What exactly is a P-state? (Pt. 1)

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What is a P-state?

When someone refers to a P-state, generally only the frequency is talked about. For example, on my Intel® Core™ processor, P0 is 2.3 GHz, and P1 is 980 MHz. In truth, a P-state is both a frequency and voltage operating point. Both are scaled as the P-state increases.

The effect of reducing frequency

It's obvious that performance is directly related to frequency. We all know that increasing the frequency, increases a processor's performance. The same applies for decreasing the frequency. If you halve the frequency, a compute bound task runs half as fast. For example, if your task is compute bound, requiring 100 % of the CPU for 1 second at 2 GHz, it will take 2 seconds to execute at 1 GHz. (This is roughly correct. There are a host of other factors influencing runtime, such as cache size and speed, interrupts, etc.)

Now wait a moment. If we reduce the frequency, increasing the runtime of an application, how does this increase battery life? If we are decreasing the frequency, we are increasing the CPU utilization and reducing the % idle time. See the frequency half of Figure A below. This shouldn't have any effect on the power usage of the processor. It's running all that time anyway.

You're right, historically. This was the case years ago with those ancient generations old processors. Though I don't know this for a fact, I suspect that in some cases, decreasing the percent idle time might have increased energy usage since increased processor activity increases instantaneous power, and we're decreasing the % idle time (i.e. time of low activity). This is where voltage scaling comes into play. There are two primary reasons for P-states, one is to reduce the peak thermal load, and the other is to save power.

Reducing peak thermal load

The reasons why you want to reduce the peak thermal load is pretty obvious. The instantaneous energy usage (power) of the processor is related to its activity. If the processor is very busy, requiring a lot of gates to do a lot of switching, it runs hotter. So reducing the frequency reduces the peak thermal output even if the total energy usage is not reduced. The advantage of reducing peak thermal load has to do with cost. The effectiveness of your cooling is based upon peak power, not average power. (I'm neglecting the effect of thermal inertia.) So if you can reduce peak power, you reduce the cost and size of the equipment having to do the

cooling.

Energy usage (W)

peak (very busy)

peak (busy)

peak (not so busy)

decreasing freq

busy

Idle