



UNIVERSITI PUTRA MALAYSIA

**THE DEVELOPMENT OF UNINTERRUPTIBLE POWER SUPPLY FOR
PERSONAL COMPUTERS**

ALI MILAD JARUSHI

FK 2000 20

**THE DEVELOPMENT OF UNINTERRUPTIBLE POWER SUPPLY FOR
PERSONAL COMPUTERS**

By

ALI MILAD JARUSHI

**Thesis Submitted in Fulfilment of Requirements for the
Degree of Master of Science in the Faculty of Engineering
Universiti Putra Malaysia**

October 2000



Dedicated to

*My Parents,
Wife
and son Anas*



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment
of the requirements for the degree of Master of Science

**THE DEVELOPMENT OF UNINTERRUPTIBLE POWER SUPPLY FOR
PERSONAL COMPUTERS**

By

ALI MILAD JARUSHI

October 2000

Chairman: Dr. Ishak Bin Aris

Faculty: Engineering

Computer systems have become very important all over the world. They are capable of doing complicated works. When the main power fails, the computer system cannot support its normal operation and it will shut down immediately. Consequently, all working data will be lost if they are not saved previously. Therefore, an uninterruptible power supply (UPS) should be designed to protect data loss and to prevent any output interruption during a power failure.

The objective of this project is to design, construct, and test UPS for personal computers. The proposed UPS is cheaper and its size is smaller than that of the conventional UPS available in the market.



The proposed UPS consists of rectifiers, a battery charger, an automatic controller, a sealed lead acid battery, regulators and a boost DC-to-DC converter

The proposed UPS is capable of supporting the normal operation of the PC for 20 minutes during power failure. This 20-minute time is enough for the user to save the current work on the PC and switch off the PC properly. The detailed analysis of the design, experimental works and simulation are discussed in this report.

Results of the experimental and simulation work showed that there was a good agreement between the hardware and software. This indicated that UPS was successfully developed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains.

**PEMBINAAN BEKALAN KUASA TIDAK BOLEH GANGGU (UPS) UNTUK
KOMPUTER PERIBADI**

Oleh

ALI MILAD JARUSHI

October 2000

Pengerusi : Ishak Aris, Ph. D.

Fakulti: Kejuruteraan

Sistem komputer adalah penting di seluruh dunia. Ia mempunyai kemampuan melakukan kerja yang kompleks. Apabila kuasa utama gagal, sistem komputer tidak dapat beroperasi dengan normal dan ia akan terpadam serta-merta. Akibatnya semua data yang sedang dibuat akan hilang jika sebelumnya tidak disimpan. Oleh itu, sebuah bekalan kuasa tidak boleh ganggu (Uninterruptible Power Supply, UPS) direkabentuk untuk melindungi kehilangan data dan mengelakkan daripada terjadinya gangguan keluaran semasa kegagalan kuasa.

Objektif projek ini ialah untuk merekabentuk, membina dan menguji sebuah bekalan kuasa tidak boleh ganggu untuk komputer peribadi. Sistem yang dicadangkan adalah lebih murah dan saiz litarnya lebih kecil berbanding sistem biasa yang terdapat di pasaran.



Umumnya, struktur yang dicadangkan adalah terdiri daripada penerus, sebuah pengecas bateri, sebuah pengawal automatik, sebuah bateri asid berplumbum, pengatur, dan sebuah pelonjak penukar arus terus ke arus terus.

Sistem yang dicadangkan berkemampuan menyokong komputer peribadi untuk beroperasi secara normal selama 20 minit selepas kegagalan kuasa. Masa 20 minit ini adalah mencukupi untuk pengguna menyimpan data kerja yang sedang dibuat ke atas komputer peribadi. Kemudian pengguna boleh menutup suis komputer peribadi dengan lebih selamat. Analisa terperinci tentang rekabentuk, kerja ujikaji dan simulasi akan dibincang dan dikemukakan di dalam laporan ini.

Keputusan dari ujikaji dan simulasi menunjukkan terdapat persetujuan yang baik di antara perkakasan dan perisian. Ini menunjukkan UPS tersebut telah berjaya di hasilkan.

ACKNOWLEDGEMENTS

I thanks Allah (S W T), the most gracious and merciful, who has given me the ability to finish this project successfully

I gratefully acknowledge the guidance, advice, support and encouragement received from my supervisor, Dr Ishak Aris, who has been advising and commenting on this project until it turns to a real success

I also thank my co-supervisor Dr Norman Mariun, for his advice, remarks, and encouragement from the beginning to the completion of this work

High appreciation is expressed to my supervisory committee member, Pn Ratna Kalos Zakiah Sahbudin, for her advice and encouragement

Great thanks to my family members, who have not stopped encouraging and supporting me to achieve this success

Appreciation is also extended to the Faculty of Engineering for providing the facilities and the components required for undertaking this project

Finally, I would like to thank everyone, who has given me help, comments and suggestions



TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL SHEETS	viii
DECLARATION FORM	x
LIST OF TABLES	xiii
LIST OF FIGURES	xiv
LIST OF PLATES	xvi
LIST OF ABBREVIATIONS	xvii
CHAPTER	
I INTRODUCTION	1
Importance of the Project	2
Problem Statement	4
Objective of the Project	8
Thesis Layout	8
II LITERATURE REVIEW	10
Concern about Power Quality	10
Power Problems	12
Causes of Power Quality Problems	13
Types of Power Problems	13
Effects on Sensitive Equipment	14
Solution for the Power Problems	16
Uninterruptible Power Supply(UPS)	20
General Construction of Conventional UPS Systems	20
UPS Types	34
UPS Operation	37
Applications of UPS	38
UPS Characteristics	40
DC- Uninterruptible Power Supply	41
DC-to-DC Converter	43
The Importance of DC-to-DC Conversion	43
Types of DC-to-DC Converters	43
The Boost Converter	44
Power Distribution in Personal Computers	50
Why 5 V and 12 V Only?	51



	The Power-Good Signal	53
	Summary	54
III	MATERIALS AND METHODS	55
	Flowchart of the DC-UPS	58
	General Structure of the Proposed System	59
	Rectifier Circuits	64
	Sealed Lead Acid Battery	67
	Regulators	69
	Charger	70
	Automatic Controller Circuit	79
	DC-to-DC Converter	82
	Printed Circuit Board	90
	Pspice Simulation	92
IV	RESULTS AND DISCUSSION	94
	Software	94
	Rectifier Circuit	94
	DC-to-DC Boost Converter	96
	Hardware	98
	Rectifier Circuit	98
	Sealed Lead Acid Battery	103
	Regulators	105
	Charger	107
	Automatic Controller	111
	Boost Converter	113
	Integrated Test	116
	Comparison Between Proposed UPS and Conventional UPS	116
V	CONCLUSION AND FUTURE RECOMMENDATION	118
	REFERENCES	119
	APPENDIX	122
	A Pspice Simulation Program	123
	B Components Data sheets	128
	VITA	160



LIST OF TABLES

Table		Page
1	Specification of Computers' Manufactures	15
2	Power Problems and Solutions	19
3	Voltage and Current Rating for PC Components of 200 W Power Supply	51
4	Voltage Requirements of Computer Components	59
5	Measurement of Discharging Current of the Battery	104
6	Battery Voltage during the Charging Cycle	108
7	Charging Current during the Charging Cycle	109



LIST OF FIGURES

Figure		Page
1	IBM Study Result	2
2	Effects of Disturbances	3
3	Current Protection of PCs Using Conventional UPS	5
4	Block Diagram of the Proposed UPS	6
5	Connection of Proposed UPS and PC	7
6	General Construction of a Conventional UPS system	20
7	Rectifier with Step Down Converter as a Charger	22
8	Block Diagram of IC3906	24
9	Charging the Battery after an Outage Causes Discharging	27
10	Various Inverter Arrangement	30
11	Uninterruptible Power Supply Control	30
12	UPS Arrangement Where Charger and Inverter are Combined	31
13	Static Switch in UPS	32
14	Block Diagram of ICL7673	33
15	Online UPS	35
16	Offline UPS	36
17	Hybrid UPS	36
18	UPS Operation	38
19	Basic Circuit of Boost Converter	44
20	Inductor Current Waveform	46
21	Arrangement for Boost Operation	46
22	Arrangement for Transfer of Energy	48
23	Power Distribution in a PC	50
24	Power Distribution of PC Power Supply	50
25	Flowchart Showing Project Activities	56
26	Block Diagram of the Proposed UPS	57
27	Flowchart of the Proposed UPS	58
28	File Menu	62
29	Window to Save a File	62
30	Start Menu	63
31	Window of the Shut-down Process	64
32	Circuit Diagram of the Rectifiers	65
33	Connection of the Battery	68
34	Connection of the Regulators	69
35	Charger Circuit Diagram	71
36	Dual-Level Float Charger	71
37	IC3906 as a Dual-Level Float Charger	73



38	Charger Indicator Circuit	78
39	Construction of Automatic Controller Circuit	80
40	DC-to-DC Boost Converter Circuit	82
41	Configuration of LM2577	83
42	Complete Constructed Circuit of Proposed System	89
43	Printed Circuit Board	91
44	Pspice Schematic Diagram for the Rectifier	93
45	Pspice Schematic Diagram for the DC-to-DC Converter	93
46	Simulated Input Voltage of the Rectifier	95
47	Simulated Output Voltage of the Rectifier without a Filter	95
48	Simulated Output Voltage of the Rectifier with a Filter	96
49	Simulated Input Voltage of the Boost Converter	97
50	Simulated Switched Pulses of the NPN Switch	97
51	Simulated Output Voltage of the Boost Converter	98
52	Measurement Method of the Rectifier Circuit Result	99
53	Input Voltage of Rectifier1	100
54	Input Voltage of Rectifier2	100
55	Output Voltage of Rectifier1	101
56	Output Voltage of Rectifier2	101
57	Output Voltage of Rectifier1 with a Filter	102
58	Output Voltage of Rectifier2 with a Filter	102
59	Discharging Current from the Battery	104
60	Method of Measuring the Regulator Voltages	105
61	Input Voltage of the Regulator	106
62	Output Voltage of the Regulator	107
63	Battery Voltage Over One Charging Cycle	109
64	Charging Current during the Charging Cycle	110
65	Measurement Method of Testing the Boost Converter	114
66	Input Voltage of the Boost Converter	115
67	Output Voltage of the Boost Converter	115



LIST OF PLATES

Plate		Page
1	Rectifier Circuit	67
2	Connection of the Sealed Lead Acid Battery	68
3	Construction Circuit of the Battery Charger	79
4	Construction Circuit of the Automatic Controller	81
5	Construction of the DC-to-DC Boost Converter	87
6	Construction of the Complete Circuit	88
7	Indication of Red LED when a Battery is Connected	112
8	Indication of Green LED during No Failure	113



LIST OF ABBREVIATIONS

AC	Alternate Current
Ah	Ampere hour
c	Capacity of the Battery
C	Capacitor
C_i	Input Filter Capacitor
C_o	Output Capacitor
CPU	Central Processor Unit
D	Diode
D_1	Duty Ratio
DC	Direct Current
En	Energy
GND	Ground
h	Hour
Hz	Hertz
I_c	Capacitor Current
I_D	Drive Current
I_m	Input Current
I_L	Inductor Current
$I_{MAX.}$	Maximum Current
I_{OC}	Over Charge Current



I_{OCT}	Over charge Transition Current
I_p	Peak to Peak Current
IC	Integrated Circuit
k	Constant
kVA	Kilo Volt Ampere
K	Duty Cycle
L	Inductor
L_{crit}	Critical Inductor Value
L1	First Static Logic Latch
L2	Second Static Logic Latch
LED	Light Emitting Diode
mA	Millie Ampere
ms	Millie Second
MG	Motor-Generator set
MOV	Metal Oxide Varistor
PC	Personal Computer
PCB	Printed Circuit Board
PQ	Power Quality
P_{bar}	Status Indicator Switch of the Primary Supply
R	Resistor
RG1	Regulator 1
RG2	Regulator 2

S	Switch
S1	Switch 1
S2	Switch 2
S_{bar}	Status Indicator Switch of the Battery
SCR	Silicon-Controlled Rectifier
t_o	On time of the switch
t_1	Time of the Close Switch State
t_2	Time of the Open Switch State
T	Thyristor
UPS	Uninterruptible Power Supply
V_{12}	Transition Voltage
V_a	Average Voltage
V_B	Battery Voltage
V_{dc}	DC Voltage
V_f	Float Voltage
V_l	Inductor Voltage
$V_{Max.}$	Maximum Voltage
$V_{Min.}$	Minimum Voltage
V_o	Output Voltage
V_{oc}	Over Charge Voltage
V_p	Primary Voltage

V_{REC}	Output Voltage of Rectifier
V_T	Threshold Voltage
V_s	Input Voltage
μs	Micro second

CHAPTER I

INTRODUCTION

The term *power quality* (PQ) has become one of the most prolific buzzwords in the power industry since the late 1980s. This issue has a sharp attention because of the increase in the number of loads sensitive to power disturbances and has become tougher as the loads become important causes of degradation of quality.

Modern electronic circuits, such as computers, data processors, and communication equipment, require extremely reliable power sources. While commercial power is normally utilised as the basic source for these circuits, many power problems may occur to this power source and affect the operation of computer circuits and the like.

To operate this sensitive equipment in a safe operation, a source of continuous, regulated power having very stable characteristics is needed. This need is met generally by one of the power conditional devices according to the type of the power problem.

Uninterruptible Power Supply (UPS) can be used overcome any kind of power problems. Even during the outage power, UPS can be switched on to maintain the operation of the system by compensating the total loss of power from the battery.

Importance of the Project

Computer systems have become important all over the world due to its capability of doing complicated work such as: calculation of mathematics, word processing, and PC based industry automation. The continuity of power supply for computer systems is very important for some applications. When there is a power failure, the computer system cannot support its normal operation and it will shut down immediately. Consequently, all working data will be lost if they are not saved previously. Therefore, an UPS system is designed to protect data loss and prevent any output interruption after the main power input fails suddenly.

According to many studies reported in the computer world, power disturbances have disastrous effects on computers such as: hardware or CPU damages, hard-disk crashes, short-term memory loss, and permanent memory loss.

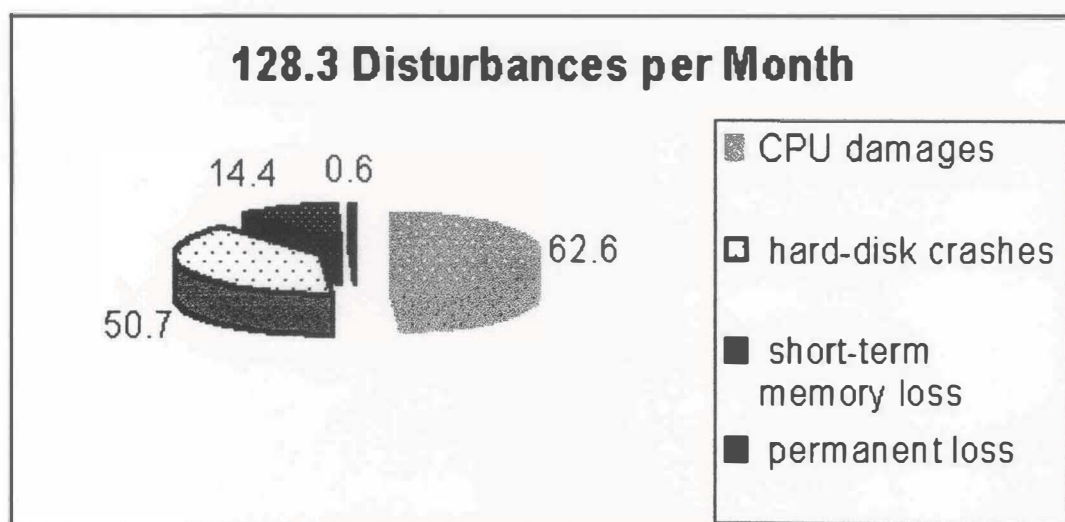


Figure 1: IBM Study Result (Aykul, 1995)

One of the studies conducted by IBM shown in Figure 1 revealed that on average, a computer can expect to encounter 128.3 power disturbances per month; these can be disruptive to its proper operation and cause increased computer service costs (Aykul, 1995).

An interesting finding of another national study by AT&T is that lightning causes damaging sags and outages in addition to spikes. The reason is that impulse suppression equipment in the AC distribution system shortly disconnects the power line when lightning strikes the system (Aykul, 1995).

In another study reported in the computer world as shown in Figure 2, it indicates that power disturbances have disastrous effects on computers such as: hardware or CPU damages (22.1%), hard disk crashes (24.6%), short-term memory loss (61.8%) and permanent memory loss (13.6%) (Aykul, 1995).

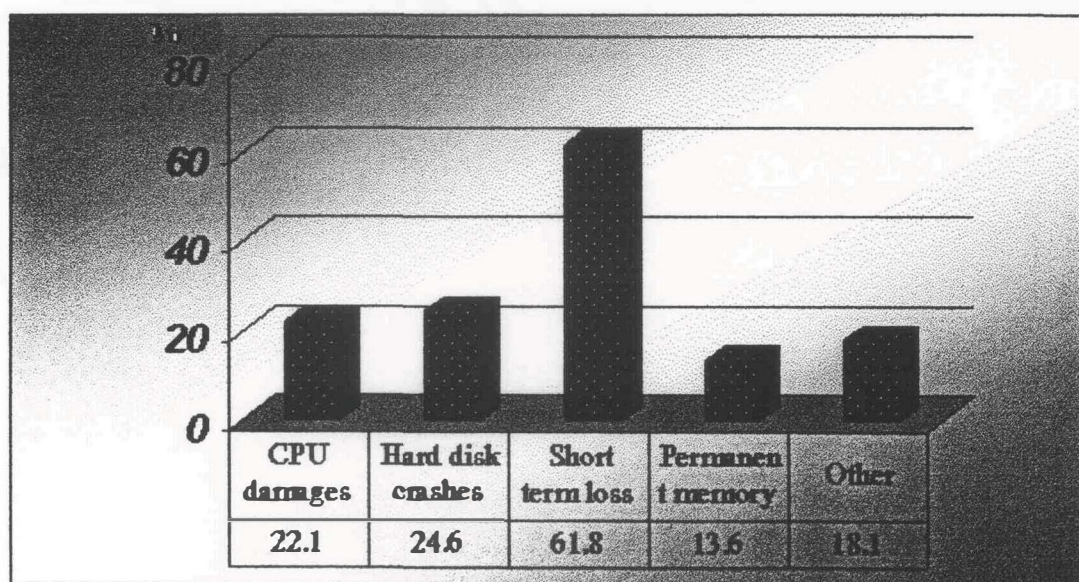


Figure 2: Effects of Power Disturbances (Aykul, 1995)

As a conclusion, the line power should not be fed to the computers, telecommunication equipment, or other sensitive and critical electronic gear. It causes lost data, downtime, increased service costs and reduces equipment life.

The following are examples of applications of computers, which require continuous power supply:

- 1- Life support systems such as monitoring systems
- 2- Hospital information systems: patient history files, treatment schedules
- 3- Paramedics and fire departments
- 4- Public utilities: electric power, gas, water and sewage
- 5- Air traffic control
- 6- Financial institutions: banks, stock markets and commodities

Problem Statement

The current protection scheme used by PCs for the power failure problem is depicted in Figure 3. The conventional UPS is used to provide power supply to a group of PCs during power failure. The disadvantage of this scheme is that it is expensive and bulky. Furthermore, it has a high maintenance cost. Consequently, not many people manage to buy this system to protect their PCs from power failure. In order to solve this problem, a low cost and small size UPS is needed.