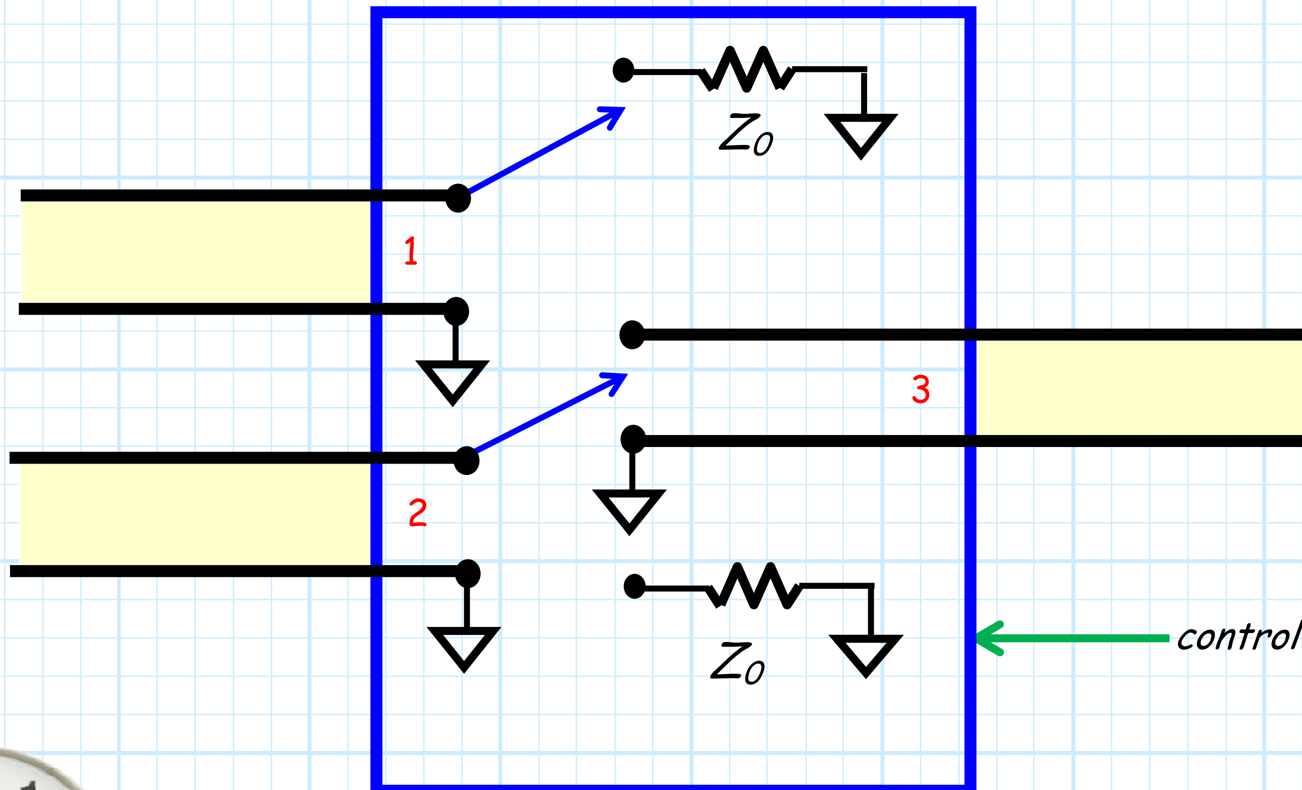
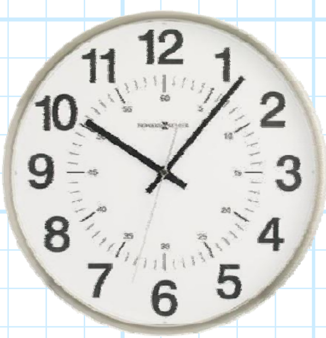
Microwave Switches

First let's consider a 3-port (**2 to 1**) microwave switch:





Unlike the other components we have studied, a switch is **not time-invariant**!

Two distinct states

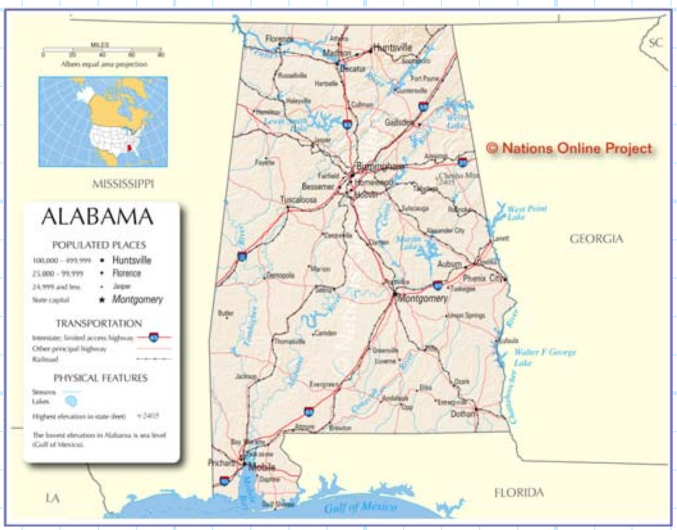
This 3-port component has **two distinct states**: some**times** it is in **one** state, other **times** it's the **other**!

These **two states** are:

A. **Port 1** is directly connected to port 3

Or,

B. **Port 2** is directly connected to port 3



Either not lossless or not matched

Now to begin, we note that a 3-port microwave switch is a **reciprocal** device.

Q: *Is it **also** matched **and** lossless?*

A: Nope: that's **impossible**!

Remember, a 3-port device cannot be reciprocal **AND** matched **AND** lossless.

Thus a reciprocal 3-port microwave switch must **either** be:

1. Matched and reciprocal (but **not lossless**)

Or,

2. Lossless and reciprocal (but **not matched**).

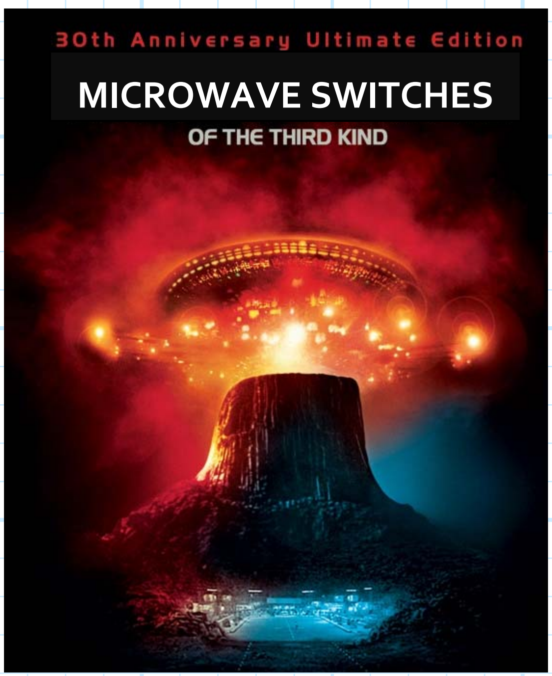
Don't even *think* about using the 3rd kind

Q: *So, **which** one is it—is a microwave switch lossy, **or** is it mismatched?*

A: It could be **either**—there are in fact **two kinds** of microwave switches!

Kind 1: **Absorptive** switches (they're **not lossless!**).

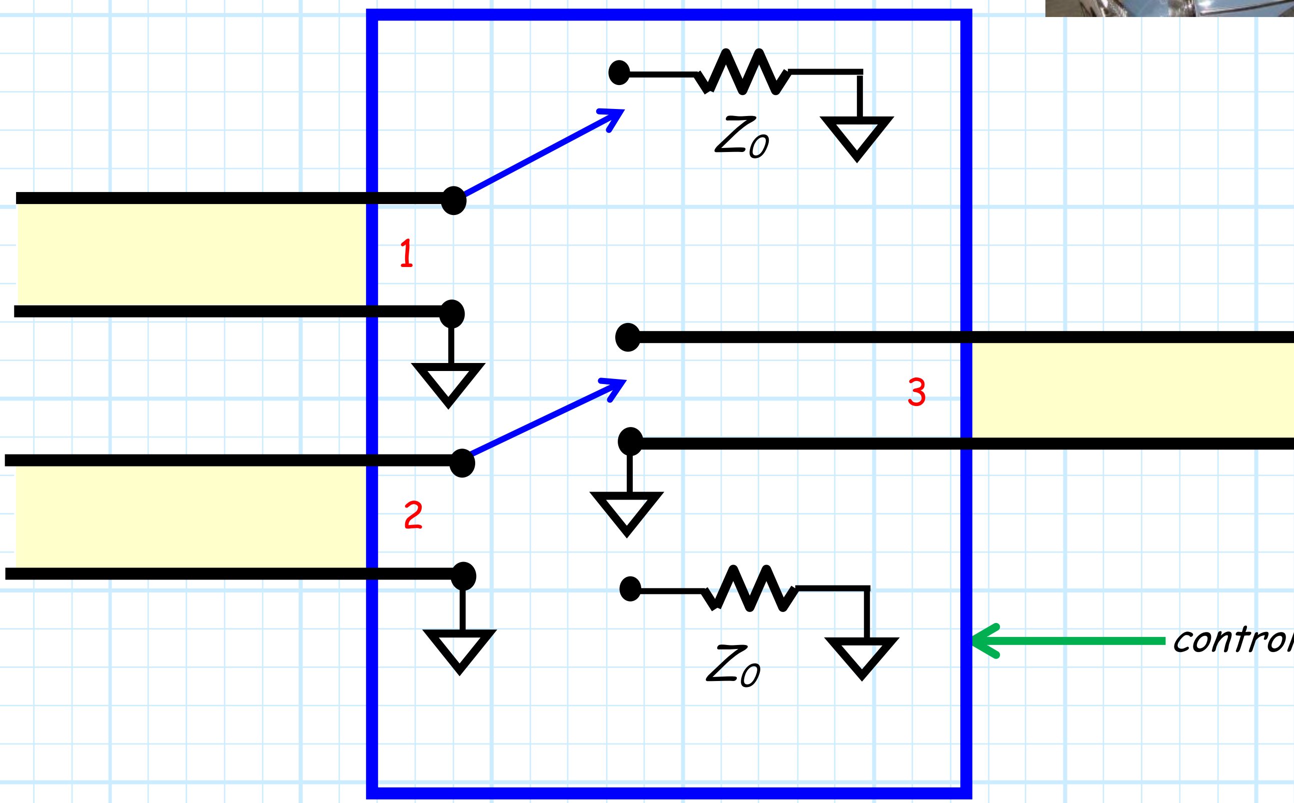
Kind 2: **Reflective** switched (they're **not matched!**).



→ Let's first examine microwave switches of the **first** kind: **Absorptive switches**.

An absorptive switch

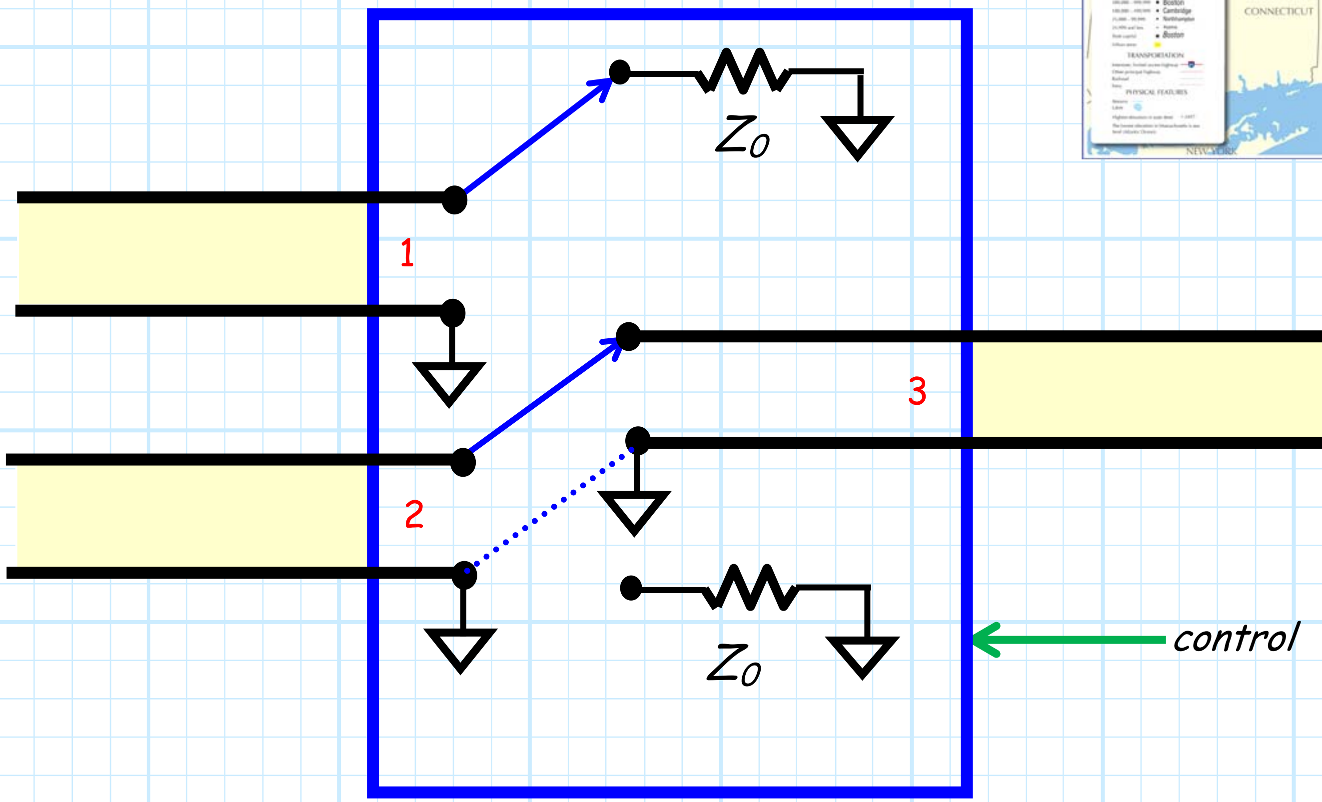
If we "open up the hood" of an **absorptive** switch, we'll see a circuit with a schematic that is **effectively** this:



One state

Say we wish to connect ports **2 and 3**.

The switch is set to "state B":



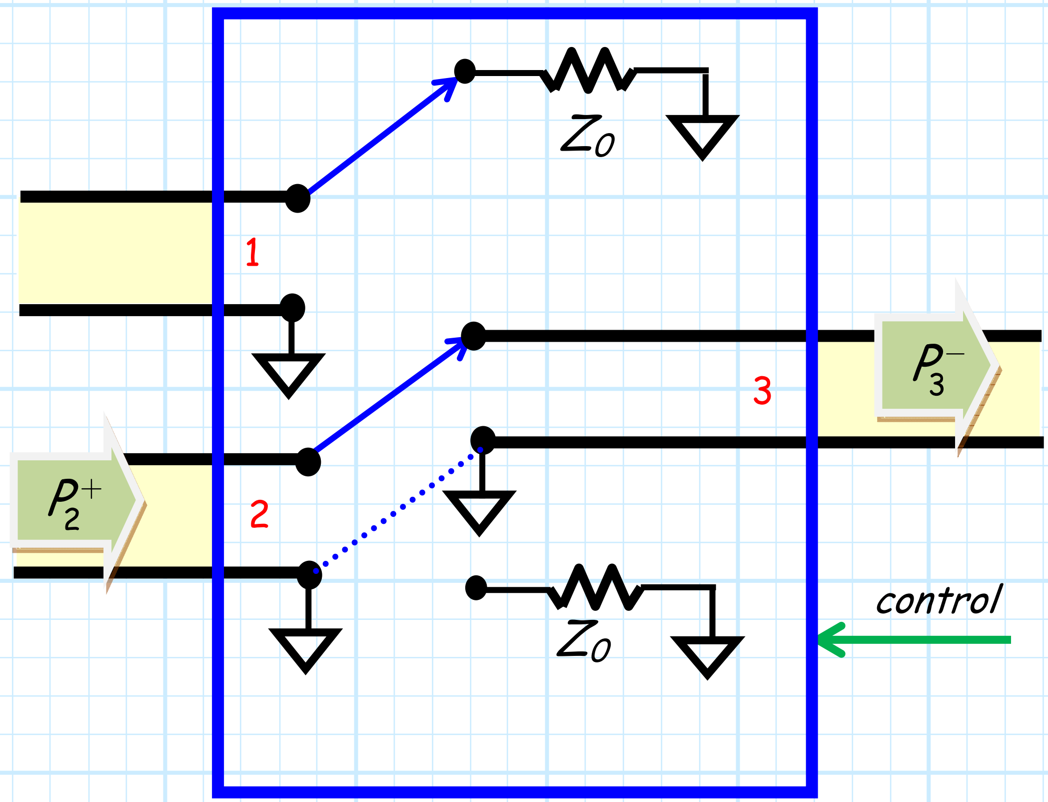
Hopefully it apparent that port 2 and port 3 are now **directly connected**!

Just passin' through

Now, like all matched microwave devices, a switched is designed to work in a **matched system**.

Thus we can assume that **all ports** of the component are attached to **matched loads** and/or **sources**.

For example, say for this case there's a matched **source at port 2**, and a matched **load at port 3**.



As a result, **all available power** P_2^+ from the matched source at port 2 will be **absorbed** by the matched load at **port 3**:

$$P_3^- = P_2^+$$

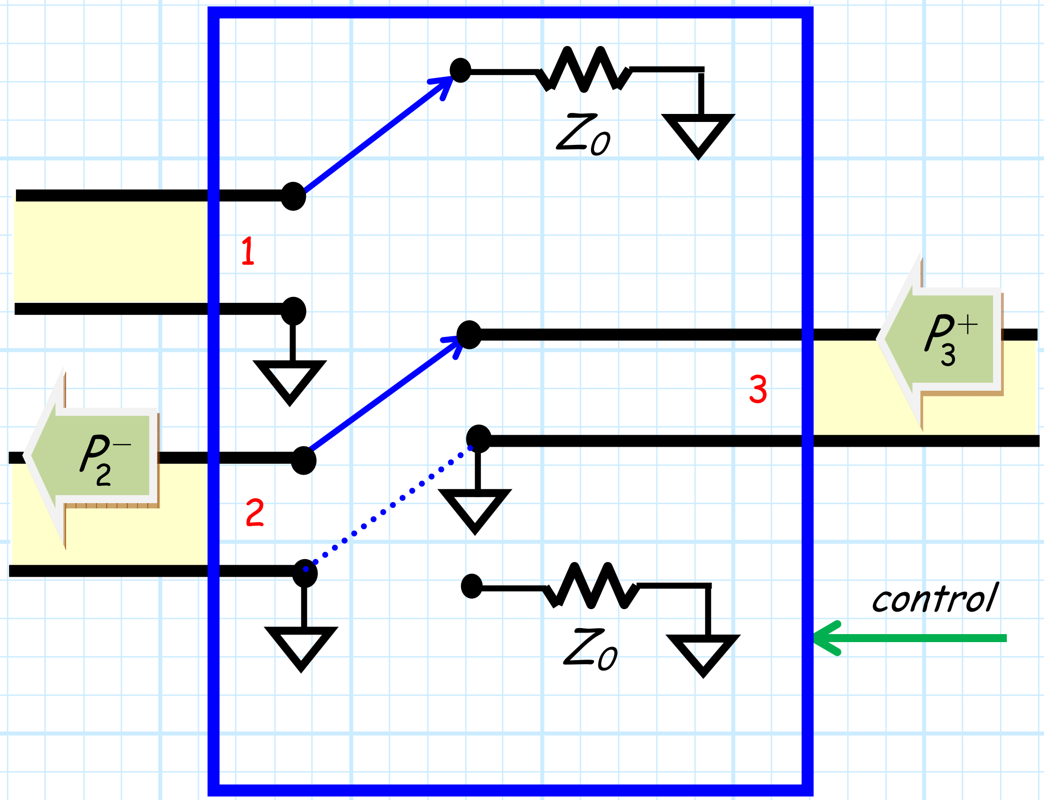
This is what reciprocal means

Q: ***Must*** *the load be at port 3? Can energy* ***instead*** *flow in the* ***other*** *direction ?*

A: Absolutely!

This is a **reciprocal** device, so if we **swap** the matched load at port 3 with the matched source at port 2, we find that—just as before—**all** available power will be absorbed by the load:

$$P_2^- = P_3^+$$

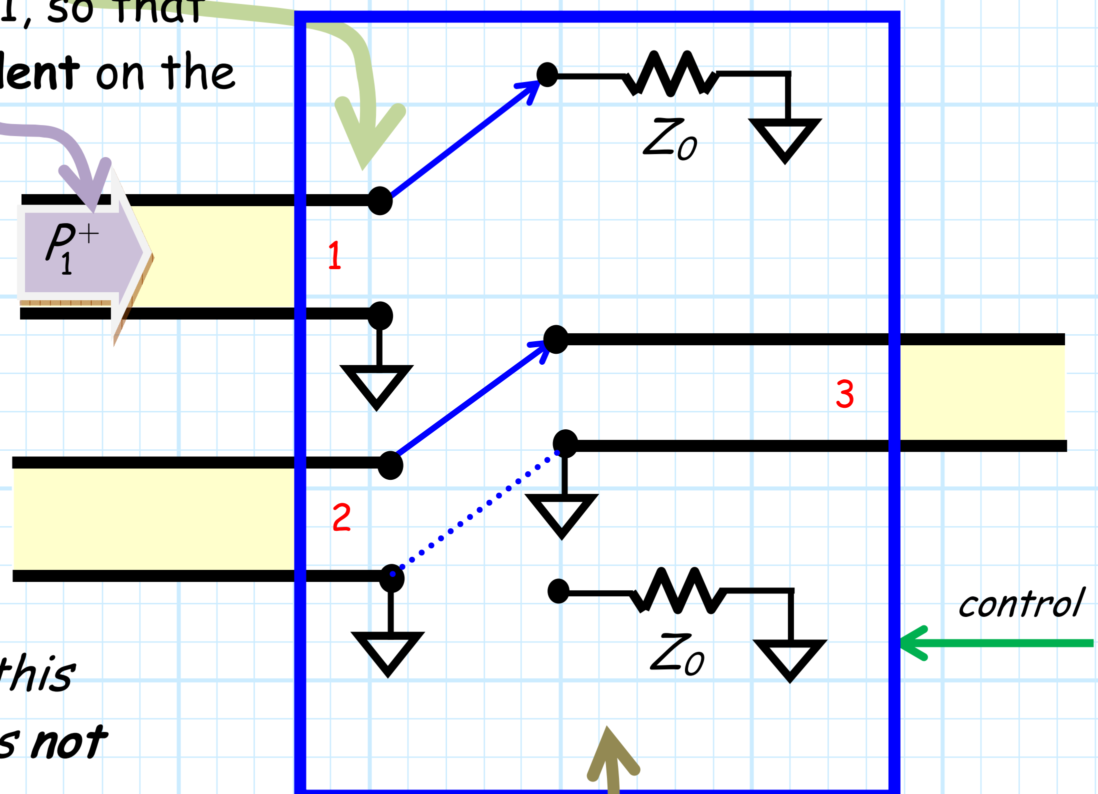


→In other words, the electromagnetic energy can propagate through the switch **equally well** in **either** direction!

Now for the disconnected port

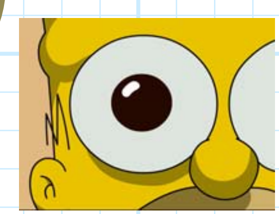
Q: *What about the **disconnected port** (i.e., port 1)? What's up with **it**?*

A: Consider the possibility that there is a **matched source** at port 1, so that all its available power is **incident** on the disconnected port.



Q: *Yikes! What **happens** to this energy—after all, this port is **not** connected to anything?*

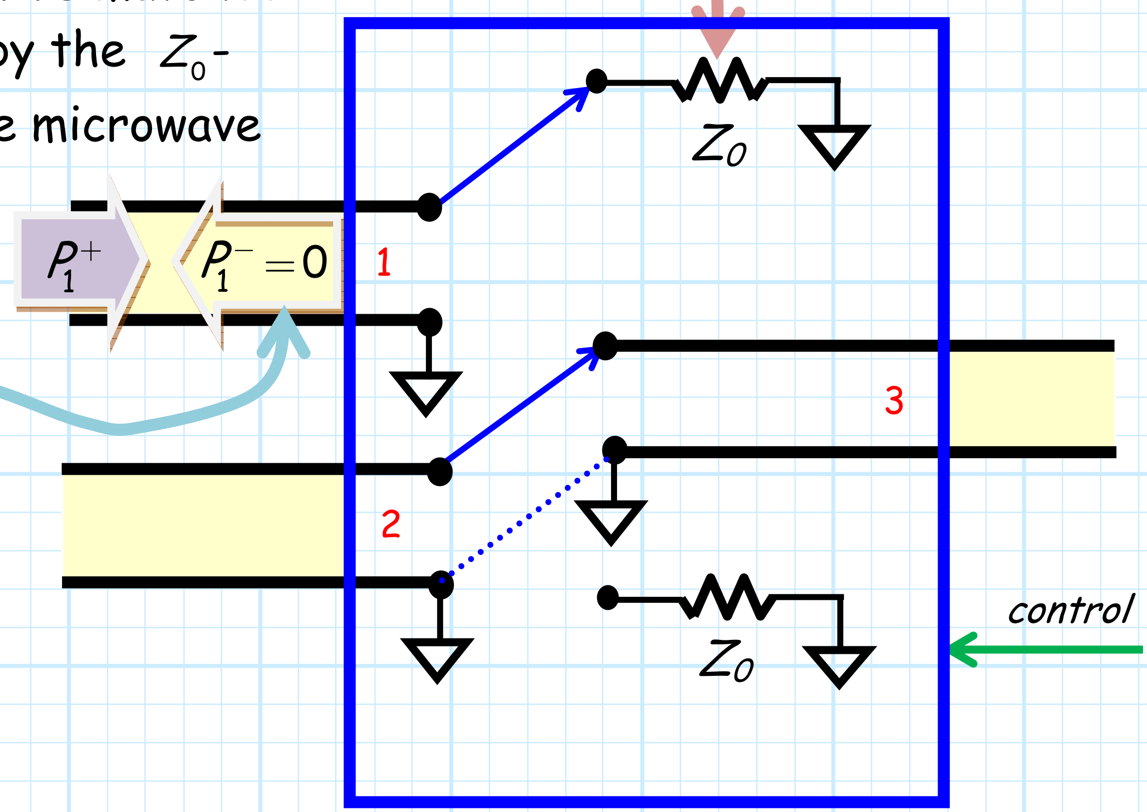
A: Just **look** at the **circuit** **"schematic"**!



The power is "dumped" inside the switch

It is apparent that this disconnected port—**inside** the switch—is terminated in a **matched load**.

All available power from **this** matched source will be **absorbed** by the Z_0-valued resistor **inside** the microwave switch!



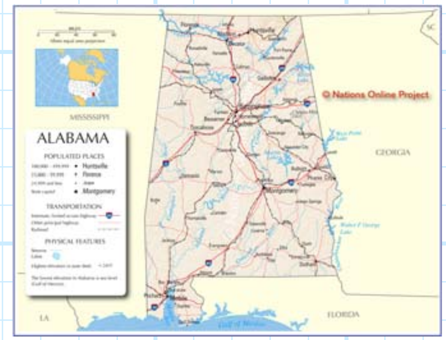
As a result, there is **no reflected power** from port 1—the **input** impedance at port 1 is a **matched** value of Z_0 Ohms.

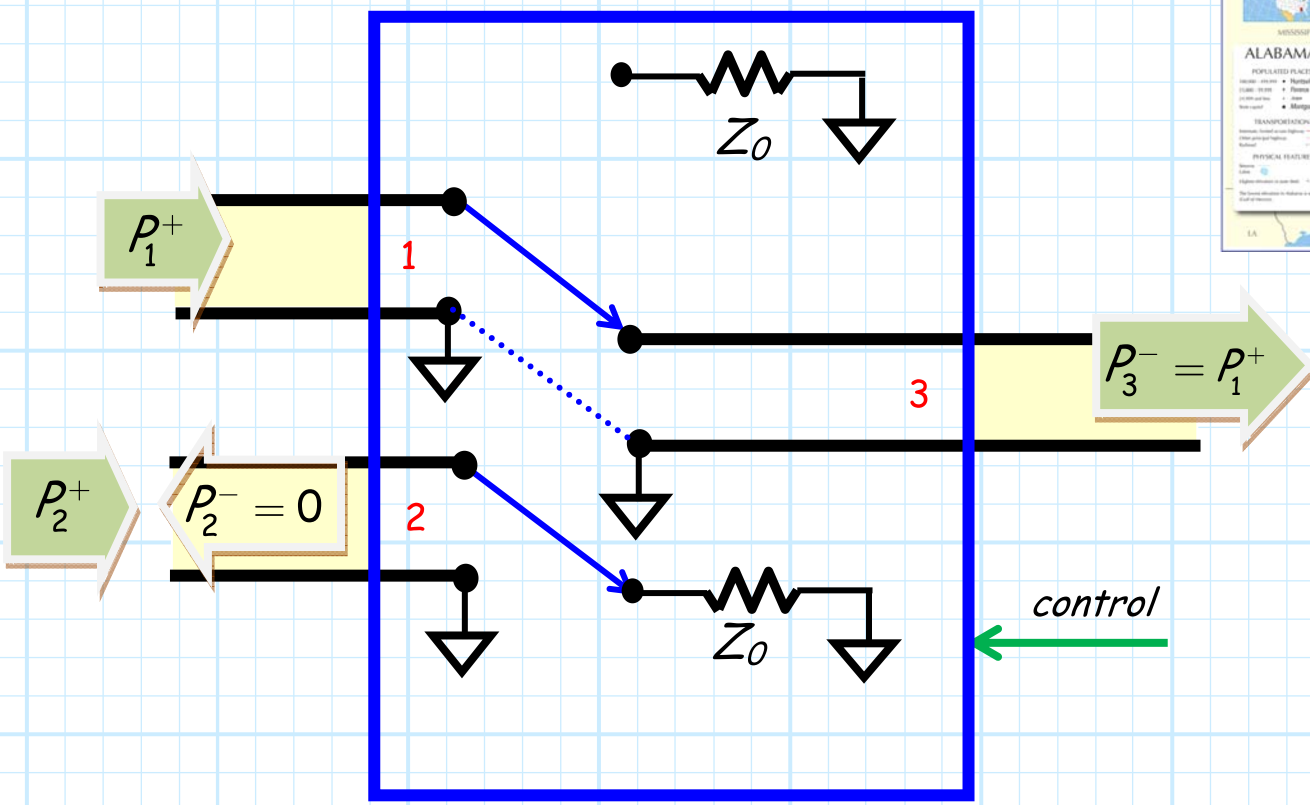
→Note since this power is **absorbed internally** in the switch, it is clearly a **lossy device**!

The other state

Q: *You said that this switch had **two** states; what about the **other** one?*

A: For the **other state**, we find that ports **1** and **3** are connected, and the disconnected port (port **2**) is internally terminated in **a matched load**.

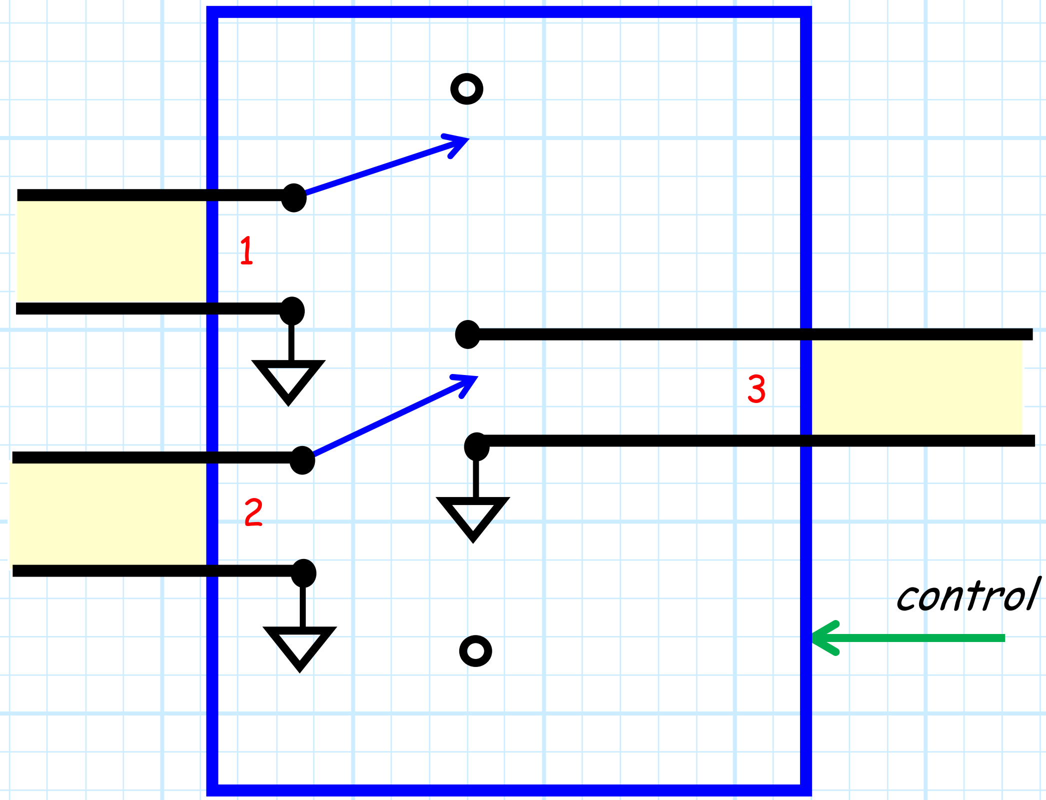




The reflective switch

Now, contrast this with the **other kind** of microwave switch—the **reflective** switch.

If we "open the hood" of a **reflective** switch, we'll see a circuit with a schematic that is **effectively** this→



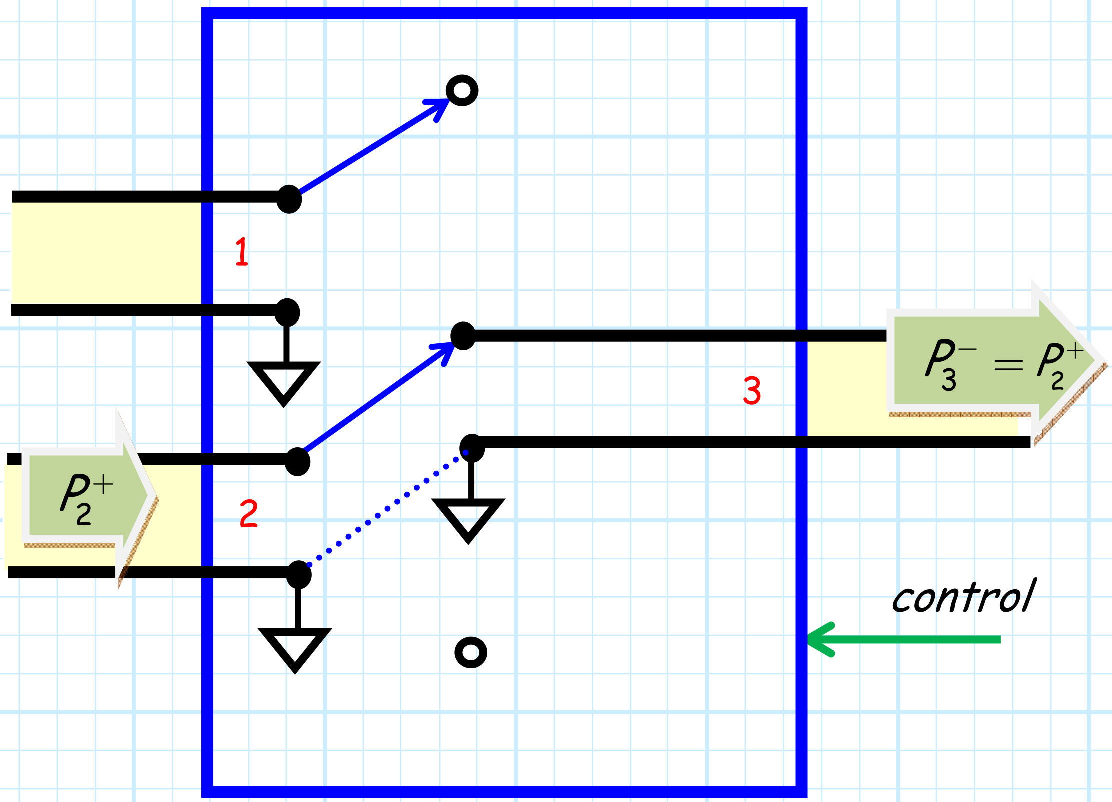
Note the **difference** between this and the **absorptive** switch is the **absence** of the two Z_0-valued **resistors**.

In some ways the same as absorptive…

Thus, when ports 2 and 3 are connected, energy flows through this **reflective** switch at precisely the same rate as that of the **absorptive** switch.

Q: *So are you telling me that the* ***absorptive*** *and* ***reflective*** *switches are the* ***same****?*

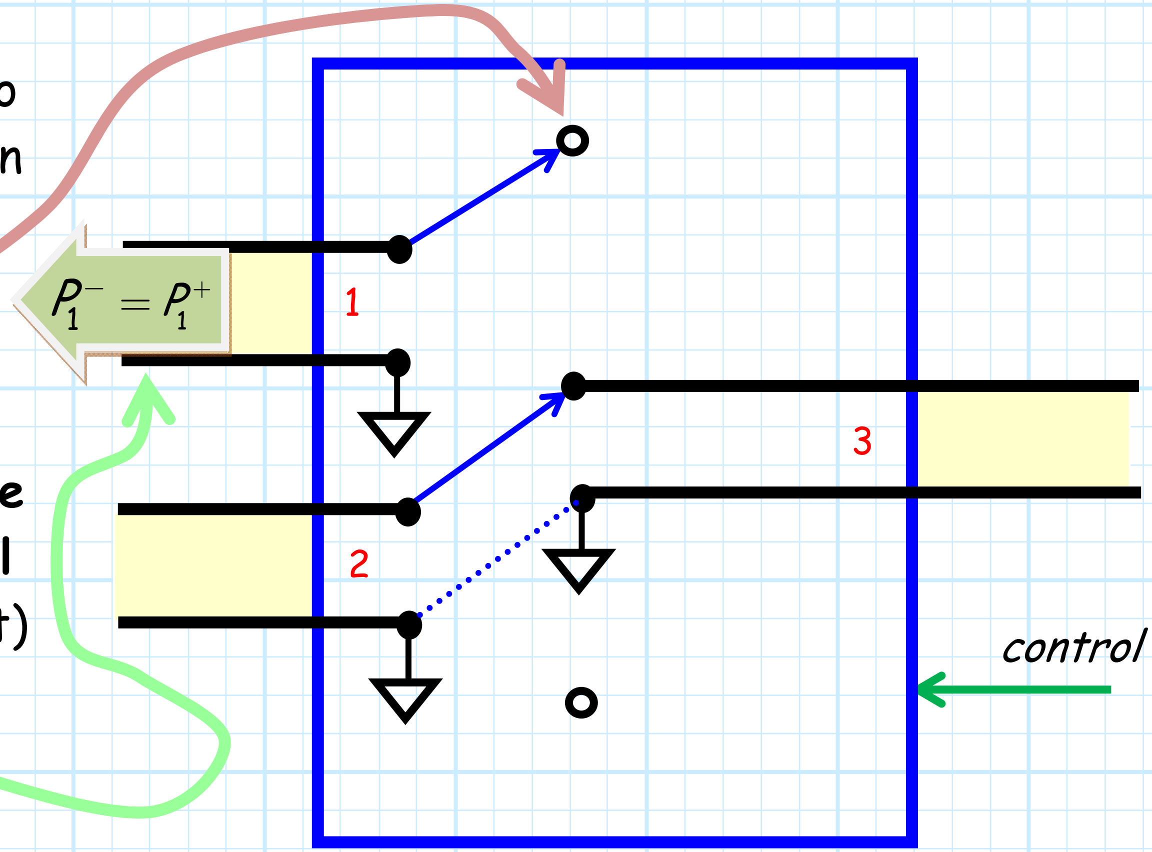
A: My goodness **no**!



...but in other ways very different!

Look at the **disconnected** port of the **reflective** switch in this example—i.e., **look** at **port 1**.

The transmission line into port 1 is terminated in an **open circuit**(!).



Thus, if a matched **source** is connected to port 1, **all** its available (i.e., incident) power will be **reflected** right back toward the source!

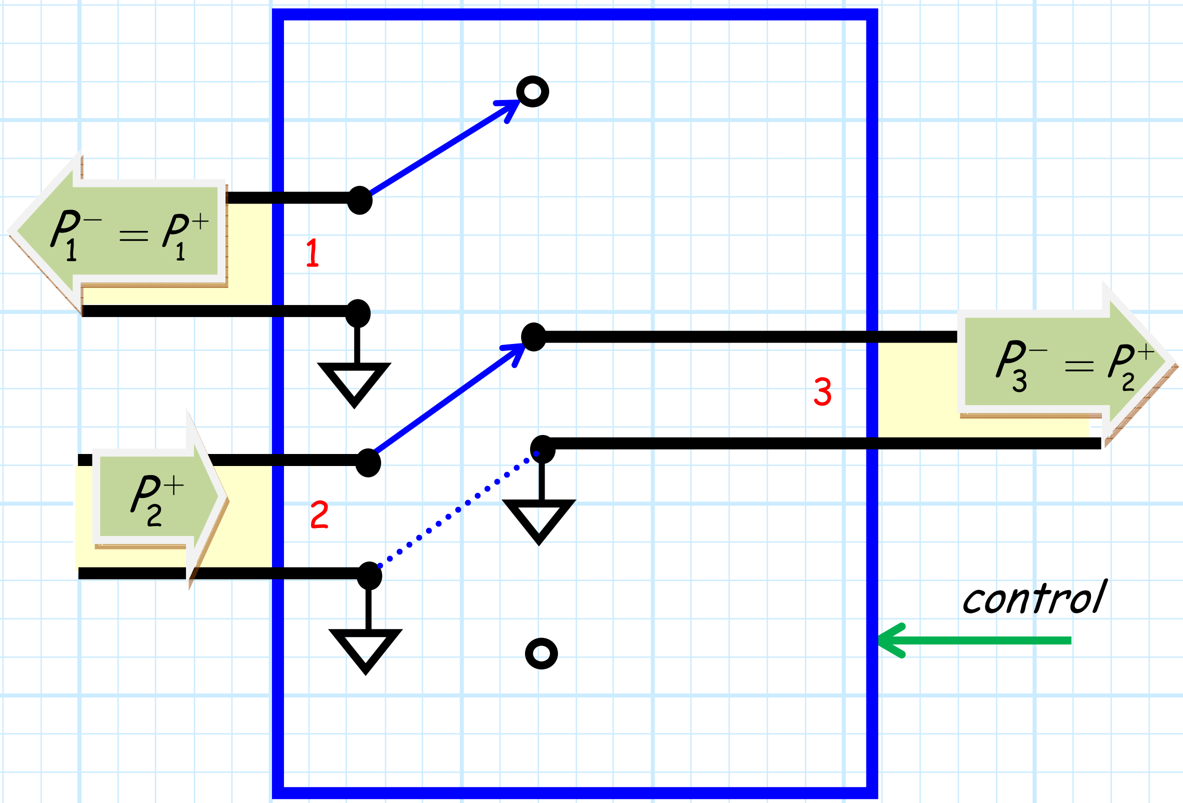
→Clearly, the **reflective** switch is **not matched**.

No resistors in this switch!

Note then, that **no power** will be absorbed by the **reflective** switch—**either** the signal will:

a) propagate **unattenuated** from one port to the **other** port to which it is **connected**; or,

b) the incident power at the **disconnected** port will be **entirely reflected**.



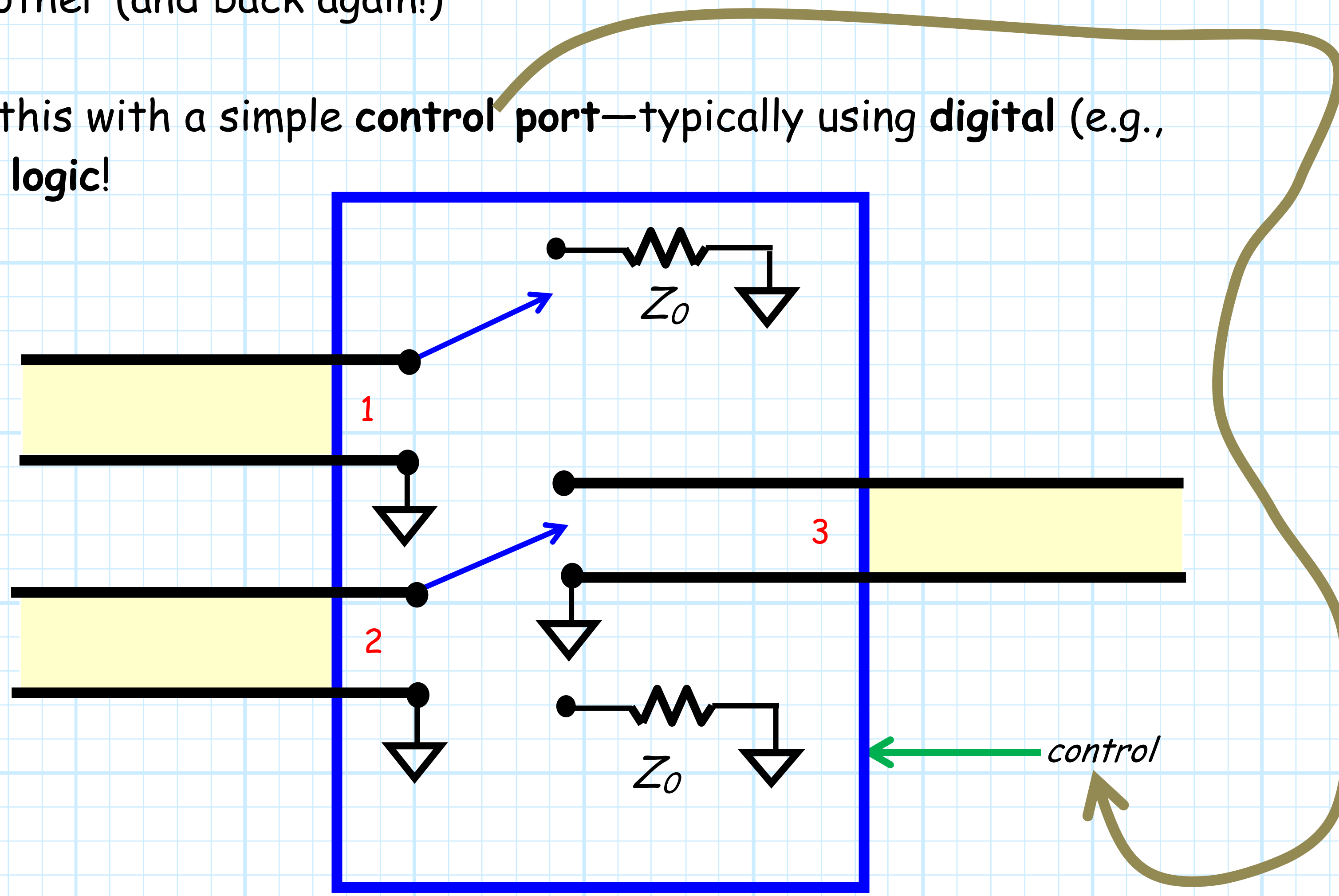
→ Clearly, the **reflective** switch is **lossless**.

What causes it to time vary?

Q: *Earlier you said that a switch is **not** time-invariant; what about that?*

A: As switch is time-varying because we can **change its state** from one to the other (and back again!)

We do this with a simple **control port**—typically using **digital** (e.g., CMOS) **logic**!



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Q: *Crud! I became a radio engineer to specifically **avoid** all this **computer hoo-ha.***

*I'm sure controlling this port requires some goofy **IP address**, or some imponderably long hexadecimal **security code**!*

A: Actually its **quite simple**, since the switch has two states, we require precisely **one bit** to control it—a **"0"** for one state, a **"1"** for the other.