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Energy efficiency of computer power supply units

prepared by

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This study was carried out on behalf of the Swiss Federal Office of Energy. All contents and conclusions are the sole responsibility of the author.

Please refer to the following website for additional information concerning the Swiss Federal Office of Energy "Electricity" programme:

www.electricity-research.ch

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Kurzfassung/Résumé/Abstract

Energieeffizienz von Computer Netzgeräten

Der Wirkungsgrad von Netzgeräten für Computer liegt bei einer Auslastung der Netzgeräte von über 20% zwischen 60% und 80%. Bei tieferer Auslastung sinkt der Wirkungsgrad rasch ab. Im praktischen Betrieb von PCs (Arbeitspunkt „ruhender Bildschirm“) wurden Auslastungen der Netzgeräte zwischen 14% und 25% und ein durchschnittlicher Wirkungsgrad von 66% gemessen.

Das benötigte Spannungsniveau auf der Ebene der Prozessoren beträgt heute nur noch 1.5 V und wird in Zukunft weiter sinken. Dazu wird die im Netzgerät produzierte Gleichspannung – typischerweise 12 V und 5 V oder 3.3 V - unmittelbar beim Endverbraucher nochmals auf ein tieferes Niveau transformiert. Für die ganze Kette von 230 V Wechselspannung bis hinunter auf 1.5 V Gleichspannung resultiert damit ein Gesamtwirkungsgrad von etwa 50%.

Die wichtigsten technischen Massnahmen zur Erhöhung der Energieeffizienz der Stromversorgung von IKT-Geräten sind:

- Verwendung eines Netzgerätes, das dem Leistungsbedarf des Endgerätes angepasst ist und bei einer Auslastung von 50% und mehr betrieben wird;
- Separat ausgelegte energieoptimierte Stromversorgung für den Betrieb der IKT-Geräte im Bereitschafts- oder Standby-Zustand.

Das technische Stromeinsparpotential dieser beiden Massnahmen liegt für PCs bei einem Drittel des heutigen Stromverbrauchs.

Auf politischer Ebene werden zwei prioritäre Stossrichtungen empfohlen:

- Einführung einer Energiedeklaration für Netzgeräte;
- Verschärfung der Anforderungen an den maximalen Leistungsbezug der IKT-Geräte im Bereitschafts-, Standby- und Aus-Zustand sowie Ausarbeitung von ähnlichen Anforderungen für den Leistungsbezug im On-Zustand.

Efficacité énergétique de l’alimentation en courant des ordinateurs

Le degré d’efficacité des alimentations en courant électrique pour les ordinateurs se situe entre 60% et 80% si l’alimentation est utilisée à plus de 20% de sa capacité nominale. L’efficacité tombe rapidement pour des taux d’utilisation plus bas. Lors d’une utilisation pratique d’ordinateurs personnels (point de travail "mode on, mais faible activité des processeur"), nous avons mesuré des taux d’utilisation de l’alimentation entre 14% et 25% et une efficacité moyenne de 66%.

La tension électrique des processeurs modernes est de 1.5 V et descendra encore plus bas dans l’avenir. Les niveaux de tension à la sortie de la boîte d’alimentation se situent entre 12 V et 3.3 V et sont ajustés au niveau final requis à l’endroit même de l’utilisation. Le degré d’efficacité de toute la chaîne de transformation de 230 V en courant continu à 1.5 V en courant continu atteint ainsi environ 50%.

Les mesures techniques les plus importantes pour augmenter l’efficacité de l’alimentation en courant électrique des équipements TIC sont:

- utiliser une boîte d'alimentation adaptée à 50% et plus de sa capacité nominale;
- concevoir une alimentation en courant séparée pour les modes d'utilisation standby des équipements TIC.

Le potentiel technique des économies de courant électrique est de l'ordre d'un tiers pour les ordinateurs.

Au niveau politique nous recommandons deux stratégies d'action:

- introduction d'une déclaration énergétique pour les boîtes d'alimentation;
- renforcement des exigences relatives à la puissance électrique des équipements TIC dans les modes standby et off ainsi que l'introduction d'exigences similaires pour le mode on.

Energy efficiency of computer power supply units

The efficiency of computer power supply units operated at least 20% of their nominal capacity is between 60% and 80%. At lower capacity levels, the efficiency decreases rapidly. For PCs in actual use (= switched on but with low processor activity), the operating points of power supply units were found to be between 14% and 25% of nominal load, while their mean energy efficiency was around 66%.

The voltage level required by modern processors is already as low as 1.5 V and will drop even more in the near future. The DC output levels of a power supply unit are usually between 12V and 3.3V, and a secondary (or even third) power transformation is needed at the electronic component itself in order to reach the 1.5V level. The resulting overall efficiency of power supply units is therefore around 50%.

The most important technical measures to increase the energy efficiency of power supply units for IT and communications equipment are:

- using power supply units with an adequate nominal capacity in order to reach load levels of 50% or more;
- using a separate power supply unit that converts from 230V AC to 1.5V DC for low power modes of the ICT equipment.

For PCs, the savings potential of these two measures is around 30% of present-day electricity consumption.

At the policy level we recommend pursuing two strategies:

- introducing an energy declaration for power supply units;
- tightening the requirements placed on maximum loads for IT and communications equipment in low power modes, and defining similar requirements for the power loads in the on-mode.

Summary

In the field of IT and communications equipment, it is well known that the energy losses associated with the power supply devices (mains adapters, power supply units) represent a significant proportion of the overall energy losses of these devices. At the request of the Swiss Federal Office of Energy, and with the financial support of the Canton of Geneva, this problem was examined in a study, which set out to determine the dependency of the degree of efficiency on the load of the power supply unit, and determine the load for typical applications. We describe a variety of potential measures for increasing the degree of energy efficiency, and formulate a number of recommendations for the attention of the Swiss Federal Office of Energy.

Power supply units produce different voltages: the typical range is between 3.3V and 12V. When converting 230V alternating current into 12V direct current, the degree of efficiency is between 70% and 80% if the load is greater than 20% of the nominal capacity of the power supply unit. If the load is below this level, the degree of efficiency drops rapidly. In the majority of the devices tested, the degree of efficiency of the output at 5V is comparable to that of a 12V output. If the output at the lower voltage level is derived from a 12V or 5V current via a downconverter – which was the case for all 3.3V (as well as for some of the 5V) outputs measured in our study – the degree of efficiency falls by around 10%.

In practice (device switched on, but at low level of activity), the load on the power supply unit is between 14% and 25% (measurements recorded for five PCs). At this low load level, they are within the sharply falling zone of the efficiency curve. The degree of efficiency is correspondingly low, namely 66% on average. The required voltage at the processor level is now only 1.5V and will be even lower in future. The voltage produced in the power supply unit is therefore further transformed. This means that, throughout the complete chain of conversion from 230V AC down to 1.5V DC, the overall degree of efficiency is approximately 50%.

The most important measure to enhance energy efficiency is the use of a power supply unit, which is adapted to the power consumption of the end device. The target should be a load of at least 50% with a maximum degree of efficiency of the power supply unit. According to initial basic estimates, if all PCs in Switzerland were to be operated in this way, it would be possible to save around 55 GWh p.a. (= 16% of total electricity consumption by PCs).

Nowadays, the power consumption in the on- and standby mode of many devices in the area of IT and communications equipment is often only a few watts, or in some cases even milliwatts, which is equivalent to (or even well below) a few per cent of the specified nominal capacity. In such cases, it would be desirable to separate and optimise the power supply from the mains socket down to the low-voltage DC. This would drastically reduce energy losses in the power supply unit in active, standby and off modes, and lower the power consumption of, for example, a PC in off-mode from 4 W to 1 W. According to initial basic estimates, if all PCs in Switzerland were to only consume 1 watt in off-mode, it would be possible to save around 62 GWh p.a. (= 18% of total electricity consumption by PCs). If both these measures were to be implemented, this would result in total savings of around 117 GWh p.a.

We therefore wish to make the following recommendations to the Swiss Federal Office of Energy:

- to extend the research on power supply units to the whole chain of power supply of components, devices and systems;
- to incorporate the findings of this study into educational material for IT students;
- to launch an initiative on an international scale calling for an energy declaration for power supply units;
- to pursue the activities associated with the updating and further development of energy labels in two directions:
    1. tightening up requirements on the power consumption of IT and communications equipment in standby and off-modes.
    2. Defining requirements for power consumption in active mode.

1 Background, purpose of study, methodology

Electricity consumption in Switzerland in the area of IT and communications equipment is equivalent to approximately 10% of total national consumption (Aebischer et al., 2000); roughly half of this is attributable to office equipment and consumer electronics, while the other half is attributable to electronic components that are used in buildings, vehicles, production lines and general consumer goods. Despite extremely rapid technical improvements[1] at processor level, electricity consumption in this field is constantly on the rise due to increasingly widespread and ever more intensive use of the existing services and the diffusion of new ones.

Studies and pilot projects – including those carried out within the scope of the Swiss Federal Office of Energy "Electricity" research programme – have revealed that it is possible to achieve significant additional savings in energy if the most efficient devices available on the market (laptops, LCD monitors, innovative printers) and existing power management systems are utilised, if networks are optimised in terms of both concept and operation from the viewpoint of energy consumption, and if the infrastructure required for the operation of electronic equipment is designed and operated in line with the principles of energy efficiency.

Infrastructure includes power supply, which, for smaller mobile devices, normally takes the form of batteries and accumulators, and for larger-scale systems, is generally in the form of internal power supply units. A number of studies have been carried out on energy losses resulting from recharging devices, particularly in view of the extremely rapid development in the area of mobile phones and the growing awareness of the high standby losses associated with battery chargers, and these studies have led to a variety of political measures (e.g. voluntary agreement with the European Commission[2]). Far fewer studies have been carried out on internal power supply units, mainly because they are not so easily accessible, but also because they require considerably more complex testing procedures. A ground-breaking study called "The Hidden Juice Guzzlers" (SFOE 1993) drew attention to the benefit of switched network components versus standard components with large, heavy 50-Hz transformers and high standby losses. The use of switched network components can increase the degree of efficiency from 30-50% to 60-90%. In the meantime, it has become clear that, in normal operating mode, office equipment and consumer electronics devices typically only have a power consumption of around 30% up to a maximum of 50% of the nominal capacity, and that systems and appliances designed in line with the nominal capacity – in particular, ventilation and air-conditioning systems intended for the removal of ambient heat – tended to be greatly over-dimensioned. What impact this partial load operation has on the relative energy losses of electrical appliances is little known to date and has generally been overlooked.

The energy losses associated with power supply devices in the area of IT and communications equipment represent a significant portion of overall energy losses. The efficiency of power supplies is typically between 60% and 70%, but varies greatly according to the load on the device (i.e. the point at which the power supply unit is operated), and

[1] The specific consumption per computer operation or transmission of information has been constantly falling by a factor of 100 every ten years since the introduction of computer technology in the early 1950s!

[2] Code of conduct concerning efficiency of external power supplies, dated 15 June 2000

drops significantly at lower load levels, e.g. when the device is in sleep mode (or when power supplies are used redundantly). No information is available from manufacturers (in the form of goods declarations) concerning variations in efficiency levels in relation to load. More detailed knowledge concerning these losses is the basis for defining technical and political measures aimed at reducing energy losses in power supply units used in the area of IT and communications equipment.

In the same way as in the building sector, when planning suitable measures, the question arises as to whether energy requirements should be defined for end devices (e.g. PCs) or specified for individual components (e.g. power supply units). One of the benefits of formulating technical specifications for power supply units is that they comprise an important energy-related component of all electronic devices. At the same time, it is possible to provide additional impulses for solving difficult questions by relating energy requirements to devices in normal operating mode (e.g. for PCs).

In view of these considerations, this study set out to answer the following questions on behalf of the Swiss Federal Office of Energy, with financial support from the Canton of Geneva and the assistance of SWICO (Swiss Trade Association for Information, Communications and Organisation Technology) and CEPE (Centre for Energy Policy and Economics):

- what is the degree of efficiency in relation to the load at typical power supply units in PCs and network communications equipment?
- What are the typical loads on PCs?
- How does the degree of efficiency vary according to the ways in which PCs are used?
- Which players would be able to contribute to a higher level of efficiency, and through which measures?

The following steps were defined for dealing with these questions:

- determination of the load of typical PCs and network communications devices.
- Procurement of power supply units for use in the area of IT and communications equipment, plus the necessary technical documentation for measuring efficiency levels.
- Detailed measurements of efficiency levels in relation to load and other characteristics of power supply units of relevance to energy consumption.
- Determination of the degree of efficiency of PC power supply units under working conditions.

These tasks proved to be unexpectedly complex and time-consuming, and we were only able to resolve them satisfactorily with the support of a number of specialists who are not cited as co-authors of this report. We would especially like to express our sincerest thanks to:

- Bruno Oldani (IBM Switzerland) and Rolf von Reding (HP Switzerland) for their technical support and for providing us with various devices.
- Professor Johann Kolar and his colleagues, Dr. Joachim Bazali and Peter Albrecht, from Power Electronic Systems Laboratory at the Swiss Federal Institute of Technology, Zurich, for their technical support and for placing both premises and testing equipment at our disposal.

- Dr. Hubert Kaeslin, Microelectronic Design Centre at the Swiss Federal Institute of Technology, Zurich, for his valuable advice concerning matters relating to the power supply of electronic components.
- Johann Miniböck for his expert experimental studies concerning the degree of efficiency of power supply units.
- Jürg Marti for his valuable assistance with measuring the first series of power supply units.
- Armin Brunner and Thomas Lier from the Communications and IT Services section and Franz Kuster and Willi Furter from the IT Services Helpdesk, both at the Swiss Federal Institute of Technology, Zurich, for kindly placing power supply units at our disposal.

2 Power supply of IT devices

The various electronic components require DC-voltages of only a few volts. In a power supply, the 230 V AC mains power is rectified and transmitted as low-voltage DC. In IT devices, power supply units normally produce the following voltage levels:

- 12V
- 5V
- 3.3V

CMOS has become the standard technology for switching. Up until about 1992, the most widely used supply voltage was 5V, but since then the level has been lowered successively in order to account for the disruptive strength of the gate dielectric and the risk of harm to the drain-source line due to avalanche breakthrough. As the dimensions grow ever smaller, it is only possible to avoid inadmissible field strengths by using correspondingly lower power supply levels or, if necessary, other materials. Current know-how suggests that this trend is likely to continue into the 0.6V to 0.9V range (Kaeslin, H., 2002b). One of the desirable secondary effects of this trend is that the power consumption required for switching purposes has also been reduced, since this is proportional to the supply voltage. With present-day 0.13µm technology, the supply voltage of processors has dropped to 1.5V. At this voltage level, a current of 33 A is required for a power consumption of 50 W. In order to avoid lengthy feeds, the 1.5V power supply is produced in a DC-DC converter immediately next to the processor or even directly within the chip. In modern PC mainboards, the 5V power supply is only of secondary importance (proportion of power supply unit, 2-3%). Approximately 2/3 of the capacity is drawn from the 12V bar, and the remaining 1/3 from the 3.3V bar (Windeck, Ch. 2002). Where necessary, these voltages are converted downwards from these levels on the board itself. According to information provided by manufacturers, DC-DC converters have a degree of efficiency of between 60% and 95% (typical range = 80-90%). The levels of efficiency of strictly on-chip converters without external capacities and inductance are probably lower (Kaeslin, H., 2002a).

A typical power supply unit in devices in the field of IT and communications equipment (with the exception of some audio appliances) is based on the technology of primary phased switching regulators. Here, the mains voltage is rectified and a switching regulator produces an alternating current with a frequency in the range 20 to 200 kHz. The potential separation is carried out with a high-frequency transformer and the secondary voltage is subsequently rectified and screened, then passed on to the device. The switch on the primary side (cf. Fig. 2-1) is used for regulating the direct current. The main advantages of this technology are its relatively high degree of efficiency and the small size and low weight of the high-frequency transformer. It is frequently the case that 12V and 5V power supplies are produced directly, and the 3.3V power supply is derived from the 5V source via converters. Then the degree of efficiency of the 3.3V power supply is approximately 10% lower than the other voltages. For the production of a 5V standby power supply, all the function blocks have to be separated in order to obtain an acceptable level of efficiency at low capacity (recommendation cited in ATX specification, max. 2.5 A = 12.5 W). From the exterior, it is possible to switch off the load component using the *PS/ON* signal (e.g. when the device is switched to standby mode and power is only drawn from the +5V SB pin).

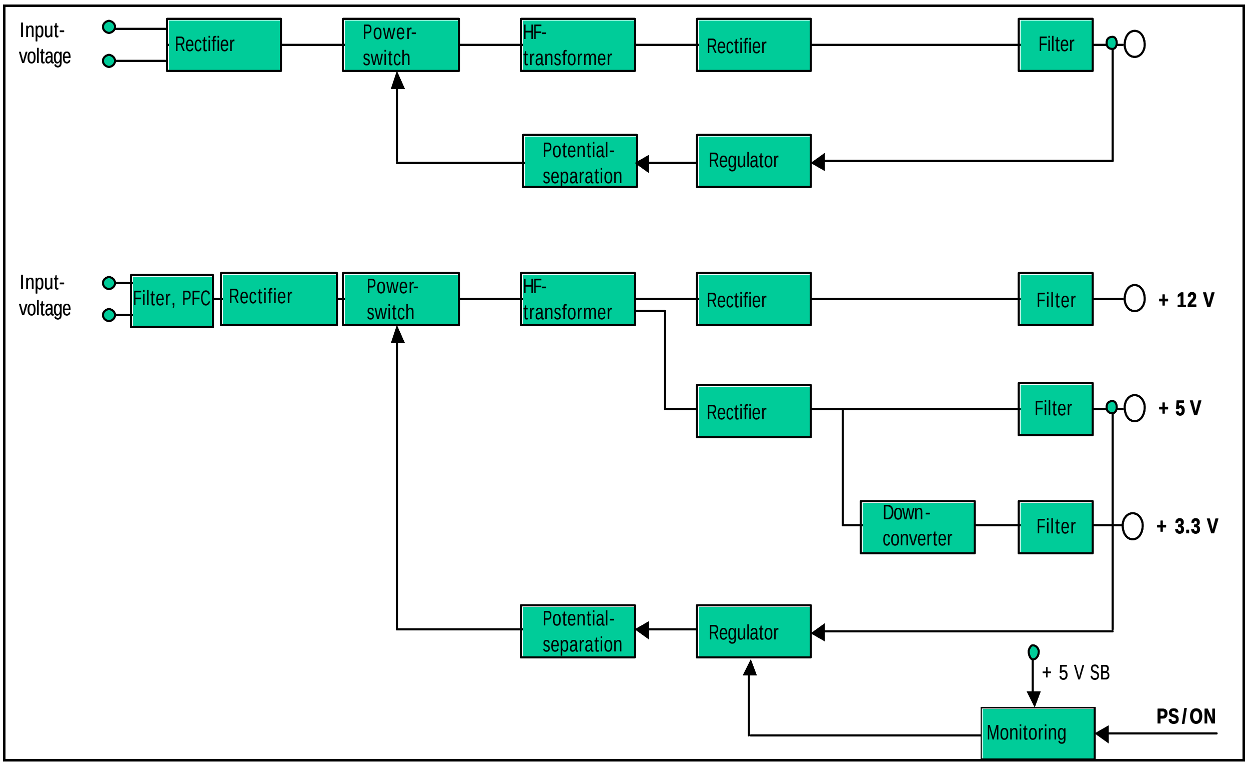

Fig. 2-1 Simplified function block diagram of a power supply unit for PCs

3 Testing arrangement

In order to determine the degree of efficiency at various loads, the outputs of the power supply unit are subjected to a variable and adjustable load (cf. Fig. 3-1).

The +12V output is loaded via a high-capacity IGBT module in constant-current mode. The gate voltage of this module is set using a potentiometer so that it is possible to specify the current level.

The +5V or +3.3V output (U2) is also loaded using an IGBT module. Due to the higher gate threshold voltage, this module is controlled via an external DC power supply unit (U4) and represents a constant-current load.

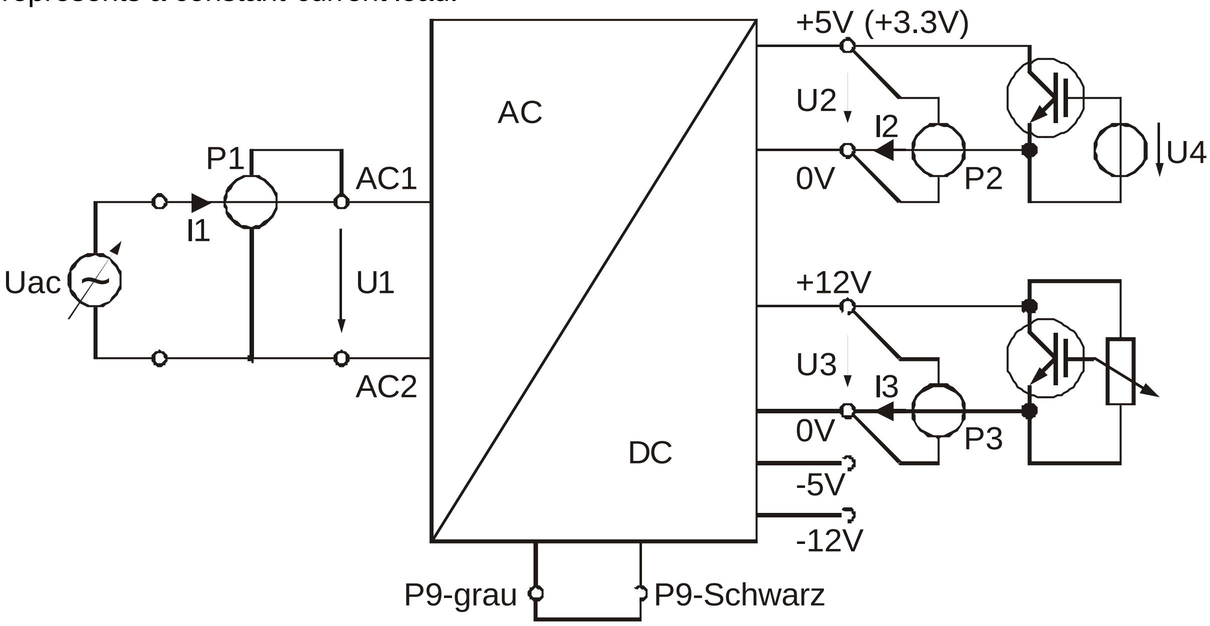

Fig. 3-1 Measurement circuit for calculating the degree of efficiency of a power supply unit

All currents, voltages and loads were simultaneously recorded in an LEM NORMA Power Analyzer NORMA 4000, thus ensuring consistent results. The specified precision of this device is ±0.1% per current or voltage channel, which means that the degree of precision of capacity measurement per channel is ±0.2%. The overall degree of precision is therefore ±0.4% at worst.

Two power supply units (Lead Year and HP) were measured in fundamentally identical testing conditions using old analogue instruments.

4 Efficiency curve

4.1 Power supply units in PCs

We measured the efficiency of 4 power supply units for PCs:

- Compaq
- Minebea 200W
- Lead Year
- HP

“Lead Year”, “Compaq” and “Minebea” were manufactured in the period from 1990 to 1995, while the HP device dated from 2001.

The nominal output varied from 145 W (Compaq) to 250 W (HP).

When the power supply is converted to 5V and 12V, the degree of efficiency is between 70% and 80% (Figs. 4-1 and 4-2) if the load is greater than 20% of the maximum nominal capacity. Below this load, the degree of efficiency drops rapidly (Figs. 4-1 to 4-3 show examples for the Compaq device).

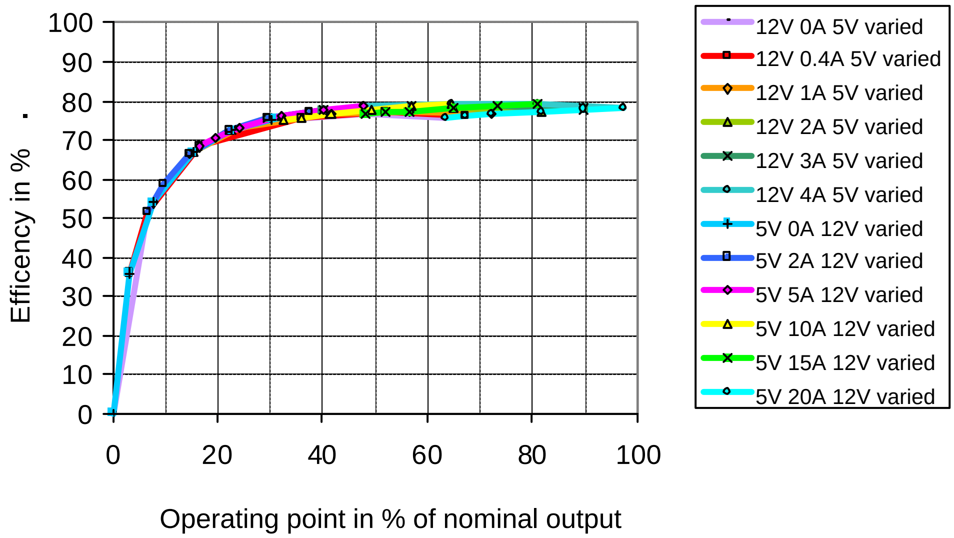

Fig. 4-1 Dependency of the degree of efficiency on the operating point with systematic variation of power consumption (operating point in % of nominal output) via 5V and 12V outputs (Compaq power supply unit)

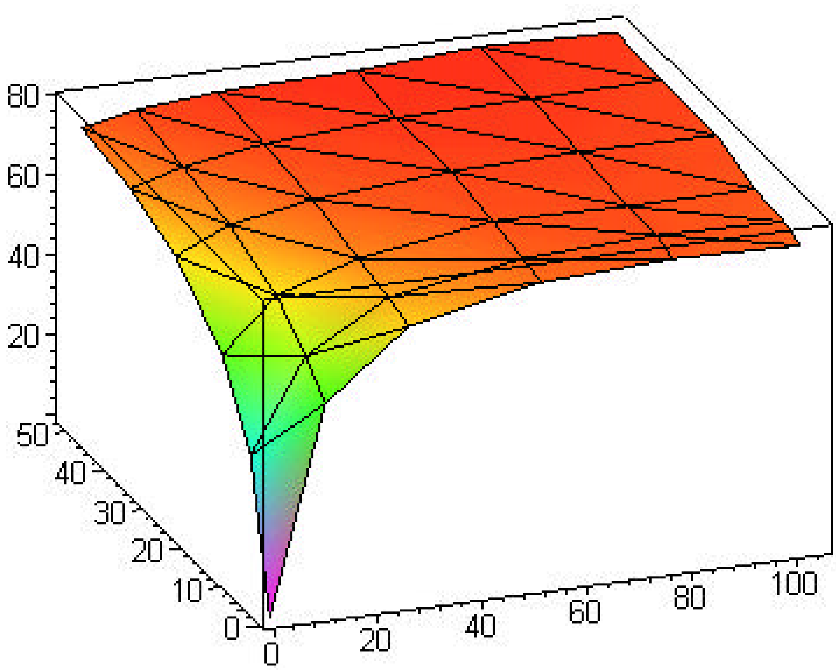

Fig. 4-2 3-D depiction of the degree of efficiency in relation to output capacity P2 (5V output) and P3 (12V output) – Compaq device

If the output is loaded at the lower power supply level of 3.3V, the overall degree of efficiency drops by approximately 10% (Fig. 4-3).

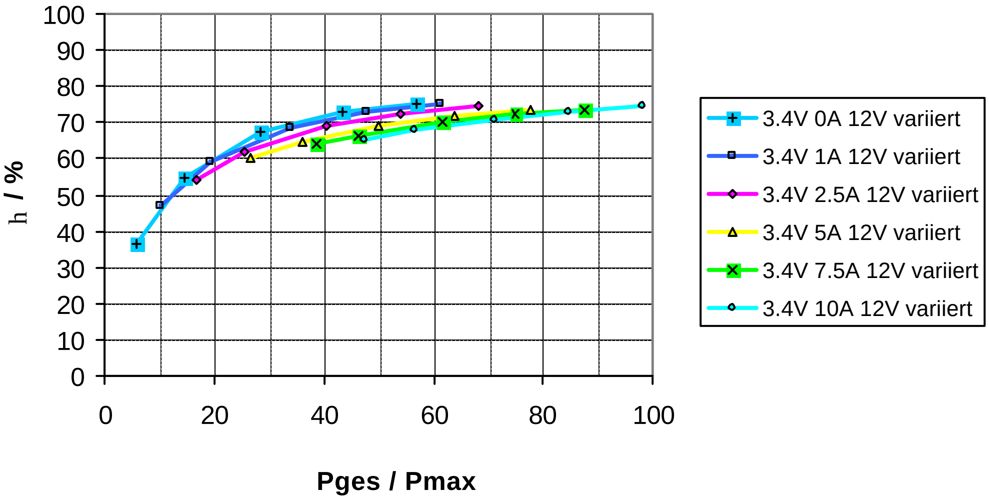

Fig. 4-3 Dependency of the degree of efficiency (h in %) of overall output capacity at varying loads (Pged/Pmax = operating point in % of nominal output) on the 3.4V output and variation of 12V output (Compaq power supply unit)

The degree of efficiency of each of the other three devices was very similar to that of the Compaq device (cf. Appendix for data and detailed evaluations), although with the Lead Year, which has only two levels (12V and 5V), the degree of efficiency of the 5V output was approximately 10% lower and was comparable to the 3.3V output on the Compaq.

The three "older" power supply units were not equipped with a special 5V standby output as has been required for sometime now by ATX specifications (Intel Corporation, 2002). This type of output provides the device with power when the PC has been switched into standby mode (also referred to as sleep mode, suspend to RAM, etc.) by the power management system. The consumption of a PC in standby mode is only a very few watts, so the load is only between 1% and 5% of the nominal capacity. Within this range, a degree of efficiency of between 30% and 60% is achieved using the special 5V SB output, which is a substantial improvement compared to a normal 5V output (Fig. 4-4).

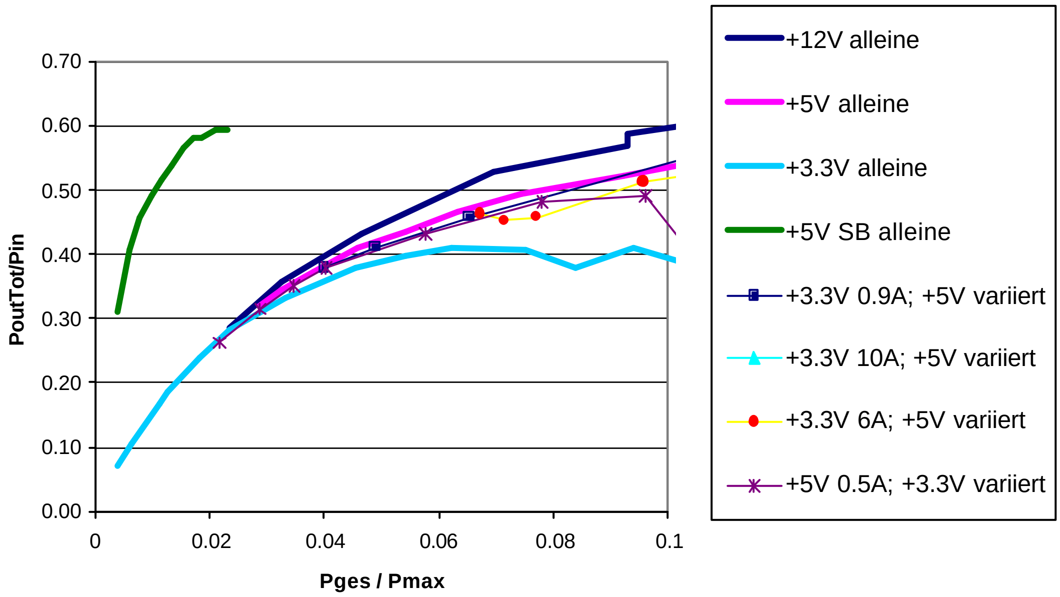

Fig. 4-4 Relation of the degree of efficiency with loads at the individual outputs and with systematic variation of the 5V and 3.3V outputs on the HP power supply unit.

4.2 Power supply units for network communications devices

We measured the efficiency of 2 power supply units:

- Cisco 34-0873-01
- Artesyn Baynet AC/PS

In both devices, the input AC was increased to a common intermediate circuit power supply of approx. 380V. The outputs (12V and 5.2V) are then generated from this common intermediate circuit via independent DC-DC converters (Fig. 4-5).

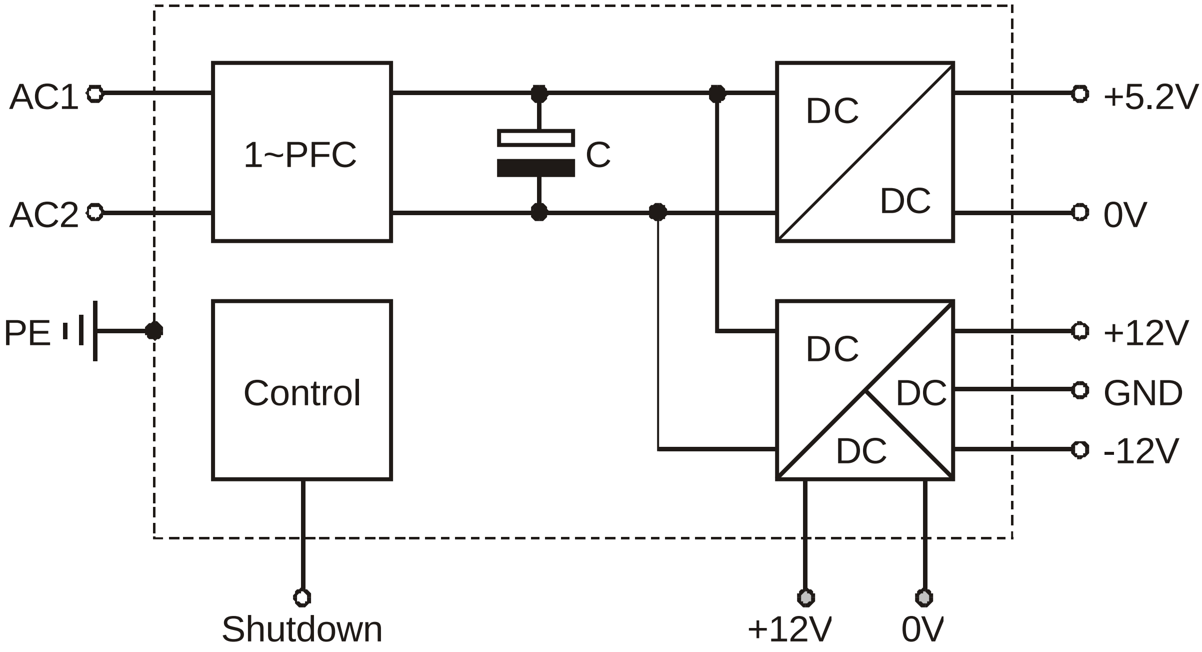

Fig. 4-5 Structure of power supply system

The Cisco device was supplied by Ascom Energy Systems Ltd, and features a 12V output and a broad input voltage range. Its maximum output capacity is 400 W.

The maximum total output capacity of the Artesyn device is 660 W.

When the power supply is converted to 5V and 12V, the degree of efficiency of the Artesyn device is between 70% and 80% (Figs. 4-2 and 4-3) if the load is greater than 20% of the maximum nominal capacity. If the load is below this level, the degree of efficiency drops rapidly. The degree of efficiency is roughly the same as that of the PC power supply units we measured.

As far as the Cisco device is concerned, the degree of efficiency after conversion to 12V is between 80% and 90% (Fig. 4-4) if the load is greater than 20% of the maximum nominal capacity. If the load is below 10%, the degree of efficiency also falls quickly.

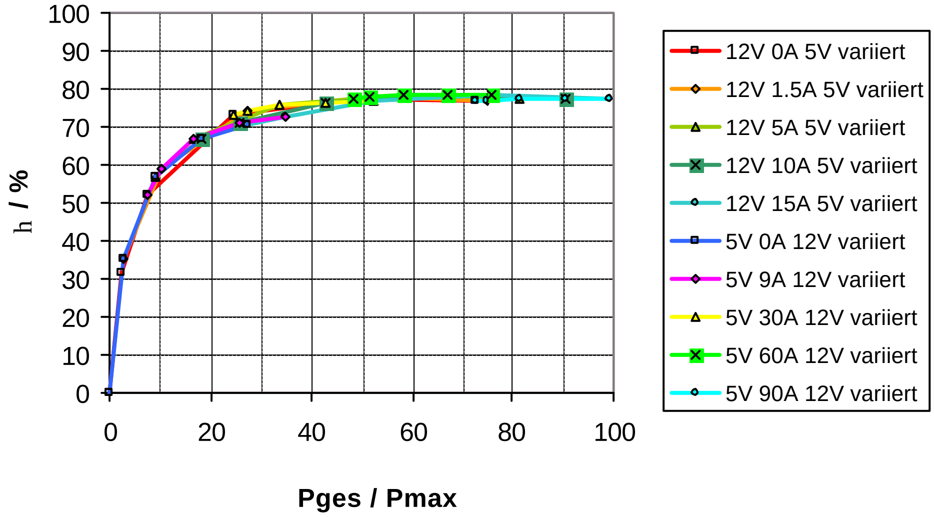

Fig. 4-6 Relation of the degree of efficiency with loads with systematic variation of both outputs on the Artesyn device

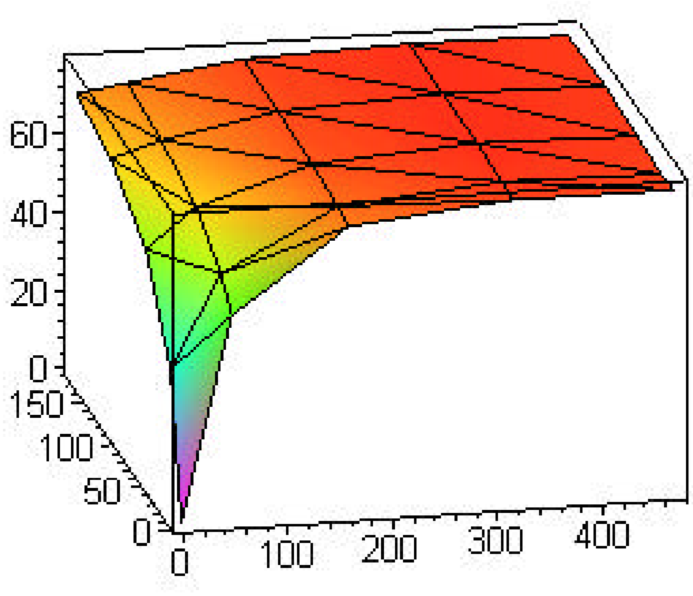

Fig. 4-7 3-D depiction of the degree of efficiency in relation to output capacities P2 and P3 on the Artesyn device

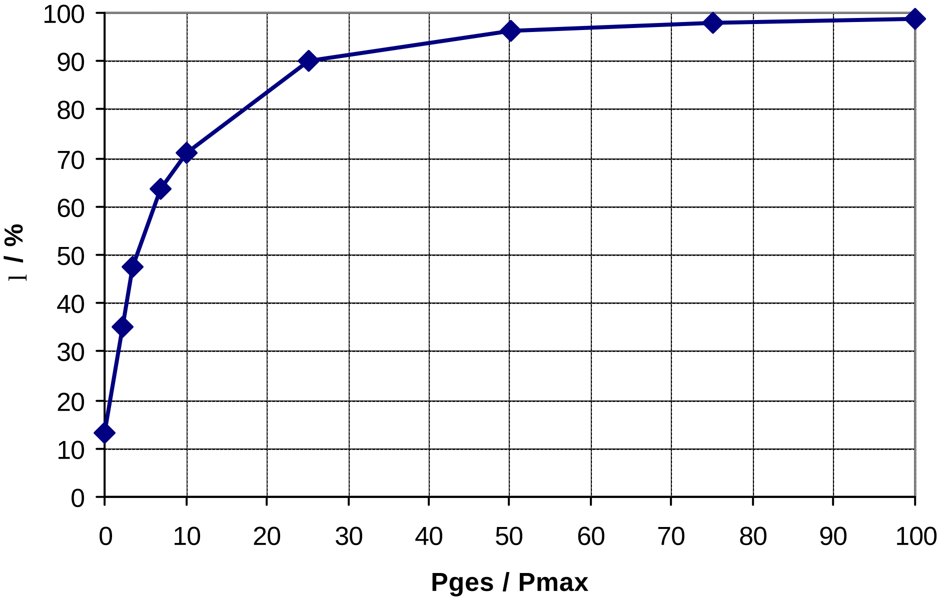

Fig. 4-8 Power factor in relation to the output capacity on the Cisco device

5 Power factor correction and degree of efficiency

5.1 Power supply units in PCs

In power supply units for PCs, the power factor was not corrected until fairly recently, so it is relatively low (50% to 60% at normal load). If the power factor is adjusted passively by introducing series inductance in the input circuit, it is somewhere in the region of 70% to 80% if the load is greater than 30%. If the load is below this level, the power factor is significantly lower (cf. Fig. 5-1). In the same way as for the degree of efficiency, the power factor is lower at the 3.4V output than it is at the 5V and 12V power supply (Fig. 5-2).

By contrast with the Compaq device, the power factor is not adjusted in the Minebea and is therefore around 15% lower in the latter (Fig. 5-3).

With active power factor correction (using a PWM switching regulator), the figure would be between 90% and 100%.

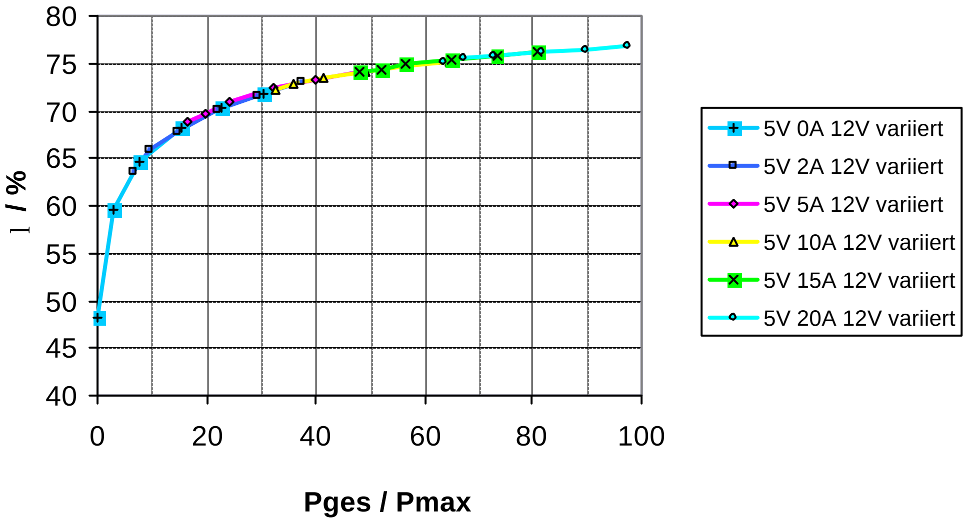

Fig. 5-1 Power factor in relation to the output capacity when the 5V and 12V outputs are under load (Compaq device)

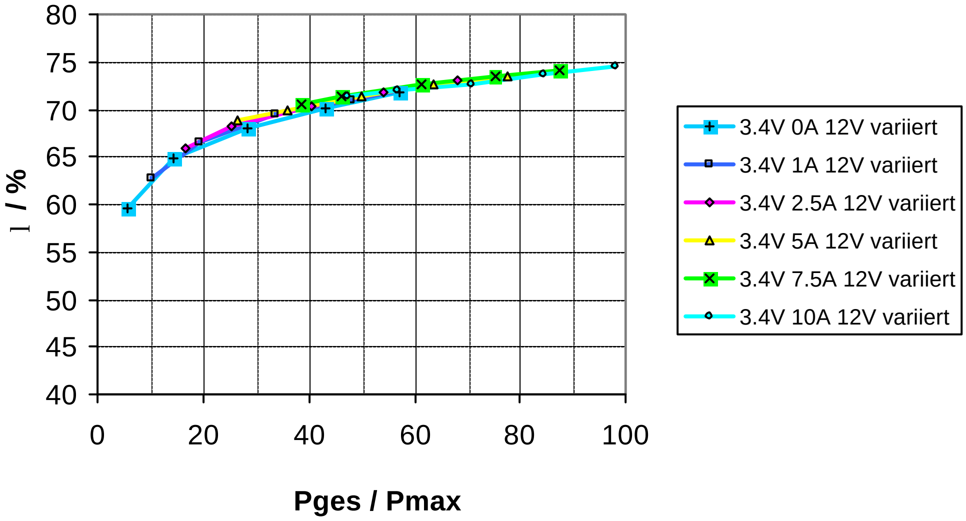

Fig. 5-2 Power factor in relation to the output capacity when the 3.4V and 12V outputs are under load (Compaq device)

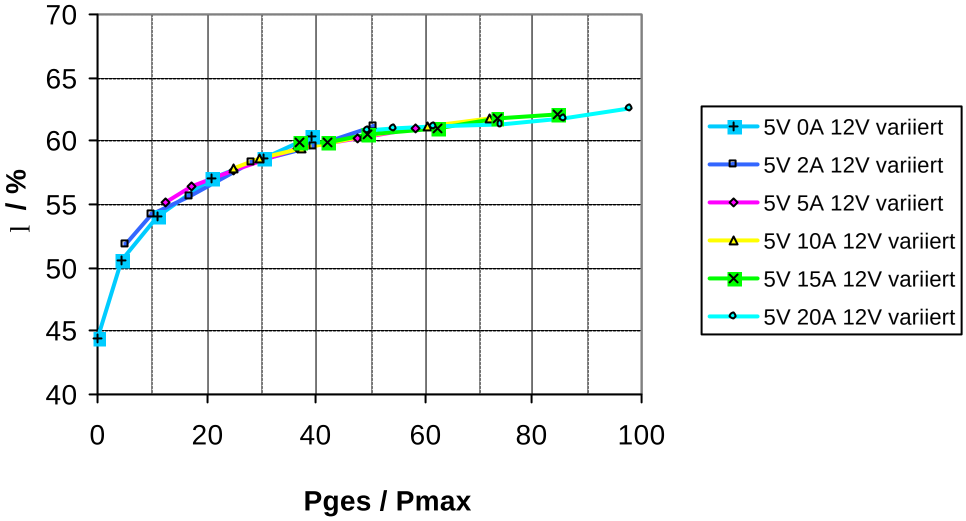

Fig. 5-3 Power factor in relation to the output capacity when the 5V and 12V outputs are under load (Minebea device)

5.2 Power supply units for network communications devices

In power supply units for network communications devices, the power factor is normally corrected via active power factor correction (with a PWM switching regulator). At a load greater than 30%, it is somewhere in the region of 90% to 100%. If the load is below this level, the power factor is significantly lower (cf. Figs. 5-4 and 5-5).

Power factor correction functions significantly better in the Cisco than in the Artesyn.

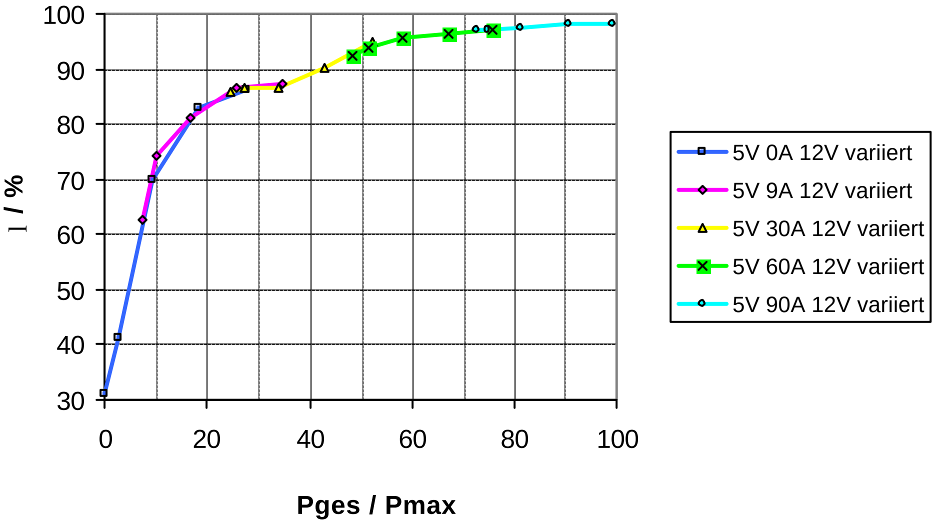

Fig. 5-4 Power factor in relation to the output capacity on the Artesyn device

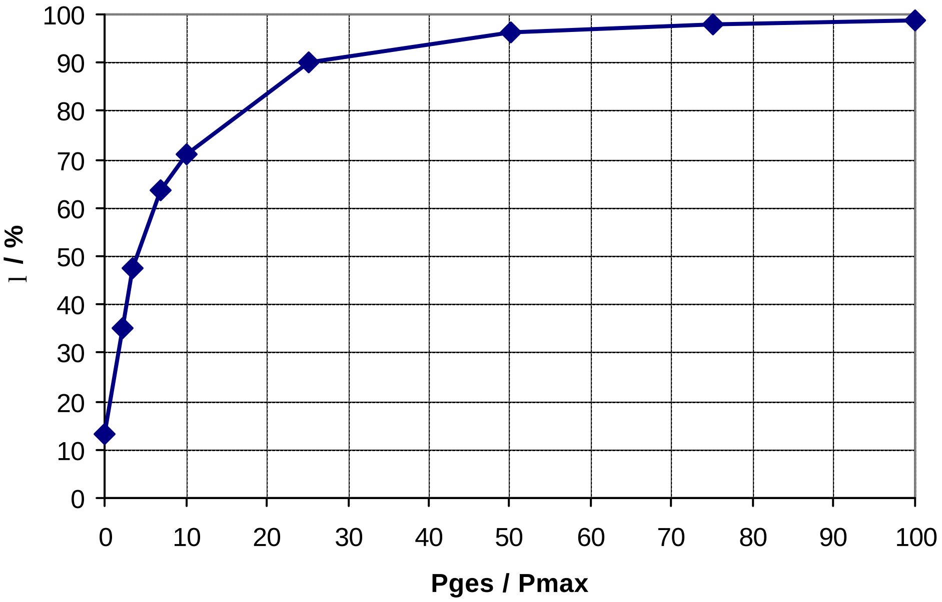

Fig. 5-5 Power factor in relation to the output capacity on the Cisco device

The degree of efficiency of power factor correction is approximately 92% to 95%, whereas a conventional bridge rectifier has an efficiency level of 99%. At lower loads (< 30%), power factor correction no longer makes sense since its effect is negligible and the degree of efficiency is much lower.

6 Operating points

As explained in Chapter 2, the power supply in a PC takes place at different levels. In a power supply unit, intermediate voltages are generated that are then transformed on the mainboard of the computer. As shown in Chapter 5, the overall degree of efficiency of a power supply unit depends on the distribution of the load over the various voltage levels of the output of the device, and on the overall load of the device in relation to the maximum nominal load. We measured the degree of efficiency at various operating points in 5 PCs of different processor generations from Pentium 3, 700 MHz through to Pentium 4, 2.2 GHz (cf. Table 6-1). Here we analysed the following operating points:

- processor fully loaded (= 100%);
- without external influence (activity) with screen in sleep mode: on mode;
- standby mode;
- off.

We measured and calculated the consumption of each device using a power measuring tool at the input and a current meter at the output (Fig. 6-1).

PC	Power supply unit	Nominal capacity of power supply unit [W]	Microprocessor, frequency, RAM	Peripheral components
Indiv. configured	Octek	250	Pentium 3, 866 MHz 256 MB	2 x CD-ROM, ZIP drive, floppy drive, 2 x hard disk
Indiv. configured	PowerMan	300	Pentium 3, 866 MHz 256 MB	2 x CD-ROM, ZIP drive, floppy drive, 2 x hard disk
Fujitsu/Siemens Cordant	Fortron	250	Intel Pentium 3, 700 MHz 128 MB	1 x CD-ROM, floppy drive, 1 x hard disk
HP Vectra VL 420 MT	Lite_ON (HP_1)	250	Intel Pentium 4, 2.2 GHz 256 MB RAM	1 x CD-ROM, floppy drive, 1 x hard disk
HP e-pc 42	Delta Electronics (external) (HP_2)	150	Intel Pentium 4, 1.8 GHz 256 MB	1 x CD-ROM, 1 x hard disk

Table 6-1 Data of devices measured

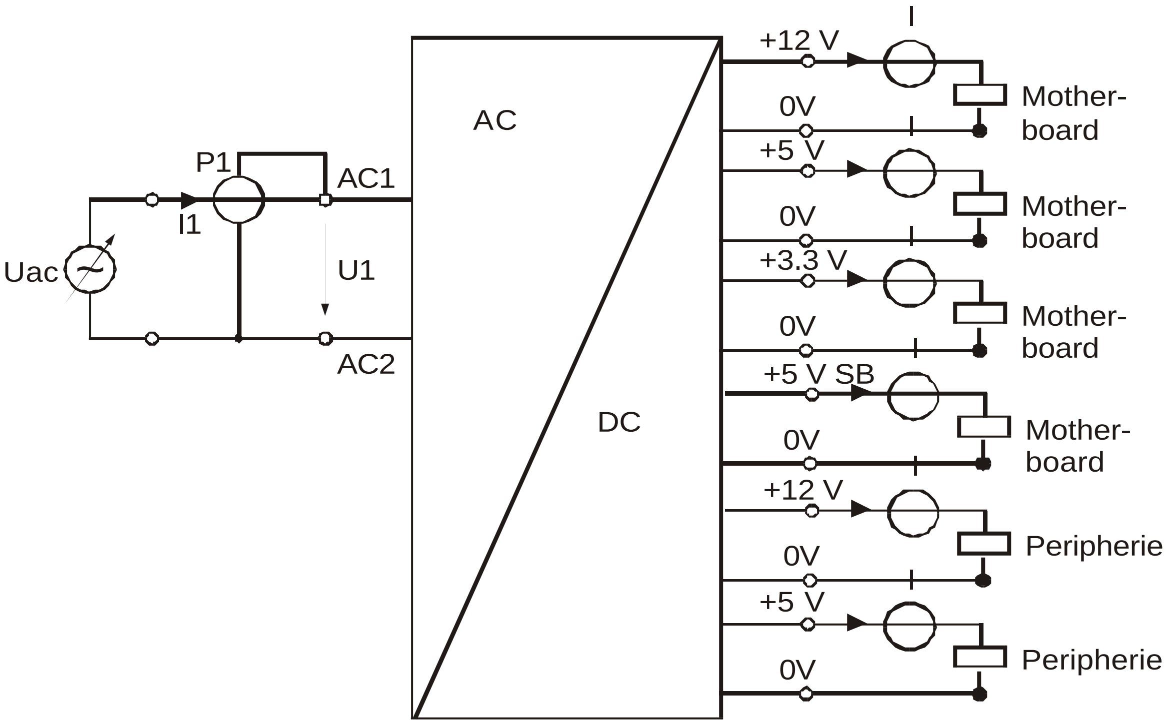

Fig. 6-1 Testing arrangement

The load at the power supply unit (with the screen in sleep mode) is between 14% and 25% (mean level, 20.2%). The associated degree of efficiency is between 57% and 78% (mean level, 65.6%) (Fig. 6-2).

The power supply units produce 3.3V to 12V, but the power supply required at chip level may be as low as 1.5V. For the DC-DC converter required for this purpose, it may be assumed that the mean degree of efficiency is around 85% with switching regulators (down or buck converters) or is between 50 and 65% if linear voltage regulators are used (details provided by manufacturer). This means that the overall degree of efficiency is approximately 50% in the complete chain of conversion from 230V AC down to 1.5V DC.

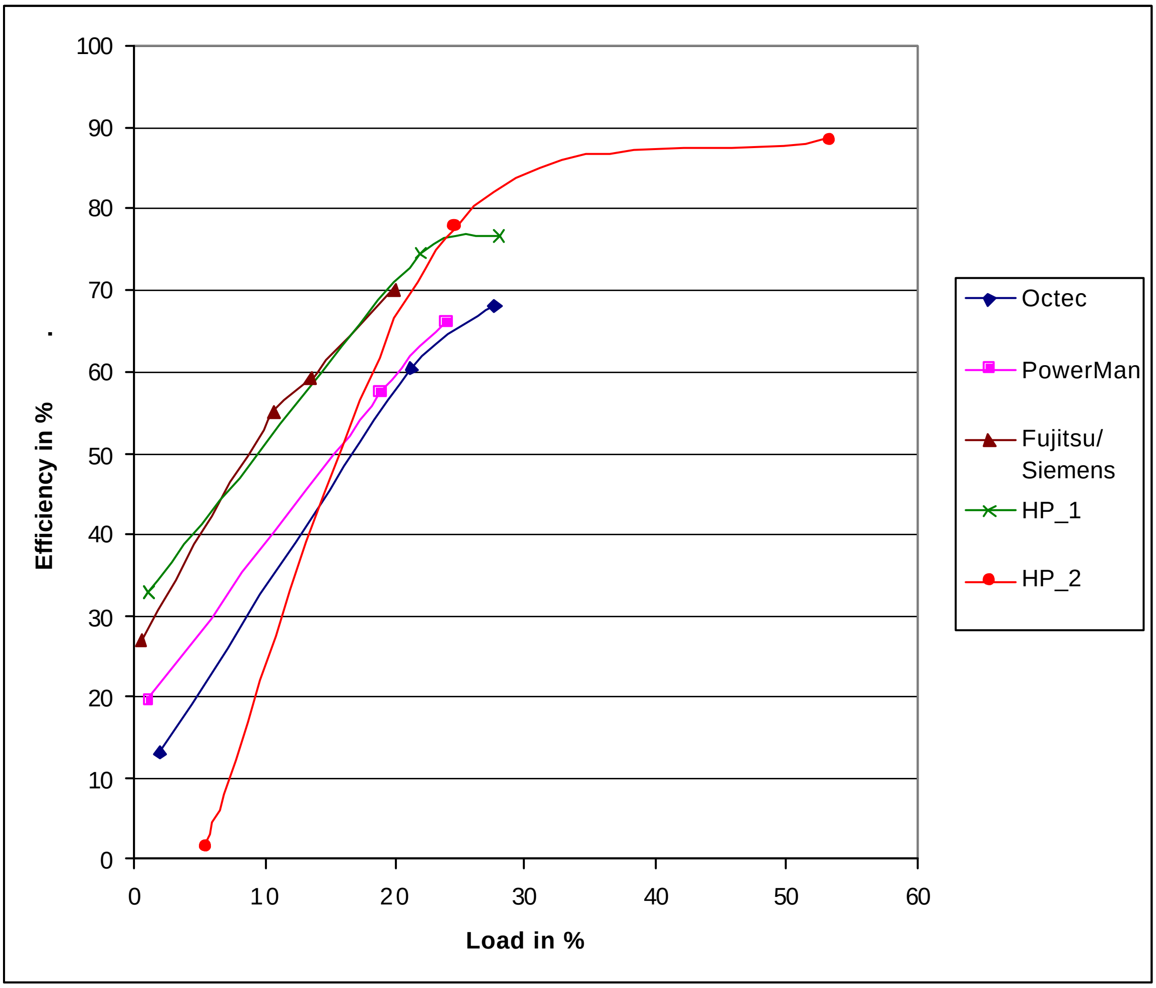

Fig. 6-2 Operating point and degree of efficiency in the PCs measured

In standby and off-modes the degree of efficiency varies from 2% to almost 50%. These large discrepancies result in effective outputs of between 1 W and 8 W at the input.

The HP e-pc model with an Intel Pentium 4 processor draws power from the power supply unit at +12V and +19V instead of the previously more common levels of +5V or +3.3V. Conversion to the processor level of 1.5V is carried out by a DC-DC converter on the motherboard. The power supply unit is not installed in the PC housing, is hermetically sealed and therefore is not equipped with active ventilation. This power supply unit has a very high degree of efficiency at high load.

In three of the tested PCs, the power supply unit is practically only under load on the +5V bar (Table 6-2). In the HP models, the processor places the 12V output of the power supply device under load.

PC and operating mode	+19V	+12V	+5V	+3.3V
Indiv. configured				
Desktop in standby mode	-	14	86	0
Processor under load	-	7	93	0
Indiv. configured				
Desktop in standby mode	-	18	82	0
Processor under load	-	10	90	0
Fujitsu/Siemens Cordant				
Desktop in standby mode	-	15	85	0
Processor under load	-	7	93	0
HP Vectra VL 420 MT				
Desktop in standby mode	-	20	1	79
Processor under load	-	32	1	67
HP e-pc 42				
Desktop in standby mode	42	58	-	-
Processor under load	19	81	-	-

Table 6-2 Distribution of power for mainboard by voltage level in the 5 PCs

It is only possible to remove the high heat load of the processor (typically 30 W/cm^2, compared with approx. 7 W/cm^2 of an electric hotplate) using an active ventilation device, though these tend to cause noise emissions. It is possible to adjust the rotating speed, and thus lower the noise level, using a speed regulator if the heat production can be partially reduced. Modern-day processors adapt their power consumption automatically to the processor load. This is done with the aid of clock gating (the clock frequency is halted), by switching off the power supply to processor components that are not required, or by lowering the clock frequency. In practice, this may have the following effects on operations carried out with an HP e-pc model: when the monitor is in sleep mode, the PC requires a power consumption of 36 W (processor load, 1-4 %); with a 100 % processor load (e. g. active screensaver with complex moving patterns), the PC consumes 63 W, which is equivalent to a 75 % increase.

On a typical working day during which most of the operations carried out were word processing tasks using the MS Office application, “Word”, the mean processor load was 7 % and the mean power consumption was 40 W. At a higher processor load (e. g. tasks carried out by a software developer), the mean processor load increased to 16.3 % (Fig. 6-3) and the mean power consumption was 44 W. These two results indicate that the mean operating point on a PC used at an office workstation does not greatly depend on the type of work carried out, and that the operating point is 10 % to 20 % higher than it is when the monitor is in sleep mode. However, more comprehensive studies would have to be carried out in order to obtain more precise findings with respect to this question.

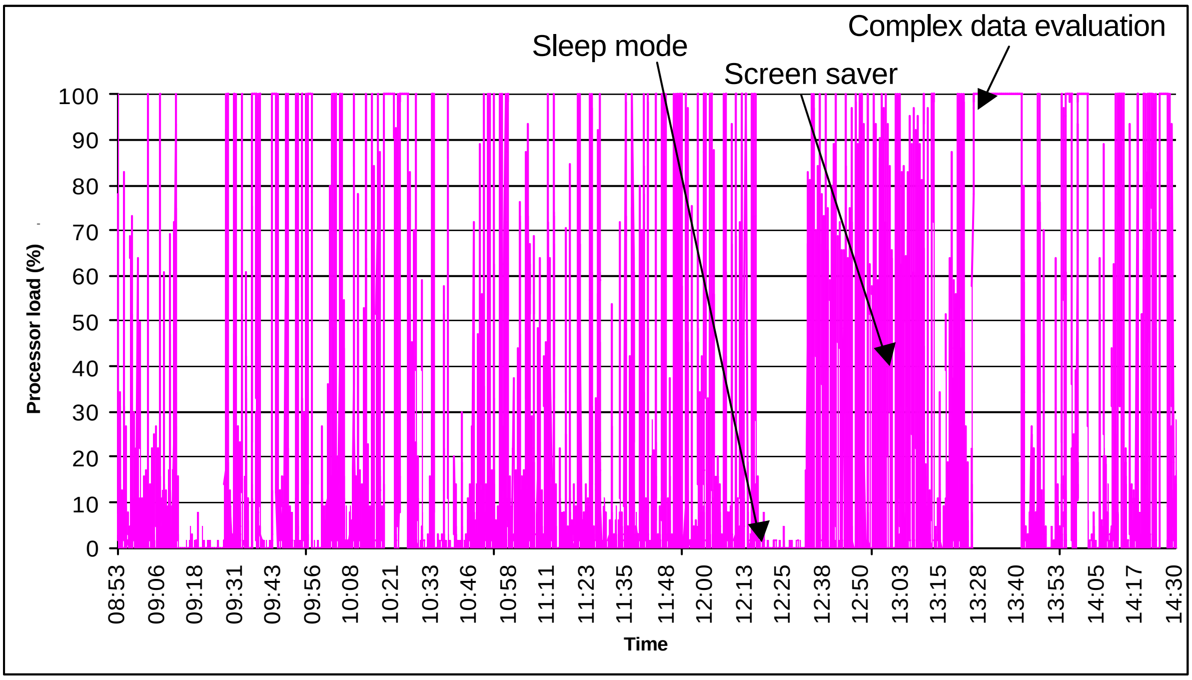

Fig. 6-3 Processor load at a software developer's workstation

7 Measures and potentials for more efficient energy use

7.1 Future trends in power supply of components in the area of IT and communications equipment

The supply voltage for processors will continue to decrease, while currents will increase. At the same time, there will be greater demands with regard to dynamics (rapid fluctuations in current requirements) which will give rise to more decentralised on-site power supplies (Margaritis and Ide, 2001). Primary voltage conversion in conventional power supply units will mean that only one or very few alternating currents will be generated which will then be subsequently distributed in the device (DC-bus) and converted down on the chip to the required voltage (DC-DC conversion).

Therefore, in order to ensure an efficient power supply, this means considering not only the efficiency of the power supply units, but also the efficiency of the DC-DC converters. The project entrusted to us did not entail a detailed study of this question, but it would be possible to pursue this issue within the scope of a follow-up project carried out in collaboration with specialists at the Federal Institute of Technology. However, we do incorporate this new development into our discussion of measures and for the purpose of formulating our recommendations: one of the benefits of placing requirements on the power consumption of equipment rather than on power supply units in the area of IT and communications equipment (e. g. PCs) is that they then encompass the energy efficiency of the overall power supply, including DC-DC conversion.

7.2 Players who (are able to) influence the energy efficiency of power supply units

It was not possible to carry out a detailed analysis of the various players within the scope of the project described in this report. To accomplish this, it would be necessary to segment the market by type of device and area of application (e. g. from the business point of view, division of the market into categories: small/medium-sized companies, large companies, public sector, private consumers). We therefore had to classify the various players in a very broad manner, and their contribution towards the implementation of any specific measures that may be adopted would need to be studied in greater detail.

Alongside the main players in the IT and communications equipment market, as outlined by Calwell and Reeder (2002) (cf. Fig. 7-1), we also have to consider those companies that assemble end-user devices, experts who decide on their final configuration, operators of data centres, as well as power supply companies and any regulators who may enter the equation.

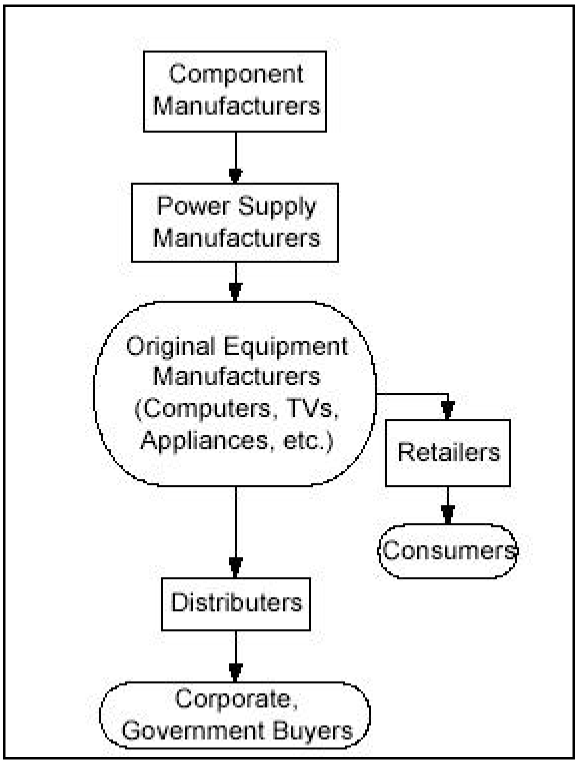

Fig. 7-1 Main players on the IT and communications equipment market (Calwell and Reeder, 2002

Each player has different functions, interests and scope for manoeuvre:

- *manufacturers of electronic components, especially processors:* for the proper operation of their products, manufacturers require an adequate and reliable power supply, as well as certain temperature conditions. These needs gave rise to the formulation of industry specifications governing the arrangement of components in a PC, and to defined requirements on electricity supply (Intel Corporation, 2002).
- *Manufacturers and assemblers of IT equipment:* large manufacturers of IT equipment outsource the development and production of power supply units to companies that are mostly domiciled in the Far East. Some major manufacturers require power supply units to be produced in accordance with their own specifications. Smaller manufacturers and assemblers usually install standard power supply units.
- *Developers and producers of power supply units:* power supply units are produced in large quantities on the basis of existing standards, primarily in the Far East. There are a very large number of suppliers on the market today. In Germany, test reports on ATX power supply units from 14 different suppliers are published in a specialised journal (Steffens, E., 2001).
- *Purchasers of IT equipment:* buyers of IT equipment make their choice on the basis of performance characteristics and investment costs. They are not interested in internal components, as long as these do not affect the equipment's performance and are not associated with undesirable emissions such as noise. Power supply units influence certain performance characteristics of end devices:
  – noise emissions from ventilation devices
  – electromagnetic emissions
  – production of heat.
- *Authorities or individuals who determine the configuration of devices (servers, etc.):* here, we refer to authorities and experts who modify the basic configuration of a device

to suit the specific requirements of the end user. This may range from extending the storage capacity through to the inclusion of options and the configuration of a redundant power supply.

- *End users:* the intended use of a given device and the settings for its power management system greatly influence its operating point and thus its degree of efficiency.
- *Operators of data and computer centres:* before data centres, computer centres and computer rooms can be used, their operators are responsible for securing a reliable and low-cost infrastructure that makes their operation possible. The scope for manoeuvre greatly depends on the type of data centre. In a corporate or dedicated data centre, the operator is responsible for the IT and communications equipment, whereas in a centre based on a collocation arrangement, s/he is only responsible for the infrastructure, and IT and communications equipment are brought in by the client. Within the scope of the study "Energy- and Eco-Efficiency of Data Centres" (Aebischer et al, 2002), one of the questions examined was whether the operator is still able to influence the energy efficiency of IT and communications equipment, and if so, to what extent.
- *Electricity supply companies:* electricity supply networks are burdened with idle and harmonic currents from power supply units. Binding standards (EN 61000-3-2, 2000) exist that regulate electromagnetic compatibility.
- *Regulatory authorities (state) and organisations (professional bodies, trade and industry associations, standards organisations):* a variety of initiatives have been launched concerning very small power supply units (chargers) that have not been dealt with here (e. g. in the EU: code of conduct regarding the efficiency of external power supply units).

7.3 Measures aimed at enhancing the efficiency of power supply units / technological potentials

7.3.1 Proper dimensioning of power supply units (i. e. using devices that are the right size for the task concerned)

Measures

The load on the power supply unit in the 5 PCs tested ranged from 14 % to 25 %. With this low load level, they are within the sharply falling zone of the efficiency curve. The degree of efficiency is correspondingly low, namely around 60 % on average. The degree of efficiency could be increased to around 80 % if the power supply units were configured so that the load would be greater than 30 % while the monitor is in sleep mode. In our opinion, this would still have allowed adequate reserves for peak loads (high processor load, peripheral devices in operation). Manufacturers explain that the high load is due to the reserve that has to be incorporated in order to ensure that the freely expandable device can still be powered without difficulty. However, with the devices we measured, it was simply not possible to install enough in the existing casing to justify the high capacity of the power supply.

A modern-day PC consumes around 40-60 W when the monitor is in sleep mode. For this purpose, a power supply unit should not be configured for more than 100-150 W in order to ensure that it is operated at a "reasonable" load. Today, most power supply units in PCs have an output capacity of between 200 W and 300 W. However, smaller power supply units are also available on the market (e. g. Fortron Source with devices from the Flex ATX series which have an output of 90 W or 150 W).

First of all we had to carry out a detailed study in order to determine whether it is also possible to meet the dynamic power requirements of modern-day PCs using smaller power supply units. Our findings showed that this is, in fact, possible, although these contradict statements by other experts, namely that "for the average computer a capacity of 230 watts needs to be budgeted. Smaller power supply units no longer have the necessary reserves for ensuring stable operation of a computer." (Steffens, E. 2001)

Potential

There are approximately 2 million PCs in use at workstations in Switzerland (Weiss, R. 2002), plus an additional 1.8 million in private households. Based on the following assumptions:

- utilisation time at workstations = 1,870 hrs p.a. in normal operating mode, 330 hrs p.a. in standby mode, and 5,250 hrs p.a. switched off,
- utilisation time in private households = 370 hrs p.a. in normal operating mode, 590 hrs p.a. in standby mode, and 5,500 hrs p.a. switched off (Cremer, C., 2002),
- average power consumption in normal operating mode = 50 W (own estimate),
- average power consumption in standby mode = 25 W (own estimate),
- average power consumption when switched off = 4 W (own estimate),

the total power requirement of all installed PCs in Switzerland (excluding monitors) is calculated to be around 345 GWh. If the level of efficiency of power supply units were 20 % higher in normal operating mode for all PCs, this figure would fall to 290 GWh, a saving of 55 GWh.

Players

The primary players are manufacturers and assemblers of IT and communications equipment. In principle, wherever the configuration of a purchased device is modified to suit the buyer's own needs, there is the potential to ensure that the power supply unit is correctly dimensioned.

At present, it is not possible for end users to make sure that the power supply unit is correctly dimensioned when purchased. If an energy declaration were to be required for power supply units, and if the power consumption of the end device with the monitor in sleep mode were also to be declared, the following rule of thumb could be applied for assessment purposes: nominal output of power supply unit <= 2.5 x output with the monitor in sleep mode, which means that the corresponding operating point would be around 40 %.

Given suitable dimensioning, operators of data centres would be able to significantly reduce the generation of heat in IT and communications equipment, and thus to cut the investment costs associated with the infrastructure. These cost reductions should not be underestimated. Aebischer (1996) cites the findings of Bänninger (1991) in this respect: CHF 20,000 per saved kilowatt of heat. Clients in a collocation data centre could also be asked to apply a rule of thumb in the same way as PC end users (nominal output of power supply unit <= 2.5 x output with monitor in sleep mode). Here, exemption permits could be granted (at a specified fee) for excessive heat generation.

As secondary players, the regulatory authorities and supervisory bodies can make a valuable contribution by placing requirements on the power consumption of end devices (cf. 7.4.3). The introduction of an energy declaration for power supply units would already exert pressure on manufacturers and assemblers, since this would mean that it would be easier for end users to assess the dimensioning of these devices.

7.3.2 High degree of efficiency for standby output

Measures

The required output capacity in off and standby mode (supply via +5V SB power supply unit output as described in Chapter 4) is very low. Power is typically required by the mainboard, network cards with “wake-on-LAN” functions, fax and modem cards on standby and USB devices. According to specifications, the maximum output is 2 A (output capacity 10 W) (Intel Corporation, 2002). However, the PCs tested within the scope of this project require less than 1 W from the 5 V standby output of the power supply unit, which is equivalent to a current of less than 2 mA. This means that, in practice, this component of a power supply unit is also usually greatly overdimensioned.

The requirements of the “Blue Angel” eco-label are that the degree of efficiency of the standby output must be at least 50 % at a load of 500 mA (*the AC input power shall not exceed 5 W when the main outputs are in the “DC disabled” state with 500 mA load on +5V SB and a 230V AC/50 Hz input.)*.

Power supply units should be optimised so that, at low consumption (< 1 W), they attain a degree of efficiency of at least 50 % via this output. The fact that it is technically possible to achieve these requirements was demonstrated as early as the mid-1990s when *Egston* launched an external plug-in power supply unit called *Mainy* with the following specifications:

- Output 6 W at 6 V DC
- Efficiency approx. 70 %
- Efficiency at 150 mA (0.8 W): 50 %
- Measured open-circuit power consumption, 0.6 W (own measurement).

Other manufacturers of switching regulators (e. g. Motorola, Power Integration, and Philips) have defined switching concepts that allow the production of power supply units in the 10 W range with an efficiency of around 70 % and an idle capacity of 50 mW or less.

In its *Code of Conduct on Efficiency of External Power Supplies* (15 June 2000), the *European Commission* negotiated a consumption level of 0.75 W for the idle mode of external power supply units in the 0.3 W to 75 W range (with effect from 1 January 2003). Manufacturers are able to meet this requirement (e. g. quote from the publicity material of Power Integration, www.powerint.com: “*Technology for practically eliminating standby losses already exists – There is no cost penalty associated with an energy efficient design”*). It would also be possible to apply these concepts to internal power supply units.

Electricity is supplied to many devices today via external power supply units. This method was originally intended for mobile devices only, but it is now also used for stationary equipment, especially within the low-end range. External power supply units are designed to provide the end-device with low voltage for standby mode via a special output (similar to ATX specifications for +5V SB), thus optimising the level of efficiency at low loads.

Potential

Measurements made at different power supply units yielded a mean efficiency of 40 % (range, 30 % to 50 %) at a load of 500 mA (Steffens, E., 2001). We assume that the mean consumption of a PC in off-mode is around 4W. In Switzerland, the total electricity requirement for PCs in off-mode is around 82 GWh (based on the same assumptions as cited in Section 9.3.1). If the power consumption in this mode were to be reduced to 1 W, this figure would fall to 20 GWh, thus resulting in a saving of 62 GWh.

Players

The primary players are computer manufacturers, who provide the suppliers of power supply units with specifications for the units that are to be installed in mass-produced end devices. But for many products, the power supply units used are those offered for sale on the general market by manufacturers, and here it is these manufacturers, who influence the level of efficiency. We are unsure whether additional costs are associated with more energy-efficient devices, and how high these may be. Should this prove to be the case, it could represent a major obstacle, since the increase would be much more pronounced if additional costs were associated solely with the power supply unit, than if they concerned the whole end device[3].

Manufacturers of power supply units are under enormous pricing pressure - the delivery price for mass-produced series is around 0.08 US dollars per watt (Calwell and Reeder, 2002) – so they are unlikely to bear any additional costs themselves, no matter how low these may seem.

Regulators would be able to influence both groups of manufacturers by specifying more stringent requirements for energy labels (cf. 7.4.3) for both end devices and power supply units. The introduction of an energy declaration would mean that end users would be able to differentiate between efficient and inefficient power supply units in standby mode.

7.3.3 High efficiency across a broad range of operations for other DC outputs

The maximum efficiency level in the various power supply units is higher in some than in others. We also noted variable plateaux with a good degree of efficiency. Within the scope of this project it was not possible to analyse the technical and economic reasons behind these variations. We also know very little about the potential interactions between the maximum level of efficiency and the maximum breadth of range with high efficiency. It may be possible for experts to answer these questions without undue effort, but here we have to limit ourselves to pointing out this possible way of enhancing efficiency, without looking more closely at the potentials and players involved. In section 7.4.2 we shall refer briefly to this question again within the scope of our discussion concerning technical requirements.

7.3.4 Energy efficiency of overall electricity supply

We are including this measure, even though the overall electricity supply of IT and communications equipment (power supply unit and DC-DC converter on the mainboard or directly on the chip) is not one of our project's topics. For this reason we are unable to describe detailed technical measures and the corresponding potentials, but this brief overview is decisive for the recommendations we put forward in Chapter 8.

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[3] The typical cost of a 200-watt power supply unit is around 16 US dollars. It is used for operating IT and communications equipment that typically costs around 1,000 US dollars (Calwell and Reeder, 2002)

Measures

The necessary measures concern the power supply unit itself (cf. 7.3.1 to 7.3.3), DC-DC converters on the mainboard and chip, and the interaction between these measures at these different levels.

The measures concerning the power supply unit were described above.

The most obvious measure at the DC-DC converter level is the use of efficient converters. According to information provided by manufacturers, these have a degree of efficiency between 60 % and 95 %[4] (typical range = 80 - 90 %). The levels of efficiency of strictly on-chip converters without external capacities and inductance are probably lower (Kaeslin, H., 2002a).

The question regarding the main factors in the interaction between the different levels is not as easy to answer. The load on the various DC voltage levels probably plays a role here, which means that the end configuration of the device needs to be taken into account. But we cannot state how significant this factor may be.

Potential

It is difficult to quantify the savings in electricity that may be realisable through this measure, but they are of course greater than with measures that only focus on enhancing the efficiency in power supply units.

Players

The relevant players at the power supply unit level were described in sections 7.3.1 to 7.3.3.

At the DC-DC converter level, these are primarily computer manufacturers (architecture) and chip designers. But here, in contrast with other areas, secondary players play a much greater (and perhaps even decisive) role. The demand for ever faster chips with ever greater processing capacity clearly influences the type and character of the overall electricity supply (cf. 7.1).

With respect to the interaction between measures at these two levels, a variety of other players are involved, including assemblers, those responsible for configuration and even end users.

7.3.5 Use of power management

The operating point of a power supply unit is greatly influenced by power management. Generally speaking, a reduction in electricity consumption results in a move out of the range in which a power supply unit has the maximum efficiency. Despite a potential increase in relative energy losses, overall energy losses are nonetheless lower. In the event of major deviations from the original optimal operating point – for example, due to the end device being switched into sleep mode – the supply of electricity in new devices is

[4] For DC-DC conversion, it may be assumed that with the use of switching regulators (down or buck converters) the mean degree of efficiency is around 85 %, or between 50 % and 65 % if linear voltage regulators are used (Siderius, 1999).

reorganised. The power is supplied via a separate optimised DC output for these low power requirements (cf. Fig 4-4).

Measures

A few years ago, importers systematically deactivated automatic power management in certain types of equipment in order to avoid potential enquiries and complaints from buyers. We do not know whether this is still the practice today. What we know for certain is that supplying devices with power management enabled is the most important measure for ensuring that end users actually use this tool.

Potential

Not part of the content of this study.

Players

End users (who should use this tool), importers / sellers / buyers (who should not deactivate it), computer manufacturers (invisible), researchers / developers (man-machine interface), software suppliers (support).

7.4 Support measures

There are certain preconditions for the measures described in 7.3 to be properly implemented. In particular, it is essential to make all relevant information available to all players. The main focus here is on an energy declaration for power supply devices, but the necessary technical know-how will also have to be available, and it is important to ensure that the mostly new and additional tasks are defined in the relevant specifications (operation/product release/product specifications). Furthermore, it is necessary to eliminate any potential legal obstacles (e. g. the question of liability with respect to adequate dynamic characteristics of power supply units), as well as to create incentives.

7.4.1 Energy declaration for power supply units

A comprehensive energy declaration for power supply units is an essential prerequisite for ensuring that players, who do not define their own specifications for these devices or develop, design or manufacture them themselves, are able to assess their energy efficiency and consider their more energy-efficient use. For this reason, in their study called "Energy declaration for electrical appliances", the authors (Aebischer and Huser, 2002) recommend that the Swiss Federal Office of Energy should formulate the principles for an energy declaration for power supply units. Our present report is a first step in this direction.

A comprehensive declaration would mean that smaller manufacturers and assemblers of IT and communications equipment would be able to use a power supply unit that best suits their requirements and has been optimised in terms of energy efficiency. To ensure that the players concerned make the most of this opportunity, it is important to provide additional information (-> education) as well as motivation (-> incentives).

Buyers of IT and communications equipment can take the efficiency of the power supply unit into consideration, but to make a sound assessment they need to know the loads at the various DC levels in the device ->-> the declaration is of little use to buyers and end users.

However, an energy declaration does not only serve as a source of information for manufacturers, assemblers, buyers and users of IT and communications equipment. In a smoothly functioning market, it can also exert a certain amount of pressure on the manufacturers of power supply units, who hope to gain a greater share of the market, or at least a better image, by producing more efficient devices!

7.4.2 Technical requirements of power supply units (voluntary agreements or admission requirements)

An energy declaration may also serve as the basis for the technical requirements of power supply units. In particular, these may take the form of minimum requirements of the efficiency of the DC output for the electricity supply at very low loads in standby and off modes (as outlined in 7.3.2). For these operating modes it would probably be appropriate to give priority to requirements of the power consumption of end devices, since these also include losses in DC-DC converters. Requirements of power supply units for components used to operate the end device in normal operating mode are more important, but at the same time more complex, since it is likely to be some time before it will be possible to specify requirements for the power consumption of end devices (especially PCs) in this operating mode. To cite Calwell and Reeder (2002): “Mandatory standards for power supply efficiency are currently under consideration in various proposed Congressional energy bills, though the focus is primarily on standby power use. Likewise, the California Energy Commission is evaluating proposed standards that would improve standby and active mode efficiency for power supplies, though the process is in its early stages and the effective date for such a standard would be many years in the future.”

One possibility would be to specify minimum requirements for the maximum level of efficiency of the individual DC outputs. However, we are unable to answer the question whether this would make it impossible to use downconverters within the power supply unit itself, nor can we judge what the consequences might be for the architecture of the electricity supply and with respect to costs.

Specifying the operating point at which this maximum should be attained makes little sense, since the load at the individual DC outputs may vary greatly from one power supply unit to another. However, it is clear that one aim should be to achieve a high degree of efficiency right across the operating point.

7.4.3 Lower thresholds for energy labels for end devices

The currently applicable EnergyStar thresholds for the power consumption of PCs in sleep mode are as follows:

- 15 W for devices with a maximum power supply unit output <200 W
- 20 W for devices with a maximum power supply unit output <300 W
- 25 W for devices with a maximum power supply unit output between 300 W and 350 W
- 30 W for devices with a maximum power supply unit output between 350 W and 400 W
- 10 % of the maximum continuous output rating for devices with a power supply unit output greater than 400 W.

The thresholds specified by the *Group for Energy Efficient Appliances (http://www. efficient-appliances.org)* are considerably more demanding. The applicable levels for 2003 are as follows:

- Off: 3 W
- Sleep mode (low-power mode): 10 W.

Within the scope of activities carried out at the International Energy Agency (IEA), a maximum level of 1 W was recommended for off-mode (http://www.iea.org/standy/ index.htm)

Low consumption thresholds for end devices exert pressure on manufacturers to consider the efficiency of power supply units at low loads. They can only be reached if power supply units are suitably dimensioned and achieve a high degree of efficiency at partial load. Unlike specifications for power supply units, thresholds for end devices have an impact on the overall power supply (power supply units and DC-DC converters).

The correlation between “consumption thresholds for end devices” and “reduction of losses in the power supply unit” also applies to normal operating mode. For this reason, Calwell and Reeder (2002) recommend extending EnergyStar and other similar labels and programmes to normal operating mode. This would probably make sense for a wide variety of devices, especially monitors and TV sets. However, in our opinion, it is still uncertain whether (and how quickly) it would be possible to do this for the market segment covered by the present report (i. e. PCs and network communications equipment).

8 Recommendations

Our recommendations are based on the following main findings:

- it is very difficult (and for end users virtually impossible) to find information about power supply units.
- End users have very little scope for manoeuvre.
- From the point of view of energy efficiency, studying power supply units as separate devices is far from optimal. In view of ongoing technological developments, it will be necessary to carry out more comprehensive studies that focus on the overall power supply.
- In the past, requirements for the power consumption of end devices have had an impact on the energy efficiency of power supply units (special DC output for standby mode).
- One of the benefits of placing requirements on the power consumption of end devices rather than on power supply units is that they encompass the energy efficiency of the overall power supply, including DC-DC converters.

Our recommendations may be divided into four areas:

- *research:* intensify know-how and fill existing knowledge gaps concerning the supply of power to components, devices and systems (including reliability). This is a major task that needs to be tackled together with the specialists at the various levels. The paper prepared by Margaritis and Ide (2001) would be suitable as a starting point at system level, while the text prepared by Kaeslin (2002b) would be useful at the component level.
- *Education:* the findings of this study, in particular the measures outlined in Section 7.3.1 concerning power supply units, would be suitable for training programmes for IT apprentices.
- *Energy declaration for power supply units:* process the results with respect to the questions of benefits, prerequisites and gaps in knowledge in order to pave the way for an initiative calling for the formulation of an energy declaration for power supply units (cf. political substantiation in the section dealing with thresholds for energy labels).
- *Requirements for energy labels:* We recommend activities in two directions:
    - tightening up requirements of the power consumption of information technology and communications equipment in on, standby and off modes, especially for PCs. A number of ongoing initiatives are already calling for this action. Support and supplementary input by Switzerland.
    - Initiatives calling for requirements to be placed on the power consumption of devices in normal operating mode in the area of IT and communications equipment. In this way it would be possible to support the three measures outlined in 7.3.1 (suitable dimensioning of power supply units), 7.3.3 (higher degree of efficiency across a broad operating range for other DC outputs) and 7.3.4 (energy efficiency of overall power supply).

In general, we feel that an approach based on energy labels (similar to that adopted in the area of key energy data for buildings) is to be recommended rather than the concept of placing requirements on individual components such as power supply units. But from the point of view of policy, instead of abandoning the latter, it probably makes sense to go ahead and initiate the process of defining and introducing an energy declaration for power supply units. This would demonstrate a willingness to focus on components' requirements in the event that the negotiations aimed at tightening and extending requirements for end devices should fail to be fruitful.

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Appendix

Recommendations regarding efficiency, in “ATX / ATX12V Power Supply Design Guide Version 1.2, Intel Corporation, 2000”

Enclosures

Results of measurements of Compaq Deskpro 575 power supply unit

Results of measurements of Minebea 200 W power supply unit

Results of measurements of Lead Year power supply unit

Results of measurements of HP power supply unit

Results of measurements of Artesyn Baynet AC/PS power supply unit

Results of measurements of Cisco 34-0873-01 power supply unit

Results of measurements of operating points and degrees of efficiency of different PC models

Recommendations regarding efficiency, in "ATX / ATX12V Power Supply Design Guide Version 1.2, Intel Corporation, 2000"

Efficiency

General recommendations

The efficiency of the power supply unit should be at least 68 % under maximum rated load. It should be met over the AC input range defined in Table 2, under the load conditions defined in Section 3.2.3, and under the temperature and operating conditions defined in Section 5.

Energy Star

The "Energy Star" efficiency requirements for power supply units depend on the intended system configuration. In low consumption / sleep mode (S1 or S3), the system should consume power in accordance with the values listed in Table 8.

Table 11. Energy Star Input Power Consumption

Maximum continuous power rating of power supply unit	*RMS watts from the AC line in sleep/low-power mode*
< 200 W	*< 15 W*
> 200 W < 300 W	*< 20 W*
> 300 W < 350 W	*< 25 W*
> 350 W < 400 W	*< 30 W*
> 400 W	*10% of maximum continuous output rating*

Note: To help meet the "Energy Star" system requirements, it is recommended that the efficiency of the power supply unit is > 50 % at low load and in standby mode.

Blue Angel, RAL-UZ 78

The +5V SB standby supply efficiency should be at least 50 % at 500 mA output. Standby efficiency is measured with the main outputs off and with PS_ON# high. To meet Blue Angel requirements, the AC input power must not exceed 5 W when the main outputs are in the "DC disabled" state with 500 mA load on +5V SB and a 230 V AC/50 Hz input.