

RESEARCH ON THE ISSUES WITH THE LOW COST POWER SUPPLIES FOR PERSONAL COMPUTERS

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Abstract

The paper is reporting some of the results from research on the implementations, usage, testability, serviceability, recycling and reuse of the low costs mass production power supplies (PSs) for the personal computers (PCs) compatible with IBM PC. A critical evaluation of the specifications and implementations of popular PSs is done. The major issues are listed and proposals to correct some of them are given. External universalized power supply with continuously reviewed specifications was proposed in order to overcome the major drawbacks of the present industry standard specifications and implementations.

Keywords: specifications, power supply, personal computers, usage, reuse, recycling, repair, environment, quality

INTRODUCTION

The first personal computer (PC) of IBM based on the microprocessor Intel 8088 was introduced approximately thirty years ago (around 1981). Ten of millions of more or less compatible PCs were produced until now. One of the problems when these PCs are used is the internal power supplies (PSs). They are noisy, overheated, put into small place, not well protected from dust and humidity, with small power factor, not well resist to the environmental changes and practically not reusable.

Although national and/or world wide statistics about the failures in PSs for the PCs, theirs reparations, reuses and recycling are not available from the author's experience the problems discussed in the paper are applicable to the most of the low cost PSs for the PCs imported or assembled in the country. It is considered that at least 1% of the PCs had a failure at the PS which requires intervention of a specialist at least once during their life time. The issues with the PS are observed into new and second hand PCs. Reliable information about mean time between failures (MTBF) of the low cost PS was not found.

The paper is making critical evaluation of the PSs for the desk top personal computers (DTPCs). The reason of doing that evaluation is the experience with failures in the PSs for the PCs leading the additional damages and losses. Most of the damaged PSs cannot be

repaired and are abandoned creating toxic garbage. They are not recycled and are creating environmental issues.

THE MAIN ISSUES AND ROOT CAUSE ANALYSIS

After detailed analysis of the subject it is found that the inappropriate, low cost oversimplified design based on ineffective design specifications is the main reason of most of the failures.

Designing and producing PSs with relatively high failure rate, low serviceability and practically impossible reuse of the electronic and mechanical components, cables and connectors is an economic and environmental issue.

The weight of a single low cost PS is from 0.5 to around 2kg. The weight of the cables and the connectors is around 0.15 kg (0.1-0.25 kg). The weight of the heat sinks from aluminum is around 50 grams. These valuable materials are lost when the damaged PS is not reused or recycled.

Most of the components in the PS cannot be replaced, because there is no access to them. As general rule the printed circuits boards (PCB) cannot support re-soldering. In all observed cases PCB is single sided.

As general rule schematic diagrams and manuals for the reparation works are not supplied with new or second hand PC or when a new PS is obtained.

The output power of the PS could vary from less than 100 W to more than 1000W. PS for the computer for games, graphic stations, work stations and servers could be with total output power more than 1000W and the design could be very different.

The portable computers (laptops, palm top, etc.) have (external) PSs with lower power e.g. from 20 to 100 W and they are usually with different specifications compared to the PSs of the desktops PCs.

Most of the low cost PSs have total output power in the range of 100W to 500W and the paper is dealing with them. PSs from twenty two models from different manufactures are evaluated [1-22]. Also design specifications and design notes for the PSs from manufactures were taken into considerations [S1-S8].

GENERAL OBSERVATIONS

After research on the subject and examining the PSs listed in the reference section of the paper and the components in them the following general observations were made:

- * No up-to date schematic diagrams and PCB layout diagrams available with the supplied PSs and PCs. There is no such up to date information on the Internet websites of the manufacturers and dealers.

- * No test connectors were found on the PCBs. This is making difficult the diagnostic of the PSs.

- * The Light emitting diodes (LEDs) on the PCB of the PS are not available and this is making the visual tests of the output voltages impossible without additional test equipment.

- * No external light indicator for applied mains power supply (110V/220V) in most of the PSs.

- * No lights indicators for particular conditions: low input power supply, power supply failure, high ripples, overload condition, thermal conditions, etc.

- * No easy to use test points on most of the PCBs.

- * No wave diagrams and explications on the found electrical schematic.

- * There are no proper identifications of the PCBs and the found schematics for many PSs. In order to be repaired the PS must be more or less reengineered.

- * The high voltage and the low voltage sections of the PCB in the PS are too close. In some of the PCBs there are traces from electrical discharges between the components in the two sections leading to damage of the PS.

- * The place where the cables are soldered is particularly difficult to test and repair.

- * In many cases the electrical fuses are soldered on the PCB and difficult to replace.

HEAT SINKS AND VENTILATORS

The size, the shape and the place of the heat sinks is making virtually impossible to have access to a lot of components, to test and to replace them.

Especially difficult is the situation with two T-shaped heat sinks which are covering significant part of the components. Changing the components mounted on the heat sinks or near to them is leading frequently to damages of the PCB and/or of the components.

Many electrolytic capacitors and other components are too close to the heat sinks. Continuously heating them is reducing the reliability of the PS.

In most of the PSs no thermal protection is observed.

Temperature sensors on the heat sinks are found only in few models of PSs. They were diodes 1N400X or low cost thermistors.

The fans in the PSs of the PC are the greatest source of noise and one of the most important sources of failures. Frequently due to dust or some other reason they became less productive or are stopping. In the cases when there is no effective over-thermal protection this is leading to failures of the PS.

The noise produced by the fan(s) is changing into time. The noise characteristics of the fans and the entire unit are one of the things to take into considerations when a new PS is selecting. The inevitable degradation of these characteristics during the exploitation should be evaluated. Most of the new fans have noise level between 16 and 35 dBa according the available data sheets but this is not tested. The produced noise from most of the old fans was audible and cannot be neglected. The majority of the fans are working from +12V and continuously. Some of the PSs have two and sometimes three fans from different types and running at

different speeds which is making the spectrum of the produced noise larger than expected.

Although some mechanical vibration on the working PSs were observed they are not evaluated here due to lack of specific equipment. It is considered that these vibrations could have some negative biological effects and should be suppressed.

CABLES AND CONNECTORS

The low voltage cables (LVC) are soldered on the PCB of the PS. When the PS is replaced and abandoned these cables with the associated connectors are abandoned and the reuse is practically not done. The typical weight of the LVC and the connectors is around 0.15 kg per PS. In case if annually around the world 100 000 PSs are abandoned that means that 15000 kg of cables and connectors are abandoned. Also it is found that the prices of additional LVCs when available as separate items are relatively high.

It is much better when the PS is replaced the cables with connectors to be disconnected and reused if they are appropriate and this is the common case.

LINE FILTERS AND POWER FACTOR

No LC line filters are available in most of the evaluated PSs. Frequently there are places on the PCB for line filters but the components are not present. Also in the cases when the inductors for the line filters are on the PCBs they are put on plastic cores and not on ferrite cores and this is making them ineffective.

Most of the PSs have only two or three capacitors for line filtering.

Rarely the PSs have single stage LC line filter with appropriate components.

Only in two models from more than twenty models of PSs were found two stages line LC filters with two inductors and associated capacitors and protection elements.

The low cost PSs are of switching type. Roughly speaking their input is equivalent to a capacitor with 150-470 μF with a small value series resistor and much bigger parallel resistor. As general rule power factor corrector (PFC) is not available in the low cost PSs. Rarely passive PFC with a single inductor was found.

The PSs are source of harmonics and have power factor far from the ideal value of 1,00.

This could be an issue in offices from type "open space" where more than hundred PCs are working, making a lot of audible and electrical noise in large spectrum.

THE REQUIRED MINIMAL ELECTRICAL LOAD

Practically all of the PSs need minimal electrical load (MEL) in order to operate properly. These MELs are different for each output and could be evaluated roughly as 5-10% from the maximal allowed current at each switching output. The linear output of PS, if present, usually does not need MEL.

Switching the PS on without MEL could produce damage or simply the PS does not work. This is making the diagnostic and repair more difficult because the required minimal load is unknown and different for different models. Test equipment for servicing PSs is not observed in several service firms where repairing of not working PSs should be done. The suspicious PSs seem to be simply replaced and not repaired as general rule.

Manually or self-resetting circuit breakers (instead of fuses) are not found in the PSs. The internal fuses are difficult to replace in case of failure.

Thermal protection is not found in most of the PSs.

Self-resetting thermal cutouts based on the temperature of the transformers and heat sinks are not found.

DESIGN SPECIFICATIONS

PSs for PCs are designed and manufactured more than thirty years. For that time a little progress seems to be made. Comparing PSs from the first models of PCs and PC XT with modern low cost PSs it appears that there are simplifications and degradation of the quality of the PSs. It is supposed that a lot of PSs cannot be repaired due to the bad design based on inappropriate design specifications.

The design specifications for the PSs are considered here the main reason for the unreliable design, the low serviceability and the low reuse of the PSs for the PCs. For example the space for the PS in the box of the PC is too small. In fact adding two more centimeters in the dimensions of the PCB is making the PSs much easier to repair. Also

using an appropriate connector(s) instead of soldering a large number of output wires on a small space was not changed during the years.

NOISE, VIBRATIONS AND DUST

Most of the desk top PCs are running near to the floor, where sometimes significant dust could exist but dust and noise filters were not found in the tested PSs.

The lack of dust filters is creating a lot of issues because after several months of work some of the fans stop working due to the dust and the PS could be damaged.

Many of the desks top PCs have three or more internal fans running at different speed and producing audible noise and mechanical vibrations. One, two or three of the fans are in the PS, one fan is on the box/case of the PC and one fan is on the processor. One more fan could be found on the graphical card.

The noise from fans and hard disks is a big issue especially in the following cases:

- * Offices from the type of “open spaces” where many PCs are running and producing a lot of audible noise.

- * Rooms with patients susceptible to the noise produced from the PCs.

- * Rooms with large quality of PCs put into small space, e.g. rooms for reliability testing where the PCs should work many days in order to be tested.

- * Rooms for any creativity work e.g. editing, writing, research and design work.

INPUT OVER VOLTAGE PROTECTION

The input over voltage protection in the low cost PSs is very simple or practically does not exist. Very frequently two or three capacitors, a “varistor” or a “transil”-like element is used, but the effectiveness cannot be trusted. When damaged these components are difficult to replace.

THE PS OF THE “SLIM PCS”

The PSs of the “slim PCs” or “compact PCs” represent much more difficulties than the PSs of the “standard desk top” PCs. Usually they are including several small PCBs and heat sinks with strange forms. The reparation works is so difficult that in almost all cases no attempts for reparations were made and the damaged PS is

immediately replaced with a new one. The damaged PS is usually abandoned.

EXTERNAL POWER SUPPLY FOR THE PCS

External power supply units (EPSs) for desk stop PCs were developed and tested and proven to be useful and effective. The following main options are seen with EPSs and each of them has several advantages:

- * The EPS could provide all of the necessary voltages and signals for the PC and for the associated equipment.

- * The EPS could provide well regulated and protected 12, 24 (+/-12V), 36 or 48 V direct current (DC). From that voltage all necessary voltage levels for the PC could be produced internally to it. The option with two, three or four well regulated and protected DC outputs multiple of 12 V is interesting because is adjustable to different external equipments.

- * It is evaluated that supply voltage from EPS multiply to 15V could be more suitable than the solution with multiple to 12 V because the PS could be used for charging accumulator batteries.

The benefits of the EPS are:

- * Cables are separated from the EPS and could be reused. They have connectors from the both sides (the PS and the PC).

- * The EPS could be the same for the PC and the computer screen.

- * The EPS could be combined with an uninterruptible power supply (UPS) providing sufficient current for e.g. 15 minutes for the PC and associated equipment.

- * The EPS could be combined with protection, line filter(s) power factor correction and additional circuits necessary for proper work of the PC and associated equipment.

- * The EPS could have additional outputs for relatively low power additional laboratory or business equipment.

- * The EPS is giving the opportunity for better thermal protection and cooling fans control. The design with no fan is also possible because the EPS could use a larger box working as heat sink.

- * The EPS could be used for additional functions.

- * The reuse and the reparation of the EPS is seen as more effective than the internal PS.

* One EPS with or without battery backup could be used for the home audio chain, TV set, PC, alarm clocks, electronic/electrical toys, medical surveillance equipment and other electronic equipment controlled by a home PC.

* The minimal load for the EPS is provided internally.

* Active power factor corrector could be implemented easily in EPS.

The outputs of typical PS for desktop PS are: +3.3V (14A), +5V (30A), +12V (13A), -5V (0.5A), -12V (0.8A), +5V standby (1.2A). All these voltages could be obtained from external DC source for 12V (15V) or 24V (30V). Removing the high voltage section from the PC is making the computer safer. Also the high voltage section is presenting in all electronic equipment working together under the control of the PC and obviously can be replaced with a single high voltage block.

LINEAR EXTERNAL POWER SUPPLIES

Experiments with originally developed and produced linear EPS (LEPS) for PC are showing the following advantages:

* Low ripple and low noise of the output voltages.

* Possibility to control precisely the output current and voltage at each output.

* Low level electromagnetic interferences.

* Easy test, control, diagnostic and repairing.

* Very low electromagnetic emissions. The power cord of the switching powers supplies is acting as antenna creating large band electromagnetic field at many meters from the PS. This negative effect is much lower or not existing at the LEPS.

* Protection of each output could be precisely controlled.

* Possibility to supply current to the PC and associated test and tested equipment under laboratory conditions.

* The power transformer of the LEPS has important protection role, e.g. electrical isolation, electrical filtering, etc.

* All outputs of the LEPS are independent. This is not true for most of the low cost internal PS for the PC.

* Usually for the LEPS there is no minimal external load current in order to start. The minimal stabilization current for the LEPS is a

few mA and is could be provided internally from the LEPS.

LEPS are very effective when the supplied power for the PC is less than approximately 200 W and the output currents are less than 15 A per output. There is lots of integrated circuit which can be used in LEPS and some of them are low dropout (LDO) regulators (Please see the reference section).

The standby secondary power supply which is incorporated in most modern PSs and cannot be switched-off is wasting energy and must be excluded in most of the cases.

CONCLUSION

The designed specification of the PSs for the PC is considered the root cause for the issue with the PSs.

The EPSs are considered better choice for most of the PCs and especially for the desktop PCs. They are more reliable, with better electrical, mechanical and environmental characteristics. The outputs could be multiple to 12V (13.2V) or better 15 V (+-4%) which make them versatile tools for the office, home and laboratory use.

The EPS is easy to be combined with UPS.

The EPS could be effectively designed without cooling fan(s) which is making them “no noise power supplies” Some mechanical vibrations could exist due to the power transformer and rectifying elements but usually these vibrations are unnoticed by humans.

The EPS and especially the LEPS could be made modular, e.g. “one module per output”, module “input filter”, module “input protection”, etc. which could be inserted or removed when necessary.

The reuse, multifunctional use and recycling of EPSs is possible and could compensate the higher initial price.

It should be noted that removing components from large quantity of PSs (as listed in the reference section) for reuse is producing bad smell, vapor, smoke and possibly headaches. It is suggested that this activity should be produced under appropriate conditions in order to avoid the negative effects on the workers.

REFERENCES:

The models of the PS listed below represent more or less typical designs and

implementations for the industry in the time span 1995 -2010. The more expensive and the more sophisticated models are not necessary the better one. Lists of the datasheets for some of the most important and typical semiconductor components used in the internal and external PSs are given below.

EVALUATED POWER SUPPLIES FOR PCS:

- [1] FSP Group Inc., Fortron/ Source, Model No. ATX-350PNF (350W)
- [2] CODEGEN 300W, Model 300X, P4
- [3] CODEGEN 350W, Model 300X, ATX 2.03 (P4)
- [4] Multirama Model LPG9-43, 500W Made in Thailand (triple fan PS).
- [5] PS Model: LC-B350ATX, SW31XA, P4 (350 W)
- [6] Rexpower, Comtex Enterprise Ltd, ATX and ATX 12, PL-400 (400W)
- [7] Bestec, Model ATX-300-12Z Rev: CC (300 W max)
- [8] KME, Key Mouse Electronics Co, LTD. Model: PX-230W ATX
- [9] JARC Model: LC-8400BTX (Total output 400W)
- [10] JARC Model: ATX400W P4 (Total output 400W)
- [11] Win power Model : PS-250WB, Made in China
- [12] G-TEC 320W, Model: 320W
- [13] PS Model: ATX-400W P4
- [14] Delta Electronics, Inc. Model DPS-200PB-7G A Rev: 01, Made In China, (200W max)
- [15] COLORS it, ATX12V P4, Model 330U-FNH (350W)
- [16] JNC Computer Corp. Model: LC-250ATX (Output: 250W), JN03X
- [17] DTK Computer, Model: PTP-2007, Output 200W
- [18] Delta Electronics, Inc, Model DPS-88AB-2A Rev 05, (Max power 100W), Made in China.
- [19] ISO Switching Power Supply Model: No: ISO-480PP (max. output power 420 W)
- [20] Model: LPK6-350WP (350 W max)
- [21] Sunny Technologies Co., LTD, Model ATX-230.
- [22] DTK PTP-2038, 200W PC ATX PS.

SPECIFICATIONS AND APPLICATION NOTES

- [S1] Intel Corp., ATX Specifications version 2.1, 1996-2002 (24 pages).
- [S2] Intel Corp. ATX 12 V Power Supply Design Guide. Version 1.3, April 2003, (38 pages); Version 2.2 from May 2005.

- [S3] Intel Corp. Power Supply. Design Guide For Desktop Platform Form Factors. Rev. 1.1. March 2007. (104 pages)
- [S4] Intel Corp. SFX12V Power Supply Design Guide. Ver. 3., March 2005, (60 pages).
- [S5] Intel Corp. EPS12V Power Supply Design Guide. Ver. 2.92, 2002-2004, (41 pages).
- [S6] Power Integrations, DI-30 Design Idea, TOP Switch-GX, 180W PC Main SFX Supply. 2008.
- [S7] Philips Semiconductors, Lutz Pape, Wolfgang Schwatz, AN468, Protecting Microcontroller Systems against Power-Supply Imperfections, May 14, 2001
- [S8] Linear Technology. AN-32. Jim Wiliams. High Efficiency Linear Regulators.

SEMICONDUCTORS AND ICS DATA SHEETS FOR MAJOR COMPONENTS FOUND IN PS FOR PC

- [D1] National Semiconductor Corp. LM393 Data sheet
- [D2] National Semiconductor Corp. LM339 Data sheet
- [D3] Texas instruments, TL494 Pulse Width Modulation Control Circuits. Data sheet. 1983-2005.
- [D4] KA7500B IC Data sheet.
- [D5] KG6105 DZ, KA6105D Data sheet.
- [D6] MOSPEC:
 - * F12C05 thru F12C20 (12A, 50-200V).
 - * F16C05 thru F16C20 (16A, 50-200V).
 - * S20C30 thru S20C60 (20A, 30-60V).
- [D7] Vishay General Semiconductor SBL (F,B) 2030 CT &SBL (F,B) 2040CT (10A x 2).
- [D8] FCI Semiconductor, VF16C05...60 Series (16A, 50-600V).
- [D9] Fairchild Semiconductor:
 - * HGTG12N60B3, 27A, 600V, UFS Series N-Channel IGBTs. Data sheet. 2003.
 - * FJP13009 transistor (400V, 12A)
 - * KA2S0680B Power switches up to 150 kHz.
 - * KBU8A – KBU8M 8A Bridge Rectifier (50-1000V).
 - * SSW2N60B/SSI2N60B N-Channel MOSFET (600V, 2A)
- [D10] Philips Semiconductor, BU2508A transistor (700V, 8A)
- [D11] BSD Semiconductor Manufacturing Ltd, AZ7500B/C Data sheet.
- [D12] SGS-Thompson:
 - * BUX98/BUX98A transistor (400/450V, 30A).
 - * STPS3045CT Power Schottky rectifier (2x15A, 45V)
 - * STP2NA50/FI N-channel MOSFET (500V, 40hm, 2/2.8A).

- [D13] Toshiba:
 * 2SC5129 transistor (600V, 10A)
 * 2SC5353 transistor (800V, 3A).
 [D14] Fuji Electric:
 * Power MOS-FET, 2SK2147-01R (900V, 6A, 2.8 Ohm, 80W)
 * 3SK2654-01 N-Channel MOSFET (900V, 2Ohm, 8A, 150W)
 * 2SK947-MR N-Channel MOSFET (250V, 0.3Ohm, 12A, 40W)
 [D15] Chenyi Electronics, SR1620 thru SR16A0 Schottky barrier rectifier (20 to 100V, 16 A).
 [D16] WTE (Won Top Electronics), SB1620CT thru SB16100 Schottky barrier rectifier (20 to 100V, 16 A).
 [D17] FMS, SR1620 thru SR1660 Schottky barrier rectifier (20 to 60V, 16 A).
 [D18] Micro Commercial Components, MBR1620CT thru MBR1660CT Schottky barrier rectifier (20 to 60V, 16 A).
 [D19] ATE Co. Ltd. DL209L NPN transistor (400V, 12A)
 [D20] AUK Semoconductor. STD13007F NPN Transistor (400V, 8A, 40W, 14 MHz).
 [D21] International Rectifier.
 * IRFP264 HEXFET Power MOSFET (250V, 0.075 Ohm, 38A).
 * IRFP540 HEXFET Power MOSFET (500V, 0.4Ohm, 12A)

LINEAR POWERS SUPPLIES AND REGULATORS

- [L1] NTE Electronics:
 * NTE935 IC +1.2 to +32V, 5A Data sheet.
 * NTE933 IC +12V, 5A Data sheet.
 [L2] Linear Technology:
 * LT1581/LT1581-2.5, 10A, Very low dropout regulators.
 * LT1083 – fixed 7.5A Regulator
 * LT1083 – Adjustable 7.5A Regulator
 * LT1580, LT1584 7A Regulator
 * LT1084/1585A/3070/LT3071 – 5A Regulators.
 [L3] National Semiconductor Corp. Chester Simpson. Linear and switching Voltage Regulator Fundamentals.
 [L4] Sharp, PQ05RD11 Series 1A low power loss voltage regulators. Data sheet.
 [L5] National semiconductors Corp.:
 * LM150 3A Adjustable power regulator.
 * LM323 5A, 5V Power regulator.
 * LM333 3A Adjustable Power regulator.
 * LM350 3A Adjustable Power regulator.

- * LM338 5A Adjustable Power regulator.
 * LM396 10A Adjustable Power regulator.
 * LM 317 1.5 A Adjustable Power regulator.
 * LM 337 1.5 A Adjustable Power regulator.
 * LM78XX Series 1A Positive Voltage Regulators.
 * LM79XX Series 1A Negative Voltage Regulators.
 * LM1084 5A Positive LDO.
 * LM1085 3A Negative LDO.
 * LM1086 1.5A Positive LDO.
 [L6] Texas Instruments:
 * UCC283TDKTTT-3 – 3A, 3.3V LDO
 * UCC283T-3 – 3A, 3.3V LDO
 * UA78xxCKC – 1.5 A Positive regulators
 * TL1963A 1.5A Regulator
 [L7] MOSPEC:
 * MJE2955T and MJE3055T PNP/NPN transistors (75W, 60V, 10A).
 * TP35/TIP36 NPN/PNP transistors (40-100V, 24A, 125W)
 * TIP120/TIP125 NPN/PNP transistors (60V, 5A, 65W)
 [L8] Siemens, IGBT BUP 314 (1200V, 52A, 300W)
 [L9] ON Semiconductor 2N6283/4/6/7 NPN and PNP Transistors (80/100V, 20A, 160W).

SOME ABBREVIATIONS IN THE PAPER

- A - Ampere
 AC – Alternative Current
 DC – Direct Current
 DTPCs - Desk Top Personal Computers
 EPS - External Power Supply
 IGBT – Insulated Gate Bipolar Transistor
 IC - Integrated Circuit
 LDO – Low Dropout (Regulator)
 LEPS – Linear External Power Supply
 LM - Linear Monolithic (Integrated Circuit)
 LVC –Low Voltage Cables
 MEL - Minimal Electrical Load
 MTBF - Mean Time Between Failures
 UPS – Uninterruptible Power Supply
 PFC – Power Factor Correction
 PCB - Printed Circuit Board
 PC - Personal Computer
 PS – Power Supply
 PWM – Pulse Width Modulation
 ShCP – Short Circuit Protection
 SR – Shottky Rectifier
 V – Volt
 W – Watt