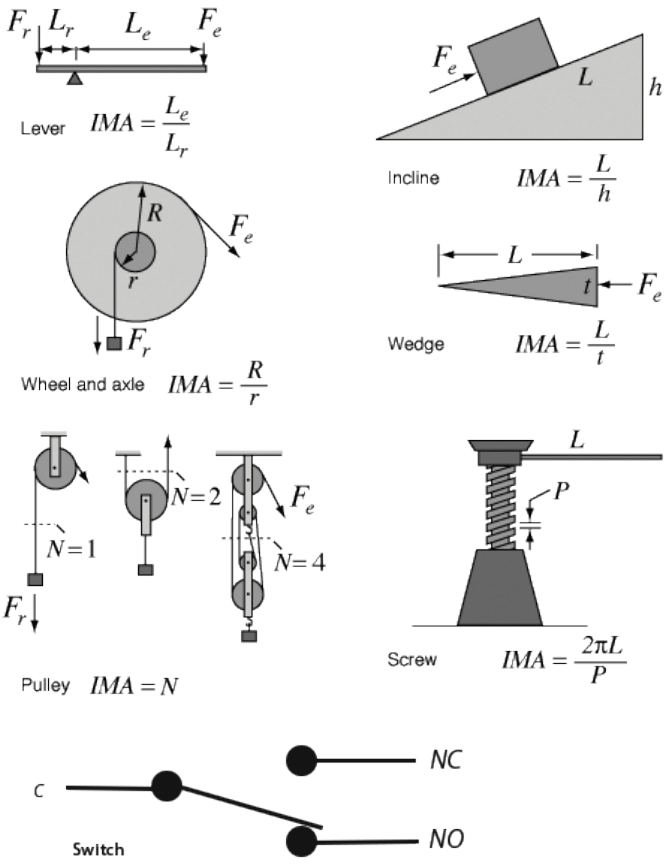
The Switch - A Simple Machine?

One of the first lessons in science we all learn is the list of "Simple Machines" which typically starts with the lever, wheel and inclined plane and often includes the pulley, wedge and screw. I take the view that the pulley is just a wheel with a rope or wire wrapped around it, and the wedge and screw are just modified versions of the inclined plane. So, the basic theory is that all other machines are simply combinations or derivations. But, I think that from an evolutionary point of view, it is time to add the switch to the list. It doesn't get much simpler than a device that allows something to be in 1 of 2 states, on or off. But more on that later.

All early machines were used to amplify the amount of force a person or animal could provide in order to accomplish work. People will make the argument that something like hydraulics should be on the list, since it is a practical and simplistic method of amplifying force but that is a very slippery slope. Hydraulics, steam, combustion and electricity are all great methods of transferring energy, but it is hard for me to think of them as anything more than exotic levers. You can move a lot of rocks with a stick of dynamite, but it is actually just a practical way of packaging a really, really powerful crow bar.

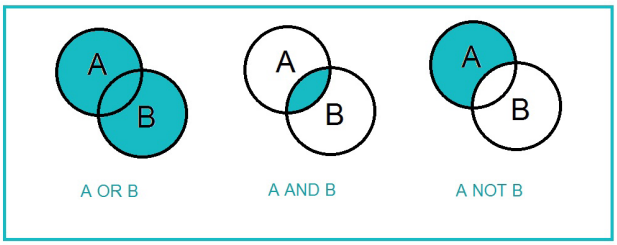


Simple machines?

The same argument could be made about switches I suppose. The first switches were really just levers which used human power to change something between different positions. In fact, the reason they are not really thought of as a simple tool is because the switch didn't really have a lot of exceedingly practical uses until we began to harness methods of transferring power. Once hydraulics and steam energy came into play we needed a method of turning that power on and off and telling it where to go. This was done using valves which are a specific kind of switch intended to control fluids and gases under pressure. What really catapulted switches into a position of importance on the tool and machine list was the combination of electricity and boolean math.

Electricity gave us a simplistic and safe (in comparison) method of transferring large amounts of power at a reasonable cost. Steam and Hydraulics are bulky, messy and require a high level of complicated maintenance. Working with the kind of pressures needed to do large amounts of work with these tools is inherently dangerous. The internal combustion engine and electricity replaced hydraulics and steam for good reason in many of the everyday applications to create and transfer power. With electricity we suddenly had a method of transferring large amounts of power with very little human force. A small lever or button on the wall allowed us to light our entire house, heat things up or turn on motors to run more complicated equipment. Switches controlled by other switches, timers or other non-human actions allowed us to automate processes like washing clothes, cleaning dishes, or factory assembly lines.

But the real breakthroughs and the explosion in the number of switches came when Boolean logic was applied to electricity and the transistor was invented allowing switches to be miniaturized.



Boolean Ven Diagram

The George Boole idea (approximately 1860) that any real world situation could be reduced to a system of logic and manipulated using algebra was probably the most overlooked mathematical concept of all time.

It took 70 years for Claude Shannon and Victor Shestakov to come along and realize that by combining Boolean logic with a binary number system you could solve all kinds of problems related to telephone switching systems and that it had applications that allowed switches to solve boolean logic problems.

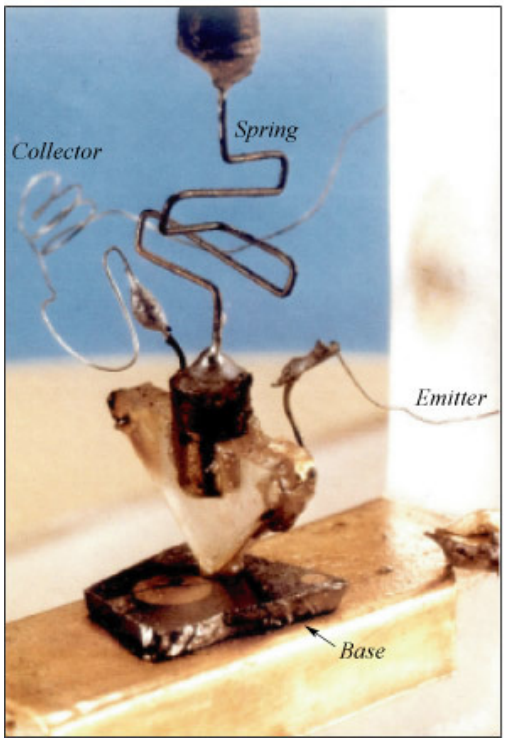
The binary number system has only 0's and 1's. It is very easy to represent binary numbers using relays where Off = 0 and On = 1 or a "high" voltage = 1 and a "low" voltage = 0. Once the implications of this were realized, the digital age of computing had begun.

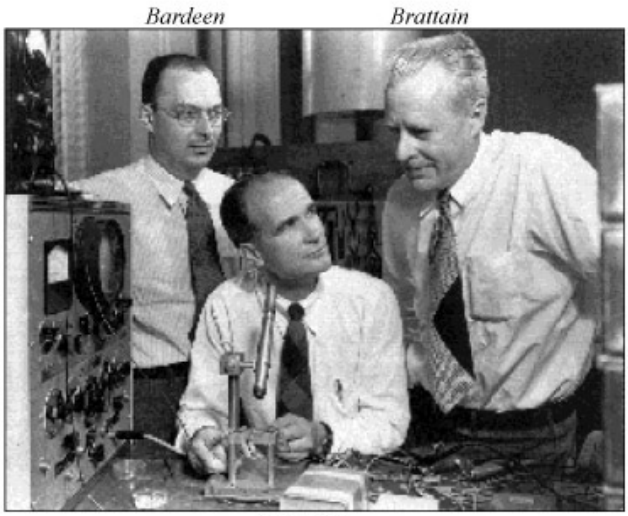
The first truly functional transistor was demonstrated on December 16th of 1947. I personally think this day probably deserves its own national holiday since it has easily changed the world more and faster than any previous invention in such a short period but I'll leave that for historians to argue over drinks every December 16th. The transistor allowed switches to be miniaturized to such an extreme that complicated electronic devices could be built at extremely low costs and small size. The explosion of electronic technology that resulted from this has been almost incomprehensible. The transistor lead to the IC (Integrated Circuit) that lead to the microprocessor, which lead to affordable computers. And all of it simply comes down to enormous numbers of switches being turned on and off in a logical manner.

The first point contact transistor

William Shockley, John Bardeen, and Walter Brattain

Bell Laboratories, Murray Hill, New Jersey (1947)



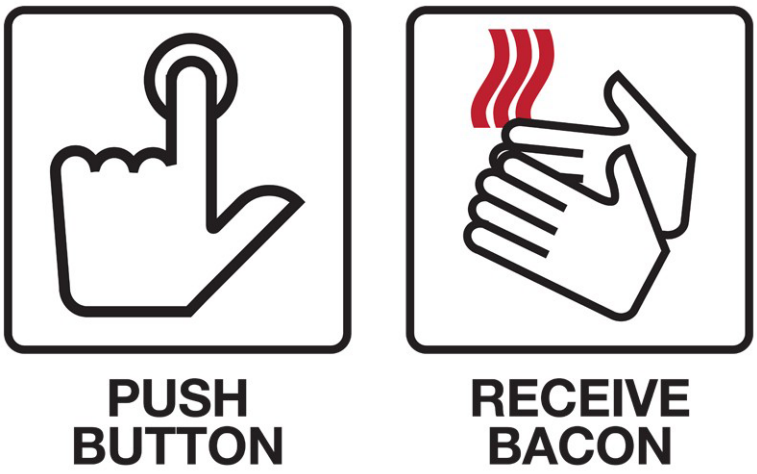


Shockley

Which brings me back to my point about switches being included as one of the simple machines or tools. While they may have achieved prominence late in the game, from an evolutionary stand point, they are completely kicking butt. One way to gauge the successful evolution of something is to look at how many of them there are.

I can look around my house and find about 100 obvious levers in my tool box, garage and kitchen and another 100 wheels or pulleys on everything from my car to my vacuum. I can look around my house and realize that I have a couple thousand inclined planes, if I include screws in the category. But when I try to count switches it becomes an impossible task and I have to resort to estimates. I can count the light switches and push buttons that I turn on and off everyday, but the number of switches in the computer I'm using to type this story boggles the mind. A typical computer in 2014 has close to a billion switches just in the microprocessor without counting the graphics cards, network adapters, monitor or peripherals. The cell phone in my pocket has 100 million more, and I'm not even counting the memory devices like hard drives and RAM, since people will argue that setting a place holder to a 1 or 0 is not specifically the same as a switch. So, being a bit of a geek, I look around my house with four computers, four cell phones, three stereos, two TV's, a hybrid car with three computer systems and various appliances that all have digital controls and I come up with a conservative estimate of around 6 billion switches. I have nearly as many switches in my house as there are people on the planet. One current estimate says that there are 10 million transistors a month being produced for *every person on the planet*. And by Moore's law, those numbers will most likely double every 2 years. So, on December 16th I think everyone who enjoys the benefits of this technology should take a moment to celebrate in whatever way makes you happy as long as it involves a switch.

I'm very biased; of course, since I've spent way too much time thinking about switches. The prolific number of switches used in digital electronic devices is pretty cool because of what it allows us to do, but this is not that upon which I've spent my time working. We live in a very competitive world and as soon as this world needs 10,000 of something, a lot of people become interested in filling the order. When the world needs one billion of something, the competition becomes crazy.



I work in what is now referred to as "the long tail" of switches. Intel and AMD fight over the billion switch microprocessors. A variety of large IC companies fight over the market for 100 million switch devices such as FPGA's. There are hundreds of companies that produce massive amounts of components, such as electro mechanical and solid state relays, and small IC's with hundreds of transistors. What I've done is provide solutions when people could not find an automated switch to do what they needed.