

Reality and myth in the quest for green computing

GOT THE POWER

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Klaus sorts out fact and fiction in the debate on saving power with some real-world tests. **BY KLAUS KNOPPER**

As the computer magazines all too often report, computers are a big-time waste of energy, and a single Internet keyword search in a browser causes an unexpectedly high peak in power consumption for network components all over the planet, manifesting itself in the results page. Many experts, who are probably related to salesmen, will tell you the “industry standard solution” is to use an operating system that supports all the “advanced power management” features, which will make all electronic parts of your computer significantly more environmentally friendly. Once you start investigating this problem, however, you cannot help noticing that this optimistic assessment is (almost) totally wrong.

In addition, I am not even talking about the extra amount of energy going into producing extra controllers and circuits for improved power management. Perhaps you have heard that many photovoltaic cells require more energy in manufacturing them than they will ever get back from sunlight during their en-

tire life cycle. This observation is not directly related to computers, but it begs the same point.

Most of the benefits in terms of power-saving effects that have been advertised for “intelligent” peripheral or mainboard features seem like a marketing gag once you actually measure the difference (see Table 1).

Power Tests

For my tests, I used three computers: an older Asus L3800C notebook, a new Eee PC model 701, and a medium-aged AMD Athlon XP 2200+ (Figure 1). To rule out any influence of battery charging or peripheral devices, I removed batteries from the notebooks and disconnected all external devices from the computers.

With the use of software controls to switch off internal components like WLAN, a built-in webcam, or a card reader, power consumption did not change significantly; therefore, it was not even mentioned in the results table.

The first surprise (if you were not already suspicious) is that even in the

“switched off” state, all tested computers consume energy – all of them around 4 watts. And I am not talking about Suspend to RAM power here – really, no lights were blinking, and the computers had not been powered up since being connected to the power supply. This situation occurs because modern power supplies are never really physically disconnected, and they need some power for themselves to support handling the button on the front of the computer that says ON. Mechanical power switches that audibly “click” when you press them, thus physically separating or connecting to the electrical network, are considered antique today, and apart from that, they would not allow Resume from RAM, which is a topic I will examine later.

So, in all measurements, you have to take into account that up to 10 watts (for really well outfitted computers or monitors in standby mode) are just wasted away when the computer is actually OFF. At the cost of EUR 0.25 per kilowatt hour, this means that you pay around

EUR 21.90 each year for a computer that just sits there and is not even switched on. (By the way, you might want to look at your TV's power consumption in standby mode now, not to mention coffee machines,)

To prevent this, you could, of course buy a switch like that shown in Figure 2, and some computer shops offer a master-to-slave socket that automatically turns peripheral devices on just when the device in the main socket is switched on. But then, these intelligent sockets still have a current of their own, which might or might not exceed that from the computer itself.

When I powered up the computers (batteries removed), power jumped to 103 watts for the desktop computer (133 watts when adding the TFT monitor), 28 watts for the L3800C notebook, and (the winner is) only 15.3 watts for the Eee PC. Once the computers were up and running Linux, power consumption went down by a few milliwatts because hard disk access had ended; besides, Linux activates some power management features of its own.

Running the computers for a year with this power consumption would cost you (at the rates mentioned above) about EUR 225.57 for the desktop, 61.32 for the L3800C, and 33.50 for the Eee PC. Although I cannot exactly tell you how much CO₂ this produces, at least in comparison, you can imagine that the most power-hungry computer of the three is probably not justifying its performance of two times the speed of the Eee PC from the energy cost side.

Now you might have heard that "computing very hard" consumes more power than just staring at the screen and doing nothing, so I will test this theory by running a little stress test for the three candidates here.

For checking throughput (and occasionally finding bad RAM when *mem-check* does not), one of my favorite tests to make a system really slow and waste resources, is

```
sudo ping -f localhost >&
/dev/null 2>&1 &
```

Each time you call this command, system load, as shown by the *top* utility (Figure 3), increases by about 1, so I start this 10 times to really give the computer something to do. Compiling a kernel with *make -j 10* should do the same trick if you also want to check to see whether the hard disk is making a difference when reading and writing. Because my *ping* commands are causing more "internal traffic" on the system rather than stressing the CPU, I also start *cpuburn* (*burnBX*, *burnP4*, ... depending on the parts of the CPU you want to heat

up). Please be advised that *cpuburn* has the potential really to burn CPUs – at least if they are overclocked or insufficiently cooled (just a warning for the curious).

The results are not really exciting. The Eee PC consumes about 14 percent more power under heavy load and the desktop about 23 percent; the L3800C needs twice as much power now as it did in the idle state, which shows that its CPU is probably the main power consumer here, as opposed to the other two computers.

From the power-saving side, you can't do much about these power maximums and also run at maximum performance because the only choice you have is to compute "less fast," taking maybe twice the time at half the power. This can be done by telling the CPU to go to sleep every now and then between computing cycles, which has been supported by most CPUs since 2000. The Advanced Configuration and Power Interface (ACPI) does this, especially the user interface provided by the Linux kernel.

By entering

```
cat /proc/acpi/processor/
CPU0/throttling
```

you can read which "computing delays" are supported (for the first CPU, you can find more CPUs or "cu cores" by increas-

ing the number after *CPU*), which will look similar to this:

```
state count:      8
active state:     T0
state available:  T0 to T7
states:
  *T0:            100%
  T1:             87%
  T2:             75%
  T3:             62%
  T4:             50%
  T5:             37%
  T6:             25%
  T7:             12%
```

If you enter, as root, the command

```
echo 4 >/proc/acpi/processor/
CPU0/throttling
```

the CPU is only working "half-time" (or so it will feel), also resulting in less power consumption. The reason someone would want to do this is usually less of an ecological issue: The use of less power also keeps the CPU cooler and avoids a noisy fan or cooling device operating when a certain temperature has been reached.

By the way, you can switch off the CPU fan and activate "passive" cooling for many notebooks with the following code:

```
echo 1 >/proc/acpi/
thermal_zone/THRM/
cooling_mode
```

Usually, the ACPI will revert to active cooling and turn the fan on – regardless of this setting – whenever the CPU gets too hot. However, I cannot completely rule out that a particular ACPI BIOS might depend completely on the operating system for turning the fan back on, even at critical temperatures. Therefore, you should check twice for any reports of failed autocooldown before taking the chance of losing your computer's CPU or motherboard in the hope of noise-free computing.

Scaling

Temperature goes up when the CPU produces more heat than it can dissipate, so in order to keep the temperature low, you can just avoid heat by "avoiding work." One way to achieve this is by



Figure 1: I also ran some power tests on an Athlon XP 2200+ desktop system.



Figure 2: Use a switch to prevent power drain from a switched-off computer.

passively (i.e., no fan) cooling the CPU, as described earlier. Another option is through frequency scaling. However, my desktop computer in the test did not support software frequency scaling, so I only tested this technique on the two notebooks.

Depending on the type of CPU, a special kernel *cpufreq* or *clockmod* module has to be loaded for different CPU types. For the Eee PC, this is

```
modprobe p4-clockmod
```

and for the L3800C, the generic *acpi_cpufreq* is sufficient. The command

```
cat /sys/devices/system/
cpu/cpu0/cpufreq/
scaling_available_frequencies
```

shows a variety of frequencies from 112,500 to 900,000 on the Eee PC, whereas the L3800C only has 1,800,000 and 1,200,000 available.

The command

```
cat /sys/devices/system/
cpu/cpu0/cpufreq/
scaling_cur_frequency
```

shows at what frequency the CPU is currently running. By echoing the desired minimum and maximum frequency to

Scaling the Eee PC

The Eee PC CPU's minimum frequency of 112,500 hertz reported by the *p4-clockmod* module is quite low and will morph the desktop into something almost unusable, with its slower than molasses performance, as soon as the kernel automatically scales down the frequency because it has nothing to do. Therefore, I use half of the Eee PC processor's "maximum" frequency as a minimum instead:

```
echo 450000 > /sys/devices/system/
cpu/cpu0/cpufreq/scaling_min_frequency
```

which is sufficient to run the 3D desktop Compiz Fusion smoothly, even when the computer is idle and, therefore, using a scaled-down CPU frequency.

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scaling_min_freq and *scaling_max_freq*, respectively, in the same directory, you can define the limits for automatic scaling (you have to be root to do this, of course).

The effect of scaling CPU frequency down, even to the very minimum on the Eee PC, drops power consumption by only 300 milliwatts – that is, a difference of only 2 percent compared with “maximum performance.” This realization was the first that made me think that I must have forgotten something. But comparing the power consumption of idle vs. “heavy computing mode” on the Eee PC leads to the more likely assumption that the CPU is really not the main power consumer – in that specific notebook anyway.

The *cpufreq* governor is the scheme that determines whether saving power or improved performance is preferred for the CPU. The best compromise is usually the *ondemand* option:

```
echo „ondemand“ > /sys/devices/system/cpu/cpufreq/scaling_governor
```

The *ondemand* governor instructs the kernel to increase or decrease frequency on an as-needed basis. This behavior saves power in idle mode but provides maximum performance when the computer has something to work on. This particular approach gives better results

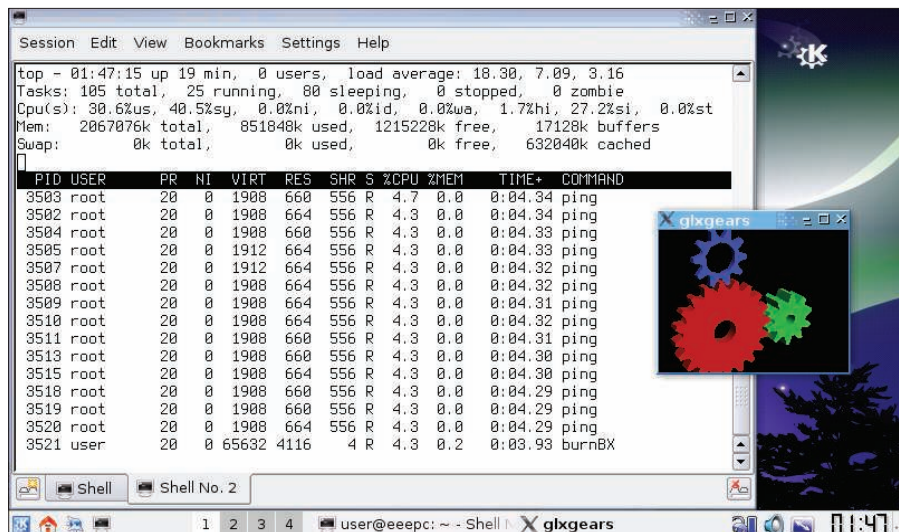


Figure 3: Like other Linux systems, the Eee PC displays system load with the *Top* utility.

mostly on the L3800C, for which the CPU is the main power factor.

Monitors

Switching the computer’s monitor or display off during a pause in processing also can save energy. In my tests, the 19-inch TFT connected to the desktop Athlon system saved 30 watts of power – when the monitor was completely turned off. For the Eee PC notebook, blanking the display (i.e., switching off the background light) saved only 1 watt; however, on the L3800C notebook computer, the savings were about 3 watts, which can extend the battery life by a few minutes. However, this was about

the only peripheral device with a noticeable effect on power.

An interesting design feature related to power savings and efficiency is the display on the “One Laptop per Child” OLPC-XO1. When operating in bright sunlight, this computer does not increase power to the backlight, as a typical notebook necessarily would do. Instead, the OLPC computer has a reflective coating built in to the display so that the sunlight works toward *amplifying* the display contrast. In this way, all graphics and text can be read very well in the difficult conditions of bright sunlight while saving battery power in the bargain. Unfortunately, I have not seen

Table 1: Power Use

		Eee PC (701), Celeron 900 MHz	L3800C, Mobile Pentium4 1.80 GHz	Desktop system, Athlon XP2200+
OFF	Plugged in, but switched off by “power” switch; operating at quiescent current	3.0W	3.0W	4.0W
NORMAL	Booted up into desktop, but no significant system load	15.3W	28.4W	103.0W
ACTIVITY	Stress-testing with <i>ping</i> and <i>cpuburn</i>	17.5W	58.1W	127.0W
S1 (sleep)	ACPI S1 state (hot-standby sleep)	12.9W	23.4W	60.0W
S3 (susp-t-r)	ACPI S3 state (cold-standby sleep with most peripherals turned off; sometimes called Suspend to RAM™)	3.0W	3.0W	–
CPUFREQ MIN/MAX	CPU set to lowest/highest speed (by software) during calculation activity	17.0/17.3W	28.4/42.0W	–
CHARGE	Battery being charged while computer is otherwise switched off	26.8W	14.0W	–
DISPLAY	Power consumption by display/monitor only	2.0W	4.0W	30.0W

this feature in any standard notebook computers yet.

Standby and Suspend

Apart from the use of power-saving modes during normal operation, most computers have the option of going into *Standby* or *Suspend to RAM* mode. Standby mode only turns off a few parts of the board (and probably the display and CPU as well), whereas Suspend to RAM actually freezes the system, including running programs, and saves its state into RAM so that work can resume at a later point in time as if nothing had happened.

Standby (ACPI S1 state) was quite inefficient for all three computers: The Eee PC still needed 12.9 of its 15.3 watts (idle) power, the L3800C still used 23.4 compared with 28.4 watts, and the desktop computer continued to consume 60 of 103 watts in the idle state.

Although the desktop computer did not support ACPI S3, both notebooks dropped power to only 3 watts in Suspend to RAM mode. Before entering this

mode, both had to unload their sound card drivers before executing

```
echo 3 >/proc/acpi/sleep
```

to wake up correctly later. In Suspend to RAM mode, both notebooks lasted up to five times longer on battery, so this is a good choice if you need to relocate while running on battery.

Conclusion

In these tests (and through personal experience running computers), I found that saving power, and thus extending time to run on battery, is less a question of ACPI or *cpufreq* settings, but rather of avoiding unneeded computation, hard disk access, or desktop effects. The Compiz screensaver, with a spinning desktop cube, reflections, and lighting effects, or OpenGL screensavers with fog and texture can waste all attempts at saving power, even in the most sophisticated setups. Sleep states (such as Standby) are sometimes not much help either, although techniques like Suspend to Disk

(which was not discussed here) and, in general, disconnecting the computer from the electrical network completely, rather than just switching it off, are the best methods of saving power.

Standby power consumption is indeed alarming if you take into account how many electrical devices – and not just computers – use standby mode today. Trying to get an old computer to use less power with software (i.e., underclocking, idle states, or frequency scaling) is almost surely a futile attempt. Sometimes just buying a smaller, less power consuming computer can help more than any promise by vendors of supported power-save modes, which typically do not really save significant power compared with the idle state. The Linux kernel as preconfigured in all modern distributions is already doing its best to avoid unnecessary work by its CPU and peripherals, so eliminating CPU-intensive “background tasks” gets the machine into the idle/power-saving state easier than a fancy setup with a manually created power configuration. ■



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