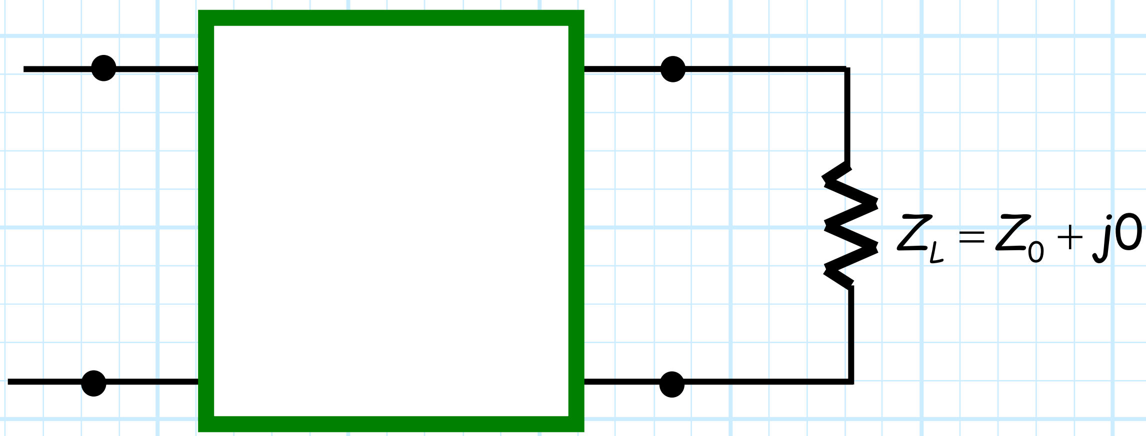
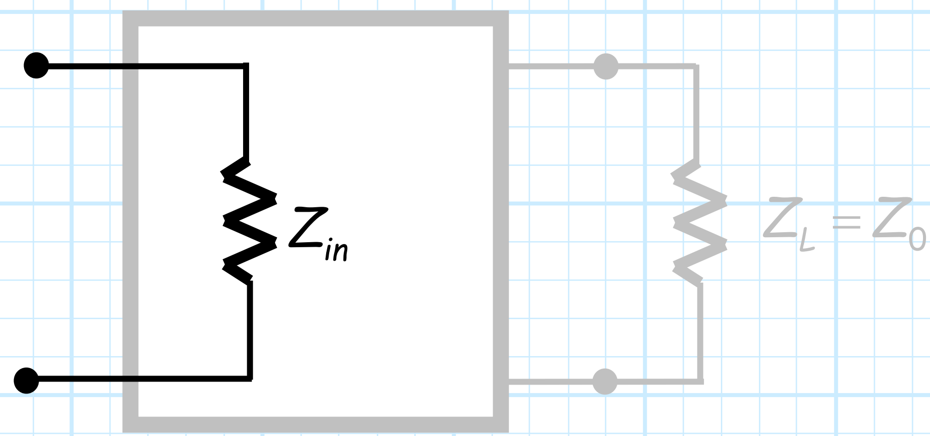
Matched Components

Consider a **two-port device** that is terminated with a **real-valued impedance** of $Z_L = Z_0 + j0$.



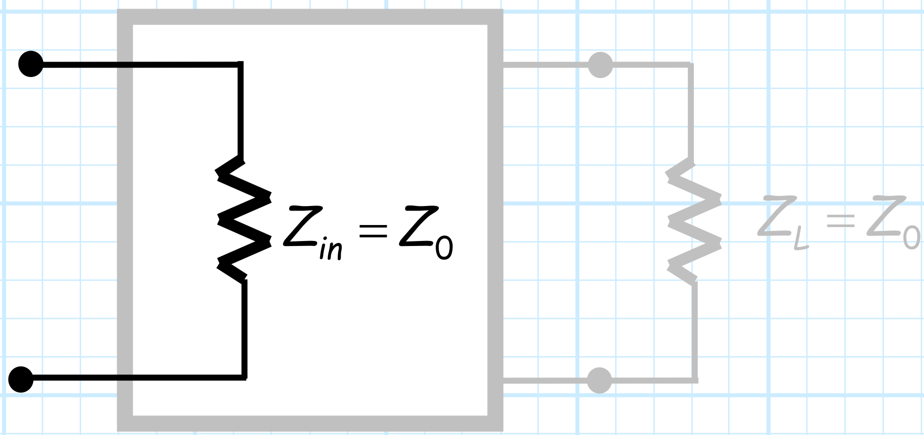
An impedance transformer

This two-port device can (of course!) be viewed as an **impedance transformer**, as it transforms this specific **load** impedance into an **input impedance** Z_{in}:



A "matched" device (that word again!)

Say though, that this two-port network transforms the **load** impedance $Z_0 + j0$ into an **input** impedance that is (**wait for it**)—**also** equal to $Z_0 + j0$!!!!

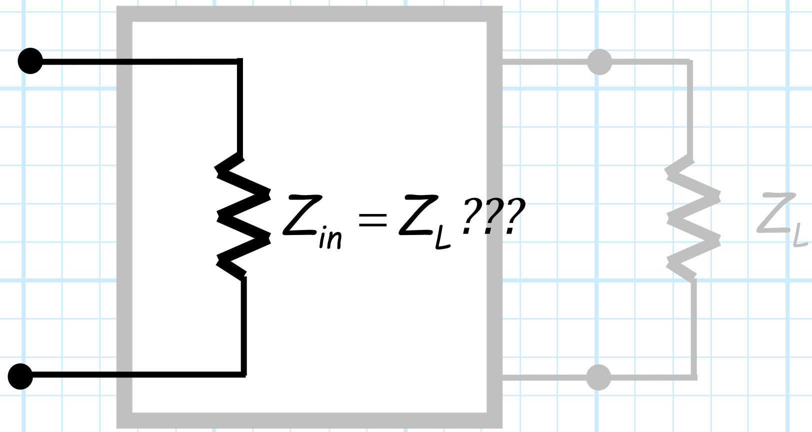


It "transforms" load $Z_L = Z_0$ into $Z_{in} = Z_0$!!!!

A two-port device with **this** property (i.e., it "transforms" a load $Z_0 + j0$ into input impedance $Z_0 + j0$) is referred to a **"matched" device**.

"Matched" to a specific value

Q: *So, does a "matched" device "transform" a **load** impedance of **any arbitrary value** into an **input** impedance of that **same** arbitrary value?*



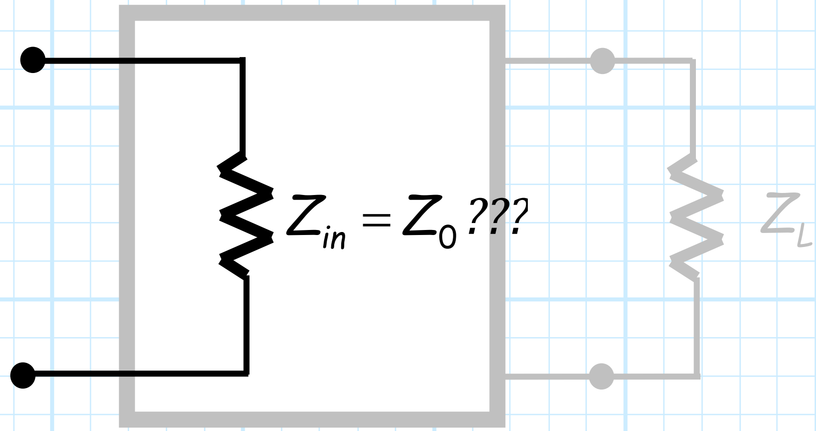
A: NO! This is **not** (in general) true.

The "transformation" of a load impedance into a **same-valued** input impedance occurs **ONLY** if the load impedance is a specific value $Z_0 + j0$.

More specifically then, a "matched" device is matched to **one numerical value** $Z_0 + j0$ (e.g., "matched" to 50Ω).

This is NOT what it does

Q: So, does a "matched" device "transform" a *load impedance of* ***any arbitrary value*** *into a specific input impedance* $Z_0 + j0$?



A: NO! This is **not** (in general) true either.

The "transformation" of a load impedance into an input impedance of Z_0 occurs **ONLY** if the load impedance also has value Z_0.

I.E., a "matched" device **cannot** "fix" a **mismatched** (i.e., $Z_L \neq Z_0$) load!

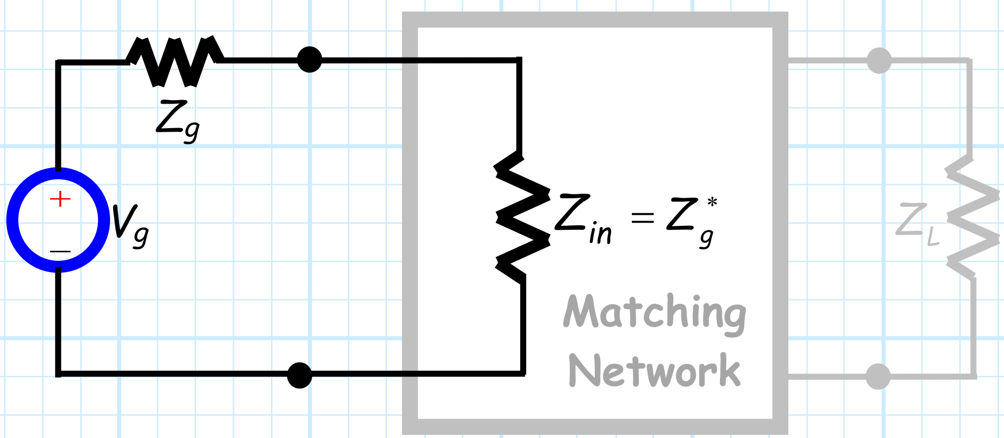
Now you are really annoying me

Q: *So are "**matched**" devices and **matching networks** the **same thing**?*

A: ACK. NO. STOP.

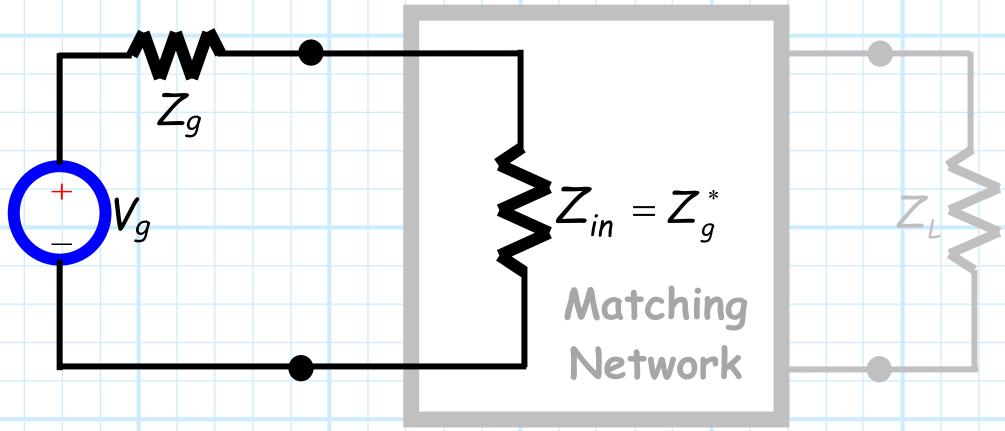
Matching networks and a "**matched**" **components** are two **very different things**!!!!!!

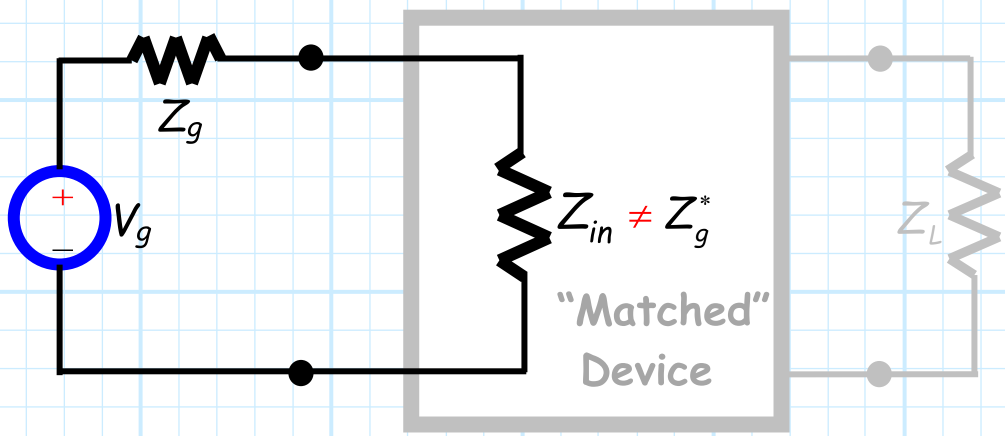
Recall a **matching network** is **lossless** two-port device **specifically designed** to provide a **conjugate match** between a source and load where **no** conjugate match would **otherwise** exist (i.e., $Z_L \neq Z_g^*$).



Matching networks are not "matched" networks

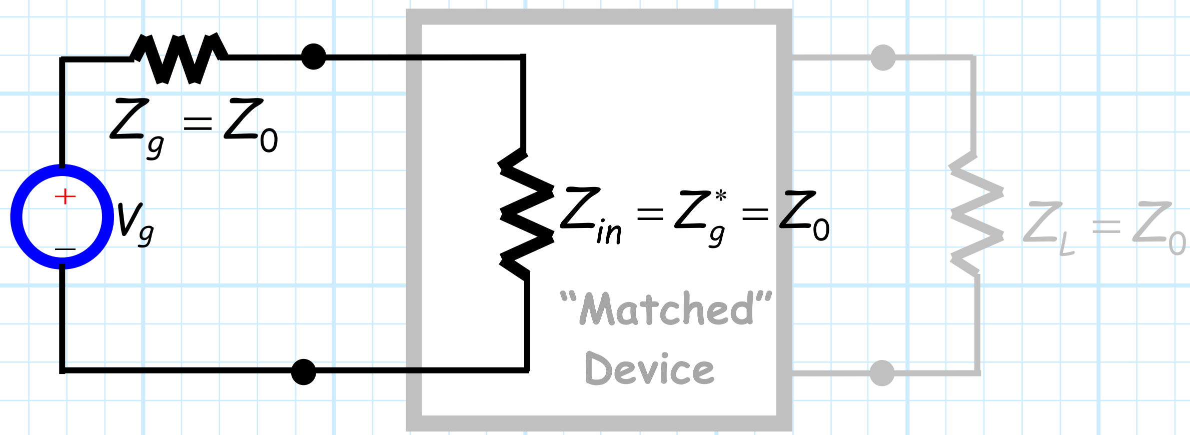
In contrast, a "matched" device would almost **certainly not** result in a **conjugate match** for this case!





But for this one special case…

The **exception** to this would be the case where **both** the source **and** load impedances are equal to Z_0.



For this special case, a matched device **would** result in a conjugate match!

But of course, **if** $Z_g = Z_0$ and $Z_L = Z_0$ then a **conjugate match** between the source and load would **already** exist, and there would be **no need** for a matching network!

A matched device is useful, and not disruptive

Q: *So then, **what's the point**?*

***Why** would we **want**, or ever **use**, a "matched" component?*

A: A **"matched" component** is a **useful** microwave device (e.g., amplifier, attenuator, coupler, filter, etc.).

These devices have many **attractive purposes**—but **none** of these purposes are to create a **conjugate match** (that's what **matching networks** are for!).

Instead, a "matched" component is designed to **both**:

A. Provide some **helpful purpose** (e.g., power gain).

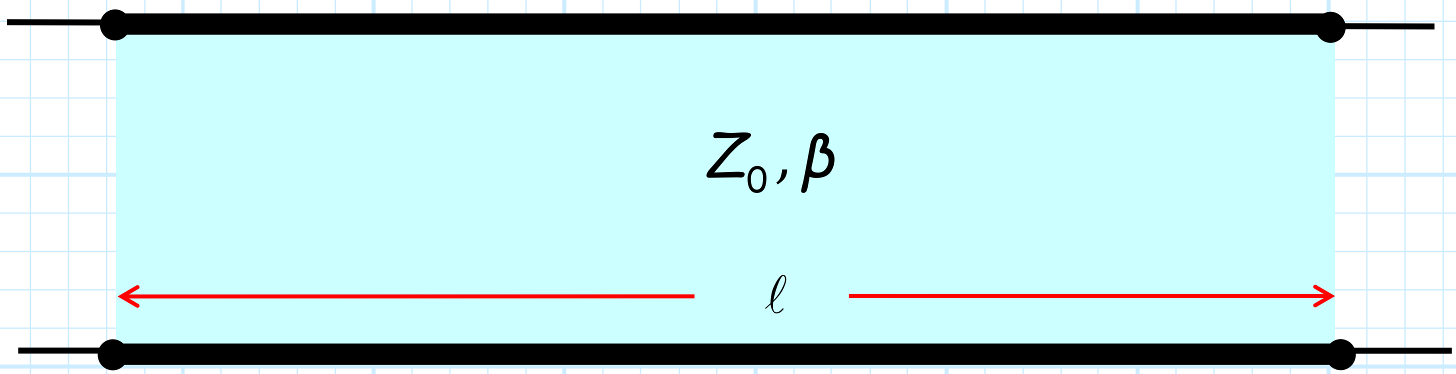
B. **Preserve** (as opposed to create) the **conjugate match** between a source with $Z_g = Z_0$ and a load with $Z_L = Z_0$.

A specific example (so get off my case)

Q: *Can you provide a **specific example** of a matched component?*

A: Sure.

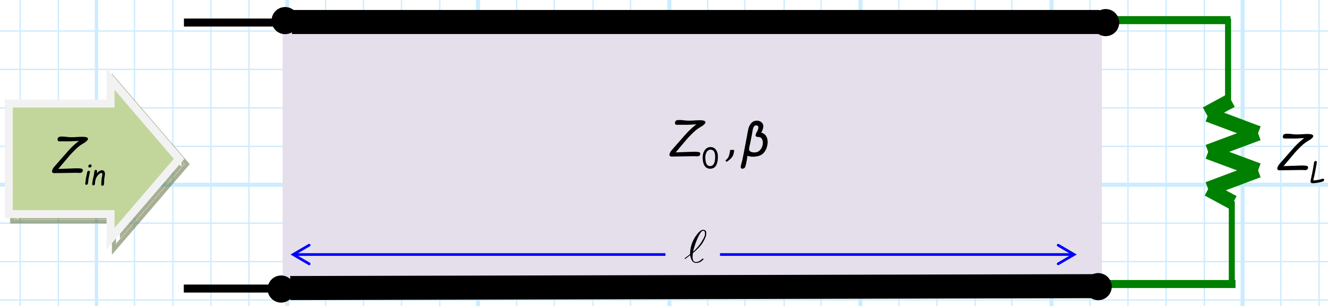
Consider an **arbitrary length** of transmission line.



This of course is a lossless **two-port device**, and we can consider it an **impedance transformer**.

Z_{in} is neither Z_L nor Z_0

We know that **terminating** the transmission line with some **load** impedance will result in an **input impedance** that is **neither** equal to the **load** impedance **nor** the **characteristic** impedance of the transmission line:

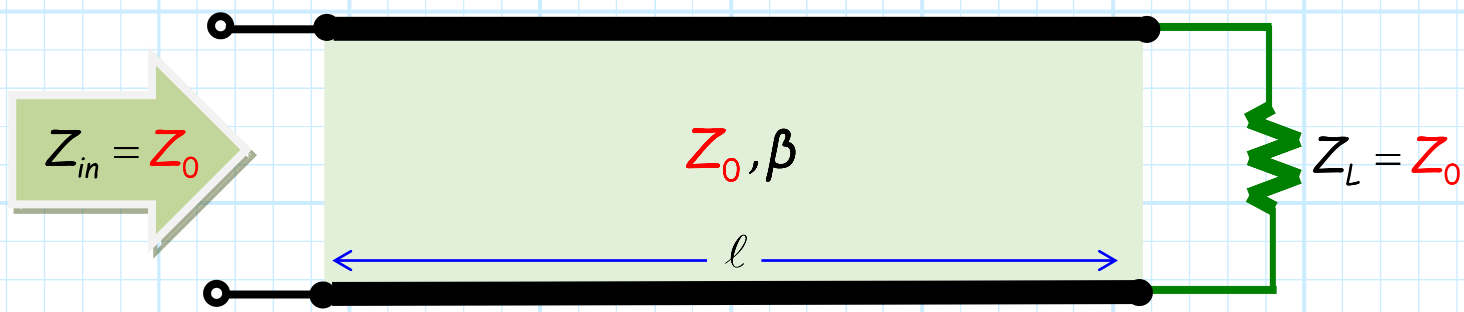


$$Z_{in} = Z_0 \left(\frac{Z_L \cos\beta\ell + jZ_0 \sin\beta\ell}{Z_0 \cos\beta\ell + jZ_L \sin\beta\ell} \right)$$

$$Z_{in} \neq Z_L \quad \text{and} \quad Z_{in} \neq Z_0$$

Unless, of course, Z_L equals Z_0

However, **if** the load impedance **happens** to have value $Z_L = Z_0 + j0$, then we **know** that the input impedance will likewise have this **same value** Z_0 (regardless of length ℓ !):

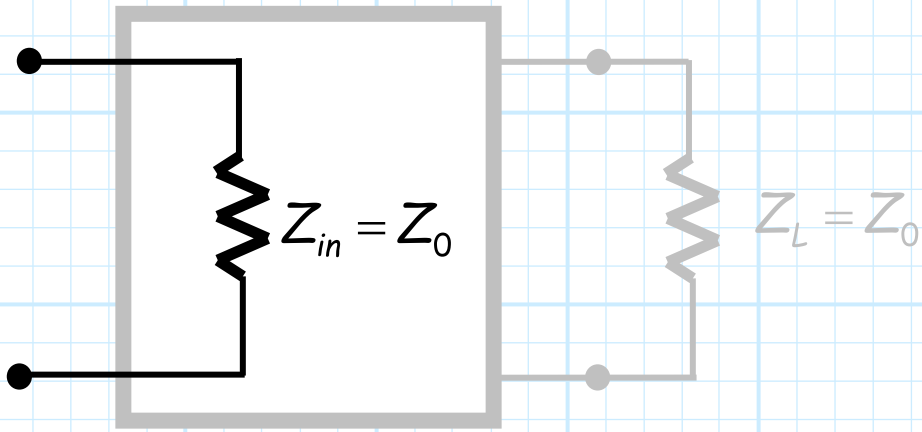


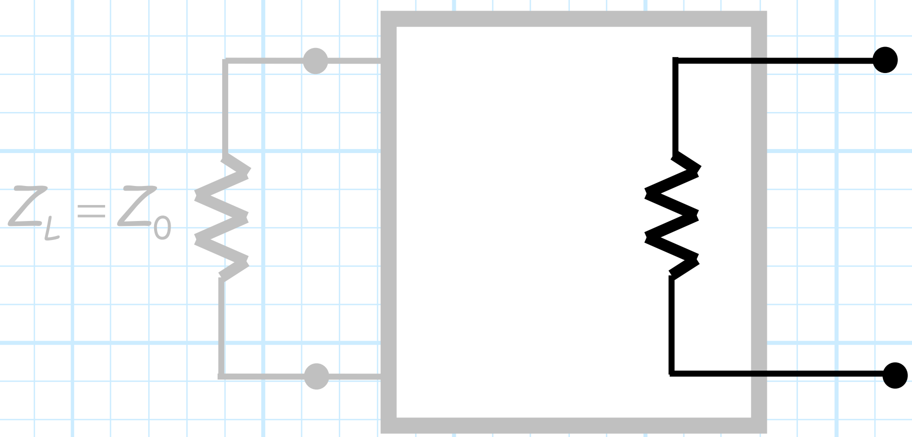
This property (transforming $Z_L = Z_0$ to $Z_{in} = Z_0$) is precisely the **definition** of a **"matched" device**.

Thus, an **arbitrary length** of transmission line is a (very important) example of a two-port **"matched" device** ("matched" to the **value** Z_0 of the transmission line).

It must work in either direction

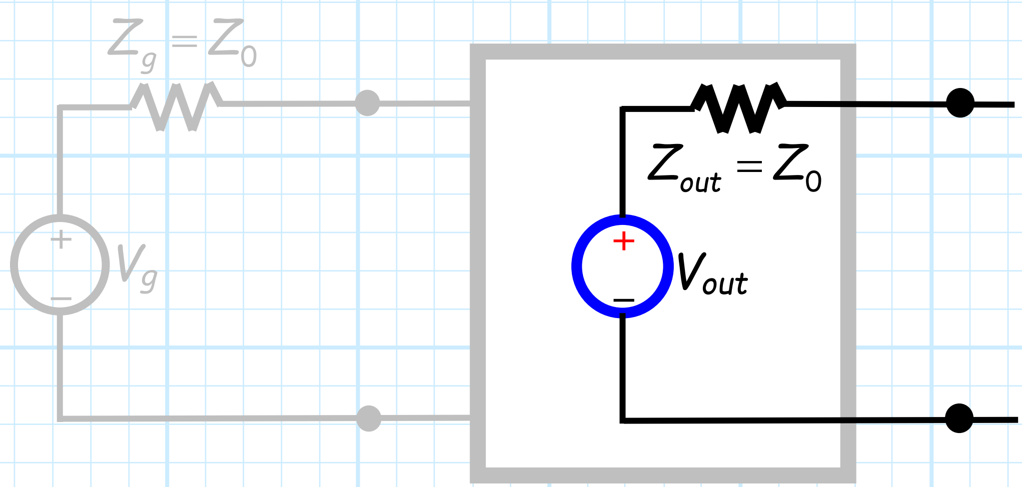
For a two-port component to be considered **"matched"**, it must transform $Z_L = Z_0$ to $Z_{in} = Z_0$ in **both** directions:





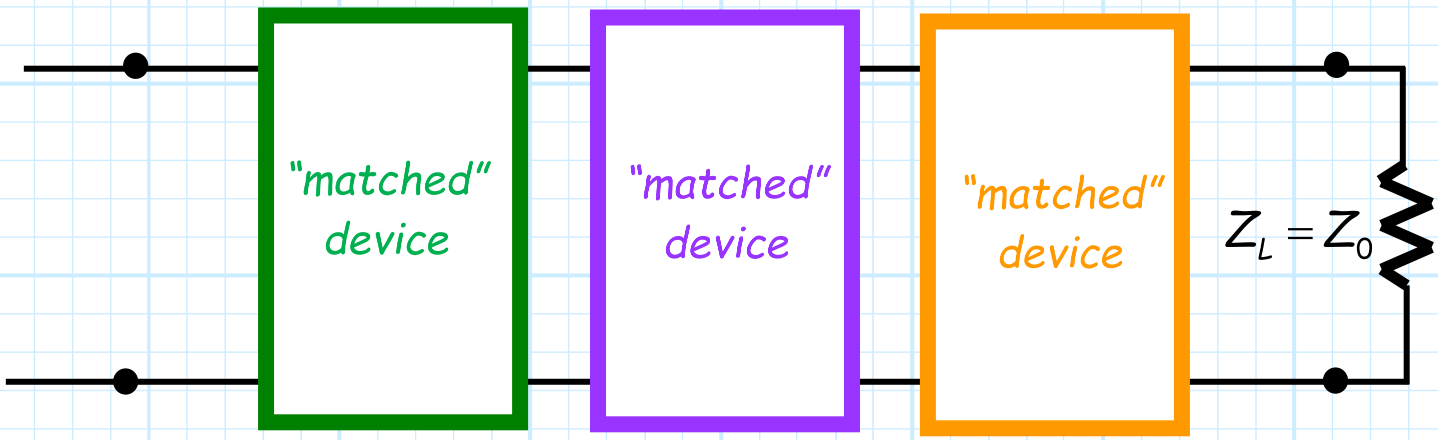
A "matched" device transforms a source as well

Note that a **"matched" device** will likewise transform a **source** with $Z_g = Z_0$ to one where $Z_{out} = Z_0$ (i.e., it transforms a "matched" source into another "matched" source!).

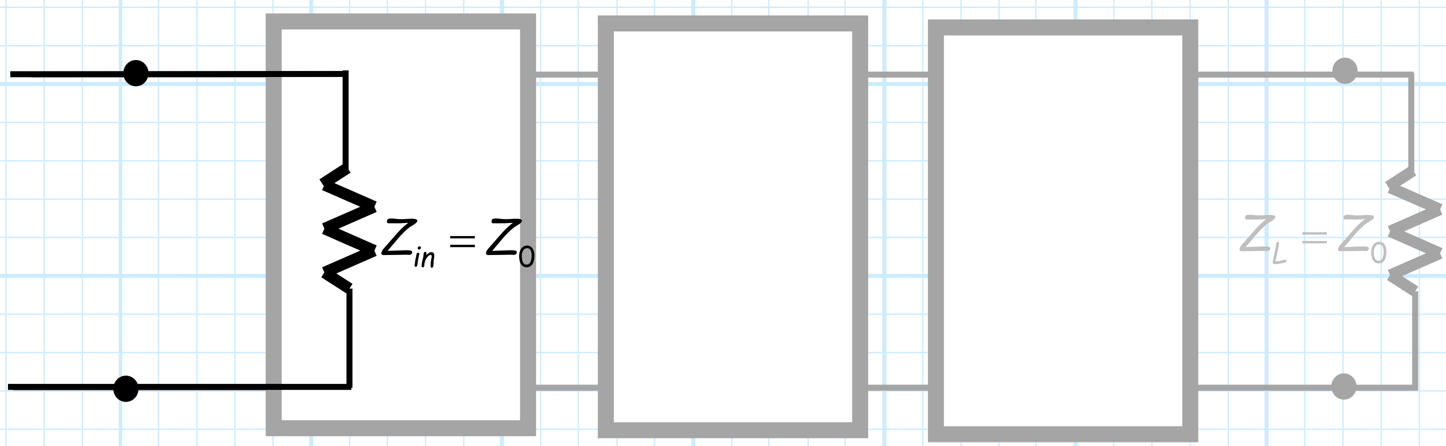


A network of "matched" devices is also "matched"

Consider now the case where we **connect multiple "matched" devices** together.



Note the transformation of $Z_L = Z_0$ to $Z_{in} = Z_0$ is likewise **preserved**!



In a "matched" system —but only in a "matched" system— line lengths do not matter!!!!

Thus, a system constructed **completely** (i.e., no exceptions) of "matched" devices is itself a "matched" device as well.

Of course, **many** of the "matched" devices in this "matched" system could be **lengths of transmission lines**.

Most importantly, the **lengths** of these transmission lines are completely **arbitrary**.

In other words, **change** the transmission line **lengths**, and you have effectively **changed nothing**.

The system is still "matched" (i.e., a **conjugate match** is **preserved**!)—**regardless of the lengths of these transmission lines!!!!!!!!!!!!**

Multi-port devices

Q: *Are all "matched" components* ***two-port*** *devices?*

A: Gosh no.

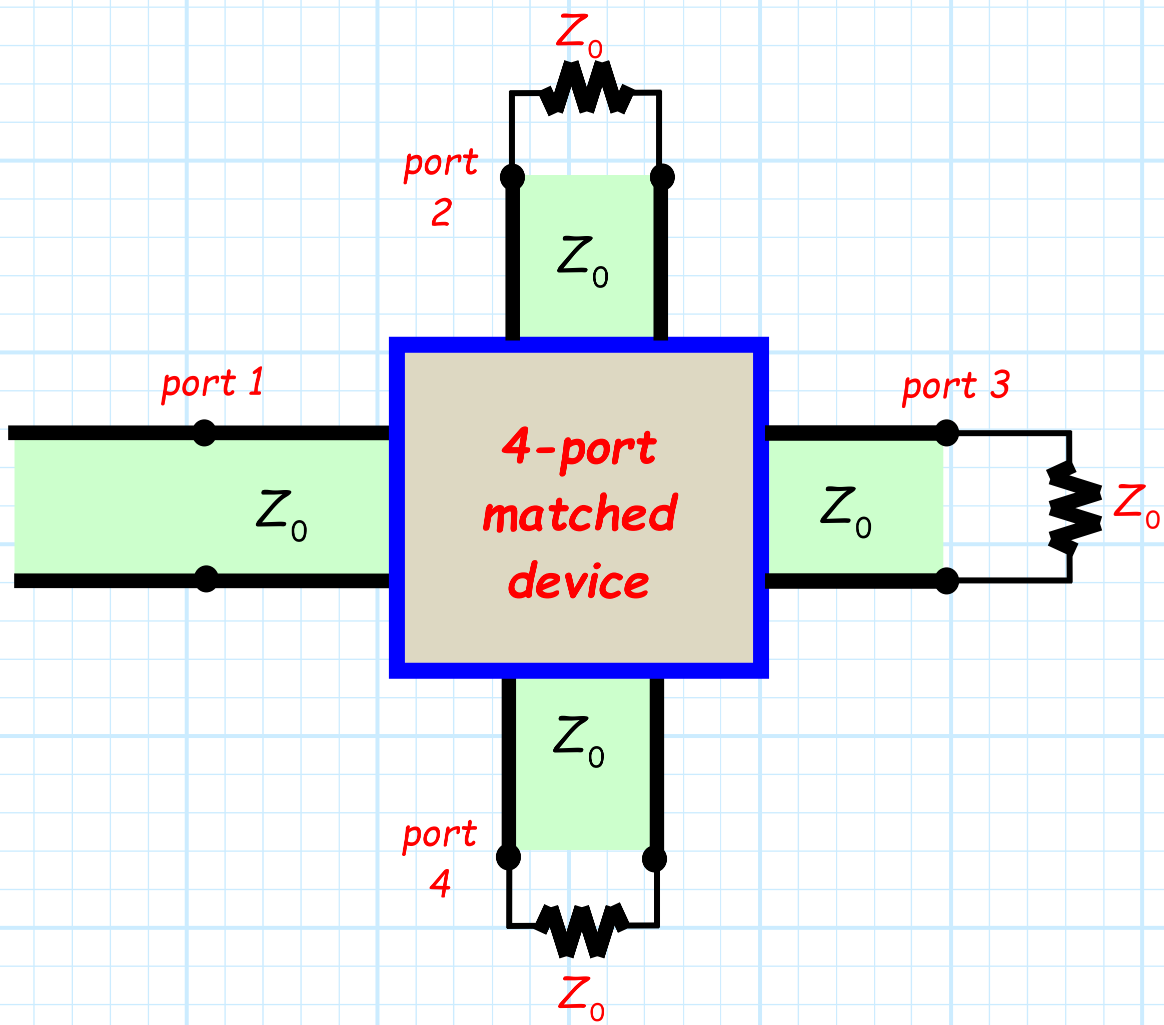
There are **many** useful microwave components that have 3 ports and 4 ports (**or more!**).

To be useful (i.e., to **not mess-up** the conjugate match $Z_{in} = Z_0 = Z_{out}$), these **multi-port** devices must also be **"matched"**.

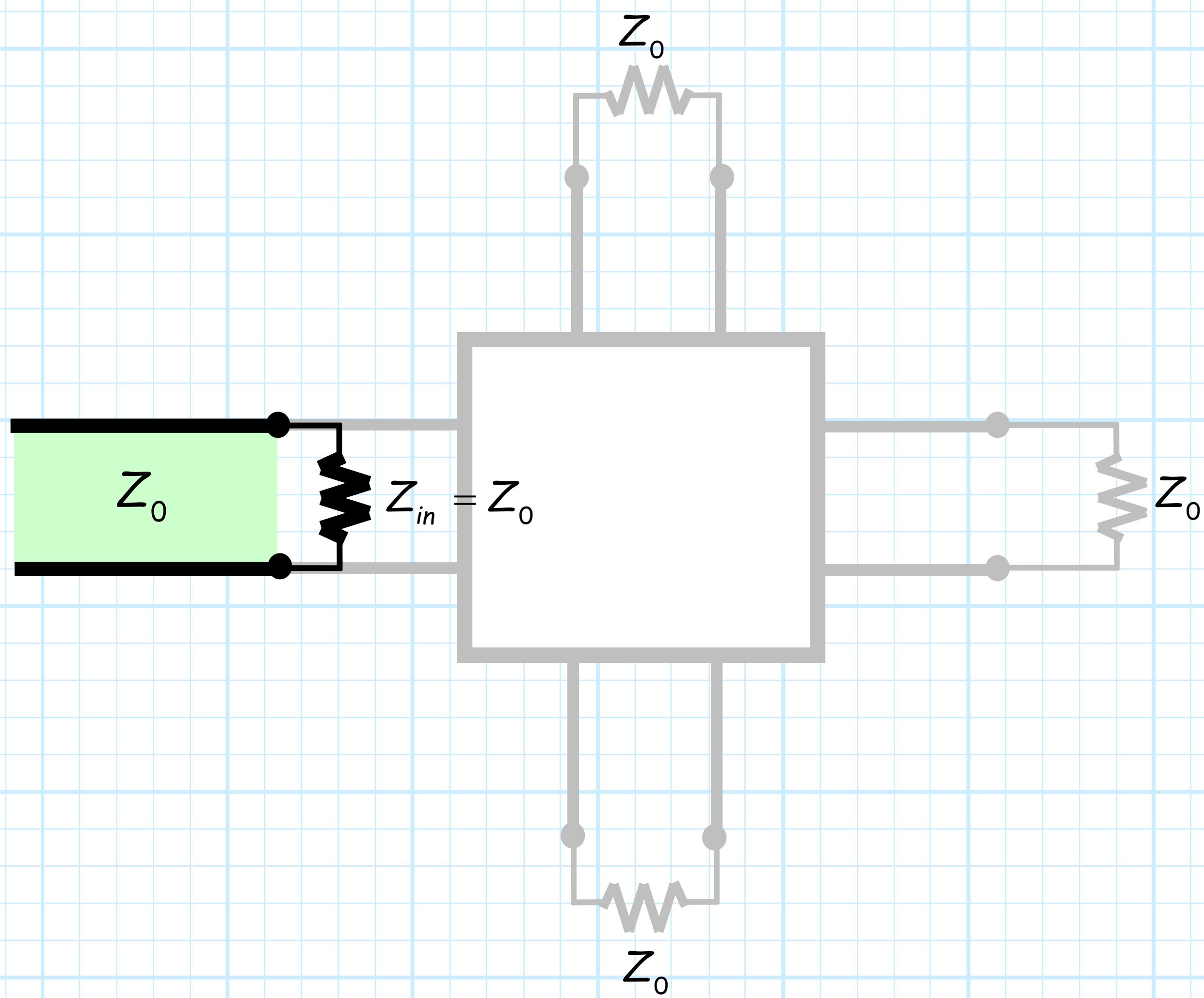
This means that the **input impedance** of each and **every** port must be equal to $Z_{in} = Z_0$, provided that **all other ports** are terminated in **"matched" loads** $Z_L = Z_0$.

Note then that **"matched" loads** and **"matched" sources** are just **one-port** manifestations of "matched" devices.

Since this four-port component is "matched"…



The input impedance at every port is Z_0



Without exception, every device must be matched

In summary, a microwave **system** (e.g., a microwave receiver) must be **constructed entirely of "matched" components** (**no** exceptions!).

In this way we find that:

A. A conjugate match is **preserved** (available power is delivered!) at **every** point in the system, and…

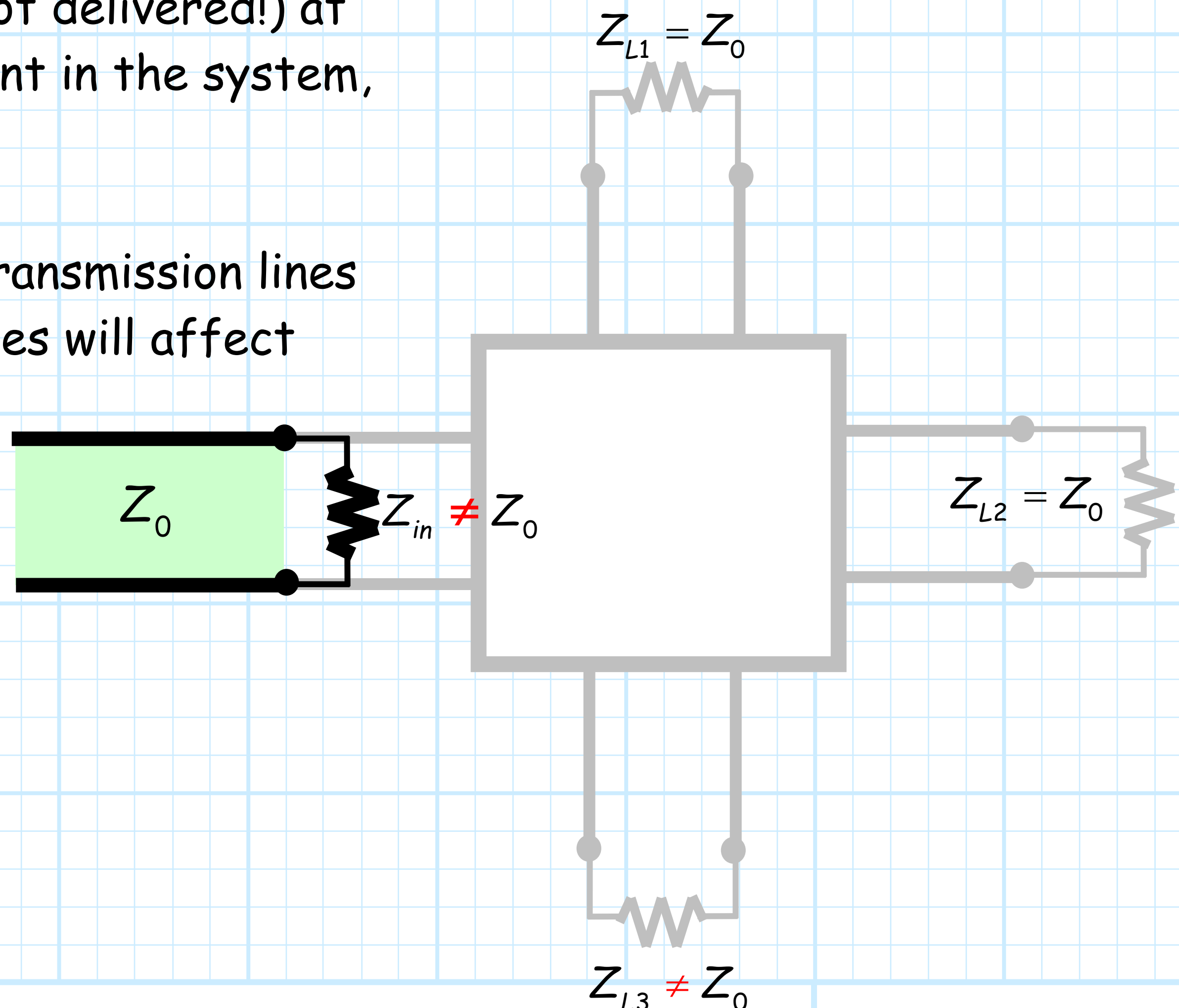
B. this is true **regardless of the lengths** of the transmission lines connecting the devices (the transmission lines are "matched" devices as well!).

Without exception !!!!

If even **one component** in the system is not "matched", then the matched system will be **corrupted**, meaning:

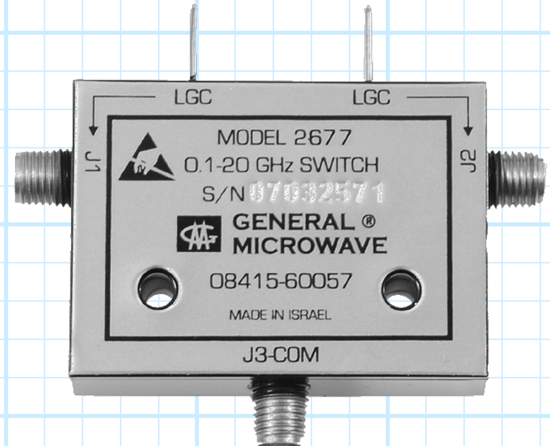
A. A conjugate match is not **preserved** (available power is not delivered!) at potentially **every** point in the system, and…

B. the lengths of the transmission lines connecting the devices will affect this power transfer.



Nobody's perfect

Q: *So, is the input impedance of* ***matched device*** *(when terminated in matched loads)* ***precisely*** *equal to* Z_0*?*

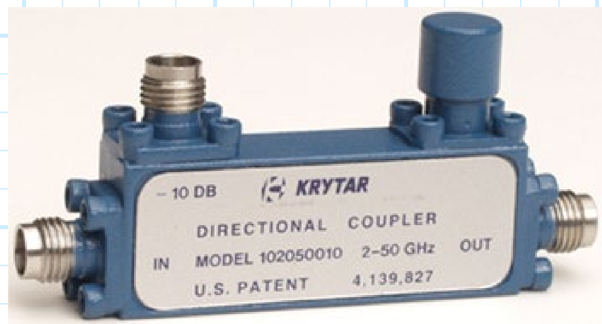


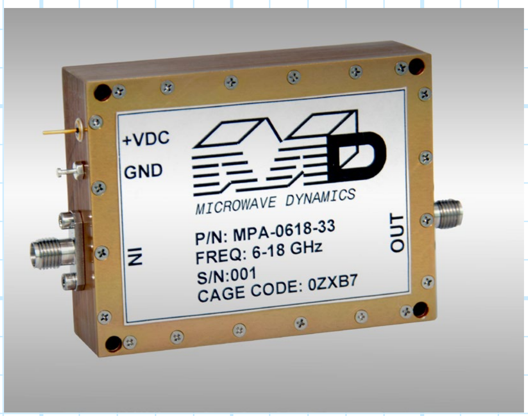
A: Not **exactly**.

Microwave vendors try very hard to make the input impedance as **close** to Z_0 as possible, but the value:

$$Z_{in} = 50.0000000000000000000...$$

is **really hard** to come by!





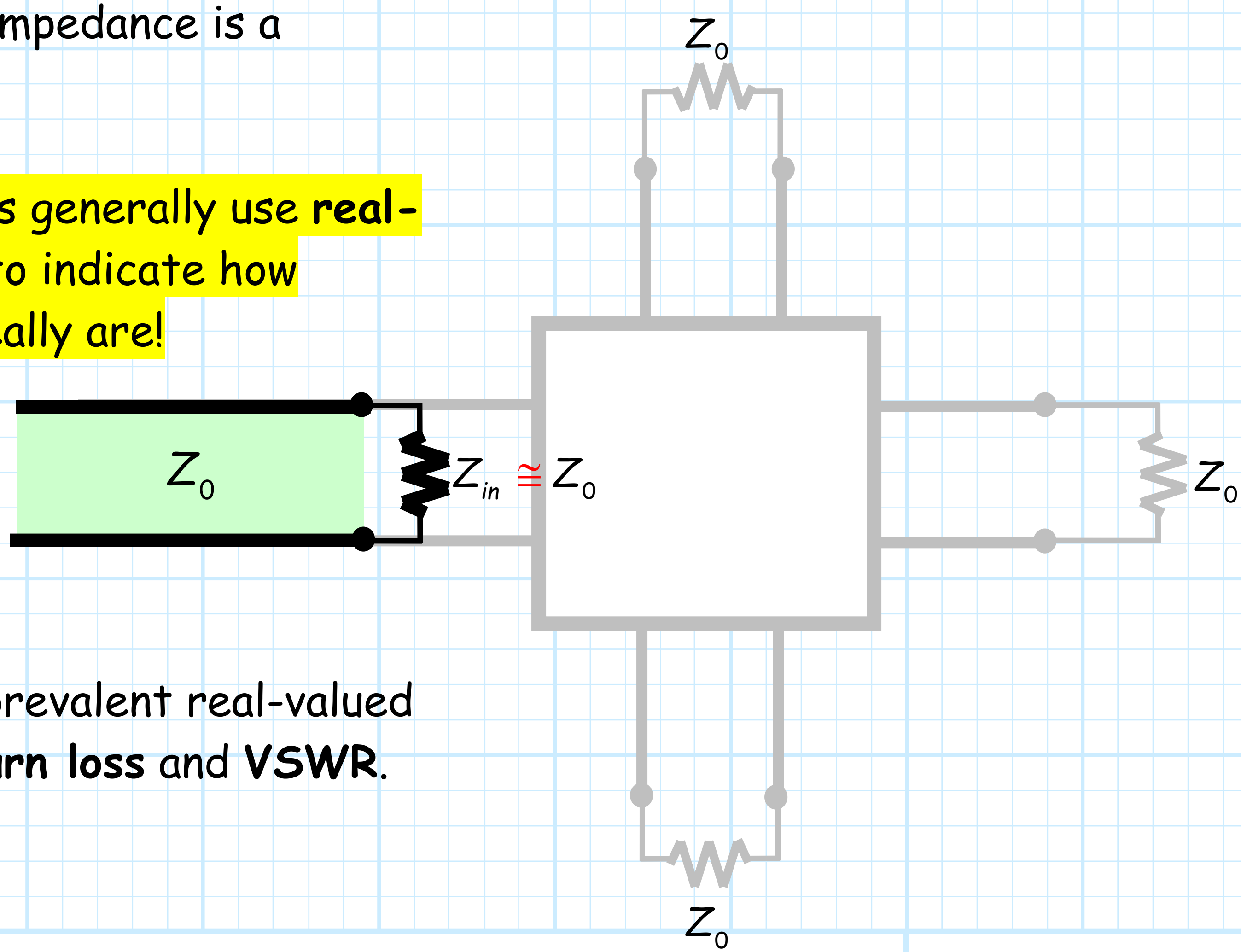
It's not like they're lying (usually)

Q: *So do vendors tell us what Z_{in} **really** is?*

A: **Not usually**!

Remember, input impedance is a **complex** value.

Therefore vendors generally use **real-valued** measures to indicate how "matched" they really are!



Two of the most prevalent real-valued measures are **return loss** and **VSWR**.