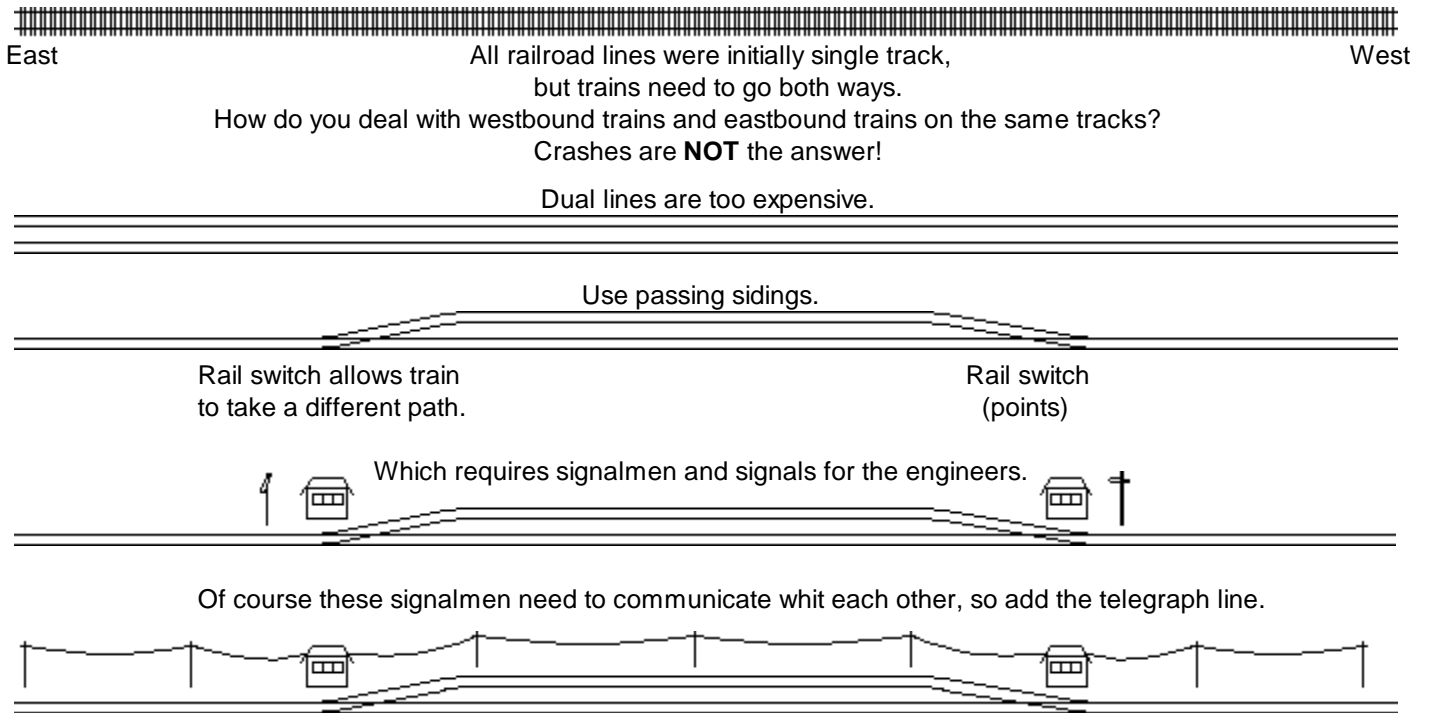


Two reasons electricity is useful: Power conversion and transmission. Power available in one location as heat or mechanical motion can be used many different ways at some other location. First major use, lighting.

Signals. A voltage or current can represent information. Information in electrical form can be transmitted to a distant location and/or recorded for later use. First major use, telegraph.

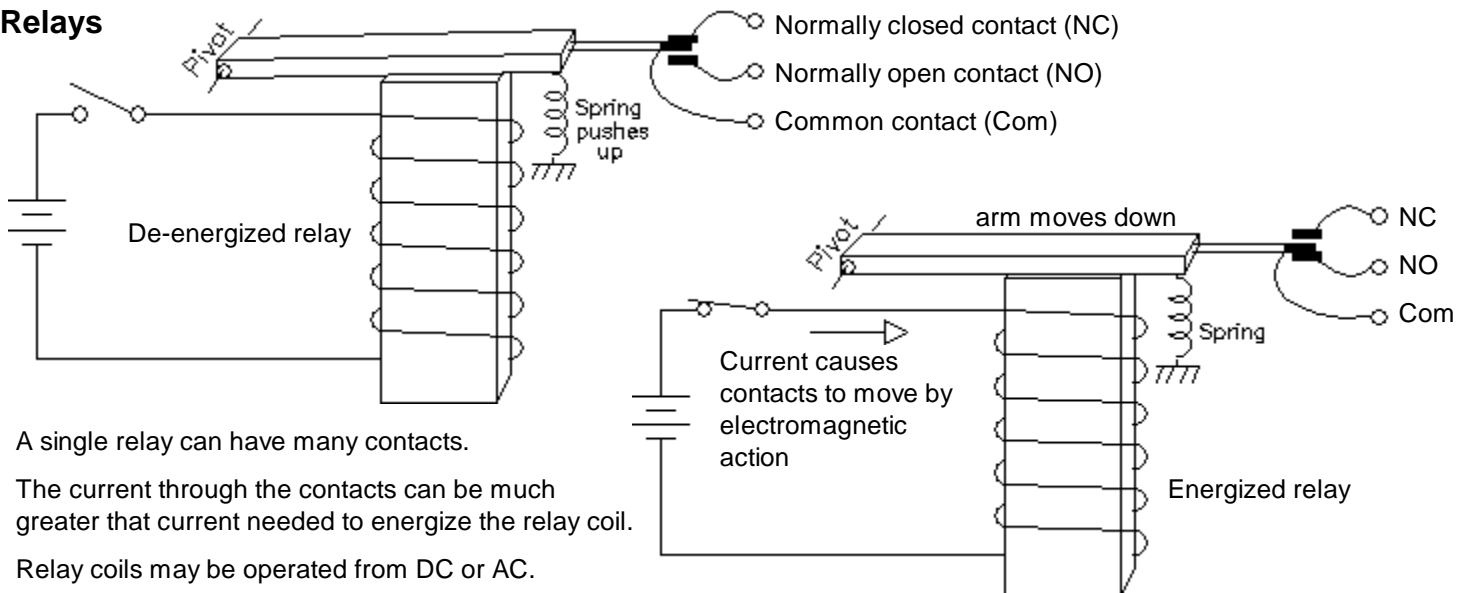
Rail Roads One of the first big users of the telegraph



Clearly this is a system which cries out for a more automated approach, but remember, this is before computers, before logic gates, before transistors, even before vacuum tubes. I know, it's hard to imagine, but such times *did* exist.

They did have *one* device that could be used for logic, a magnetically operated switch, commonly called a relay.

Relays



A single relay can have many contacts.

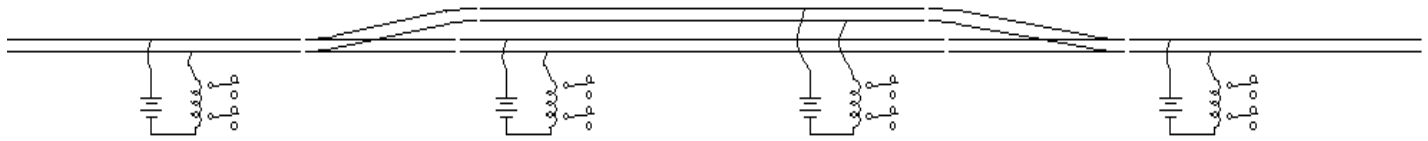
The current through the contacts can be much greater than current needed to energize the relay coil.

Relay coils may be operated from DC or AC.

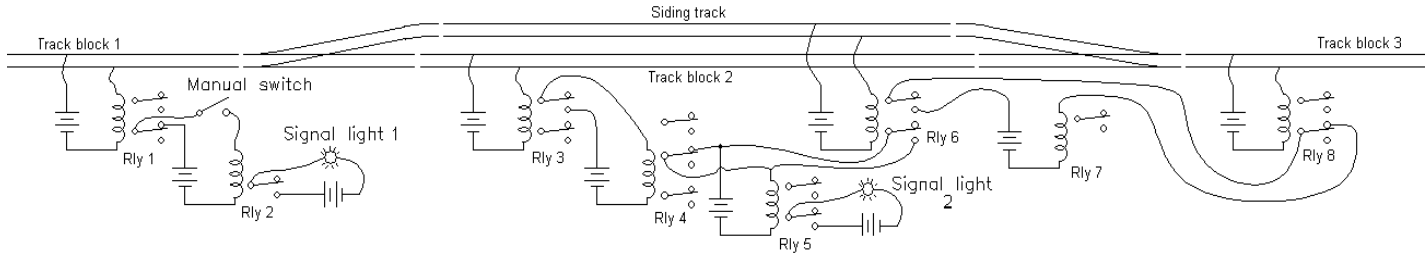
Fancier relays may have a time delay before switching the contacts.

Even fancier relays may rotate a drum with many contacts that connect in sequence. And the fanciness doesn't end there.

Relay-relay logic



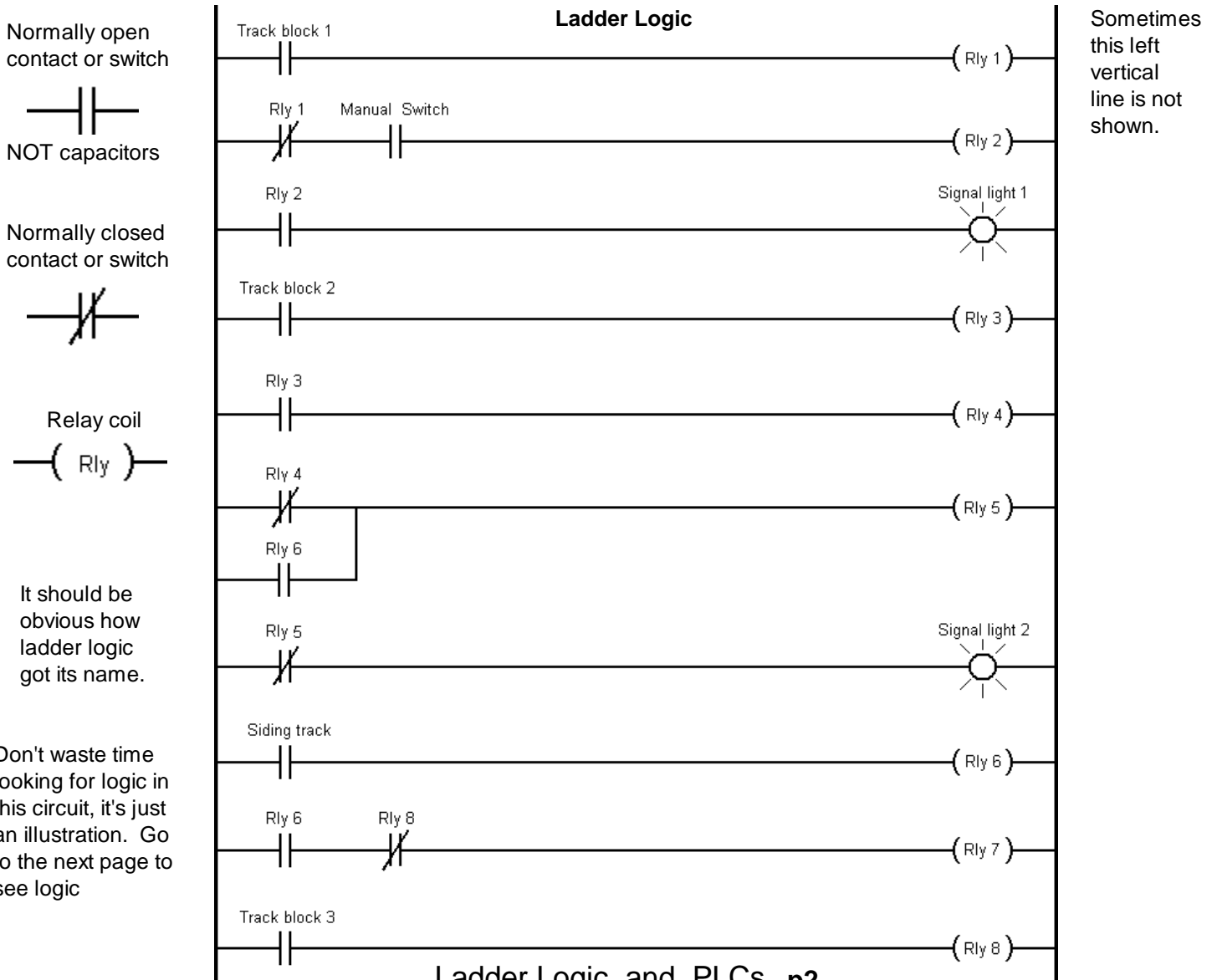
Notice the little gaps in the rails, they electrically separate the tracks into different regions, or blocks. When a train enters one of these regions, it makes contact between the two rails and the corresponding relay will be energized.



Relays can be hooked to one another and to other switches to create logic systems which could operate signal lights or switch points or do many other things. But the logic is VERY hard to follow.

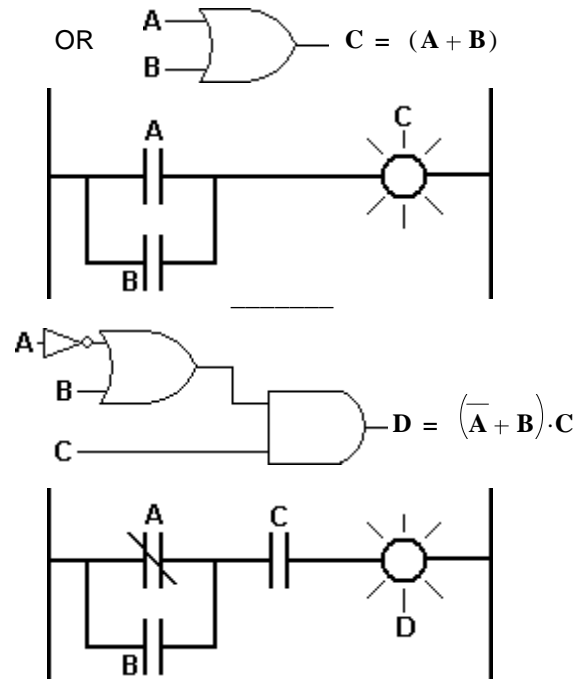
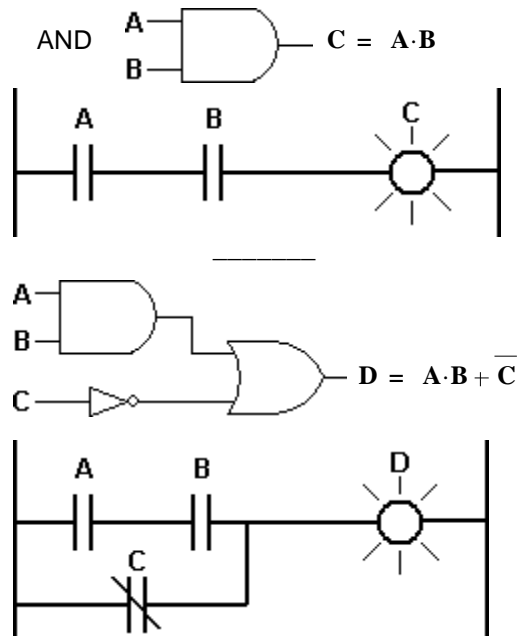
Ladder Logic

To more easily deal with the logic of all these relays and switches a new way to draw the schematic was developed. The power source for the relays was drawn as a vertical line on the left side. The ground or common was drawn as a vertical line on the right side. The individual logic circuits were drawn horizontally with switches and contacts on the left and relay coils and outputs on the right. Contacts and switches are the symbols that look to us like capacitors.



Logic

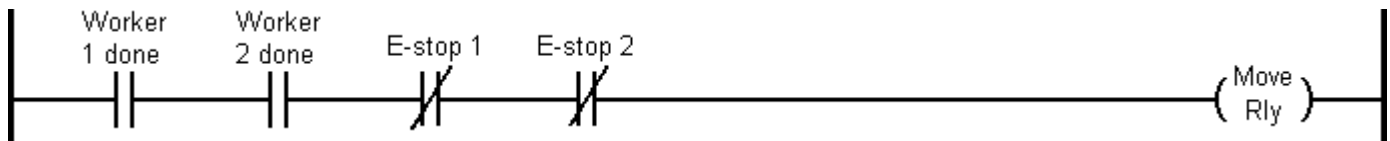
You are probably far more familiar with digital logic gates than this relay logic, so let's look at some analogies.



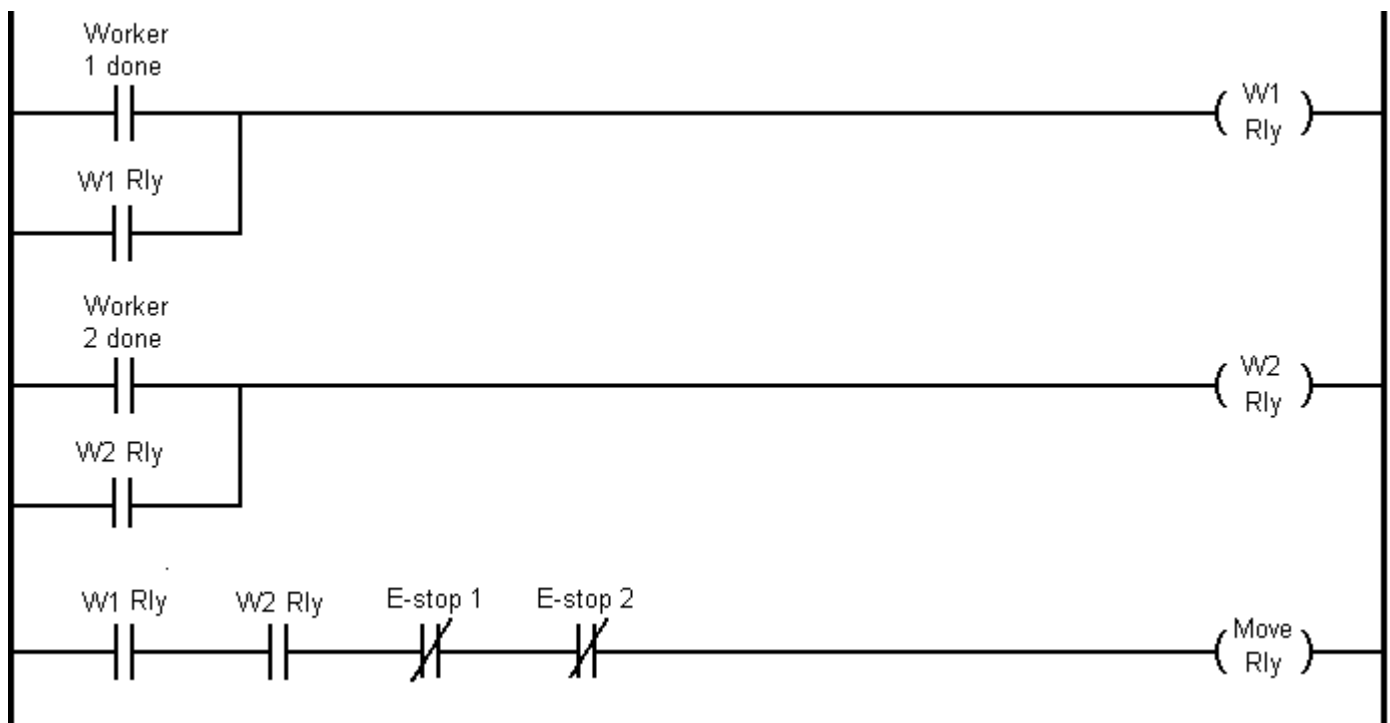
Industrial Control

This is where ladder logic is still used extensively, because it is so well suited to simple on/off logic.

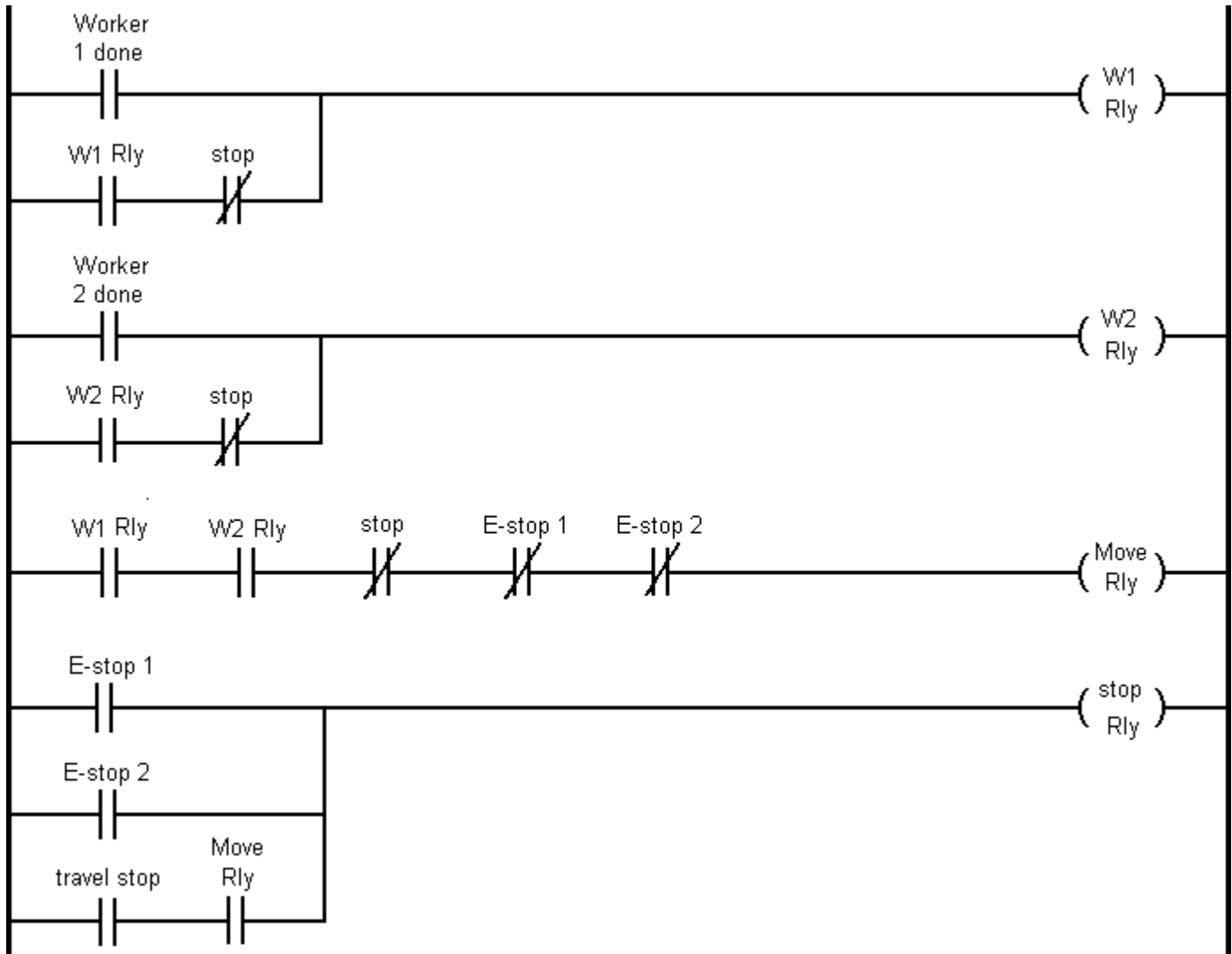
Ex Say 2 workers are performing tasks on an item on an assembly line. Each worker must push a button when he is done to allow the item to move to the next station. Each worker also has an emergency stop (E-stop) button.



Maybe you'd like to change this so the workers don't have to hold down the buttons while the other worker finishes and the item moves to the next station.



Unfortunately, now it won't stop moving unless one of the workers holds down their E-stop button. Let's put in a stop relay.



I've also added a "travel stop" input to stop the movement when the item reaches the next station and a reset method (which may not allow the next movement unless you roll past the "travel stop" sensor). Also note that emergency stop buttons work in two ways, one of which does not rely on the stop relay.

What I haven't done is build this circuit to see if it will really work as expected. Wouldn't it be nice if I didn't have to build the circuit with real relays. What if most of these relays could be simulated with a computer and all I would need to do is wire up a few switches and sensors and one big relay for the motor. A Programmable Logic Controller (PLC) does exactly that.

PLCs

Actual relays may still be used to control large currents to motors and such, but they're not used for the logic anymore. Programmable Logic Controllers (PLCs) have replaced the logic-only relays. They are faster, more reliable, more flexible, and way easier to program than rewiring relay circuits. PLCs are programmed with special software that runs on a normal desktop or laptop. The software runs a form of ladder logic and can often run some C code or other high-level language as well. They also simulate the entire program operation, including inputs and outputs so that you can make sure your program works before connecting to any hardware.

The main purpose of these notes and the supporting lecture and homework is to give you a short introduction to a very common way of implementing industrial control systems. I want you to know the terms and have confidence that you could quickly become proficient with this type of programming. That way, if you are ever asked about ladder logic and PLCs in a job interview, you won't come off as an ignorant idiot.

In the homework you will use PLC programming software to learn more about ladder logic and run some simulations. You will not become an expert, but at least will know you can become one.