



UNIVERSITI PUTRA MALAYSIA

**DEVELOPMENT OF POWER SEMICONDUCTOR DEVICES
DATABASE FOR KNOWLEDGE-BASED SYSTEMS**

GHASSAN MOHAMMED SHAHEEN

FK 2000 16

**DEVELOPMENT OF POWER SEMICONDUCTOR DEVICES DATABASE
FOR KNOWLEDGE-BASED SYSTEMS**

By

GHASSAN MOHAMMED SHAHEEN

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

April 2000



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

**DEVELOPMENT OF POWER SEMICONDUCTOR DEVICES DATABASE
FOR KNOWLEDGE-BASED SYSTEM**

By

Ghassan Mohammed Shaheen

April 2000

Chairman: Norman Maruin, Ph.D.

Faculty: Engineering

Since 1970, various types of power semiconductor devices have been developed and become commercially available. Meanwhile database management and expert systems have been used in the field of power electronics for various applications. The large available number of power semiconductor devices makes it difficult to compare their numerical ratings such as voltage, current ratings and switching frequency.

The objective of this thesis is to develop a database system for the power semiconductor devices in order to build the power electronics design aided system (PEDAS). PEDAS is a knowledge-based system for power electronic circuits that enable the user to get a suitable solution for the design problem through an attractive interface.



The devices database system is an important and essential part of PEDAS. Using the devices database system, the user is able to get the suitable device available in the PSPICE simulation package and use its model for the design problem through a simple and attractive interface. The user can also get a comprehensive information about most of the power semiconductor devices commercially available by accessing the devices data sheets.

A three-phase inverter was designed and simulated to illustrate the use of the devices database system. The inverter was designed using 180° and 120° conduction angle. 5kW-output power was achieved using 120V DC voltage source.

The devices database system was used successfully by some of the researchers of the electrical engineering department in the Control and Automation System Centre (CASC).



Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan memperolehi ijazah Master Sains.

**PEMBINAAN ALAT PENGKALAN DATA DARI KUASA
SEMIKONDUKTOR UNTUK SISTEM DAYA MAKLUMAT**

Oleh

Ghassan Mohammed Shaheen

April 2000

Pengerusi: Norman Maruin, Ph.D.

Fakulti: Kejuruteraan.

Sejak 1970, pelbagai jenis peralatan kuasa semikonduktor telah dibina dan boleh didapati secara komersil. Sementara itu, pengurusan pengkalan data dan sistem pakar telah diggunakan di pelbagai bidang penggunaan elektronik kuasa. Bilangan peralatan kuasa semikonduktor yang banyak didapati membuatkan sukar untuk membezakan perkadaran angkanya seperti voltan, kadar arus dan kekerapan pensuisan.

Objektif utama tesis ini ialah membina satu sistem pengkalan data untuk peralatan kuasa semikonduktor dengan membina Sistem Rekabentuk Berbantu Elektronik Kuasa (Power Electronic design Aided Sestem, PEDAS). PEDAS ialah satu sistem pengetahuan asas untuk litar elektronik kuasa yang membolehkan pengguna mendapat penyelesaian yang sesuai untuk masalah rekabentuk melalui satu paparan yang menarik.

Sistem peralatan pengkalan data adalah satu bahagian penting dan mustahak bagi PEDAS. Ini membolehkan pengguna yang ~~sedang menggunakan sistem~~ peralatan pengkalan data mendapat peralatan yang sesuai dan boleh didapati dalam pakej simulasi PSPICE, dan menggunakan model ini untuk masalah rekabentuk dengan mudah dan paparan yang menarik. Pengguna juga mendapat maklumat yang tepat tentang peralatan kuasa semikonduktor yang didapati secara komersil, dengan memasuki peralatan lampiran data.

Satu pembalik 3-fasa telah dirkabentuk dan disimulasikan bagi mengambarkan sistem peralatan pengkalan data yang diguna. Pembalik telah direkabentuk menggunakan sudut pengaliran 180° dan 120° . Jumlah kuasa 5kW telah dicapai menggunakan punca voltan 120V DC.

Sistem peralatan pengkalan data telah digunakan oleh beberapa penyelidik dari Pusat Sistem Kawalan dan Automasi (CASC) di Jabatan Kejuruteraan Elektrikal dan Elektronik, UPM.

AKNOWLEDGEMENTS

I wish to express my grateful thanks to Dr Norman Mariun, Chairman of my supervisory committee, for his keen interest, guidance, encouragement, and support throughout the work.

I wish also to express sincere appreciation to Dr Ishak Aris and Dr. Nasrullah Khan, members of my supervisory committee, for their meaningful supervision and support.

I would like to take this opportunity to show my appreciation to my parents, brothers, sisters, and all my friends for their support. I wish to represent this work as a gift to my family back home in Jordan.



TABLE OF CONTENTS

		Page
ABSTRACT	.....	ii
ABSTRAK	.....	iv
ACKNOWLEDGEMENTS	.....	vi
APPROVAL SHEETS	.....	vii
DECLARATION FORM	.....	ix
LIST OF TABLES	.....	xii
LIST OF FIGURES	.....	xiii
LIST OF ABBREVIATIONS	.....	xv
 CHAPTER		
I	INTRODUCTION	1
	Importance of the Work.....	1
	General Structure of PEDAS.....	2
	Aims and Objectives.....	4
	Scope of the Work.....	4
II	LITERATURE REVIEW	8
	Power Electronics.....	8
	Introduction.....	8
	The Main Areas of Power Electronics Research.....	9
	Power Semiconductor Devices.....	14
	Power Semiconductor Materials.....	14
	Types of Power Semiconductor Devices.....	14
	Summary Comparison of Devices.....	24
	Database Management Systems.....	26
	Object-Oriented Database Management Systems.....	28
	Deductive Database Management Systems.....	29
	Intelligent Database Management Systems.....	29
	Relational Database Systems.....	29
	Microsoft Access Database.....	30
	Expert Systems.....	31
	Designing an Expert System.....	33
	The Need for Expert Systems.....	36
	Benefits of Expert Systems.....	37
	Engineering and Manufacturing Applications of Expert Systems.....	38
	Computer-Aided Design and Engineering.....	39
	Power Electronics and Computer.....	40
	Simulation Packages for Power Electronics.....	41
	Simulation Program with Integrated Circuit Emphasis (SPICE).....	45
	Semiconductor Devices Modelling in SPICE.....	47
	Disadvantages of SPICE.....	48



A Brief History of Programming Languages	49
Machine Language	49
Assembly Languages	50
High-Level Languages	50
Procedure-Oriented High-Level Languages	51
The Introduction of Windows	51
Visual Basic	52
Visual Basic Objects	53
Types of Objects	54
Writing Visual Basic Code	54
Inverters	55
Features of the AC output	55
Inverters Applications	57
Types of Inverters	57
Three-Phase Inverters	59
III	MATERIALS AND METHODS
Introduction	61
Power Electronics Design Aided System (PEDAS)	61
The Devices Database Module	64
Database Design	64
Interface Design	66
Interface Program	72
Three-Phase Inverter Design	72
Switching Device Selection	72
Circuit Configuration	75
Switching Sequence	76
IV	RESULTS AND DISCUSSION
Devices Database Results	80
Linking the Database to PEDAS	91
PSPICE Simulation Results	97
Discussion	104
V	CONCLUSION AND FUTURE STUDY
	105
REFERENCES	107
APPENDIX	
A: Devices Table	111
B: Visual Basic Program	124
BIODATA OF AUTHOR	167



LIST OF TABLE

Table	Page
1 Comparison between the Power Semiconductor Devices.....	25



LIST OF FIGURES

Figure		Page
1	PEDAS General Structure.....	2
2	Database Process Flowchart.....	6
3	Thyristor. (a) Symbol,	15
	(b) I-V characteristics.....	16
4	Triac (a) Symbol, (b) I-V characteristics.....	17
5	GTO (a) Symbol, (b) I-V characteristics.....	18
6	BJT (a) Symbol, (b) I-V characteristics.....	19
7	MOSFET (a) Symbol, (b) I-V characteristics.....	21
8	IGBT (a) Symbol, (b) I-V characteristics.....	22
9	MCT (a) Symbol, (b) I-V characteristics.....	23
10	Three-Phase Bridge Inverter.....	60
11	Block Diagram for PEDAS System.....	63
12	Sample of the Devices Classification Table.....	66
13	Power Semiconductor Devices Models Database Form.....	68
14	Summary of the Devices Capabilities.....	70
15	Data Sheets Form.....	71
16	Searching Result for a Suitable Device to Design the Inverter..	75
17	Six-Step Three-Phase Inverter Circuit.....	76
18	Gate Pulse Voltages for 180° Conduction.....	77
19	Gate Pulse Voltages for 120° Conduction.....	78
20	The Main Interface Window of the Devices Database.....	81
21	Devices Selection Mechanism.....	82



22	Database Search Results	83
23	Device Not Available	84
24	List of Devices Closest to the Entered Values	85
25	Linking the Database to PSPICE	86
26	Data Sheets Search Window	87
27	Linking the Database to the Devices Data Sheets	88
28	Linking the Database with the Chart of the Devices Rating Capabilities	89
29	Select Device to Design a Three-Phase Inverter Circuit	90
30	Linking to a Three-Phase Inverter Circuit	90
31	PEDAS Main Window	92
32	PEDAS Main Parts Window	93
33	Linking the Devices Database to PEDAS	94
34	The Circuit Database in PEDAS	95
35	Power Electronics Applications in PEDAS	96
36	The Load Voltage and the Load Current with 120° Conduction	98
37	Three-Phase Load Voltages with 120° Conduction	99
38	Three-Phase Load Currents with 120° Conduction	100
39	The Load Voltage and the Load Current with 180° Conduction	101
40	Three-Phase Load Voltages with 180° Conduction	102
41	Three-Phase Load Currents with 180° Conduction	103

LIST OF ABBREVIATIONS

AC	Alternating current
ADD	Addition
ASCR	Asymmetrical thyristor
BASIC	Beginner's all-purpose symbolic instruction code
BJT	Bipolar junction transistor
CAD	Computer-aided design
CAE	Computer-aided engineering
COBOL	Common basic oriented language
DBMS	Database management systems
DC	Direct current
EDA	Electronic design automation
EMI	Electromagnetic interference
FET	Field effect transistor
GTO	Gate turn-off thyristor
GUI	Graphical user interface
IGBT	Insulated gate bipolar transistor
I_O	Output current
I_P	Phase current
I_T	Current through the switch
JFET	Junction field effect transistor
MCT	MOS-controlled thyristor
MOS	Metal oxide semiconductor
MOSFET	Metal oxide semiconductor field effect transistor

MUL	Multiplication
NC	Numerical control
OLE	Object linking and embedding
P	Three-phase power
PCBs	Printed circuit boards
PEBB	Power electronics building block
PEDAS	Power electronics design aided system
PFC	Power factor correction
PWM	Pulse width modulation
PWM	Pulse width modulation
RCT	Reverse conducting thyristor
SCR	Silicon-controlled rectifier
SIT	Static induction transistor
SITH	Static induction thyristors
SPICE	Simulation program with integrated circuit emphasis
THD	Total harmonic distortion
TRIAC	Bi-directional triode thyristors
UPS	Uninterruptible power supplies
V_P	Phase current

CHAPTER I

INTRODUCTION

Power electronics has recently emerged as an important discipline in electrical engineering. Its use is growing extensively in industrial, commercial, residential, aerospace and military environments. The most important elements of power electronics are the power semiconductor devices. A wide variety of devices are available, the most common devices are power bipolar transistors, power metal oxide semiconductor field effect transistors (MOSFETs), insulated gate bipolar transistors (IGBTs), thyristors, phase control thyristors (SCRs), gate turn off thyristors (GTOs), bi-directional triode thyristors (TRIACs), and some other types.

Importance of the Work

It is difficult to compare the power semiconductor devices, especially their numerical ratings that include voltage ratings, current ratings and switching frequency because not only the ratings vary widely from one device type to another, but also there may be a wide variation of ratings within one type of device. Manufacturers specification sheets show a considerable amount of tolerance of parameters for a particular device. Some software packages such as simulation program with integrated circuit emphasis (SPICE) and SABER provide models for many of these devices. But these packages lack information about the devices, such as ratings and manufacturers.

This research is an essential part of power electronics design aided system (PEDAS), which is a computer software package for power electronics done by a group of researchers in the department. PEDAS system aims to develop an expert system for power electronic circuits, which enables the user to get optimal and practical solutions for circuit design problems given a nominal inputs.

General Structure of PEDAS

PEDAS system is being developed by a PEDAS research group in the department of Electrical and Electronics Engineering at the University Putra Malaysia. It is a very helpful and useful system in which the user can gain information of the subject of power electronics from the basic to the advanced level in an interactive manner. The general structure of PEDAS is shown in Figure 1 and below is a brief explanation of its main modules.

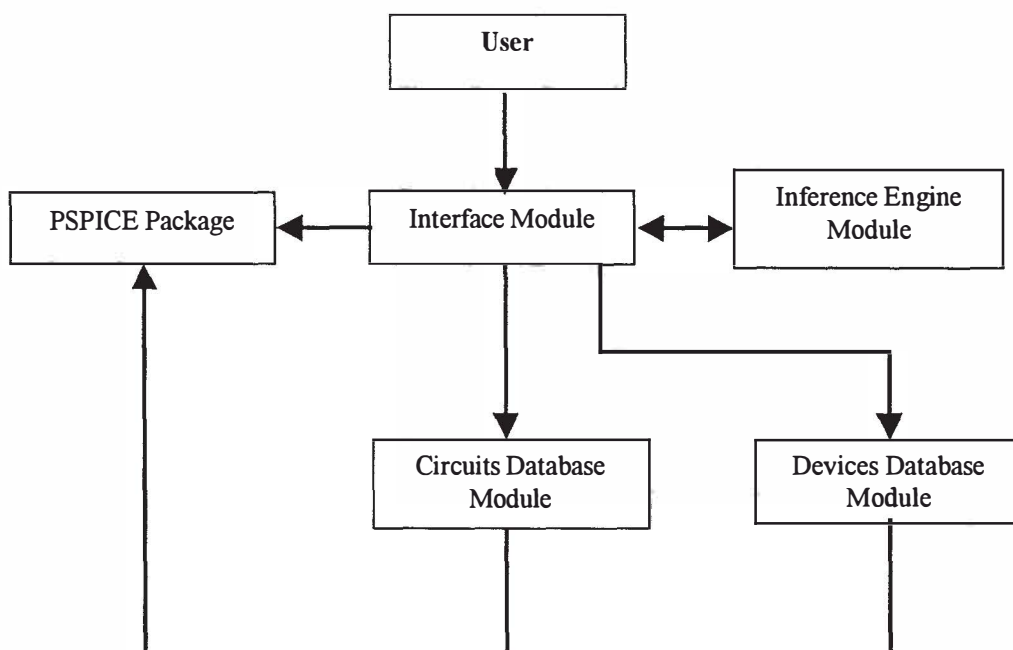


Figure 1. PEDAS General Structure

The system consists essentially of several modules interacting with each other; and also consists of interface that handle the flow of information between the PEDAS components and the external simulation package (PSPICE). The user interface which has been designed by a member of PEDAS consists of interactive components designed to facilitate communication between the user and the PEDAS system. The Circuits Database module which has been designed by another member of PEDAS includes development of a database circuits library which enables the user to design and simulate different circuits such as AC/AC, AC/DC, DC/AC and DC/DC converters. The Inference Engine Module provides the user with the design steps of different circuits that have been designed and tested by other members of the electrical and electronic engineering department. Such as DC/DC converter for electric vehicle, smart battery charger for electric vehicle and development of 6KW variable power supply for electric vehicle.

The author has designed the database system for power semiconductor devices. This database has performed an essential part in building PEDAS system. The user can find useful information about most of the devices available by accessing their data sheets. The user also can get the PSPICE model of the selected device and use it in designing and simulating different circuits.

Aims and Objectives

Three following objectives are achieved at the end of this project.

The first objective is to develop a database that includes most of the devices produced by various manufacturers for knowledge base system. Using this database the user can select the suitable device for his circuit by entering the ratings of the required device. The system also allows the user to use the models of the chosen device in PSPICE simulation package. More than that, the system is providing the manufacturer's name for every device as well as the data sheet.

The second objective is to link the devices database system with PEDAS.

The third objective is to design and simulate a three-phase inverter to illustrate the use of the devices database. Power MOSFET is used as the switching device for this inverter. The input of the inverter is 120V and the output is 5 KVA.

Scope of the Work

The process of developing the database system is shown in Figure 2 and explained below.

The system consists of a database that includes the power semiconductor devices. This database has been developed using Microsoft Access database package. An interface has been designed using Visual Basic, which aims to allow

the user to search for the devices models or for the devices data sheets. The searching process is the same for either one. The user has to choose firstly the type of the device he is interested in from a list of the available device types. The next step is to enter the required ratings for the device, which include the voltage rating, the current rating, and the switching frequency. The system will search the devices database to provide the user with the available devices based on these inputs. A list of the devices that match the inputs will appear with the name of the manufacturer beside each device. If there is no device available that matches the inputs the system will provide the user with the closer devices available in the database. The user has two choices to search the database; he can search by entering the voltage rating, the current rating and the frequency rating, or he can search the database by entering only the voltage and the current ratings. The system then allows the user to retrieve the model for the selected device by clicking on the device name in the list and use it in PSPICE simulation or he can view the data sheet of the selected device.

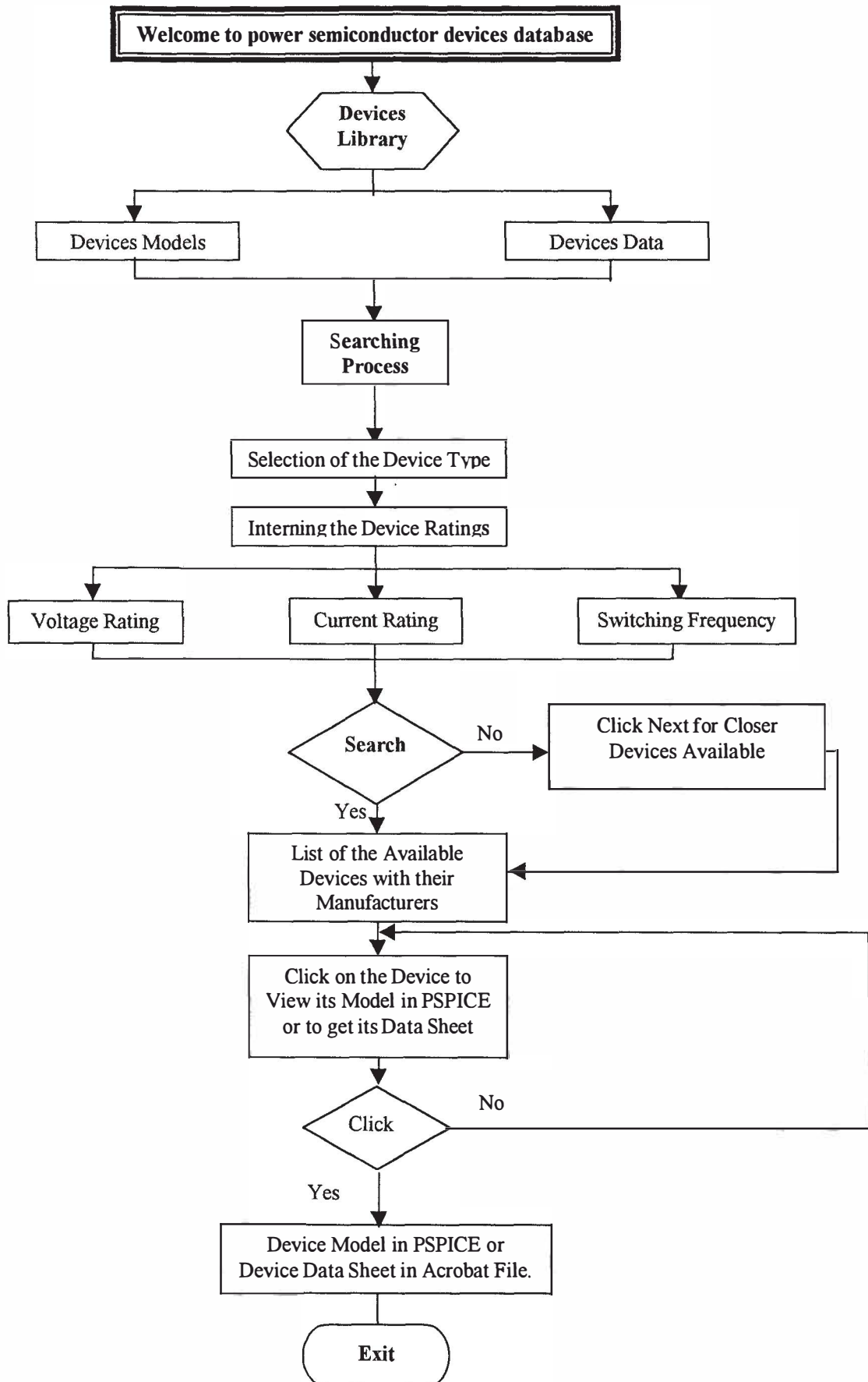


Figure 2: Database Process Flowchart.

This dissertation is organised thus:

Chapter 2 reviews the literature on power electronics, power semiconductor devices, database management systems, and expert system. Different simulation programs are discussed and SPICE package is explained. Inverter types and applications are illustrated.

In Chapter 3, the design of the devices database system is explained, including the techniques used to link the system with PEDAS system. The design of the three-phase inverter is also explained.

Chapter 4 discusses the performance of the devices database system, and simulation results for the three-phase inverter is discussed. Conclusion about the work and recommendations for future work are given in Chapter 5.

CHAPTER II

LITERATURE REVIEW

Power Electronics

Introduction

Power electronics is the technology of converting electric power from one form to another using electric power devices, (Vithayathil, 95). The term power electronics covers a wide range of electronic circuits in which the objective is to control the transfer of electrical power from a source to a load. This control may take many different forms. We may have more interactions with power electronics than we think. If someone drives a car, use a computer, cook with a microwave, talk on any type of telephone, listen to a stereo, or make holes with a cordless drill, then he comes in contact with power electronics. Thanks to power electronics, the electricity needed to run the things we use everyday is processed, filtered, and delivered with maximum efficiency, smallest size and minimal weight. In formal terms, this technology encompasses the use of electronic components, the application of circuit theory and design techniques, and the development of analytical tools toward efficient electronic conversion, control, and conditioning of electric power. This means that power Electronics is everywhere we look. Power electronics is used in many fields such as computers, automobiles, telecommunications, space system and satellites, motors, and alternate energy.