CPU Processor Speed vs. the Speed of Light.

I put together this series of calculations to relate the frequency of operation of today's modern CPU's to the speed of light. If you can follow the math…great! If not, don't worry...just think about the end result. Now, comparing Processor speed is to the speed of light is like comparing the proverbial apples to oranges. But this hopefully will put the speed of today's processors into perspective.

The speed of light is roughly 186,000 miles per second or 3 x 10^8 meters per second (300,000,000 meters/sec) for you metric folks. Stated another way, *light can travel around the circumference of the earth at the equator more than 7 times in one second!* That's pretty fast. Relating things to our class room, the distance from the projector screen to the back row in the classroom (depending upon the classroom) is about 6 ½ ceiling tiles. Since "ceiling tiles" are not an accepted unit of measure (by most) we need to convert to something a bit more standard. Since each tile is 4' x 2', that makes the distance about 28' (or 8.5 meters, a definite accepted unit of measure.) However, I don't want this little series of calculations to promote the habit of students "sitting in the back", so let's make the distance about 24' (5 ½ ceiling tiles), or 7.315 meters.

First…the speed of light calculations. Just how long does it take light to travel 24 feet? Somewhere in your past, you most likely were presented with the well known formula "rate times time equals distance", or **r x t = d** , in algebraic shorthand. In our case **r**, rate, is the speed of light (3 x 10^8 meters/second), **d** is the distance of travel (7.315 meters) and the time, **t**, is the unknown. So doing a bit of algebraic juggling, we arrive at the formula:

t = d/r .

t = 7.315 meters/3x10^8 meters/second

t = 24.38 x 10^{-9} seconds, or 24.38 nanoSeconds or nSec.

Or **t = 0.000 000 024 380 Seconds.**

A nanosecond is one billionth of a second.

Now…back to computers and CPU's…Let's assume we have a 3.2 GHz CPU. The 3.2 GHz (giga hertz) means there is a clock signal creating 3,200,000,000 pulses per second that synchronizes the operations of the CPU. The 3.2 GHz is called a "frequency". Related to this "frequency", **f**, is the "period", **T.** The "period" is the time it takes for one complete cycle of the signal to complete. The period is equal to **1/frequency** or: **T = 1/f .**

$T = 1/3{,}200{,}000{,}000 = 0.000\ 000\ 000\ 312\ 500$ Seconds
$T = 312.5 \times 10^{-12} = 312.5$ picoSeconds or 312.5 pSec.

A picoSecond is one trillionth of a second.

So now all we need to do is to figure how many of these clock cycle "periods" of 312.5 pSec fit into the 24.38 nSec it takes the light to travel 24'. The formula for this is pretty straight forward, just divide 24.38 nSec by 312.5 pSec.

# of cycles = $24.38\text{x}10^{-9} / 312.5\text{x}10^{-12}$
# of cycles = 78.016 cycles…which we'll conveniently round to **78 cycles**.

So far we've determined that a 3.2 GHz CPU will execute 78 cycles in the time it takes light to travel about 24'. But what does this really mean in terms of how much "thinking" the CPU does? Well, CPU instructions can require 1, 2, 3 or many more clock cycles per instruction. So it's impossible to state how many "instructions" the CPU will execute unless we know the exact instructions. However, we could assumed an average of 5 cycles per instruction. Dividing 78 by 5 yields the result of roughly 15 instructions.

So, in the time it takes light to travel 24' - the distance from the projector screen to your eyes - a 3.2 GHz CPU might perform an average of 15 instructions.

Electronically, the upper limits of cranking up the processor clock speed have just about been reached using currently available technologies. So new ways have been, and are being, found to continue to get more processing power. Hyper-threading, which allows several pipelines of instructions to be executed in "parallel" is one such trick. Multiple CPU cores is also quite common in today's CPUs. Two cores, four cores, six cores and more! Another recent development from Intel is "Turbo-boost", which allows automatic "over-clocking" whenever it is possible to do so without generating damaging heat.

Our CPUs ARE still getting faster and more powerful, even though the raw "clock speed" figure is not really increasing. What does it mean? Well...if that 3.2 GHz CPU we used above is a 6 core chip, we're up to 90 instructions for this example. Add in hyper-threading and that number could potentially double to 180 instructions. Throw in a bit of random over-clocking, and the number 200 is certainly within reach. Two hundred instructions executed in the time it takes the light from the projector to reach your eye. Mind boggling. Don't blink!!!! Ahhhh...you may have just missed over 100 million instructions in the blink of an eye (about 100 mSec.).