Elementary Science for Elementary Students

Demonstration: How Computers Make Decisions

Core Concepts:	Binary numbers and binary logic, analog, digital
Other Concepts:	Logic gates (invert, buffer, XOR, OR, AND)
	Fundamental components of a digital computer
	Differences between a digital computer and the brain
Equipment:	Clock radio
	Binary logic transparencies (pictures expressing XOR, AND, OR)
	Computer and binary logic lecture board, Lecture board signs/labels
	Sample electronic circuit board
	Computer programming protoboards (10) and batteries (30)
Facilities:	Large table, working tables for experimentation activities

Introduction:

This demonstration emphasizes the fundamental differences between a digital computer (PC) and an analog computer (the human brain) and the basic decisions that a digital computer (PC) makes. Students have the opportunity to see some of the key components or parts of a digital computer and relate them to parts of their own computer (the brain). An analogy between the digital computer and the human body is described on the following page and can be used as appropriate to clarify concepts in a digital computer. The primary difference between an analog and a digital computer is that a digital computer understands only two things at one time: a "0" or a "1". The difference between a digital and an analog computer is similar to the difference between a light switch that is only bright (on) or dark (off) as compared to a dimmer switch which allows levels of illumination in between bright and dark.

This demonstration will explain the basic decisions that a digital computer makes using 5 fundamental decisions: buffer (=stay the same), invert (=become the opposite), AND (=on only when ALL inputs are on), OR (=on when at lest ONE input is on), and XOR (=on only when EXACTLY ONE input is on). These five decisions can be performed using special electronic circuits (digital circuits) and combined to allow digital computers to add, subtract, multiply, divide, interpret text, communicate with a printer or keyboard, and many, many other functions.

This demonstration is divided into 3 major components as are all (ES)^2 demonstrations. Each component along with its major highlights is described below:

- **Pre-demonstration Exercise: This exercise explores preconceptions about computers. Each student should complete the worksheet on page 7 of this document.**

- **Interactive Lecture: The lecture covers the core concepts and other concepts of the demonstration**

    - Inside the computer (lecture board): covers basic components inside a computer
    - Binary Decisions (lecture board), alarm clock, transparencies: covers binary logic

- **Experimentation Exercise 1: allows students to apply binary decisions to household functions.**

- **Experimentation Exercise 2: allows groups of 4-5 students to experiment with programming a segmented display, using inverters and buffers, two of the basic binary decisions.**

Analogy: digital computers vs. the human body

Since the decisions that computers make are made using electricity (current and voltage), it is difficult to see what they are doing. The modern digital computer makes deciisions so fast (millions of decisions per second) that it would be difficult to watch and keep track of these decisions even if we could see them. Since the PC and the human body/brain are both fundamentally, computers, we can relate them to each other to more easily understand what goes on in the aritifical, digital computer. This analog is particularly useful, because where it falls apart are the important differences between analog and digital.

In the hardware (what is used to make circuits), the human body and a personal comptuer are very different. In the human body, food is converted to fuel for cells to transmit electricity; all the hardware is wet and slimy. In a personal computer, all the circuits are made from a refined version of sand, called silicon and of metal; personal computers can't get wet and their food comes from an electrical power supply such as a battery or a wall outlet.

In how well the computer performs, the human body and personal computer do not share much in common either. A personal computer has wires that are faster, but takes more space as all the circuits are two dimensional. The human brain has slower wires, but takes less space as the circuits are all three dimensional. Personal computers understand only "on" and "off" conditions; wires inside personal computers can only carry a "1" signal or a "0" signal, hot or cold, black or white.The human brain understands more than just these two states and can understand warm or gray as well as hot and cold and black and white. Because of these differences, personal comptuers are typically better at computing things like multiplying two numbers or sorting information alphebetically. Human brains, however, are better at recognizing patterns: your grandmother vs. your dog, for example.

We make the following analogies between the digital computer and our human bodies:

- **The core of the computer:**
  - human body: the brain: three dimensional
  - personal computer: the microprocessor (like the Pentium): two dimensional
- **The wires:**
  - human body: the neurons connect brain, nerves, muscles, spinal cord
  - personal computer: traces or wires on PC boards or on integrated circuits (faster than human wires)
- **The connections:**
  - human body: synapses make connections between neurons using chemicals and electricity
  - personal computer: pins or connectors make connections between wires using electricity
- **The senses:**
  - human body: can see, smell, taste, hear, and touch
  - personal computer: can only hear using the keyboard
- **The muscles:**
  - human body: can run, jump, walk, lift, talk, blink
  - personal computer: can only hear, talk (through the monitor or the printer)

Interactive Lecture: Inside the Computer

This part of the demonstration uses the side of the lecture board entitled "inside the computer". Six major components of the computer are explained here: wires or cables, connectors, keyboard, motherboard, hard disk drive, and floppy disk drive.

Part 1: Wires

A sample of a wire is the gray ribbon cable on the upper left corner of the lecture board. Wires connect two points electrically so that current can flow between them in response to an applied voltage. Wires in a personal computer transfer either an "on" state ("1") or an "off" state ("0"). How many wires does the gray ribbon cable contain? What other forms of wires are found inside the computer? Traces on PC Boards (printed circuit boards), tiny, thin strips of copper or aluminum inside the comptuer chips. Can you think of other forms of wire inside a personal computer?

Part 2: Connectors

A sample of a connector is shown in the upper left corner of the lecture board. Connectors connect one type of wire to another type of wire so that electricity can flow from one wire to the next. What other types of connectors do you see inside a computer? What types of connectors do you see in your body (joints, ligaments, tendons)?

Part 3: Keyboard

The inside of a keyboard is shown in the upper right corner of the lecture board. The keyboard allows the user of the computer to "talk" to the computer using "touch" as the interface "sense". The keyboard is shown without the alphabetic and numeric keys we are accustomed to seeing covering this type of keyboard pad. Under each key on your keyboard is one of these copper colored "sensors" which respond in a "binary" way to the touch of your fingers; at any moment in time, you are either touching the key (activating the sensor or turning it "on") or leaving it "off". Each sensor is connected to the computer to let it know which letters or numbers you are choosing to communicate with it.

The sensors used to record your touch at certain keys are called "capacitive" sensors; capacitive sensors allow you to send your signal or command to the keyboard without actually touching the electronics. The sensors pick up a difference in spacing between the key and the electronic contact pad (on the exposed keyboard). They sense the change in the amount of air between the electronic contact and the key, so as you depress a key, an electronic signal is sent back to the computer, telling it which keys have been depressed.

The electronics are very fast. Can you type faster than the computer can receive your signals? Try it. The computer can accept signals almost a million times faster than a very fast typist (100 words per minute).

Part 4: The floppy disk drive

The floppy disk drive is shown in the lower right hand block of the lecture board (on the right). The floppy disk drive is part of the computer's memory. It is the slowest type of memory in a computer. Hard disk drives are faster, CD ROM drives even faster and RAM (random access memory) the fastest. The floppy drive is so named because it stores information in a floppy piece of material called a diskette. When you insert a floppy diskette into the computer's floppy disk drive, the disk is spun so that a pointy "head" can read the information on the diskette stored in a magnetic field. Although floppy disks are slow, they are useful for storing information or memory that has to be transferred from one computer to another. A typical

floppy diskette can store over 1 Megabyte (over 8 million binary pieces of information stored as "1"s or "0"s. The ZIP disk is another form of floppy disk, but can store up to 100 Megabytes of information.
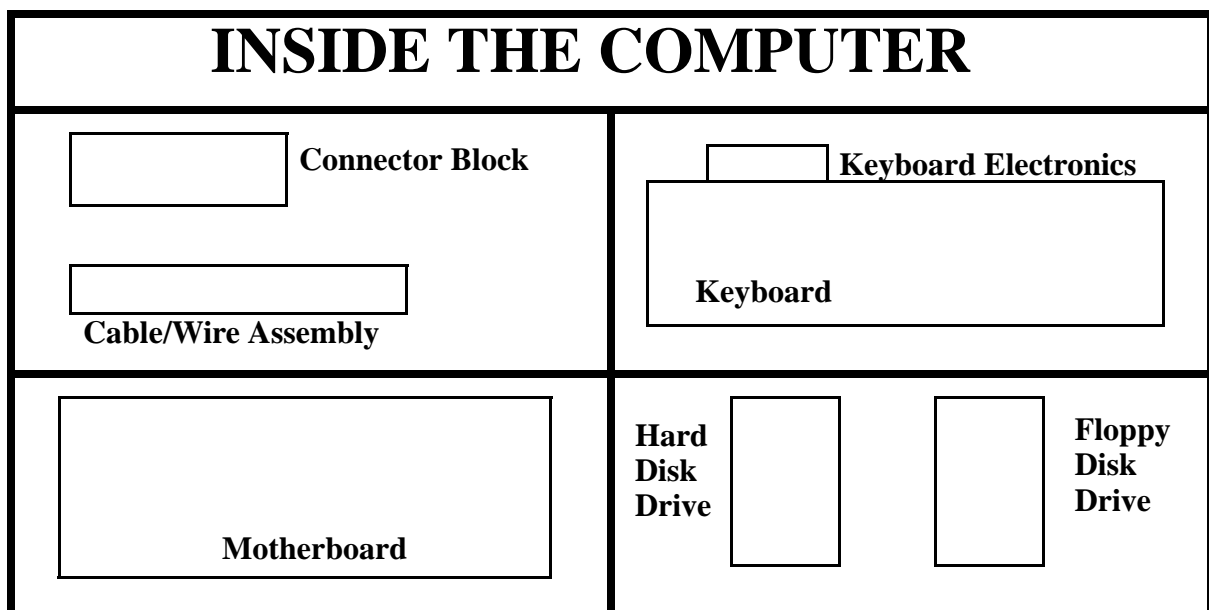
Part 5: The hard disk drive

The hard disk drive is shown in the lower right hand block of the lecture board (on the left). The hard disk drive is also part of the comptuer's memory and like the floppy disk drive, stores information that can be read and written magnetically using the pointed head that hovers over the disk as it spins. THe hard disk drive is so named because it stores information on a hard piece of material. In general, a hard disk drive is not portable and stays with the computer in which it is originally installed.

Part 6: The motherboard

The motherboard is shown in the lower left corner block of the lecture board. It does most of the work for the computer including interpreting sequences of letters and numbers entered using the keyboard, under-standing commands issued by a mouse, and interacting with the monitor, printer, disk drives, and many other external components. The "brain" of the motherboard is the microprocessor, a larger integrated circuit which today can go by the name of Pentium or PowerPC.

Part 7: Other components

Many other components can be found inside a computer that are not shown here. The power supply converts the wall outlet electricity (AC) to a form the computer can understand (DC, typically 5 volts or less). The monitor converts electricity information (voltages) to light signals. Other PCBs (printed circuit boards) inside the computer case tell the monitor what to do ("video" card), tell the speakers what to do ("sound" card), talk to other computers across a phone line ("modem" card), or talk to other computers via a special, ultrafast connection ("ethernet" card). The big black fins on some of the integrated circuits inside the computer are called "heat sinks"; they cool the computer chips to which they are attached and prevent them from burning up.

INSIDE THE COMPUTER

Connector Block	Keyboard Electronics
Cable/Wire Assembly	Keyboard
Motherboard	Hard Disk Drive Floppy Disk Drive

Interactive Lecture: Binary Decisions

This part of the demonstration uses the side of the lecture board entitled "binary decisions". Here is where we discuss the five major decisions that a comptuer can make. These five decisions may seem very simple and very basic, but they are the fundamental building blocks of adders, multipliers, sorters, and other complex decision making components of a microprocessor (the brains of the computer).

Each of the five decisions are described below. After presentation of the six decisions depicted in pictures on the lecture board, some more tangible examples of basic binary decisions are demonstrated. Experimentation exercise 1 allows students to interpret the decisions that common household items are through their typical function in the household. Experimentation exercise 2 is more complex and is recommended only for grades five and above; this exercise allows the student to program his or her own miniature computer and display the output on a alphanumeric display.

BINARY DECISIONS	
INVERTER BUFFER	OR
AND	XOR
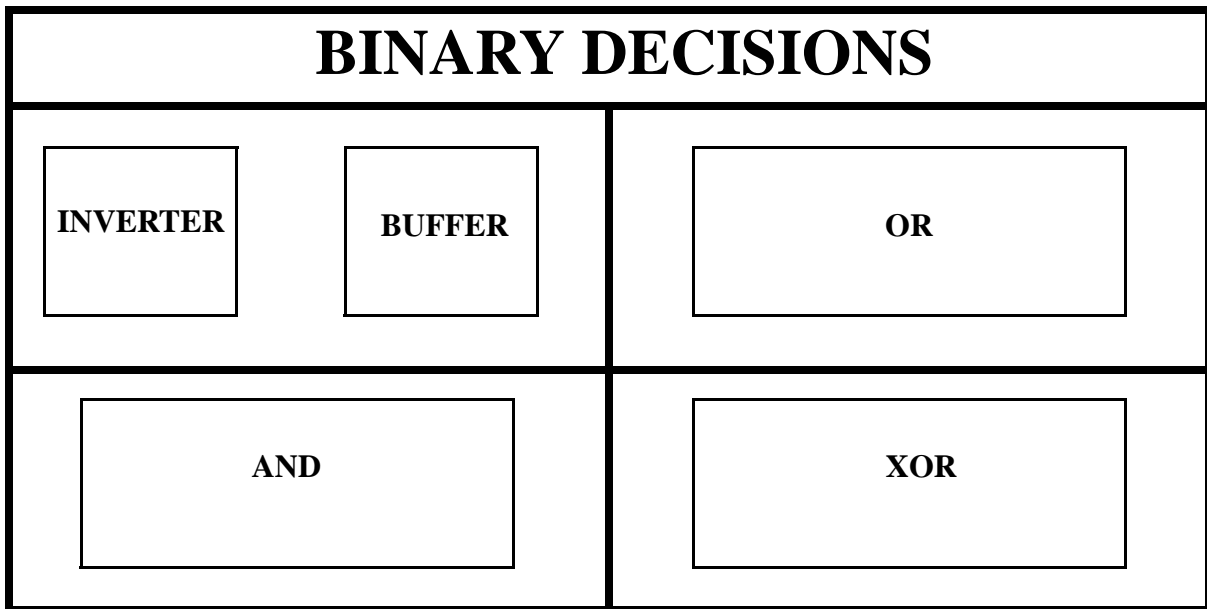
Decision 1: The Inverter

When you stand someone on their head, they are inverted. They are "not" what they were before. This decision is called an inversion. In binary decision making, their are only two things an electrical signal can be, a "0" or a "1". If we put a "0" into an inverter, it comes out a "1". If we put a "1" into the inverter, it comes out a "0".

Decision 2: The Buffer

Put a pumpkin in, get a pumpkin out ... that is a buffer. Why would we do that? Well, we might have wanted the seeds or the juice from the pumpkin to make pumpkin pie; even though what we get out (a pumpkin) is the same, we might be getting something we can't see from it that is very important. In binary decision making, the buffer allows us to put a "0" in and get a "0" out, but with more juice. Likewise, the buffer allows us to put a "1" in and get a "1" out, but with more juice. In electronic terms, "juice" refers to

current; for example, if we want our computer to drive a heater or a speaker, we have to put a buffer in between, so that the buffer can supply enough current to make the heater hot or the speaker loud.

Decision 3: The OR Gate
On the lecture board, in the OR block, we see a picture of a cloud and a picture of the sun. It is possible to see a cloud in the sky OR the sun in the sky OR the cloud and the sun in the sky at the same time? This is called an OR decision, because either OR both gives us an output of 1. If both inputs are 0, the output is 0; otherwise, the output is a one. The table at the end of this section shows a "truth" table expression for the decisions made by "OR", "AND", and "XOR".

Decision 4: The AND Gate
On the lecture board, in the AND block, we see a picture of a stopped car and a moving car. What is needed for us to go driving? Just the car? Just the keys? Do we need both? Yes, we need the keys AND the car to move. Only when both inputs are "1", do we get an output of "1" (moving car).

Decision 5: The XOR Gate
On the lecture board, in the XOR block, we can see a picture of a weed and a flower. Can a plant be a weed? Can it be a flower? Can it be both a weed and a flower? No. The plant can be EITHER OR BUT NOT BOTH, or abbreviated, we call this exclusive OR (XOR). Only when EXACTLY 1 input is a 1, is our output a "1".

Binary Decision: OR

Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	1

Binary Decision: AND

Input 1	Input 2	Output
0	0	0
0	1	0
1	0	0
1	1	1

Binary Decision: XOR

Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	0

Binary Decision: Inverter

Input	Output
0	1
1	0

Binary Decision: Buffer

Input	Output
0	0
1	1