Energy related issues of Consumer Electronics
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Appendix I: Overview of existing test procedures 1
Abstract

Consumer Electronics’ share of household electricity consumption has increased in the past 10 years and expectations are that the growth will continue in the (near) future. The trends in (energy consumption) of consumer electronics depend on several factors, e.g. the increasing number of consumer electronic appliances in the home, increasing functionality like additional IT related features, portability, remote control and the (big screen) home theatre. Manufacturers are now introducing new (ad hoc) standards which can accelerate these trends. The report covers energy consequences of these trends related to the modes of operation, hardware and software, the development of new ICs, power management, power supplies etc. Furthermore attention is paid to measurement methods for power consumption.
A summary of energy related issues per appliance category will be presented in combination with conclusions on most important issues and possible solutions, with a focus on power management.
1 Introduction: a framework for energy related issues in consumer electronics

1.1 Introduction; overview of the report

Consumer Electronics’ share of household electricity consumption has increased in the past 10 years and expectations are that the growth will continue in the (near) future. In the Netherlands the energy consumption of consumer electronics as percentage of total household electricity consumption increased from 8 % in 1992 to 12 % in 1996 (De Groot and Siderius 1998).

The trends (in energy consumption) of consumer electronics depend on several factors, e.g.:

- the (increasing) number of consumer electronic appliances in the home
- (increasing) functionality
- standby mode as a standard feature
- an increasing number of complementary devices, i.e. appliances that need another device to deliver a service to the consumer

This report provides a framework for energy relevant (technical) issues of consumer electronics to discuss the factors given as example above and others. It gives an overview on trends in general and on the appliance level, and - qualitatively - their impact on power consumption. Furthermore, attention is paid to measurement methods for (standby) power consumption, because these are a prerequisite for determining (improvements in) energy relevant issues.

In the next section of this chapter the framework is introduced. Chapters 3, 4 and 5 deal with the main aspects of the framework (functionality, usage and technical characteristics) in more depth and relate them to appliance specific aspects. Chapter 6 pays attention to aspects of measurement methods. Finally, chapter 7 presents conclusions and possible solutions for increasing efficiency with emphasis on power management.

1.2 A framework for energy related issues in consumer electronics

Energy consumption of appliances is in general related to the following interrelated aspects (see figure 1.1):

- functionality
- usage
- power consumption (related to technical characteristics, both hardware and software)

The functionality relates to the function fulfilment (the services) the user gets from the appliances, either as stand alone or in combination. With regard to the function fulfilment of the product, we will only consider the technical-economical function of a product, and not the esthetical and psychological functions for which no electricity is used. The psychological function of the product is connected with the possession of the product. E.g. by possession of a sports car people want to impress upon their neighbours.

The functionality also indicates the purpose for which appliances are bought (or hired, leased, etc). In case of consumer electronics these purposes can be grouped into the following broad categories:

- entertainment, education (infotainment)
- communication
- control
- shopping (teleshopping, telebanking, etc.)

Figure 1.1 Aspects related to energy consumption of Consumer Electronics

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Usage</th>
<th>Technical characteristics</th>
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Of course, these categories are not strictly defined but indicate main functions. Recent developments, e.g. regarding WEB-TV, enable consumers to communicate (e-mail) via their TV. So one appliance (or a group of appliances) can fulfil several functions. Furthermore, it can be argued that many consumers do not use all the functionalities of their consumer electronics.

The usage is related to aspects like the frequency of use and duration of use, but also to the way in which appliances are used. The last item refers to e.g. user settings like brightness and sound level for a TV and to habits of charging for portable appliances.

Power consumption refers to the instantaneous energy use (W = J/s) and is related to the technical characteristics of the appliance, e.g. the efficiency of the power supply. Technical characteristics refer not only to the hardware but also to the software of consumer electronics. Technically speaking, (a combination of ) consumer electronic appliances can be viewed as a system. The input for this system are broadcast signals or commands by the user, and the output are pictures on a (TV) screen, sound from loudspeakers, status information on a display or commands to other appliances. The system receives the input, does processing, including decoding and storage (on tape or disk) if required, and produces output.

Functionality, usage and technical characteristics are related. A greater functionality, e.g. achieved by a widescreen TV, can imply a higher frequency or duration of use. More appliances can lead to a larger total power consumption. The introduction of a standby mode can change usage characteristics.
2 Functionality

The functionality provided by consumer electronics has been categorised in 4 general categories: (1) entertainment and education, (2) communication, (3) control and (4) shopping. Entertainment and education is the classical function of consumer electronics. If we don’t count the telephone as a consumer electronic appliance, the other categories are relatively new.

Issues regarding the functionality and energy consumption are:
- the number of appliances
- integration through networking
- increasing functionality

2.1 Number of appliances

The number of appliances can be interpreted in several ways:
- different type of appliances, i.e. appliances with a different function, e.g. TV, VCR, CD-player, etc.
- the number of models of a type (of an appliance) on the market, e.g. the number of models of CD-players
- the number of appliances of one type available in the home, i.e. the ownership of a type of appliance, e.g. the average number of TVs in the home is 1.4

An increasing number of types and models of appliances generally leads to an increasing chance that a household owns one (or more) of these (new) types. Although it may take quite some years before a product has been accepted by the public – and some products never reach acceptance – the list of consumer electronic products is growing. Quadraphonic sound was introduced in the seventies, but not successful. Nowadays surround sound stands a better chance to penetrate into the living rooms.

Table 2.1 gives some examples of consumer electronic products that existed 20 to 30 years ago and have (almost) disappeared, or didn’t exist and are new on the market.

The penetration level has also been increasing. For TVs, the penetration level is above 100 %, indicating that – on average – households have more than 1 TV. The drivers of increasing ownership are increasing income, decreasing prices and individualisation. Table 2.2 shows penetration levels for the US and the Netherlands for several appliances.

<table>
<thead>
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<th>Table 2.1 Evolution of Consumer Electronic products</th>
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### Table 2.2 Penetration levels (average number of appliance per 100 households) for selected consumer electronic appliances

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### 2.2 Integration through networking

A further trend is integration through networking. In the past integration in consumer electronics was achieved by physically integrating different appliances, e.g. a hi-fi-set or a TV-VCR combi. Although one main reason for physical integration – compactness – may persist, integration of functionality will be realised ever more by networking the appliances.

An important hindrance for physical integration is lack of standardisation whether formal or defacto. As long as the appliance – or an important functionality of it – that is a candidate to be integrated, e.g. an Integrated Receiver Decoder (IRD) into a TV, is not standardised, manufacturers will be reluctant to (physically) integrate it.

The main hindrance for networking is the compatibility issue: compatibility between appliances of the same brand and of appliances of different brands. Recently, 8 consumer electronic manufacturers published ‘The HAVi Specification’ (HAVi 1998): a specification for the Home Audio/Video Interoperability Architecture. “Once connected as a network, HAVi compliant electronics appliances are immediately interoperable, sharing their resources and capabilities to offer increased functionality and greater ease-of-use. Specifically, these appliances will provide the consumer with the convenience of hot plug-and-play connectivity, appliance interoperability, and future-proof operation.” (Philips News, December 10, 1998).

Furthermore, plans were announced to collaborate in connecting the HAVi architecture with Sun’s Jini technology.

Networking, as sketched by the HAVi concept above, can have several impacts on energy consumption:

- Appliances will be “not off” for a longer time because they can expect messages or instructions from other appliances.
- Appliances are in the on-mode all the time, unless power management is implemented.
- In addition appliances need several standby modes to prevent that they are in an active mode – with probably a higher power consumption – whilst they are only waiting for messages.
- The possibility to use more often several appliances at the same time:
  - VCR or DVD to record or to watch a movie,
  - audio devices (amplifier) dedicated to extra sound capabilities (home theatre)
  - new functionality for new services (Teletext, EPG, Internet)

In practice networking concepts may result in the situation that all consumer electronic appliances are always in the standby mode in which it is possible to receive messages from other appliances.

Figure 2.1 shows an example of a networked multimedia system consisting of several appliances. This system provides the user with multimedia functions: audio, video, and other services, e.g. teleshopping and banking. From a user perspective the function-

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1 By DVB this system is called MHP (Multimedia Home Platform); it indicates a set of potential resources available in a single piece of equipment or in interconnected pieces of equipment.
ality of the system (and not so much of the individual boxes) is important. From an energy efficiency perspective however, both the system level and the equipment level are relevant. Requirements regarding energy efficiency can be defined on the system level. However, they should also be translated to the equipment level, because otherwise individual equipment manufacturers do not know which specifications to meet. The two levels are indicated in figure 2.1. The system level provides a reference for what is external, i.e. outside the system and what is internal, i.e. within the system.

The availability of an external network offers possibilities for changes in distribution of sound and vision. Audio content can be downloaded via internet instead of distribution via compacts discs or tapes and videos can be distributed via cable or satellite (video on demand).

2.3 Increasing functionality
Increasing functionality has been a driver for new appliances ever since. An appliance that is state of the art at a certain moment in time, is obsolete after a certain period because of increasing functionality of successors. It may not even be possible to buy an appliance with that (obsolete) functionality anymore. Examples are black and white TVs or a TV without a remote control.

For consumer electronic appliances the following trends resulting in increasing functionality can be indicated:
- remote control (including standby)
- portability (including battery powered operation)
- digital processing and digital broadcasting (including Integrated Receiver Decoder)
- improved sound quality: surround sound

A growing number of consumer electronic appliances features remote control and standby function. In standby mode the appliance will not perform the primary function but can be put into the on mode at any desired moment. Especially (new) TVs, VCRs and hifi-sets are standard equipped with a remote control and a standby mode; VCRs and most hifi-sets...
do not have an on-off switch with which the appliance can be switched to 0 W power consumption. For consumer electronic appliances three standby modes can be distinguished: standby-passive and standby-active low and high. In the standby-passive mode the appliance is waiting for an internal signal or a signal from the remote control to be switched into another mode, e.g. the on-mode. In the standby-active low mode the appliance is waiting for an external signal to be switched into another mode, e.g. from a service provider by satellite. In the standby-active high mode the appliance is communicating (exchanging data) with other appliances. At this moment the standby-active high mode is only realised in some (high-end) TVs and IRDs.

The standby mode should not be confused with the on mode of appliances that are continuously in the on mode, e.g. ventilation or burglar alarm. The difference can be explained by the function fulfillment of the appliance: if the appliance fulfills the primary function, it is by definition not in the standby mode. Whether the (primary) function is actually used, is another question. E.g. radios and television sets are often playing without anyone listening or watching; yet they are in the on mode and not in the standby mode.

Please note further that the modes defined above are given mainly from a consumer perspective, and not from an energy consumption perspective. So, some appliances could have a higher energy consumption in the off mode (e.g. because of a switch on the secondary side of the transformer) than others in the standby mode.

However, the existence of different modes and power management are closely related. Power management requires different modes (with different power levels) but the existence of different modes doesn’t mean that an appliance has power management.

Furthermore, a growing number of portable (rechargeable) battery powered appliances appear, e.g. portable CD-players, disc-man. This type of appliances has a natural driver for applying power management: extending operation period between recharging. However, the batteries of these applications have to be charged. This can lead to the situation where the appliance is always connected to the grid (to charge the battery), unless it is used. The functionality of a TV is influenced to a large extent by the development of digital broadcasting (European Commission 1997). Digital broadcasting facilitates advanced television, offering the consumer the following benefits:

- Enhanced realism: wide screen (16:9) 100 Hz television and high definition television (HDTV) both offer this. Furthermore, digital TV will give the consumer the ability to view different perspectives and to choose from them.
- Improved choice of programmes and other services, e.g. Electronic Programme Guide (EPG), Video On Demand (VOD) using digital compression technology to deliver films, tele-shopping, etc.
- Increased involvement and stimulation for the user: interactive VOD and multimedia products, e.g. CD-ROM, offer active enjoyment.

High-end TVs and VCRs often have surround sound capabilities. By using more than 2 loudspeakers (as needed for stereo sound) and possibly a (separate) surround sound amplifier, the impression can be created that the listener is within the scene. The combination of a wide screen with a large diagonal and surround sound is also called “home theatre”.

In the rest of this section, some appliance specific issues will be discussed.

It can be brought up for discussion whether the TV as it exists today will maintain its full functionality as a stand alone appliance in the future. A digital TV, i.e. a TV able to receive digital broadcasting, consists of the following subsystems:

- tuner and demodulator
- decoder
- digital processing
- display

These subsystems could evolve as separate boxes or units. The tuner and demodulator are specific for the

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2 According to the Cenelec draft on definitions and measurement methods for audio and video equipment (Cenelec TC206/32a, 20 April 1999).

3 This development is stimulated by environmental requirements of ecolables which require a modular design of the product.
type of transmission (cable, terrestrial, satellite). The decoder is partly standardised, but partly depends on the conditional access (CA) system. The digital processing delivers the picture manipulation features like picture in picture. The display will also be directly – like a computer monitor – used by other appliances, e.g. a VCR, DVD-player or a PC. Therefore, chances are that the (high end) TV will evolve into a set of separate boxes with a display. However, a requirement will be the networking (interoperability) capacities of appliances of different brands.

Another item is the relation between consumer electronic equipment and the (personal) computer and related equipment (e.g. printer, scanner). During the last years the functionality of these types of products are overlapping more and more. Through add-ons like internet boxes surfing the WEB is also possible on a TV; on the other hand PC-cards are available that enable HDTV watching on a computer monitor. For both consumer electronics and personal computers concepts have been developed to control appliances in the home. However, this trend doesn’t necessarily mean that the TV is replacing the PC or vice versa. It can be expected that both the enhanced TV and enhanced PC with overlapping but also separate functions will penetrate the homes. The relation between functionality and energy consumption of the appliance can be:

- direct, e.g. a TV with a larger screen diagonal has a higher energy consumption
- indirect: via external requirements e.g. of a service provider

Regarding the direct relationship, in Huenges Wajer and Siderius (1998) it is shown that power consumption of a TV is related to the following functional characteristics:

- screen size: larger screen size, higher power consumption
- scan rate: higher scan rate, higher power consumption
- screen format: wider screen format, higher power consumption

All these characteristics are related to screen technology. In section 4.4 screen technology will be discussed in more detail.

The indirect relationship holds for e.g. Integrated Receiver Decoders (IRDs). With the rise of digital broadcasting an appliance is needed that can convert broadcast digital signal into a signal that can be used by the TV. Because a (MPEG) decoder is standard available in such an appliance, it is called integrated receiver decoder. IRDs come in various types: cable-IRD, satellite-IRD and terrestrial-IRD, referring to the way the signals are broadcast. Also hybrid types, which combine two (or three) types, will become available.

Important aspects of functionality of IRDs are:

- the processing capacity and memory (programmability)
- the return channel (telephone, in future also satellite): enables two-way communication

Furthermore, types with basic and enhanced functionality can be distinguished. Enhanced types have:

- more memory
- increased processing capacity
- increased IO (input output) possibilities: RS232, USB, IEEE 1394, IDE/SCSI

Not the power consumption in the on-mode, but the availability of a low power standby mode is critical for IRD energy consumption. Market conditions play a critical role regarding this issue. In the case of distribution of paid services some kind of conditional access system is needed. Conditional access means that only those who are authorised to receive a certain service (mostly because they pay for the service) can use this service. For this purpose it is necessary that the identity of the (user of the) IRD can be retrieved and checked. This requires regular communication of the IRD with other parts of the system. This can lead to the situation that the IRD must be on 24 hours per day, to enable the service provider access to the box at any time.

Besides IRDs, other types of set-top boxes appear on the market to enhance the functionality of the TV. An example are set-top boxes with which it is possible to connect to the internet with the TV, e.g. WEB-TV. The connection with the internet is established with a (cable)modem. Since WEB pages cannot be displayed directly on the TV screen, the WEB-TV box also contains a processing part to convert the WEB pages into TV signals. Furthermore, the box
has a harddisk to store the WEB-pages for immediate use.
Regarding energy consumption the following issues are important. Because a TV is used to display the WEB-pages, power consumption can be higher than in the situation where a PC is used for surfing the WEB. However, the result of this comparison in energy terms depends on the size of the monitor and the TV screen. Another item is whether the WEB-TV box has to be in the on-mode continuously to enable updating of WEB pages and storing these on harddisk.

Like the IRD, the VCR is an example of a complementary consumer electronic appliance, i.e. an appliance that can deliver (part of) its function only with the help of one or more other consumer electronic appliances. Therefore the functionality of the VCR – especially regarding picture quality – follows the functionality of the TV.
Modern VCRs achieve improved functionality through the SCART connection with the TV. Combinations of TV and VCR (of the same brand) are able to exchange tuner data (on programme frequencies).
The aspect of functionality related most to the energy consumption of a VCR is the ability to program recordings through the VPS signal. The VPS signal is transmitted with the broadcast signal and indicates the start and end of TV programmes. To enable the use of the VPS signal, the tuner and most of the processing part of the VCR must be on to detect the VPS signal for the programmed recording.

In the future, the VCR could be replaced by the recordable DVD-player. However – if this is a true replacement – consequences for energy consumption are small because power consumption values are expected to be about the same.
It is uncertain whether the (local) VCR (or DVD-player) could be replaced by a (central) VOD system, since the possibility of individual recordings would be lost.

Although increasing functionality as such need not result in a higher energy consumption, it often does because energy aspects do not get as much ‘design attention’ as other design aspects (functionality, safety, aesthetics, etc.). Within budget constraints those design aspects get most attention that are expected to result in (new) products for which a higher price (or a larger profit margin) can be achieved. Since consumers in general evaluate performance aspects, e.g. improved picture quality for a TV, higher than energy efficiency, product development is focussed on these performance aspects, even if improvements in energy efficiency would be cost effective for consumers.
3 Usage

Regarding usage the following aspects can be identified:
• usage characteristics
• duration and frequency of use
• parallel usage versus single usage

3.1 Usage characteristics

Usage characteristics – or the usage settings of the appliance – are appliance specific.

The most important usage characteristics for the TV are:
• brightness (luminance)
• sound level

In Huenges Wajer and Siderius (1998) it is shown that luminance is linear related to power consumption. Furthermore it was noticed that several of the sets tested had a (very) high default luminance level. These high default settings result in a 10% higher power consumption over “normal” luminance settings as used by consumer associations in their viewing tests.

The relation between sound level and power consumption is linear up to a normal listening level (70 dBA), beyond that level the relation is exponential. High end sets are almost standard equipped with surround sound which also increases power consumption.

Since VCRs generally have no on-off switch which results in a 0 W power consumption and the usage in the on-mode is on average about 1 hour per day, VCRs are most of the time in the standby-mode. Regarding energy consumption, a difference exist between the following modes:
• the VCR is programmed to record (and is waiting for the beginning of the programme to record)
• the VCR is waiting for signals from the remote control
• the VCR is “off” but able to feed through signals through the SCART matrix

Some VCRs allow the user to choose whether the display will be on or off in standby (or off) mode.

3.2 Duration and frequency of use

Duration and frequency of use depend on the required functionality of the system. However, with the increasing penetration of software in consumer electronic appliances, the booting and shutting down of the system could influence usage. If starting up or shutting down takes a long time (> 30 s?), people will be inclined to leave the system on when they are not using it.

Although the time spent to watch television seems to stabilise, new services (more TV channels, access to internet, development of CD-ROM, downloading of games, software) could lead to an increase of the time the TV is in the on-mode. Viewing hours will be strongly related to the type of usage:
• collective watching TV
• individual watching TV
• internet
• playing video games or CD-ROM, DVD, etc.

It can be argued that viewing hours for collective watching TV (first TV set) will not be affected but that viewing hours of 2nd and 3rd TV sets will at least not decrease even if the number of persons per household is decreasing. Multimedia PCs could compete with second or third TV sets and video games in terms of viewing hours. In conclusion, even if it is difficult to predict the time that people will spend for new usage, a slight increase of total viewing hours can be expected due to the increase of penetration rates of 2nd and 3rd TV sets and due to the stability of viewing hours.

Not only for TVs, but also for audio equipment the penetration of 2nd and 3rd sets is increasing. Although the usage time of second and third appliances may not be as high as the usage time of first (or main) appliances, in most cases total usage time per household increases.

3.3 Parallel usage versus single usage

Regarding total energy consumption the aspect of single or combined usage of products is relevant. If a product can (or will) be used together with other products, it’s energy consumption adds to the total
consumption of the household. On the other hand, if a product ‘inhibits’ the use of other products, total energy consumption might decrease. An example could be a portable CD-player with headphones that is used in stead of the hifi-set. However, such a portable device might also be bought to be used as an extra set.

This also means that when an appliance is on, it is not always used. The PC is an example: in the office environment a PC is used 30% of the time it is on. This opens the possibility for power management, since if the appliance is not used, (most of it) need not be powered.
4 Technical characteristics

For a given level of function fulfilment and usage, technical characteristics determine the energy consumption of an appliance.

Important technical aspects related to energy consumption are:
- hardware versus software
- development of ICs
- power supply
- display technology

4.1 Hardware and software
Dedicated hardware is ‘out’, software is ‘in’. The functionality of consumer electronic appliances is ever more determined by the software. Consequences are that products are delivered with beta software that will contain bugs, and also further generations of the product will contain bugs. Although it is claimed that the hardware has a longer life if the software (and thus the functionality) can be updated, this is only true in situations were the hardware can cope with the new requirements of the software. The PC world is an illustration of a hardware-software race that leads to continuously updating of software and hardware.

Furthermore, because of the possibility of updating software, some products might need to be in a mode in which they are continuously able to receive software updates.

4.2 Development of ICs: integration and low power electronics
With ongoing integration of ICs, the total small signal processing in a TV set is done with a few ICs, even when the number of features is increasing. Power consumption expressed in absolute Wattage is low for the small signal processing part of the TV.

In general, the small signal circuitry would, in the best LSI implementation provide a small signal board power requirement of under 4W with a single principal power rail low voltage requirement (typically 5V). It should be noted that the introduction of digital television services (satellite, cable, terrestrial) will require manufacturers to develop completely new small signal boards for integrated digital television receivers. The mains input power requirement of the digital TV small signal board based on current LSI chip sets will be three times higher than the most efficient analogue board at 14 W typically. However some functionalities associated with 100Hz/Digital picture processing will be included in the digital small signal board. Therefore the net power input increase for a typical 100 Hz/Digital Picture processing TV chassis, currently using an efficient analogue small signal board, will be approximately 3W.

Increasing integration of ICs also results in a decreasing number of ICs to make an IRD. Increased integration – in combination with a lower supply voltage of ICs (see hereunder) – allows manufacturers to increase efficiency or to build smaller appliances. However, increased efficiency does not necessarily mean lower energy consumption in absolute terms.

Low power electronics are especially used in portable, battery powered appliances, like mobile telephones and portable CD-players. However, as clock frequencies of microprocessors increase, low power electronics become also interesting for non-portable appliances to lower the dissipation and the heat produced. In general power consumption is proportional to the square of the supply voltage.

There are several ways to reduce power consumption of integrated circuits based on the equation

\[ E = V \times I \times t \]

- reduce the operating voltage, e.g. from 5.5 V to 3.3 V
- reduce the current consumption, e.g. by the operating frequency
- reduce operational time of (parts of) the circuit (partial power down).

Lowering IC supply voltages, e.g. from 5.5 V to 3.3 V, offers in theory substantial savings because power consumption of ICs is proportional to the voltage squared. However, in practice lowering ICs supply voltages is used to decrease chiparea or increase the number of transistors on the chip. Furthermore clock frequencies are increased to improve performance. Due to these developments power consumption is
not decreased as much as it could be. Therefore, because of the lower voltage, the current will increase, which will cause more filter losses in the rectifying circuit (proportional with 0.5 * I).

4.3 Power supplies

4.3.1 Introduction, categorisation of power supplies

Every appliance that has components that cannot be fed directly by the grid (230 VAC, 50 Hz) needs a power supply, i.e. a component that transforms the voltage delivered by the grid into a voltage that can be used by the other components in the appliance. A power supply mostly has the following functions:

- transformation of the grid voltage (230 V AC, 50 Hz) into a suitable voltage, e.g. 12 V DC
- rectification: changing AC to DC
- isolation: electrical separation of the appliance from the grid

The power needed for the components not only has to be “generated” by the power supply but also distributed at the right voltage levels and the right places in an appliance. The following situations can occur:

a) the (main) power supply generates all the required voltages; these are distributed through the appliance
b) the (main) power supply generates one or two basic voltages; these are distributed through the appliance and converted to the required voltages where needed

In case b) separate voltage converters (regulators) are needed. Generally, two types of regulators can be distinguished: the shunt regulator and the series regulator. However, the series regulator - which is more efficient - can only be applied in low power situations. Table 4.1 shows some losses in voltage regulators.

In general losses vary between 35 % and 50 %. So it is worthwhile from an efficiency perspective to design for a minimal number of voltage regulators (and choose efficient regulators).

Categorisation of power supplies

Although a large variation in power supplies exists, this report will use a simple categorisation only. Firstly, internal and external power supplies are distinguished.

An internal (component) power supply is a power supply that is an integral part of the appliance it provides the power for, i.e. the power supply and the rest of the components are in the same casing. The appliance has a 230 V AC input and can be directly connected to the grid.

An external (stand alone) power supply is a power supply that is in a housing separate from the appliance it provides power for. The appliance itself has no 230 V AC input and therefore cannot be connected directly to the grid.

A second distinction can be made between general or universal and dedicated power supplies. A power supply usually is a standard unit. Furthermore, these supplies have also to provide power for expansion cards and extra components (e.g. hard disk drives) installed by the user.

An external (stand alone) power supply is a power supply that is in a housing separate from the appliance it provides power for. The appliance itself has no 230 V AC input and therefore cannot be connected directly to the grid.

On the other hand dedicated (external) power supplies are intended to be used with one (or a few) appliance models, e.g. printers.

Table 4.2 gives some examples for each category.
The distinction between general and dedicated power supplies is most clear for external power supplies. However, also for internal power supplies economies of scale is a driving force towards more general power supplies. E.g. a power supply is designed for several TV chassis in stead of one.

From a technical point of view, main categories are linear power supplies and switched-mode power supplies (SMPS).

### 4.3.2 Energy aspects of power supplies

Several aspects of power supplies influence the energy consumption of consumer electronics:

- the efficiency
- the no-load power consumption

Furthermore, power quality issues can be relevant.

The **efficiency** of a power supply can be defined as:

\[
\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\% \quad [4.1]
\]

The efficiency varies with the output power, i.e. a power supply has an output power (or an output power range) where the efficiency is maximum. The nominal output power normally falls in this range. So, for power levels outside the nominal range, the efficiency of the power supply can be (much) lower than the nominal efficiency.

This is relevant for appliances that can run in various modes with different power levels, e.g. on mode and standby mode. From an appliance energy efficiency point of view, having various (operating) modes can be advantageous because the functionality (and the power) can be tuned more specifically.

The **losses** of a power supply can be defined as the input power drawn at zero output power:

\[
P_{\text{loss}} = P_{\text{in}} \bigg|_{P_{\text{out}}=0} \quad [4.2]
\]

This value is especially relevant for AC-adapters because in general these adapters:

- do not have an on/off switch on the primary side
- are left in the wall-socket continuously

The above considerations lead to a more general remark on energy aspects of power supplies, i.e. that they should be able to support the power management strategy of the appliance. This means that they should be able to work at nominal efficiency at various power outputs and should have minimal losses.

Regarding power quality, two definitions are important: the power factor and the Total Harmonic Distortion of the current.

The **power factor** is the active or real power P divided by the apparent power S:

\[
PF = \frac{P}{S} \quad [4.3]
\]

Equation [4.3] shows that for a PF<1 the real power is less than the apparent power. This can have the following impacts:

- Extra network and power generating capacity is needed: because the power factor is less than 1, more apparent power has to be generated and distributed compared to the situation where the power factor is 1 (pure resistive load). Power generating and distribution capacity have to be designed for the (maximum) apparent power.
- Impairment of performance of equipment connected to the electricity network and possible premature ageing of components (e.g. capacitors and transformers).
- Larger voltage fluctuations.

<table>
<thead>
<tr>
<th>Table 4.2</th>
<th>Examples of types of power supplies</th>
</tr>
</thead>
<tbody>
<tr>
<td>internal (component)</td>
<td>universal</td>
</tr>
<tr>
<td></td>
<td>PC power supplies</td>
</tr>
<tr>
<td>external (stand alone)</td>
<td>AC adapters</td>
</tr>
</tbody>
</table>
Therefore, although households only pay for the real power they use, utilities are interested in having a power factor close to 1. A power factor less than 1 can be caused by a (sinusoidal) current that is not in phase with the (sinusoidal) voltage, due to an inductive or capacitive load. Another item regarding power quality is harmonic distortion. Harmonic distortion occurs when the current waveform is not sinusoidal but distorted e.g. by a switch mode power supply (see figure 4.1).

Besides the fundamental (sinusoidal) wave, also higher order harmonics appear resulting in a power factor less than 1. Note that a low power factor and harmonic distortion are not equivalent, i.e. harmonic distortion results in a power factor less than 1, but a power factor less than 1 need not be caused by harmonic distortion.

For the parameter indicating the amount of harmonic distortion two different definitions exist. In Europe the Total Harmonic Distortion of the current (ITHD) is the relative value of all harmonics combined, as a percentage of the total current $I_{\text{RMS}}$:

$$ITHD_{EU} = \frac{\sqrt{\sum_{i=2}^{\infty} I_i^2}}{I_{\text{RMS}}} \times 100\% \quad [4.4]$$

In the US ITHD is relative value of all harmonics combined, as a percentage of the fundamental current $I_{\text{Fund}}$ (= $I_1$):

$$ITHD_{US} = \frac{\sqrt{\sum_{i=2}^{\infty} I_i^2}}{I_{\text{Fund}}} \times 100\% \quad [4.5]$$

Figure 4.1 Distorted waveform
(Source: Macebur 1998, p86)
There is another difference between the US and Europe: VRMS, EU = 230 V and VRMS, US = 110 V. This means that at a power consumption of 1 W - assuming a power factor of 1 - the respective currents are \( I_{\text{RMS, EU}} = 0.004 \) A and \( I_{\text{RMS, US}} = 0.009 \) A. Table 4.3 provides an overview of some typical values for two categories of power supplies.

### 4.3.3 Miscellaneous: solar cells and muscle power

The power for consumer electronic appliances need not be provided by a power supply connected to the grid or batteries. Several other options exist which will be discussed shortly in this section.

In general, the lower the power consumption of the appliance is, the more useful these options become.

#### Solar cells

Solar cells with a large capacitor for energy storage are used to power e.g. calculators and watches. Also battery chargers powered by solar cells exist. The apparent disadvantage of solar cells is that they deliver no power if they catch no light. Thus the reliability of operation is dependend on the consumer taking care of exposing the appliance to (sun)light. Since convenience is an important item for consumer electronics, this hurdle might be too high.

#### Muscle power

Another option is to use muscle power to generate the electrical energy needed. Several appliances exist that operate on this energy source:

- a watch with a very small generator that is driven by movements of the arm (energy is stored in a capacitor)
- a remote control where the pressing of the buttons is used to generate electricity
- a radio that is powered by a spring generator. The spring is winded up by hand.
- a more radical approach was proposed to replace the electrical tooth brush. The energy in the spring is directly transferred to the mechanics of the tooth brush, without the electrical intermediate stage.

Whether muscle power will become an alternative for battery or grid power in consumer electronic appliances depends on several factors, e.g. the reliability of the mechanics, the noise the spring generator produces and the period of operation provided without the user repowering the appliance. The best chances are probably for replacing or supplementing batteries in portable appliances.

### 4.4 Screen technology

Excluding the power supply losses, 80 % of the input power of a TV is used for the screen and the screen drive circuitry. Therefore, developments in screen technology could have a major impact on power consumption of TVs.

Ziemer (1996) gives an overview of display technology for “household” use (see table 4.4). He distinguishes:

- current technology (cathode ray tube (CRT))
- projection techniques
- flat screens

Although Ziemer clearly indicates the disadvantages of the CRT technology, experts expect this technology to be dominant for the next years. Besides the high picture quality, also the mature production techniques and installed production capacity play a role. Major efficiency improvements in the tube

<table>
<thead>
<tr>
<th>Energy aspect</th>
<th>Linear power supply</th>
<th>SMPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficiency at nominal load</td>
<td>40 – 60 %</td>
<td>60 – 80 %</td>
</tr>
<tr>
<td><strong>Losses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no-load power consumption</td>
<td>2 - 3 W</td>
<td>1 – 2 W</td>
</tr>
<tr>
<td><strong>Power quality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Harmonic Distortion</td>
<td>n.a.</td>
<td>&gt; 100 %</td>
</tr>
<tr>
<td>power factor</td>
<td>0.60 – 0.90</td>
<td>0.50 – 0.90</td>
</tr>
</tbody>
</table>
itself are not to be expected. However, driving circuits can be improved. Whether these improvements will happen, is uncertain. If (some) manufacturers decide to put (more) effort in flat screen technology, they are less likely to invest in the improvement of driver circuits for the CRT technology.

All projection techniques require a light source of which the light is split into the 3 basic colours: Red, Green Blue. Separate pixels of the screen are controlled by separate LCD cells (LCD projection technique) or mirrors (DMD device). If the LCD cell is transparent or the mirror is in the right position, the pixel will be projected on the screen, otherwise it will not. An alternative version of the LCD projection technique works with reflective LCD cells: if the LCD cell is reflective the pixel will be projected on the screen.

Regarding power consumption, the main disadvantage of the projection techniques is the light source required. Power consumption of lamps varies from 100 W to several hundreds of Watts, dependent on the required luminance. An extra problem with the LCD projection technique is that the LCD panel is not 100 % transparent or reflective, which leads to a loss of light. This loss can be as large as 30 % with transparent LCD cells, and about 7 % with reflective LCD cells.

Flat screens (or flat panel displays) can be divided into two types:
- emissive displays
- non-emissive displays

Non-emissive displays need an external light source to produce a picture, whereas with emissive displays the light is produced in the display itself.

Several types of technologies can be used for realising flat screens:
- LCD (liquid crystal display)
- Plasma display
- FED (Field Emissive Display)

At the moment, LCD and Plasma displays are produced for the TV market. However, LCDs are unlikely to be developed to produce competitively priced large screen (17"- 32") displays within the next five years. In any current instrumentation of these displays each pixel must be individually addressed. This is a costly technology for large area screens with an inherently high manufacturing failure rate. However a breakthrough in this technology would introduce a 60% reduction in video large signal power for a medium to large screen LCD equipped receiver.

Further away from realisation is e.g. the development of LEDs for displays. Research into screen technology has as primary goals achieving larger screens with higher contrast (brightness), a better viewing angle etc.

Although energy consumption of (non-backlit) LCD screens is very low, flat screens that are (planned to be) produced still have a considerable energy consumption (see table 4.5 for some data on power consumption of flat screens). According to manufacturers power consumption of flat screens eventually will be comparable to energy consumption of an ordinary CRT (of the same screen size). However since the screensize of flat screens will be larger than current CRT screens, power consumption will be higher.
Table 4.4 Overview of display technology
Source: Ziemer (1996, pgs 286-289)

<table>
<thead>
<tr>
<th>System</th>
<th>State of the art</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Evaluation for future use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional CRT</td>
<td>realised up to 90 cm screen size</td>
<td>compact design</td>
<td>not feasible for screensizes larger than 1 m</td>
<td>not suitable for large screens</td>
</tr>
<tr>
<td></td>
<td>TVs up to 80 cm available in shops</td>
<td>very good picture quality</td>
<td>high weight and volume high costs</td>
<td></td>
</tr>
<tr>
<td><strong>Projection techniques</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRT projection</td>
<td>realised up to 3 m screen size</td>
<td>good picture quality high resolution</td>
<td>low luminance (low ambient luminance levels necessary) convergence problem low efficacy</td>
<td>good opportunities for cinema scope format less suitable for home use</td>
</tr>
<tr>
<td>Light projection</td>
<td>realised up to 5 m screen size</td>
<td>large screen size high luminance small appliances high resolution display of large bright pictures</td>
<td>small life time of cathode complex system heat-up time loss of light through absorption high light output mechanical stress complex mechanical system</td>
<td>suitable for large audience participation</td>
</tr>
<tr>
<td>LCD projection</td>
<td>realised up to 1.8 m screen size</td>
<td>high resolution display of bright pictures</td>
<td></td>
<td>good future opportunities</td>
</tr>
<tr>
<td>DMD projection</td>
<td>realised up to 1.5 m screen size</td>
<td>high resolution display of bright pictures</td>
<td></td>
<td>good future opportunities</td>
</tr>
<tr>
<td>Laser TV</td>
<td>realised up to 2 m screen size</td>
<td>high light output large screen size high luminance no convergence problems</td>
<td>high power consumption asynchronous scan rate high mechanical precision required</td>
<td>not clear whether suitable for home use</td>
</tr>
<tr>
<td><strong>Flatscreen TV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat CRT</td>
<td>realised up to 25 cm screen size</td>
<td>high luminance high contrast low power consumption high contrast flackerfree large viewing angle</td>
<td>limit to screen size large weight deflection errors bad resolution large voltage needed bad electro-optical efficiency problems with colour display bad luminance small life time high control voltages needed</td>
<td>not suitable for large screens good future opportunities might be the dominant long term display technology</td>
</tr>
<tr>
<td>Plasma display</td>
<td>realised up to 51 cm screen size</td>
<td>low power consumption low weight high contrast high luminance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electroluminescence display</td>
<td>realised up to 46 cm screen size</td>
<td>low power consumption low weight high contrast high luminance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid Crystal display</td>
<td>realised up to 35 cm screen size</td>
<td>small size high resolution low control voltages</td>
<td></td>
<td>suitable for small to medium screen sizes no present results regarding large screen sizes suitable for large screens and use in the home</td>
</tr>
<tr>
<td>Plasmatron</td>
<td>realised to 1.27 m screen size</td>
<td>good picture quality simple construction high contrast small depth</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A energy efficiency disadvantage of Plasma Display Panels lies in the fact that the level of light from each pixel cannot be controlled in a practicable system by addressing each plasma pixel source. In practice each complete picture frame is composed of several sub frames which are modulated in luminance to provide a good subjective grey-scale. This technique means that the power consumption of the panel is constant for the luminance range of the display.

Table 4.5 summarises some of the scarce data on power consumption of flat screens.

The main conclusion on the relation between developments in screen technology and power consumption is that possibilities for savings exists, but that it is not likely that these will be implemented autonomously. In the short term, power consumption of a 42” flat screen TV is about twice the power consumption of a 100 Hz TV of that size, if it would exist.

### Table 4.5 Power consumption of flat screens

<table>
<thead>
<tr>
<th>Brand and model</th>
<th>Power consumption [W]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fujitsu PDS4203 (42” plasma display)</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Pioneer PDP-V401E (40” plasma display)</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Philips Flat-TV 42” (42” plasma display)</td>
<td>around 300</td>
<td>experimental TV LCD-screen (200 cd/m²)</td>
</tr>
<tr>
<td>Sharp 15” colour TFT-LCD display</td>
<td>9.5</td>
<td></td>
</tr>
</tbody>
</table>
5 Measuring methods for standby power consumption

5.1 Introduction
Measuring standby power consumption looks simple enough: connect the appliance to a power supply and a power meter, switch the appliance into the standby mode and read the meter. The result learns you whether a certain criterion has been met or not. This simple procedure contains the basic elements of a test procedure for standby power consumption:

1. the appliance
2. the standby mode
3. the power meter
4. the power supply
5. the measurement (reading the meter)
6. the verification: the check whether the goal has been reached

Unfortunately, the simple looking procedure contains several pitfalls and things to think over before measurements can be carried out. Already several test procedures for standby power consumption exist. In appendix I these procedures are summarised, and the various elements will be discussed at the appropriate point in this chapter.

5.2 The appliance and the standby mode(s)
Before starting the measurement the appliance and the mode to be measured must be defined.
Definition of the appliance to be measured can give problems in case of systems and part of systems (e.g. loudspeakers). Therefore a clear definition is needed for each (type of) appliance, including indication of connections to other products.

Regarding the standby mode, two complications can arise:
a) the standby mode can have several (stable) power levels, some of which might be (indirectly) chosen by the consumer
b) the appliance can switch automatically from one (standby) mode into another (standby) mode and back

Situation a) occurs e.g. with VCRs where the user can choose between a standby mode with the display on and one with the display off. In general, appliances should be measured as shipped to the consumer, i.e. with factory settings.

Situation b) occurs e.g. with TVs that have an EPG (Electronic Programme Guide) function which has to be updated every 24 hours. If the TV is not used in that period, it switches automatically from standby-active low into standby-active high to receive updated EPG information, and after that back to standby-passive. If the conditions for switching are known, these situations can be avoided or taken into account during measurements.

To get an overall picture of the energy consumption, a duty cycle can be defined. Such a duty cycle should contain a representative share of time of each mode. Disadvantage of a duty cycle is that the duration of the measurement can become quite large.

In general the following definitions of modes can be used (see table 5.1, based on Cenelec TC206/32a fourth draft of April 20, 1999).
5.3 The power meter, the power supply and other equipment

Measuring standby power consumption requires equipment; at least a power meter, but probably also a power supply, an oscilloscope and a power analyser.

5.3.1 The power meter

In general it is not so easy to find an affordable meter that can accurately measure power consumption of appliances down to 1 W (or less). The main reason lies in the harmonic distortion of the current, resulting in a waveform for which the true power is not easily measured or calculated. This distortion can be – amongst others – caused by a (switch mode) power supply operating in a burst mode to provide power for the standby mode.

In general power meters should meet requirements regarding:
- sensitivity: crest factor and frequency response
- accuracy
- resolution

The requirement for the resolution is the most easy to deal with: most test procedures require the result to be stated in one decimal, so a resolution of (at least) 0.1 W is needed.

Sensitivity is a necessary condition for accuracy. Sensitivity refers to the peak value of the current that can be detected and the harmonics that can be taken into account. The crest factor of a current waveform is defined as the ratio of the peak current to the RMS value of the current:

$$ Crest \ factor = \frac{I_{\text{peak}}}{I_{\text{RMS}}} [5.1] $$

For sinusoidal currents the crest factor is $\sqrt{2} = 1.4$ (by definition). For appliances with a switch mode power supply the crest factor will always be higher. Regarding the harmonics that can be taken into account, EPA recommends for the Energy Star Program a meter with a frequency response of at least 3 kHz. At 60 Hz, this will account for harmonics up to the 50th. However, measuring ITHD requires a power analyser.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disconnected</td>
<td>The appliance is not connected to any external power source</td>
</tr>
<tr>
<td>Off</td>
<td>The appliance:</td>
</tr>
<tr>
<td></td>
<td>a) is connected to an external power source</td>
</tr>
<tr>
<td></td>
<td>b) is not performing it’s primary function(s)</td>
</tr>
<tr>
<td></td>
<td>c) cannot be switched into another mode, except by an action of the user at the appliance</td>
</tr>
<tr>
<td>Standby-passive</td>
<td>The appliance:</td>
</tr>
<tr>
<td></td>
<td>a) is connected to an external power source</td>
</tr>
<tr>
<td></td>
<td>b) is not performing it’s primary function</td>
</tr>
<tr>
<td></td>
<td>c) is waiting to be switched into another mode by means of the remote control or an internal signal</td>
</tr>
<tr>
<td>Standby-active low</td>
<td>The appliance:</td>
</tr>
<tr>
<td></td>
<td>a) is connected to an external power source</td>
</tr>
<tr>
<td></td>
<td>b) is not performing it’s primary function</td>
</tr>
<tr>
<td></td>
<td>c) is waiting to be switched into another mode by means of an the remote control or an internal or external signal</td>
</tr>
<tr>
<td>Standby-active high</td>
<td>The appliance:</td>
</tr>
<tr>
<td></td>
<td>a) is connected to an external power source</td>
</tr>
<tr>
<td></td>
<td>b) is not performing it’s primary function</td>
</tr>
<tr>
<td></td>
<td>c) is communicating (exchanging data) with an external source</td>
</tr>
<tr>
<td>On</td>
<td>The appliance:</td>
</tr>
<tr>
<td></td>
<td>a) is connected to an external power source</td>
</tr>
<tr>
<td></td>
<td>b) is performing (one of) it’s primary function(s)</td>
</tr>
</tbody>
</table>

Table 5.1 Definitions of modes for consumer electronic appliances (based on Cenelec TC206/32a fourth draft of April 20, 1999)
Not in all situations expensive equipment is needed. If the appliance has no switch mode power supply, or if it is known that the power consumption of the appliance is well below the required value, the measurement can be carried out as indicated by figure 5.1.

Measure power consumption of the appliance and the resistive load (e.g. an incandescent lamp of about 10 W) and measure the power consumption of the lamp alone. Make sure that the power consumption of the lamp is stable. The power consumption of the appliance follows from:

\[ P_{\text{appliance}} = P_{\text{lamp+appliance}} - P_{\text{lamp}} \] [5.2]

Although this approach might lead to relatively large errors because the difference between \( P_{\text{lamp+appliance}} \) and \( P_{\text{lamp}} \) is small, it might be a cost effective way to do a first check.

5.3.2 The power supply and other equipment
In the foregoing it is assumed that a stable power supply is used, with a ‘fixed’ voltage and frequency. In most test methods the voltage and frequency shouldn’t deviate more than 2 (or 5) %.

Sometimes the grid will be stable enough, otherwise a separate stabilised power supply can be used. An oscilloscope can be used to determine the peak current and to check the current waveform.

5.4 The measurement and measurement conditions
If the right power supply is available, the correct meter installed, the appliance is in the standby mode and other measurement conditions are met, the measurement can start.

The ‘other measurement’ conditions (see Appendix I) generally refer to:
- the temperature of the appliance
- the ambient temperature
- humidity
- placing of the appliance
- ambient illumination level

An important item is the duration of the measurement: should it be 1 hour, 15 minutes, 1 minute? Mostly it is stated that the measurement should be long enough to determine the (stable) power consumption accurately. This means that after switching the appliance into the standby mode the power consumption should stabilise first, and then the measurement can start. Having reached a stable standby power level a measurement period of 15 minutes should be sufficient.

The power consumption can be measured directly by reading the average power consumption from the power meter. An alternative is to read the energy consumption and the elapsed time since the start of the measurement, and calculate the average power consumption by dividing energy consumption by elapsed time.

Measured values should be rounded to the first decimal to arrive at the standby power consumption value.

5.5 Verification
Very often measurement methods are used to check whether a certain goal (target value) has been reached. Suppose the goal is 1 W and one measures 1.1 W. Is the goal reached or not? The answer to this question depends on several aspects which will be discussed in this section. Of course, when the start-
ing point was 5 W, one might consider it a waste of time to discuss the last 0.1 W. However, there must be clear rules to decide whether a target is reached or not, e.g. when a label is used to indicate products that comply with the 1 W value or when a rebate programme is started for “1 W products”.

The most simple way is to set the 1 W level as a maximum value. Any appliance that – assuming it is properly measured – has a standby power consumption of 1 W or less complies, other appliances do not comply. Note that in this case it is solely the responsibility of the manufacturer (or importer) to deal with measurement and product deviations.

An alternative for a maximum level is to have a more detailed verification procedure, taking into account measurement and product deviations. If a maximum product deviation of ±5 % and a maximum measurement error of -0 % and +10 % is assumed, the following two step procedure applies: the measured value of 1 appliance should not exceed the declared value by 15 %. If it does, 2 extra appliances are measured and the average value of the 3 measurements is calculated. This average value should not exceed the declared value by 10 %. In this case, a measurement result of 1.1 W on the first appliance results in a decision that the appliance is compliant.
6 Conclusions and recommendations

6.1 Overview per appliance category
In this section the results of the discussion in the foregoing chapters will be summarised per appliance (category).

TV
- The functionality of the TV is influenced to a large extent by the development of digital broadcasting, offering new services like Electronic Programme Guide (EPG), Video On Demand (VOD), teleshopping. To receive digital broadcast signals a (separate) IRD is needed or the IRD should be integrated in the TV.
- There will be increasing overlapping between functionality of (the main) TV and PC, but in the near future a replacement of the TV by the PC (or vice versa) is not to be expected.
- Subsystems of the TV could evolve as separate boxes, integrated through networking.
- Power consumption is determined to a large extent by the power consumption of the screen; developments like large screen sizes, higher scan rate and widescreen are expected to increase power consumption.
- The luminance and sound level influence significantly the power consumption of a TV.
- Total usage time of all TVs in the home is expected to increase.

IRD, WEB-TV
- The functionality of the IRD is determined by software, which can be updated.
- WEB-TV enhances functionality of TV by enabling WEB-surfing via the TV.
- (Further) IC integration could result in increasing functionality at stable (or even lower) power levels.
- Energy consumption of the IRD and WEB-TV is determined to a large extent by external requirements:
  - e.g. specifications of service providers that require the IRD to be continuously in the on-mode.
  - e.g. possibility of continuously updating WEB-pages and storing them on hard disk.
  - VCR.

The functionality of the VCR could be eventually replaced by the (recordable) DVD-player, which would however not change energy consumption much.
- The standby mode has most impact on power consumption, especially the mode in which the VCR is programmed to record.

Audio equipment
- Individualisation results in an increased number of (portable) audio equipment. Thus, the total usage time of all audio appliances in the home could increase.
- Increasing number of audio appliances with standby mode, and some audio appliances do not have an on/off switch anymore.
- Improved sound quality by surround sound, which integrated with a (widescreen large screen) TV results in the “Home Theatre”.

Network concepts
Providing compatibility issues are dealt with adequately, consumer electronic appliances will become networked appliances to offer increased functionality. Consequences for energy consumption could be:
- Appliances will be “not off” for a longer time because they can expect messages or instructions from other appliances.
- Appliances are in the on-mode all the time, unless power management is implemented. In addition appliances need several standby modes to prevent that they are in an active mode – with probably a higher power consumption – whilst they are only waiting for messages.
- The possibility to use more often several appliances in the same time.

6.2 Solutions and recommendations
Obvious and straightforward solutions to higher efficiency of consumer electronic products are:
- more efficient components, and especially
- more efficient power supplies
- an efficient (electrical) lay-out of the components
Although usage characteristics are difficult to influence, setting the default levels to a less power consuming level, could result in significant savings. Examples are the luminance setting of the TV. Calculations in Huenges Wajer and Siderius (1998) showed that a 10 % saving is possible when manufacturer default luminance settings are decreased to a level of 130 cd/m², the level that is used by consumer organisations for their viewing tests.

Another example could be the display of the VCR or hifi-set, that could be set off in the standby mode as a default.

However, regarding the developments on networked appliances and increased functionality, power management seems to be the most important option to increase energy efficiency of consumer electronic appliances. Therefore, beside a short remark on measurement methods, the rest of this section is dedicated to power management.

Harmonised *measurement methods* are a prerequisite for determining (improvements in) power consumption of consumer electronics. Existing measurement methods should be further harmonised and conditions for measurement of (standby) power consumption of networked appliances should be taken into account.

**Power management** was originally introduced in battery-operated appliances (e.g. laptops) to enable a longer usage time with the same battery capacity. Meanwhile power management has become useful also in mains-operated appliances, especially PCs. Advantages are lower power consumption and thus lower dissipation and less heat generated.

Power management ensures – without user interference – that the appliance is always in the mode with the lowest power consumption related to the required functionality.

In general power management is useful in the following situations:

a) When the function fulfilment of the appliance can end without user interference, e.g. a CD-player that has finished playing a CD or a battery charger that has fully charged the battery. In case of the battery charger, some chargers switch to a ‘trickle charge’ mode to prevent discharge of the full battery while it is in the charger.

b) When the need (or absence of need) for the function fulfilment can be detected by the appliance, e.g. when an occupancy detector detects that nobody is watching TV (anymore).

c) When an appliance can fulfil several (sub) functions, some of which are not needed at a particular moment or for a particular period. E.g. in a hifi-set playing a CD, the tuner fulfils no function and need not be powered.

d) When the appliance functions in a network and should be able to receive commands or information from other appliances or from external sources.

e) When ambient conditions influence functionality (and power consumption), tuning the functionality to the ambient conditions is also a form of power management. E.g. the luminance level of a TV can depend on the ambient lighting conditions, sunlight (high luminance level required) versus artificial lighting (lower luminance level required).

The standby mode is a well known example of situation c). The function of an appliance in standby is waiting for a signal to become ‘active’ (i.e. fulfil the primary function). So all parts of the appliance that do not contribute to the waiting need not be powered.

The more complex a product is, the more (power management) modes it could have. Consider e.g. a hifi-set with a CD-player, an amplifier (with speakers connected), a tuner and a cassettedeck. The following modes would make sense (referring to the parts that are functioning):

- standby
- amplifier + tuner/CD-player/cassette-deck
- amplifier + CD-player/tuner + cassette-deck
- CD-player/tuner + cassette-deck

The situations above also apply for appliances in a network. Since the number of combinations for modes will grow exponentially with the number of
appliances, a software solution for power management is needed in this case.
A system (or individual equipment) could use an “energy management stack” (EMS) to implement power management. In each state tasks can be running. At the beginning of each task (e.g. recording of a certain programme by a VCR) a message is put on the EMS, when the task is finished the message is removed from the EMS. When the EMS is empty, the system can switch to a state with a lower power consumption.

The implementation of power management has also implication for the power supply of the appliance: it should be able to support the power management strategy of the appliance.
This means that it should be able to work at nominal efficiency at various power outputs and should have minimal losses.

Energy Saving Devices are appliances that enable to implement a (simple) form of power management in existing appliances that have e.g. no standby mode or a standby mode with a relative high power consumption. Energy Saving Devices have been developed for audio and video appliances but also for vending machines and copiers. In the latter cases, the Energy Saving Device “learns” in which periods the machine is used – and thus should be on – and in which periods the machine is not used – and thus could be off.

An Energy Saving Device for TVs (or other consumer electronic appliances) functions as follows. About 10 seconds after the user has switched the TV into standby passive, the Energy Saving Device switches off the TV (0 W power consumption). The Energy Saving Device has an infrared receiver that can detect the signal of the remote control to switch the TV on. The power consumption of the Energy Saving Device itself is low (< 0.5 W). However, several TVs on the market have a lower standby power consumption, so the Energy Saving Device probably will be most effective as a retrofit device.

Looking at current TV design, the only area where power management could be used is the audio part, if the set is equipped with stereo or surround mode. Power management would switch off stereo sound or the surround mode when broadcasting is not in stereo. However, most sets with surround sound offer the possibility of having a (quasi) surround sound when no surround (or stereo) signal is available. Thus it is not to be expected that consumers - who paid a lot for their “home theatre” with surround sound - would like this feature to be switched off because of power management reasons.

A concept that is used in some TVs on the market is Auto Power Off (APO). After the user has switched the TV into the standby passive mode, the TV switches itself off (0 W power consumption) after a 1 hour period (maximum). If the TV is switched off, the use can only switch on again with the on/off switch on the TV, not with the remote control.

Looking at future developments power management could be a good strategy when the TV gets more computer-like functions and/or will become a networked appliance. Parts that are not used, e.g. a CD-ROM or DVD-drive could be powered down.

Furthermore, with EPG becoming a standard feature in all new television chassis, power management could keep the time the TV is in the standby-active mode (to update EPG information) to a minimum. If the EPG information is not updated during use, e.g. if the TV is left in standby-(passive) for 24 hours, the TV could automatically switch from standby-passive to standby-active mode. After having received the EPG update, the TV could switch back to standby-passive.

The power management concept is a powerful tool to increase energy efficiency of IRDs also. The concept can be tuned to the complexity of the IRD (and the system).

A (simple) IRD should have a standby-(passive) mode with low power consumption. The (minimal) functionality in this mode should be that the IRD is waiting to be switched into another mode by means of an external or internal signal. The IRD should switch automatically to this standby-(passive) mode if tasks in other modes are finished.

For complex IRDs with event driven communication with service providers and other equipment (in the home), power management should be introduced. Power management implies the existence of different power mode/functionality combinations. It should
ensure that the IRD (and connected equipment) is (are) always in the lowest possible power mode, and that not more hardware is powered then necessary for the functionality at that moment.

Power management can be based on a state transition table together with an algorithm to ensure that the system is always in the lowest possible mode (from an energy point of view), i.e. all equipment of the system is always in the lowest possible mode.
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Ziemer, A., Digitales Fernsehen, 2., überarbeitete und erweiterte Auflage, Hüthig Verlag Heidelberg, 1996
## Appendix I: Overview of existing test procedures

<table>
<thead>
<tr>
<th>Item</th>
<th>Cenelec draft</th>
<th>GEA/VIA</th>
<th>EACEM (propos for IEC 107-1)</th>
<th>Energy Star</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. General</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Power supply</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>voltage</td>
<td>&lt; ± 2 %</td>
<td>rated</td>
<td>&lt; ± 2 %</td>
<td>± 5 %</td>
<td>&lt; ± 2 %</td>
</tr>
<tr>
<td>frequency</td>
<td>&lt; ± 2 %</td>
<td>rated</td>
<td>&lt; ± 2 %</td>
<td>± 6 %</td>
<td>&lt; ± 2 %</td>
</tr>
<tr>
<td>harmonic content</td>
<td>&lt; 5 %</td>
<td>&lt; 3 %</td>
<td>&lt; 5 %</td>
<td>&lt; 3 %</td>
<td>&lt; 5 %</td>
</tr>
<tr>
<td><strong>Environmental conditions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>appliance temperature</td>
<td>equal to room temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>room temperature</td>
<td>15 °C to 35 °C (pref. 20 °C)</td>
<td>22 ± 4 °C</td>
<td>15 °C to 35 °C (pref. 20 °C)</td>
<td>22 ± 4 °C</td>
<td>pref 20 °C ± 2 °C (5 °C to 35 °C)</td>
</tr>
<tr>
<td>humidity</td>
<td>45 % to 75 %</td>
<td>25 % to 75 %</td>
<td>45 % to 75 %</td>
<td>pref. 65 % (45% to 85%)</td>
<td></td>
</tr>
<tr>
<td>air pressure</td>
<td>86 kPa to 106 kPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ambient lighting conditions</td>
<td>incident luminance vertical to the tube surface = 75 lux</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>place of appliance</td>
<td>&gt; 0.5 m (TV and TV-VCR combi) or &gt; 0.1 m (VCR) from walls or other obstacles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>other</td>
<td>EMC shielded room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Measurement device</strong></td>
<td>Preferably a mechanical watt-hour meter and time measuring device. Other measurement equipment, e.g. electronic watt meters, being able to measure the power consumption of power supplies working in a burst mode with a low duty cycle can be used as well.</td>
<td>Preferably a calibrated mechanical watt-hour meter and time measuring device.</td>
<td>True power meter with frequency response of at least 3 kHz and a resolution of 0.1 W. The watt meter should be calibrated every year with a standard that is traceable to the U.S. National Bureau of Standards.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Measurement error</strong></td>
<td>&lt; 5%</td>
<td>-0% , +10%</td>
<td>&lt; 5%</td>
<td>-0%, +10%</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Cenelec draft</td>
<td>GEA/VIA</td>
<td>EACEM</td>
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<tr>
<td>4. Measurement procedure</td>
<td>Measure the power consumption of the appliance 15 minutes after it has been switched into the relevant operating mode. The measuring time shall be sufficiently long to measure the correct average value. If the appliance switches, after a time delay, automatically to a mode with a lower (or zero) power consumption, the power consumption before and after the automatic switching has to be determined.</td>
<td>Switch the appliance under test to the standby mode to be measured. Measure power consumption of the appliance 15 minutes after the appliance has been switched to the standby mode with a calibrated Wh-meter. The measuring time shall be sufficiently long to measure the correct average value. If the appliance switches, after a time delay, automatically to a mode with a lower (or zero) power consumption, the power consumption before and after the automatic switching has to be determined.</td>
<td>Measure the power consumption 15 minutes after the appliance has been switched to the standby mode with a calibrated watt-hour meter (preferably a mechanical watt-hour meter) with a maximum permitted error of 5% by dividing the reading by the measuring time. The measuring time shall be sufficiently long to measure the correct average value. If the appliance switches, after a time delay, automatically to a mode with a lower (or zero) power consumption, the power consumption before and after the automatic switching has to be determined.</td>
<td>Record the test conditions and test data. If the device has different standby modes that can be manually selected, the measurement should take place with the device in the most energy consumptive mode. If the modes are cycled through automatically, the measurement time should be long enough to obtain a true average that includes all modes. Bring the test unit into standby mode (not off mode) either by using the remote control device or by using the ON/OFF switch on the test unit cabinet. After the test unit reaches operating temperature and the readings on the power meter stabilise (approximately 90 minutes), take the true power reading in watts from the power meter</td>
<td>Tests shall be carried out after the appliance reaches sufficiently stable conditions.</td>
</tr>
<tr>
<td>5. Results</td>
<td>The results should be given in watts, rounded off to the first digit after the decimal point.</td>
<td>The results should be given in watts, rounded off to the first digit after the decimal point.</td>
<td></td>
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</tr>
<tr>
<td>6. Verification</td>
<td>The verification procedure is a two step approach: the measured value of 1 appliance should not exceed the declared value by 15%. If it does, 2 extra appliances are measured and the average value of the 3 measurements is calculated. This average value should not exceed the declared value by 10%.</td>
<td></td>
<td>Energy Star value is maximum value. A model may qualify as Energy Star compliant if testing indicates that 95% of the units sold under this model name/number will meet the specifications contained within the MOU</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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