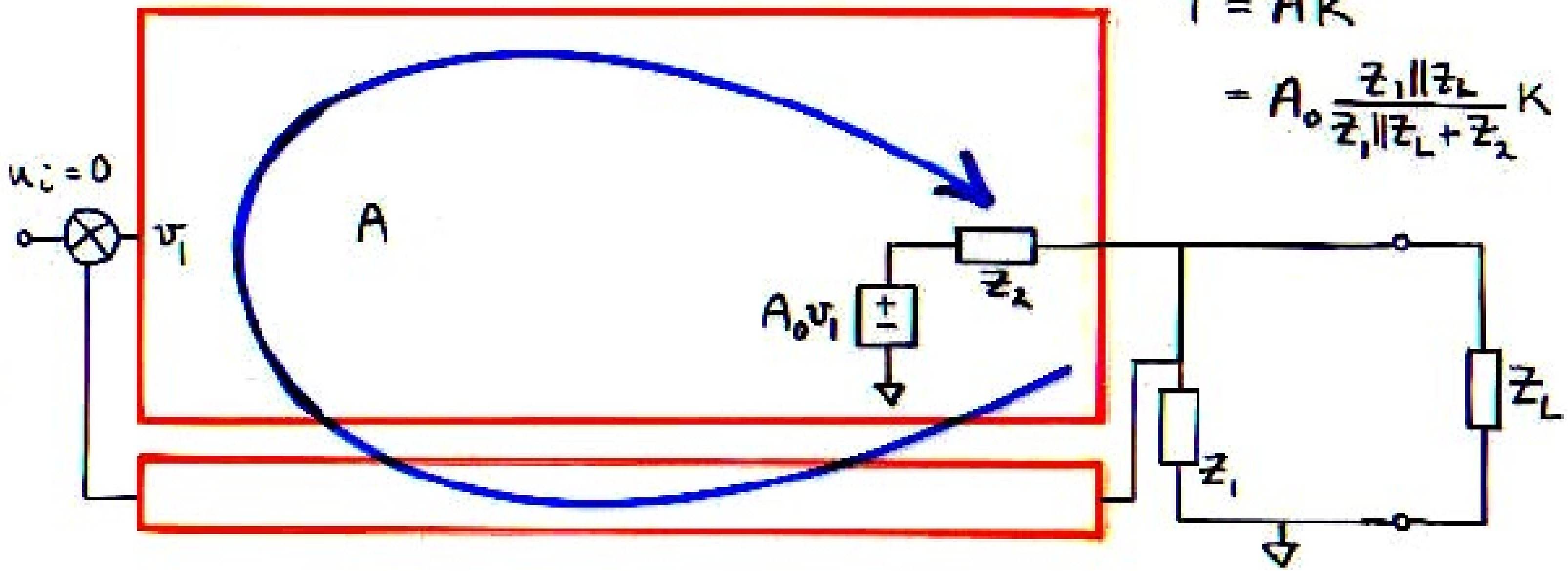
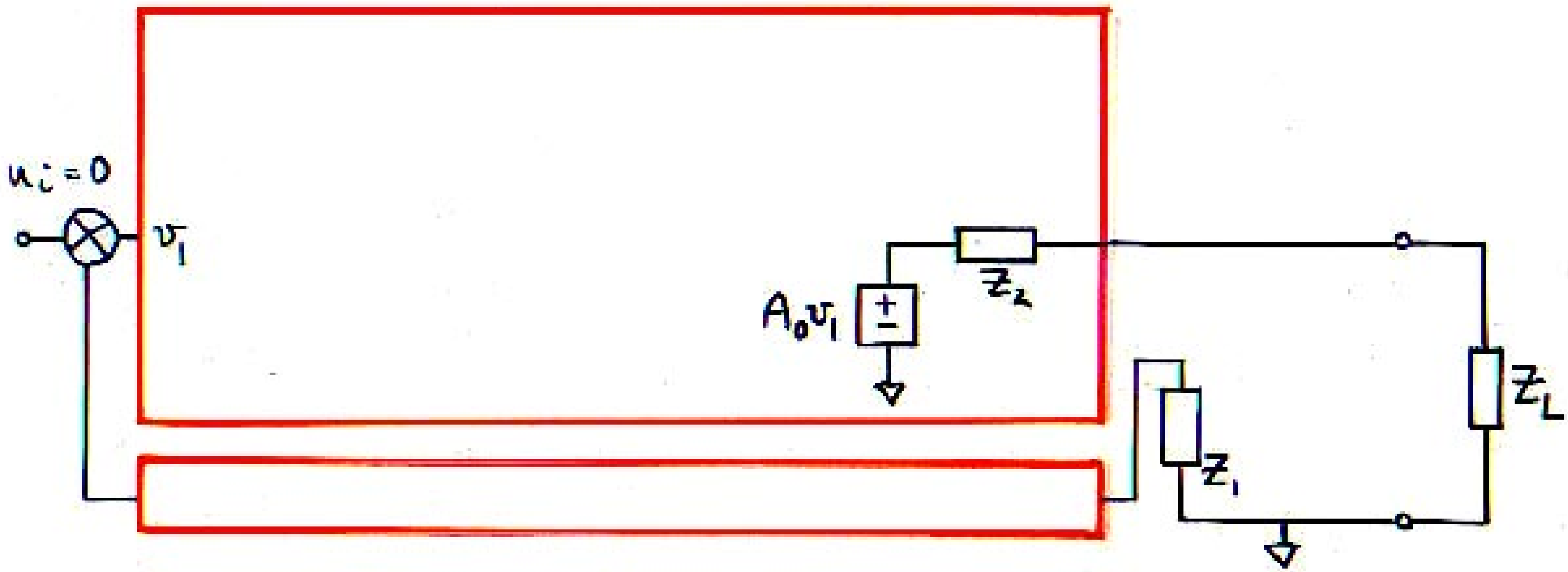
9

ALL ABOUT T

$$T = AK$$

$$= A_0 \frac{Z_1 \| Z_L}{Z_1 \| Z_L + Z_2} K$$

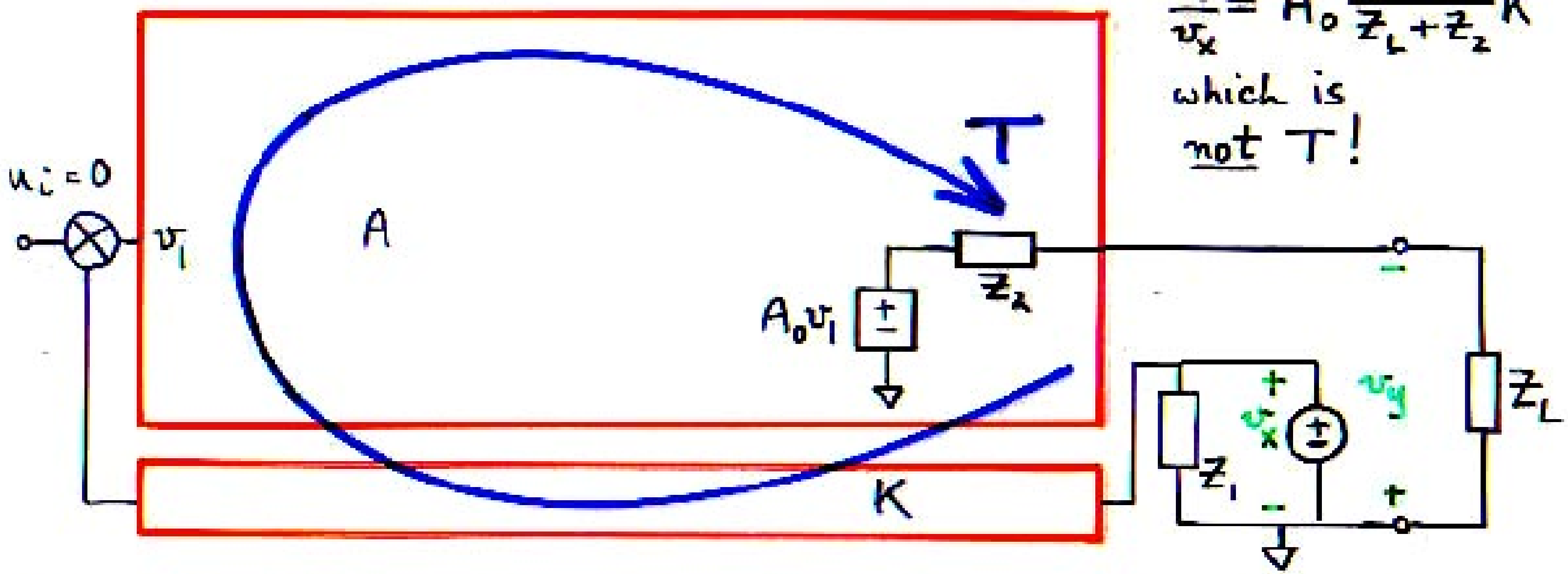




$u_i = 0$
v_1
$A_0 v_1$
Z_2
Z_L
Z_1

$$\frac{v_y}{v_x} = A_0 \frac{Z_L}{Z_L + Z_2} K$$

which is <u>not</u> T!

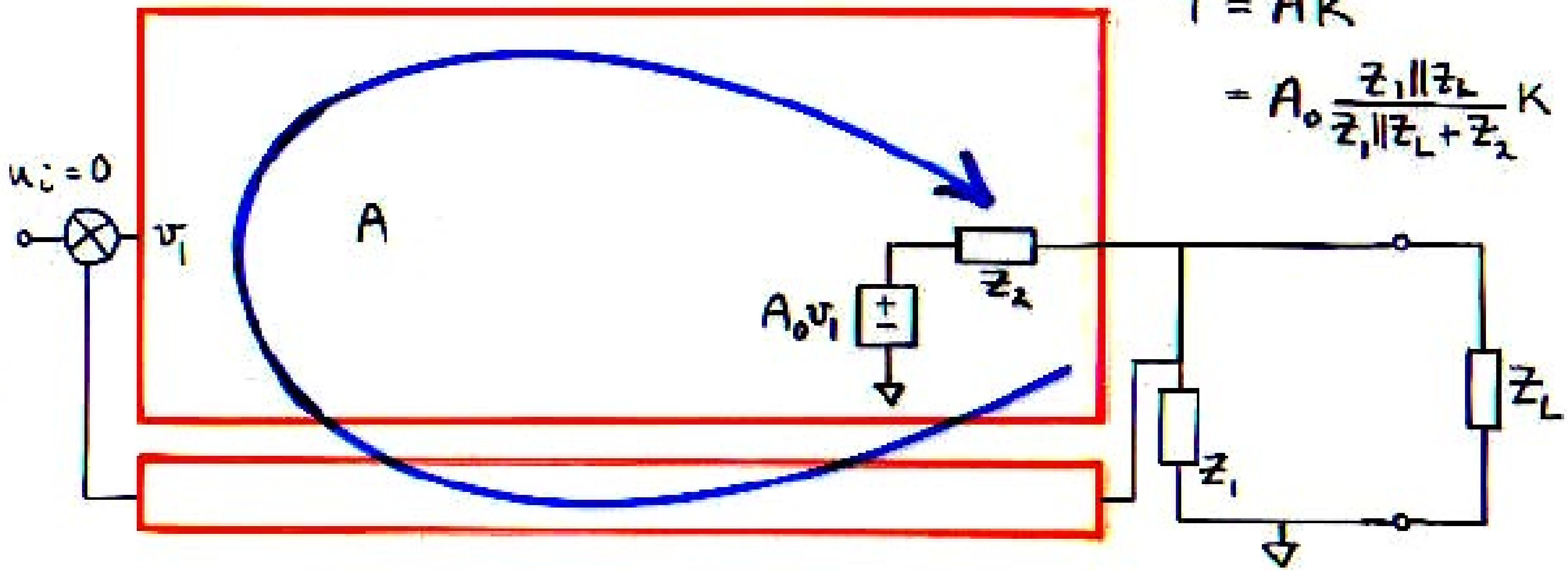


Conventional procedure: break the loop at the output (or input) of the forward path, and find $T = \frac{v_y}{v_x} = AK$.

However, often the feedback path loads the forward path at the output (or input), so the value found for A and/or K is not the same as when the loop is closed, and so the wrong answer is obtained for T.

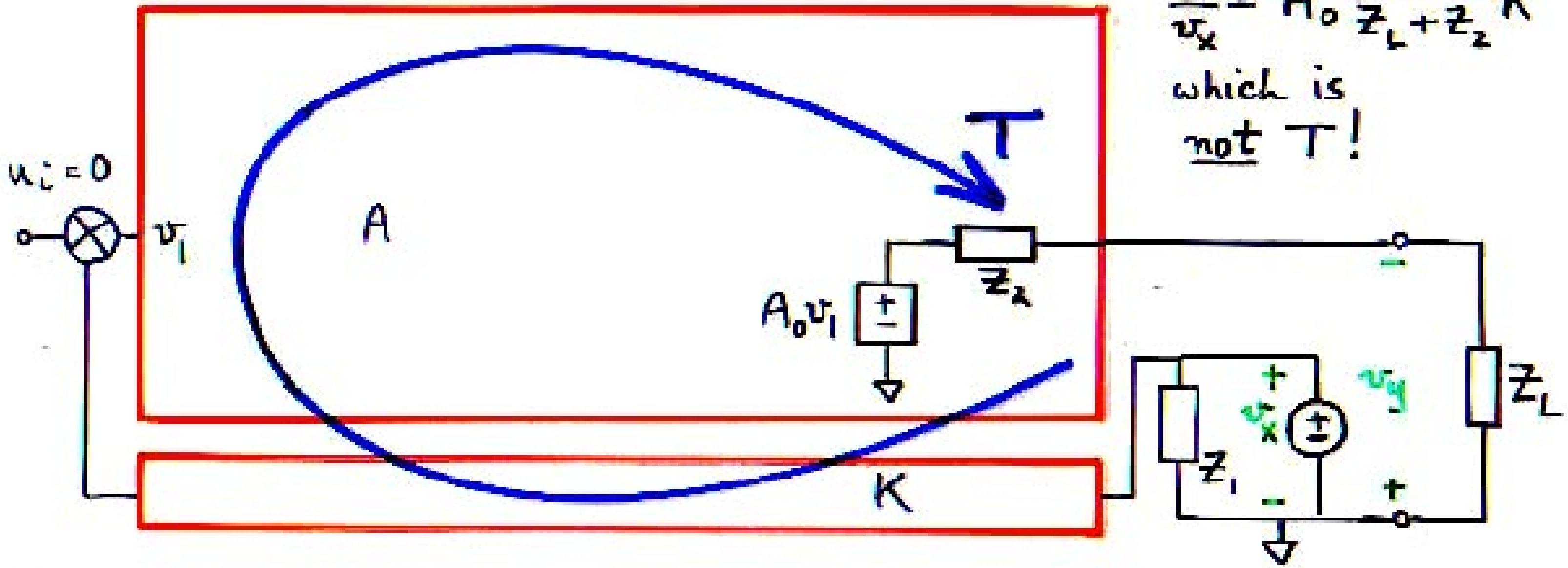
In some cases the loading may be simulated, but involves guesswork.

$$T = AK$$
$$= A_0 \frac{Z_1 \| Z_L}{Z_1 \| Z_L + Z_2} K$$



$$\frac{v_y}{v_x} = A_0 \frac{Z_L}{Z_L + Z_2} K$$

which is <u>not</u> T!



Conventional procedure: break the loop at the output (or input) of the forward path, and find $T = \frac{v_y}{v_x} = AK$.

However, often the feedback path loads the forward path at the output (or input), so the value found for A and/or K is not the same as when the loop is closed, and so the wrong answer is obtained for T.

In some cases the loading may be simulated, but involves guesswork.

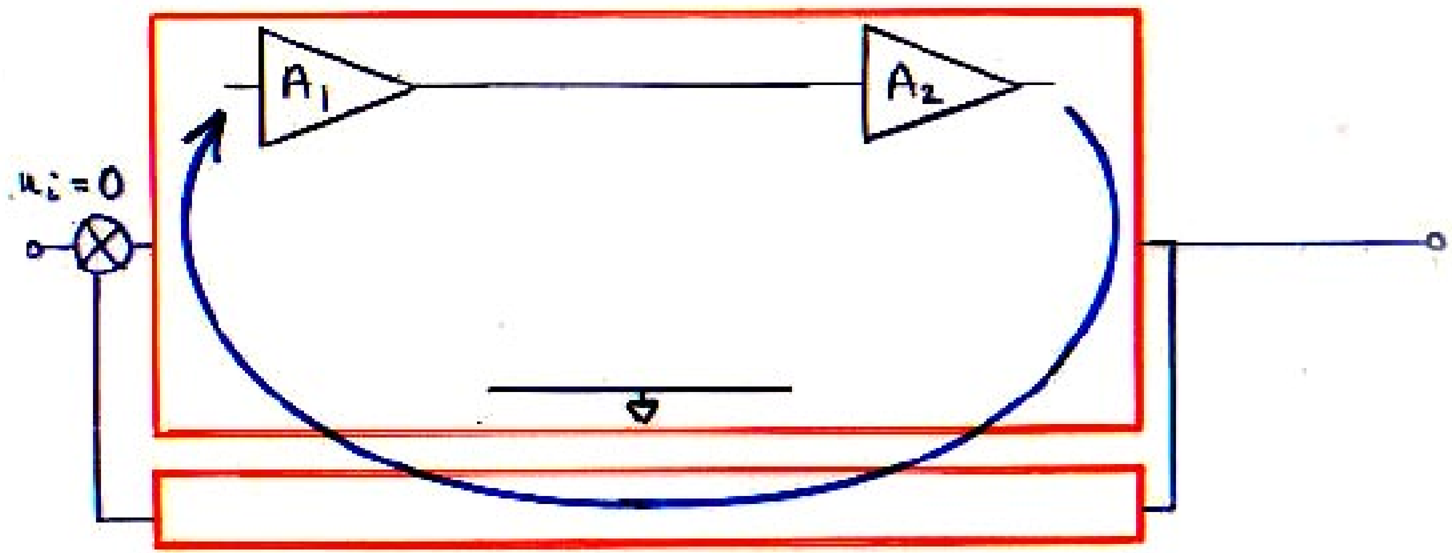
Instead, since A need not be known separately, break the loop at a point where the loading is not disturbed (usually somewhere in the forward path).

Loop Gain by Signal Injection into the Closed Loop

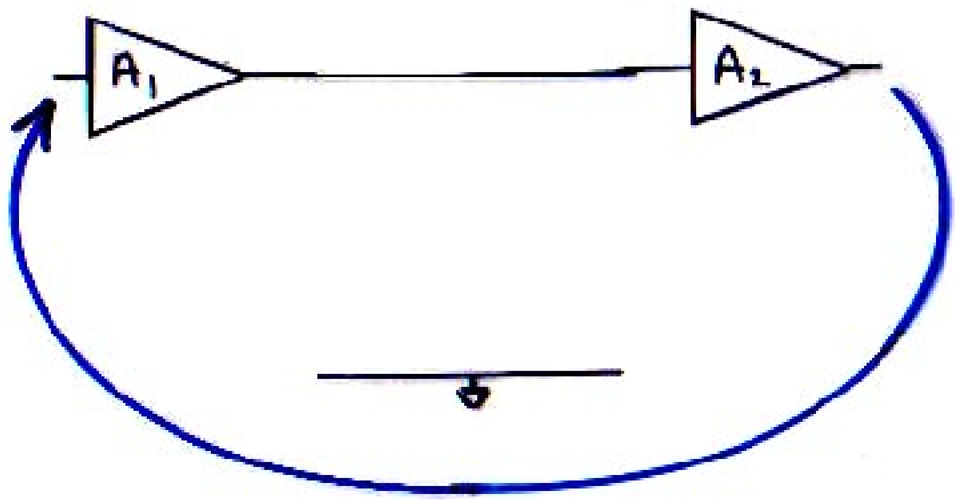
One of the most valuable benefits of the improved feedback formula is that, since A does not have to be known separately, the loop need not be broken at either the input or the output.

Instead, the break can be made anywhere in the loop, so that a test point can be chosen where the loading is not upset by the break.

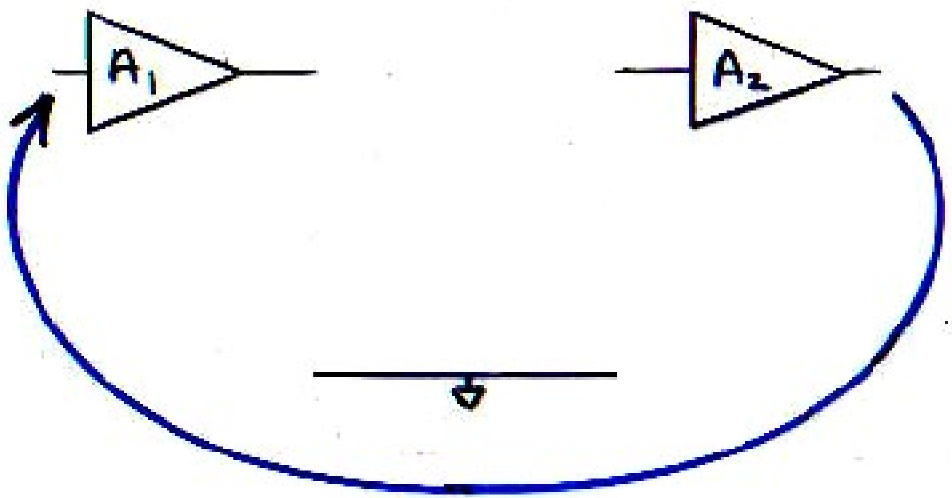
A convenient test point is at a dependent generator in the model.

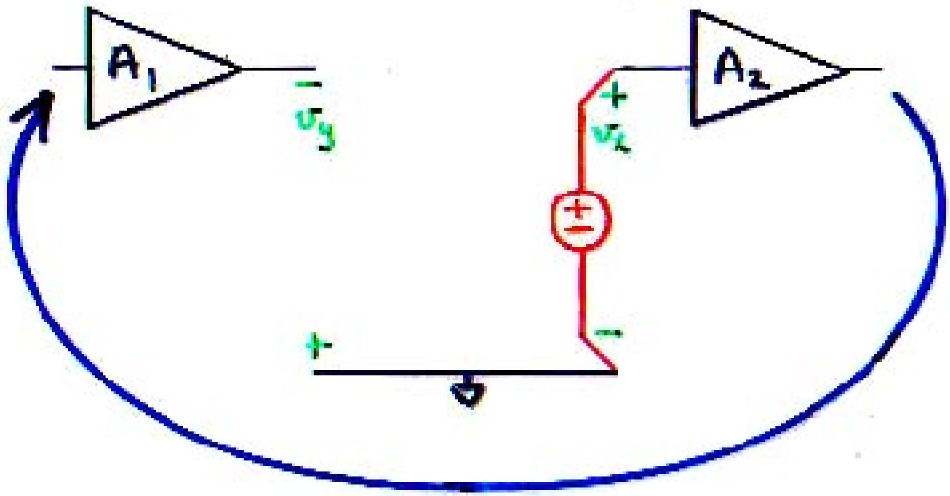


A1
A2
ui=0



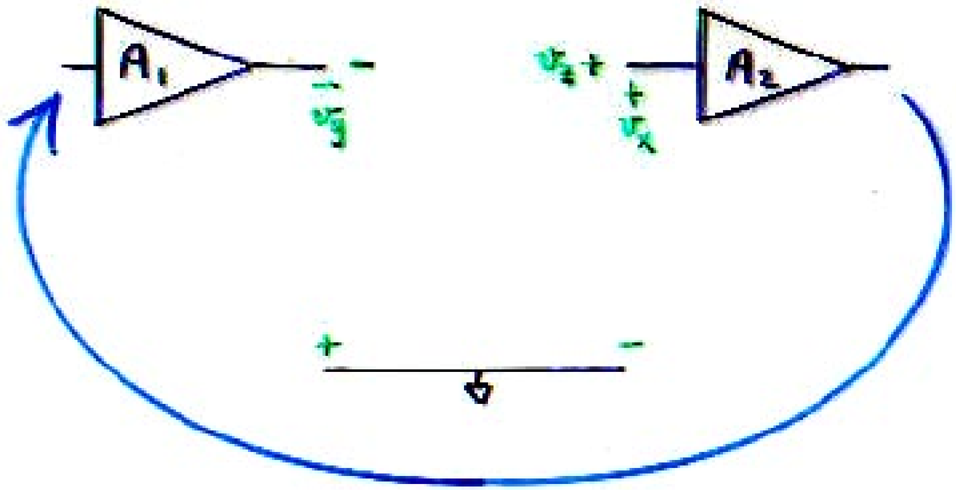
A1
A2


A1
A2



If A_1 and A_2 are unaffected by breaking the loop between A_1 and A_2, a test signal v_x may be applied at the input of A_2, and the resulting signal v_y at the output of A_1 gives the correct value of the loop gain T as

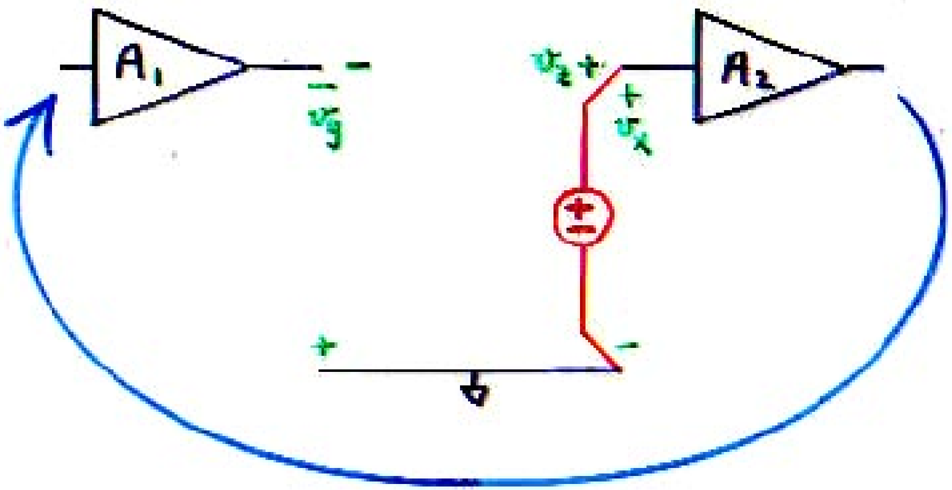
$$T = \frac{v_y}{v_x}$$



Under such conditions, a voltage $v_z = v_x + v_y$ exists across the break.

It makes no difference to the ratio v_y / v_x whether the driving signal is v_x or v_z.

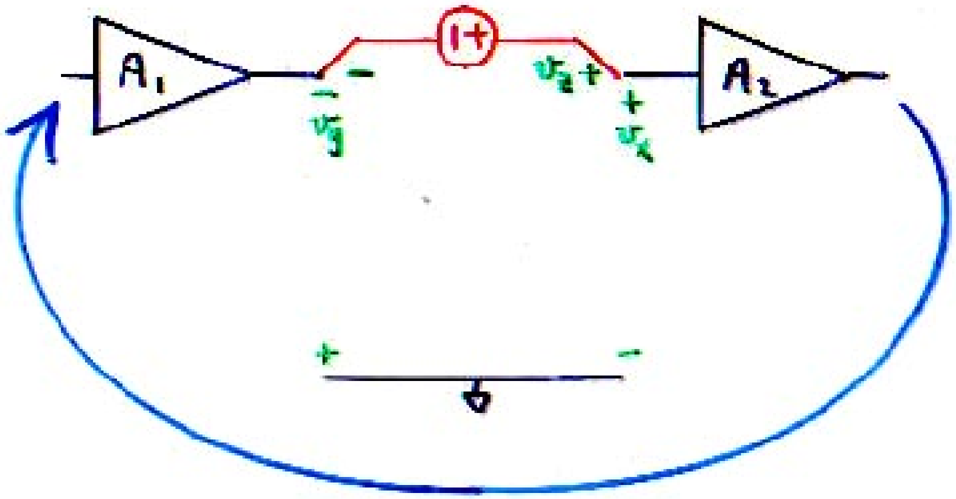
Hence $T = \frac{v_y}{v_x}$, regardless of whether the system is driven by v_x or v_z.



Under such conditions, a voltage $v_z = v_x + v_y$ exists across the break.

It makes no difference to the ratio v_y/v_x whether the driving signal is v_x or v_z.

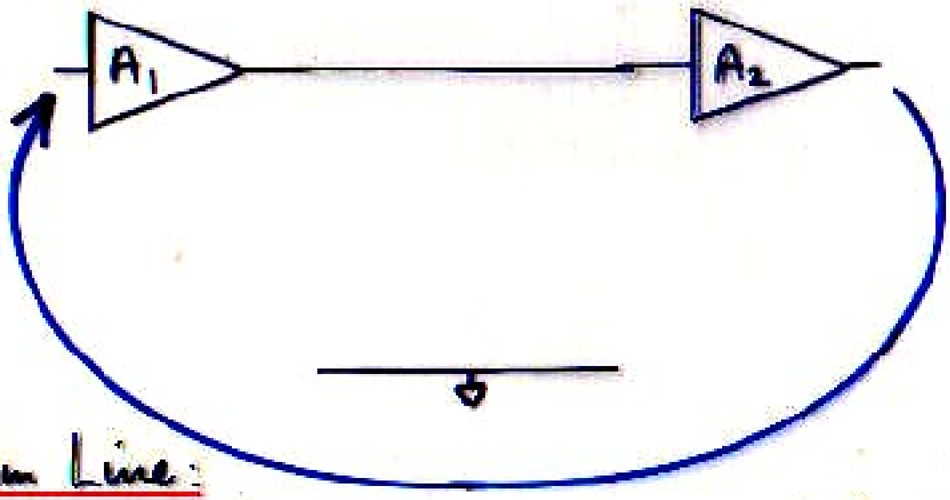
Hence $T = \frac{v_y}{v_x}$, regardless of whether the system is driven by v_x or v_z.



Under such conditions, a voltage $v_z = v_x + v_y$ exists across the break.

It makes no difference to the ratio v_y/v_x whether the driving signal is v_x or v_z.

Hence $T = \frac{v_y}{v_x}$, regardless of whether the system is driven by v_x or v_z.

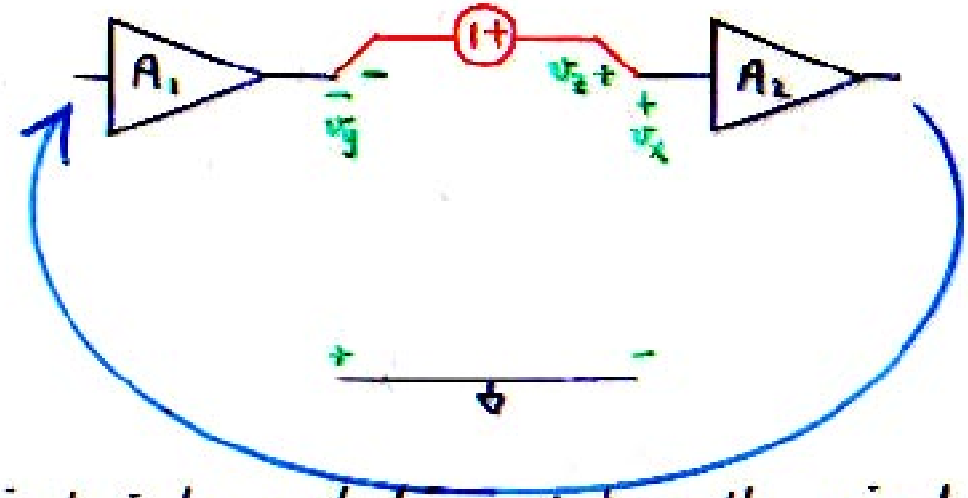


Bottom Line:

There are great advantages, especially for experimental application, in use of an injected test signal into the closed loop:

1. The loop does not have to be broken, with consequent difficulties in maintaining the proper operating point.

2. The circuit remains in the same configuration (loop remains closed).



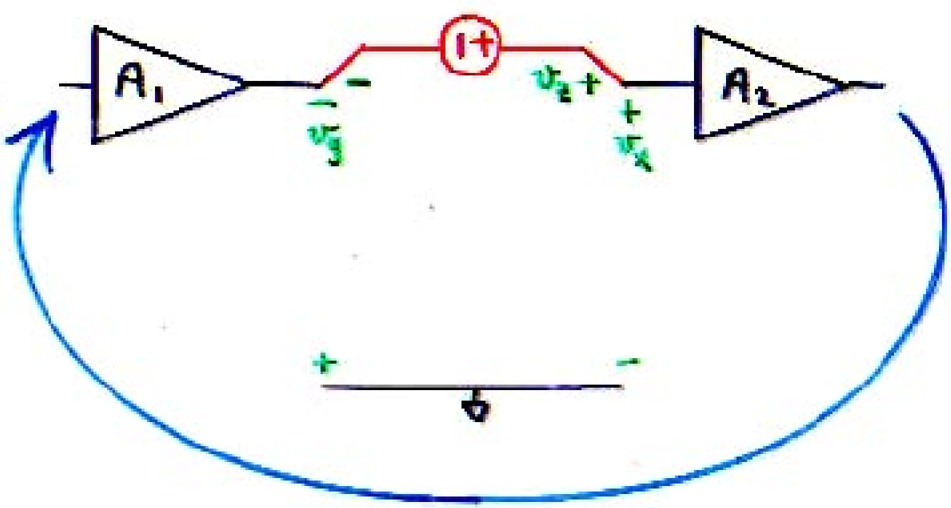
Physical interpretation of how the signals adjust to injection of a test signal into the closed loop

$v_x + v_y = v_z$ phasor sum, fixed by the drive v_z

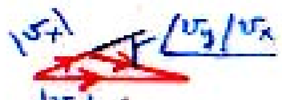
$\frac{v_y}{v_x} = T$ phasor ratio, fixed by the circuit

Hence, the values of v_x and v_y adjust themselves to satisfy simultaneously these two conditions:

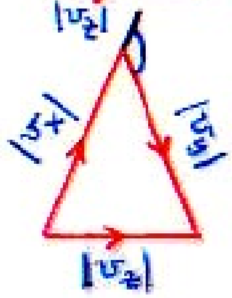
$$v_x = \frac{1}{1+T} v_z \qquad v_y = \frac{T}{1+T} v_z$$



Phasor diagrams for given $|v_z|$ at increasing frequencies:



Below crossover frequency, $f \ll f_c$: $\left|\frac{v_y}{v_x}\right| \gg 1$



At crossover frequency, $f = f_c$: $\left|\frac{v_y}{v_x}\right| = 1$

Above crossover frequency, $f \gg f_c$: $\left|\frac{v_y}{v_x}\right| \ll 1$

Generalization: Determination of Loop Gain by Injection of a Test Signal into the Closed Loop

Preferable to application of a test signal to a broken loop, because:

1. The loop remains closed, avoiding disturbances of operating point.
2. The circuit remains in the same configuration.

However, injection must be done at a point where, if the loop were broken, there would be negligible change in the loading effects.

Determination of Feedback System Parameters — General

The method of Loop Gain T determination T by injection of a test signal into the closed loop can be generalized and, by inclusion of the Null Double Injection technique, also leads to determination of the Ideal Closed-Loop Gain G_∞.

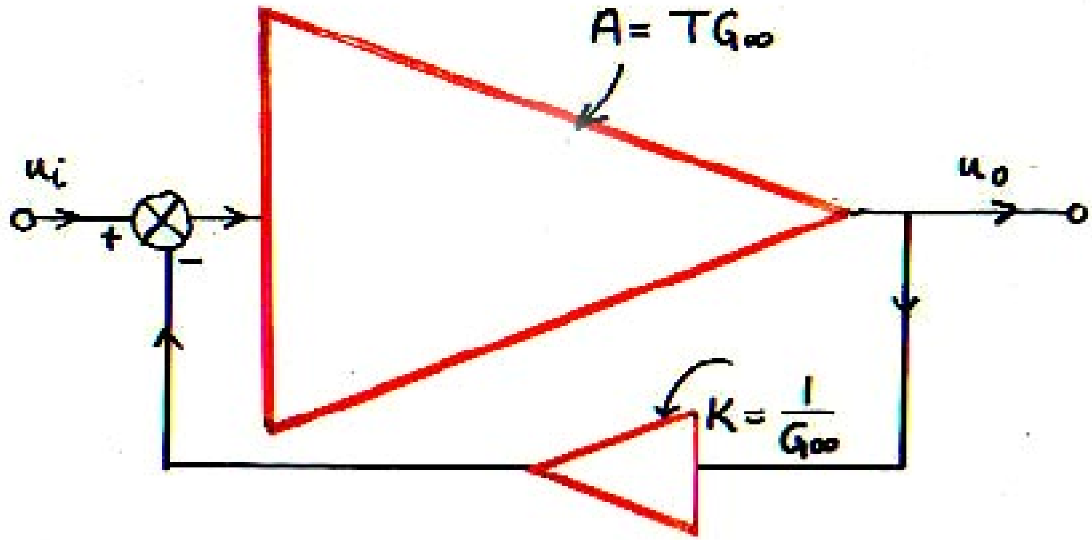
Basic relations:

$$G = \frac{A}{1+AK} = \frac{A}{1+T}$$

$$= \frac{1}{K}\frac{T}{1+T}$$

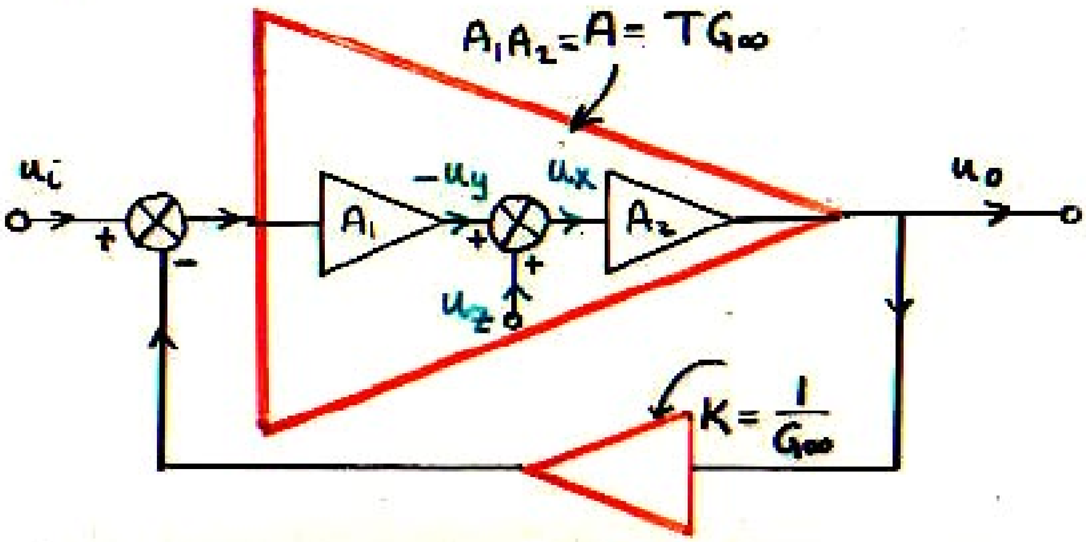
$$= G_\infty D$$

Note that $A = TG_\infty$ and $K = 1/G_\infty$:



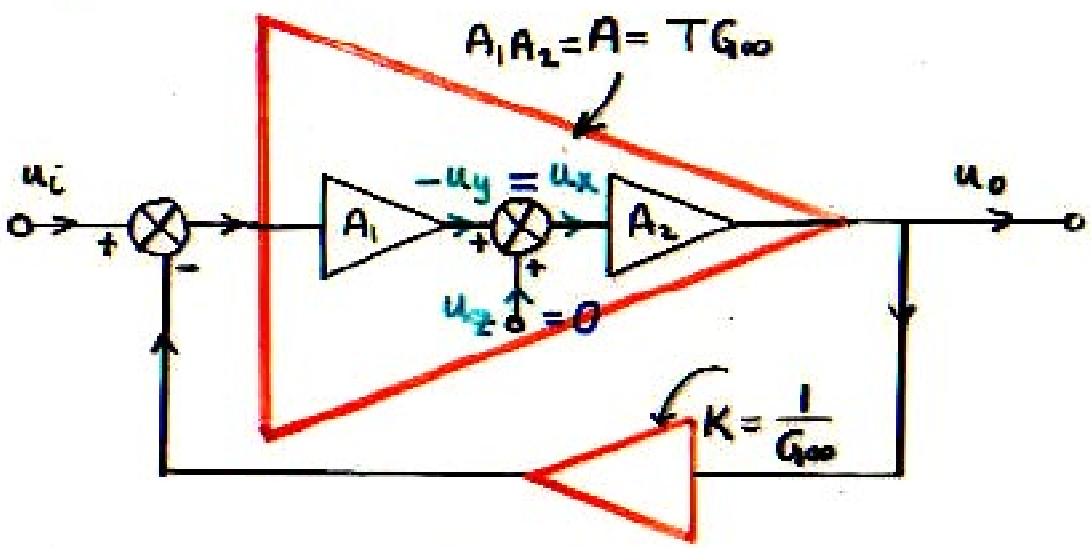
Note that $A = TG_\infty$ and $K = 1/G_\infty$:

Consider a second driving signal u_z injected into the forward path:



Note that $A = TG_\infty$ and $K = 1/G_\infty$:

Consider a second driving signal u_z injected into the forward path:

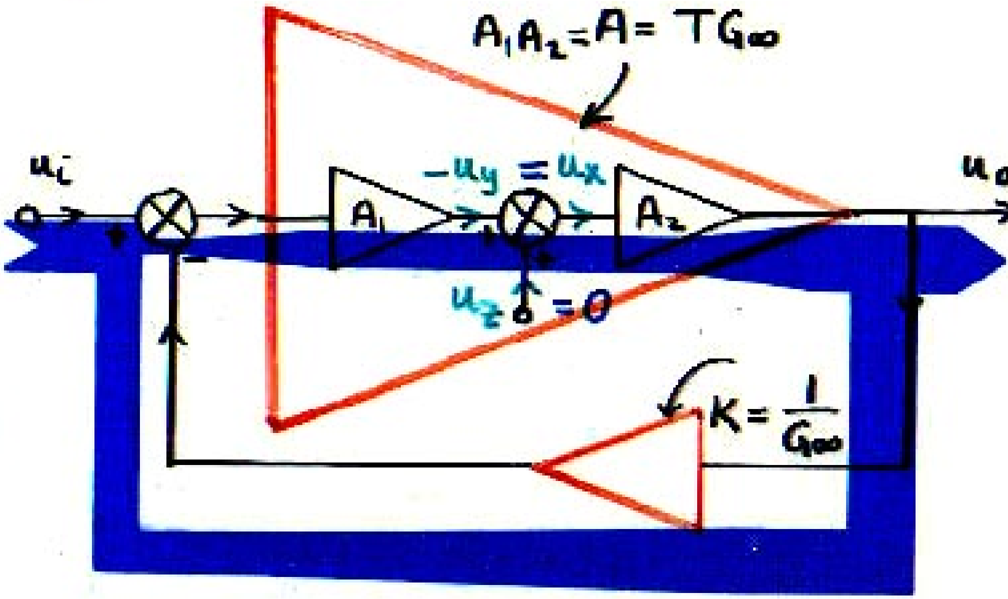


For single injection, u_i only (normal operation):

$$\left.\frac{u_o}{u_i}\right|_{u_z=0} \equiv G = G_\infty \frac{T}{1+T} \quad \text{closed-loop gain}$$

Note that $A = T G_\infty$ and $K = 1/G_\infty$:

Consider a second driving signal u_z injected into the forward path:

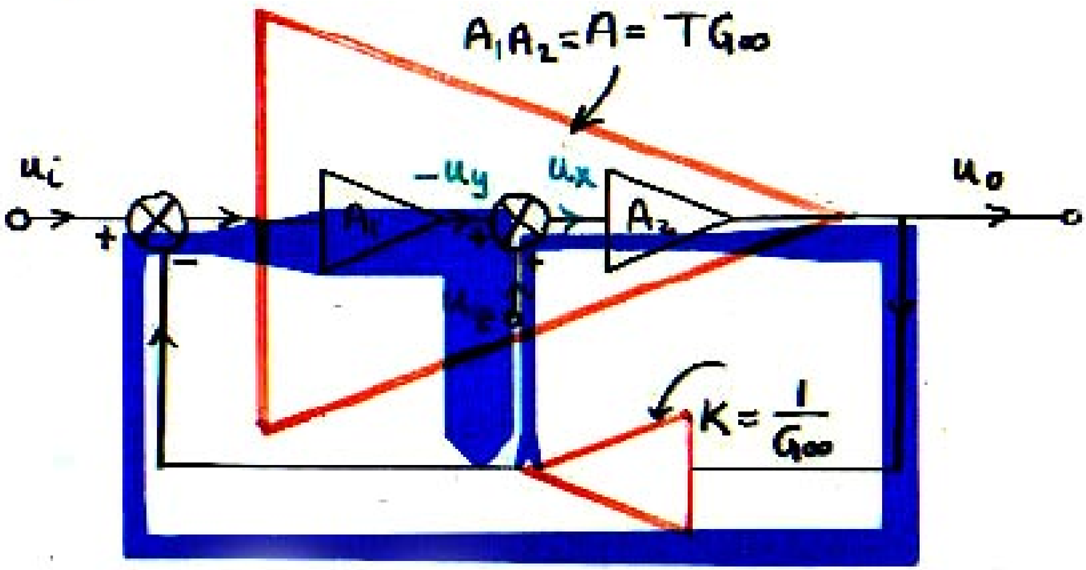


For single injection, u_i only (normal operation):

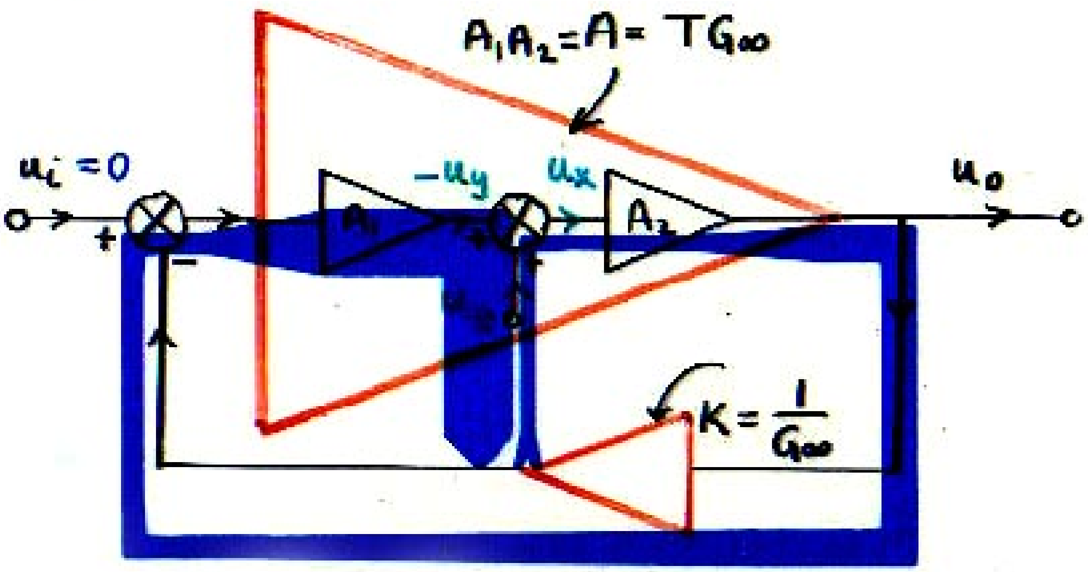
$$\left.\frac{u_o}{u_i}\right|_{u_z=0} \equiv G = G_\infty \frac{T}{1+T}$$ closed-loop gain

Note that $A = TG_\infty$ and $K = 1/G_\infty$:

Consider a second driving signal u_z injected into the forward path:



Note that $A = TG_\infty$ and $K = 1/G_\infty$:
Consider a second driving signal u_z injected into the forward path:

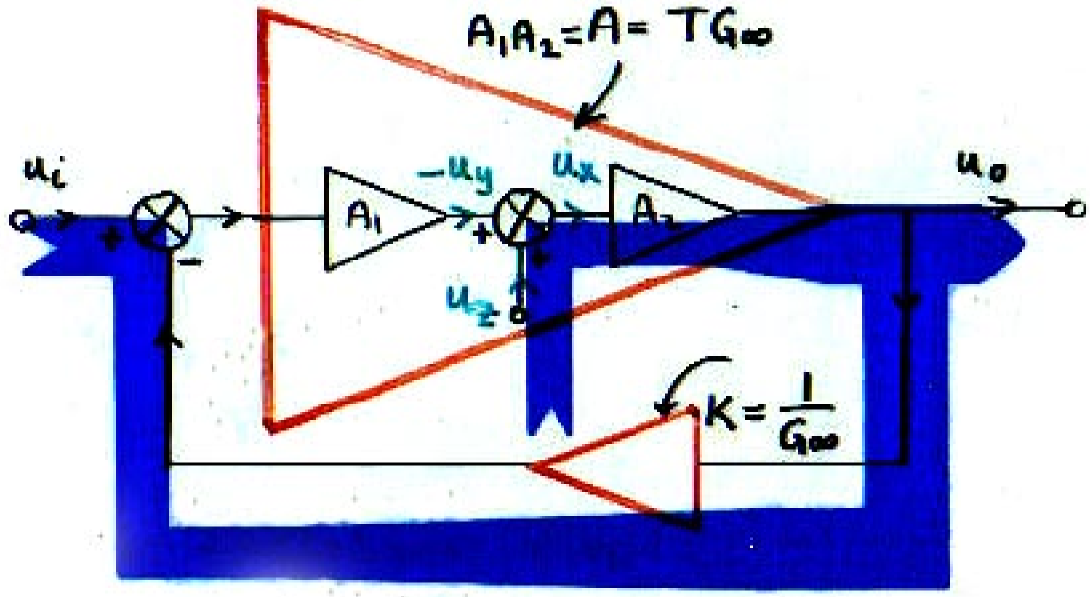


For single injection, u_z only,

$$\left.\frac{u_y}{u_x}\right|_{u_i=0} = A_2 K A_1 = AK \equiv T \quad \text{loop gain}$$

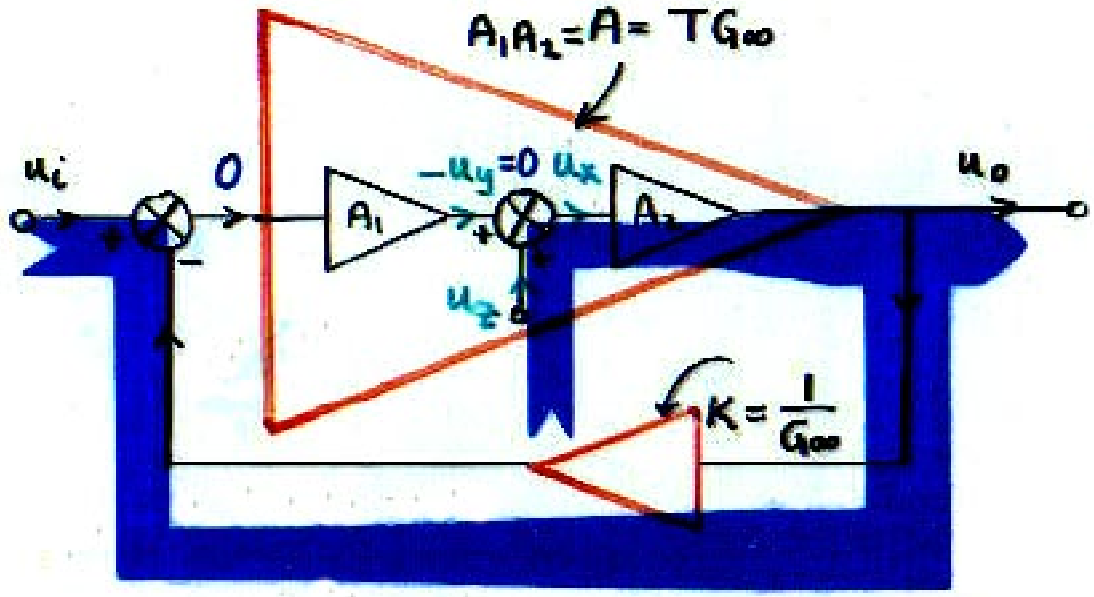
Note that $A = TG_\infty$ and $K = 1/G_\infty$:

Consider a second driving signal u_z injected into the forward path:



Note that $A = TG_\infty$ and $K = 1/G_\infty$:

Consider a second driving signal u_z injected into the forward path:



For double injection, u_i and u_z, adjusted to null u_y:

$$\left.\frac{u_o}{u_i}\right|_{u_y=0} = \frac{1}{K} \equiv G_\infty \quad \text{ideal closed-loop gain}$$

Generalization: The Feedback Theorem

The feedback path does several things:

1. Provides the feedback signal — ideal (desired)
2. Loads the output
3. Loads the input

$\}$ nonideal (undesired)

Conventional form of the theorem:

$$G = \frac{A}{1+T} \qquad \text{where } T \equiv AK$$

Disadvantages:

Breaking the feedback path at the input or the output disturbs the loading effects.

Recommended form of the theorem:

$$G = G_\infty D \quad \text{where } G_\infty \equiv \frac{1}{k} \quad D \equiv \frac{T}{1+T}$$

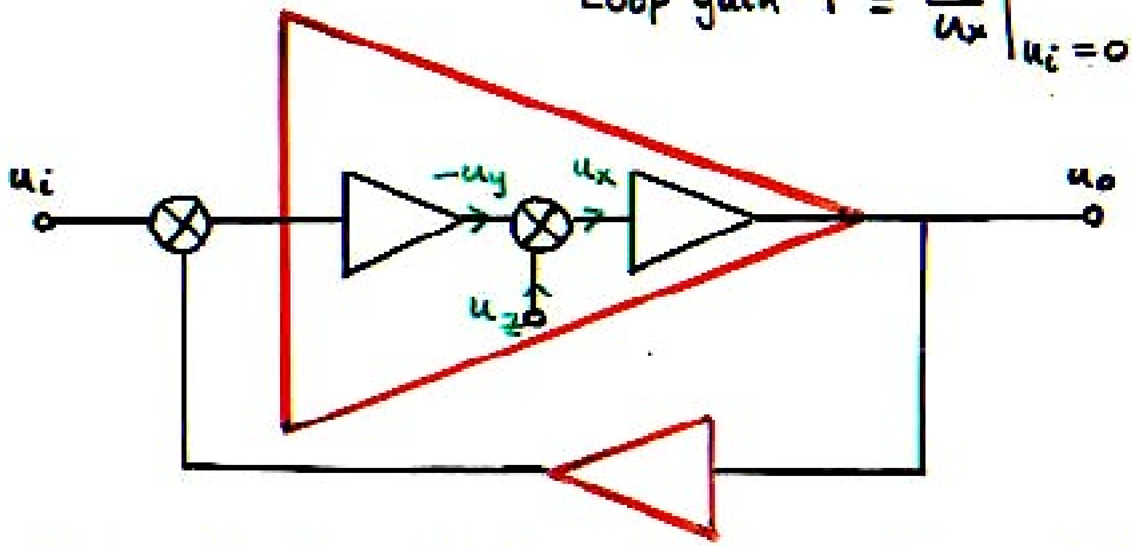
Advantages:

1. G_∞ and D are directly related to the important properties of the system:
   G_∞, the Ideal Loop Gain, is the design Specification;
   D, the Discrepancy Factor, must be designed to be close to unity over the specified frequency range.
2. T can be found by injection of a test signal into the closed loop, without disturbance of the feedback path loading effects, and G_∞ can be found by Null Double Injection of both the input and a test signal.

NOTE: It is never necessary to know A, the open-loop forward gain: A is always embedded in T, which is why the nonideal loading effects of the feedback path are automatically accounted for.

Implementation of injection of second signal for loop gain determination

Loop gain $T \equiv \left.\frac{u_y}{u_x}\right|_{u_i = 0}$



Conditions to be satisfied by injection point:

1. Must be inside the feedback loop

2. Injected signal must add to the forward signal without affecting the impedance loading