EEL 5245 POWER ELECTRONICS I
Lecture #2: Chapter 1
Introduction to Power Electronics

Discussion Topics

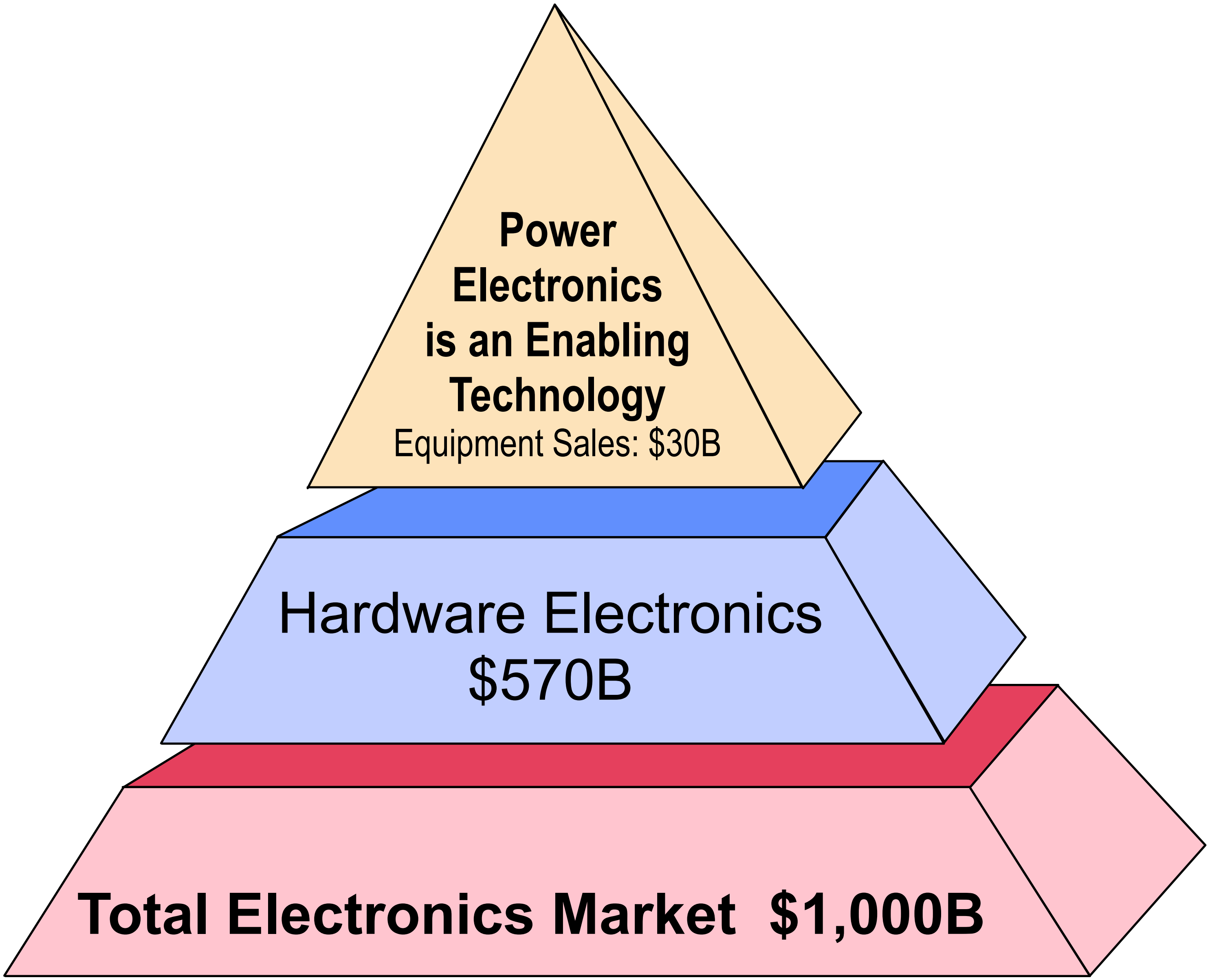
- **Definition of Power Electronics**
- **Industry Overview/Market Share Analysis**
- **Multidisciplinary Nature of Power Electronics**
- **The Need for Power Electronics**
- **Types of Power Conversion**
- **Figures of Merit for Power Electronics Converters**
- **Applications for Power Electronic Converters**
- **Future Trends**

What is Power Electronics?

- **Electronics:** Solid State Electronics Devices and their Driving Circuits.
- **Power:** Static and Dynamic Requirements for Generation, Conversion and Transmission of Power.
- **Control:** The Steady State and Dynamic Stability of the Closed Loop system.

POWER ELECTRONICS may be defined as the application of Solid State <u>Electronics</u> for the <u>Control</u> and conversion of <u>Power</u>.

The Worldwide Electronics Market Overview



Source: Microtech

National Critical Technology Areas

Technology Category

- Energy
- Environmental Quality
- Information and Communication
- Living Systems
- Manufacturing
- Materials
- Transportation

Technology Area

Energy Efficiency
Energy Storage
Power Conditioning
Power Distribution

Distributed Power Supplies

Process Control Automation

Avionics and Controls
Power System Integration
Propulsion for Mass Transit
Hybrid Electric Vehicles

Source: President's Committee of Advisors on Science and Technology

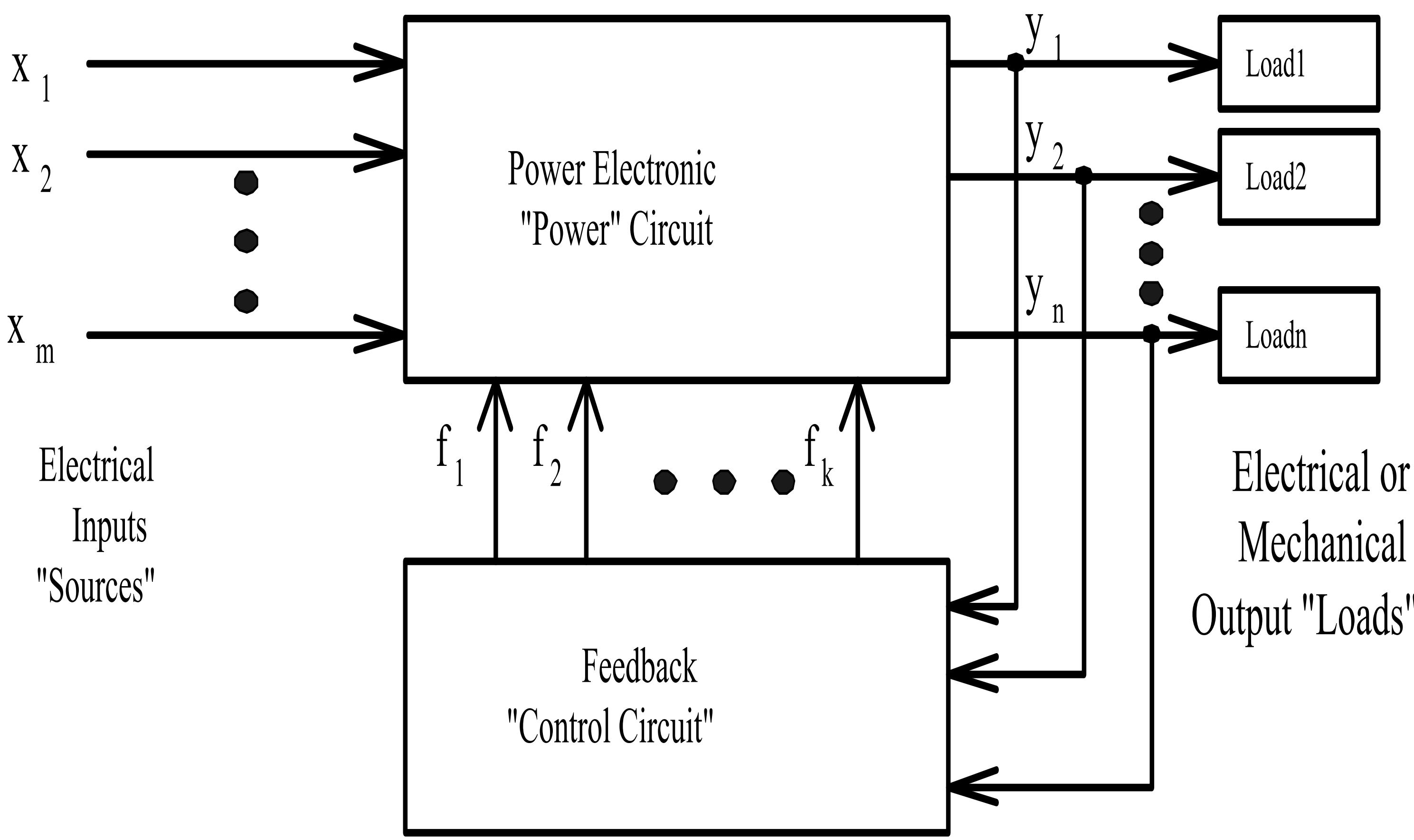
Historical Perspective

- Traditional power conversion
  - Linear Electronics- Transistors in active mode (linear region)
    - Transistor acts as variable resistor for control
    - Terrible efficiency (50% not uncommon)
    - Low conversion range (greater Vd smaller efficiency)
    - Low power applications
  - Motor-Generator Sets (AC-DC or AC-AC)
    - Can still be found in use
    - Large physical size
    - Maintenance intensive
    - Low efficiency
    - Poor Load regulation

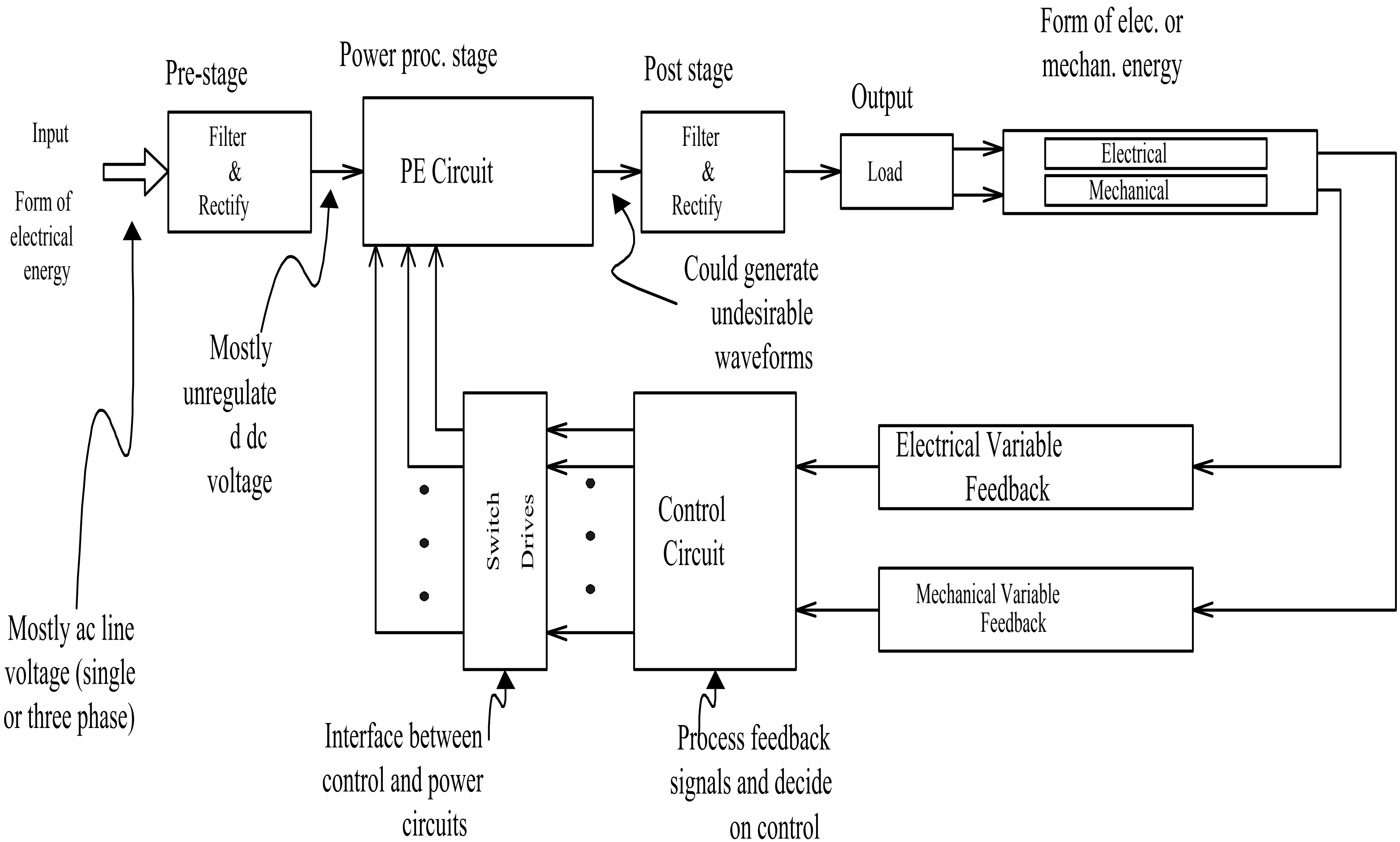
Modern Power Electronics

- **Can have efficiencies approaching 100%**
  - **Uses switches in saturation mode (On of Off)**
  - **On state-resistance can be down in tenths of Ohms**
- **Are much smaller than predecessors**
  - **High switching frequency means smaller magnetic components.**
  - **Reduced losses means smaller package size**
- **Net effect is better efficiency, greater power density (5W/ in^3 attainable)**

Simplified Block Diagram of a Power Electronics System



Detailed Block Diagram of Power Electronics System



Multidisciplinary Nature of Power Electronics

- Power electronics is comprised of:
  - Semiconductor Devices
  - Analog Circuits
  - Control Design
  - Magnetics
  - Electric Machines
  - Power Systems Engineering
  - Circuit Simulation

Power Electronics Focus Areas

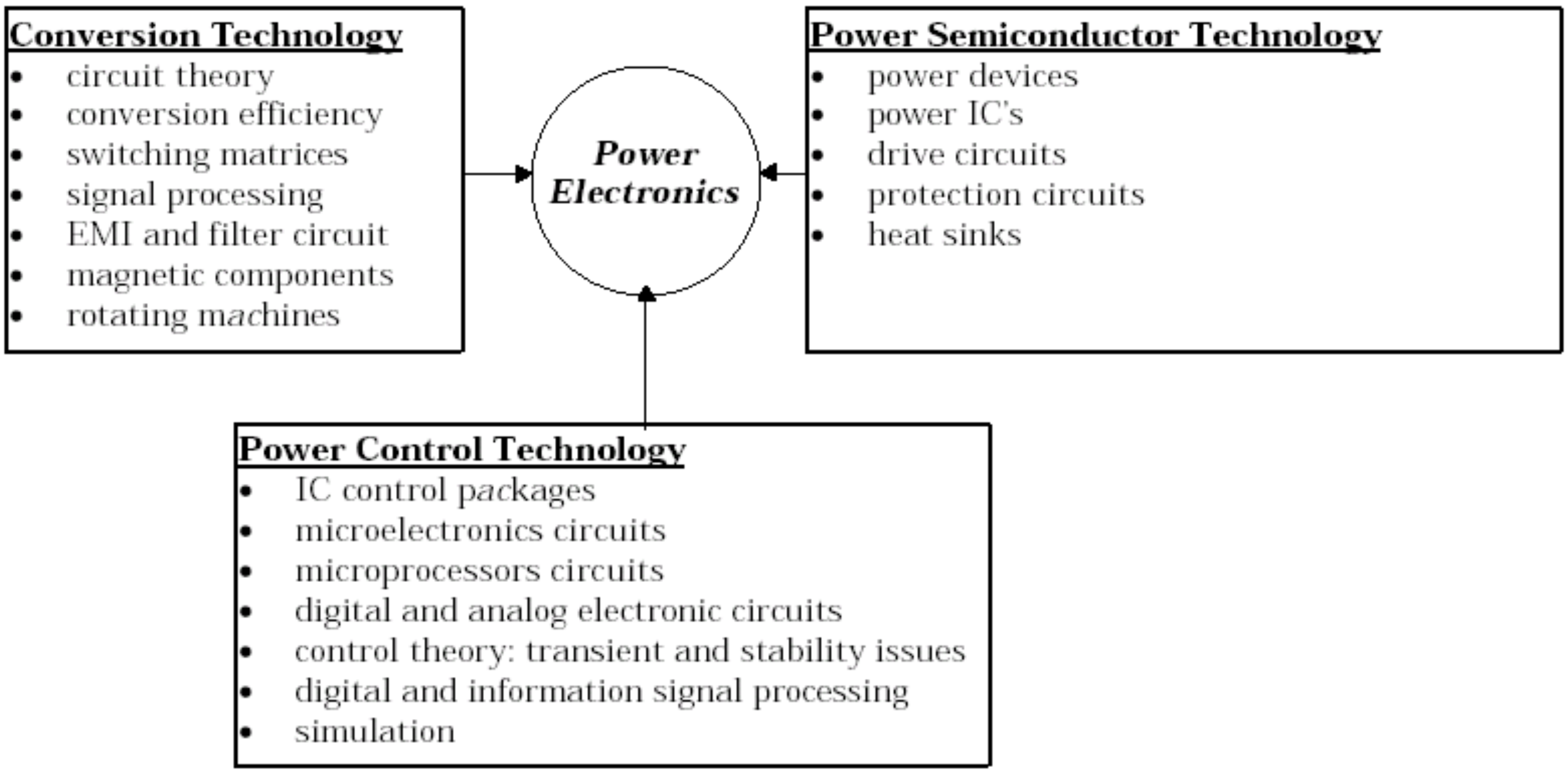


Fig. 1.1 Power Electronics encompasses three Technologies: Conversion, Power Semiconductor, and Power Control Technologies

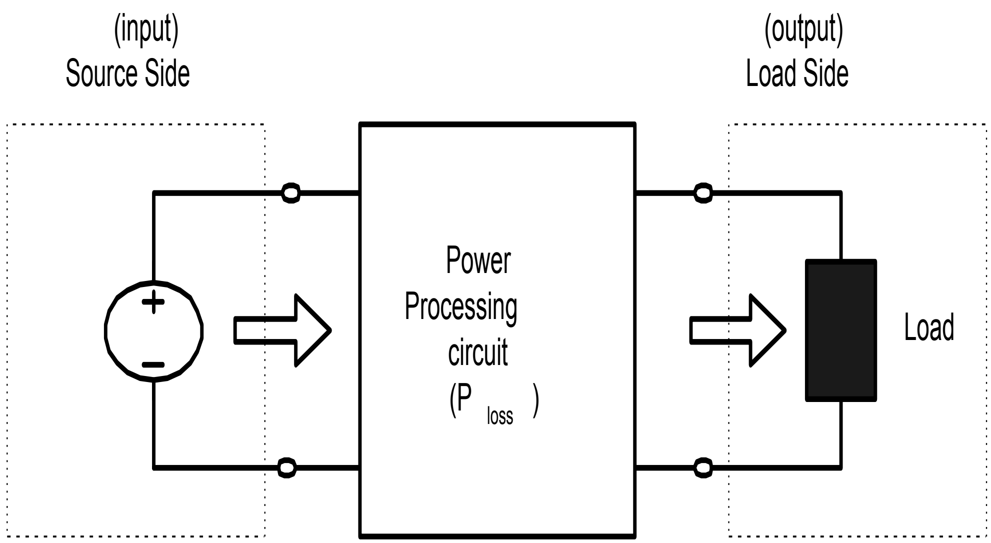
Growth In Power Electronics

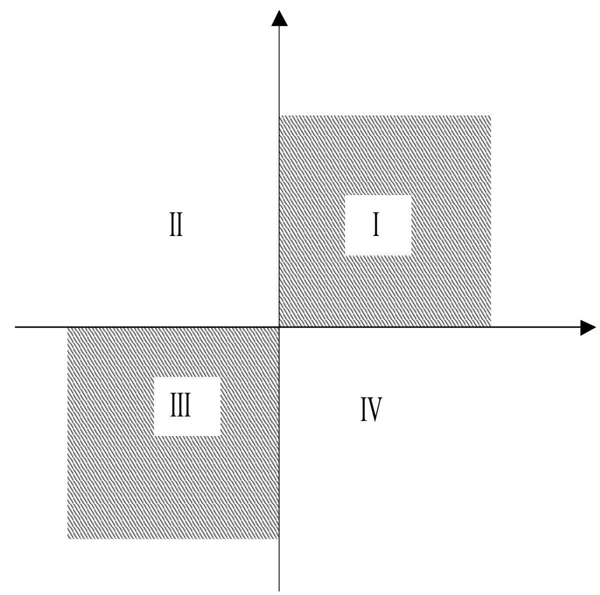
- **The technology boom of the semiconductor market creates power devices with significant power handling and switch speed capability (ICs for control as well)**
- **The expanding market demand for new power electronic applications that require the use variable-speed motor drives, regulated power supplies, robotics, uninterruptible power supplies.**
- **The ever increasing demand for smaller size and lighter weight power electronic systems.**
- **A result of this increasing reliance on power electronic systems made it mandatory that all such systems have radiated and conducted electromagnetic interference (EMI) be limited within regulated ranges.**

The Drivers for Power Electronics

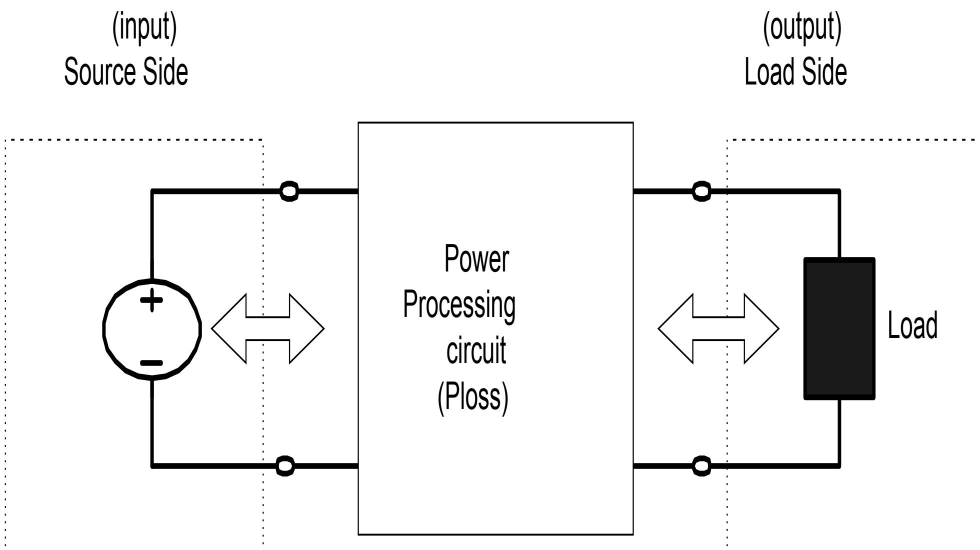
- **Primary Factors Locally (KSC/Florida)**
  - **Microprocessor-based technology has been producing devices that often require tight regulation and uninterruptible power**
  - **Increased sensitivity to power system harmonics**
  - **Energy Conservation and Environmental Management are now grouped within US Domestic Policy and are receiving significant focus from Bush Administration**
    - **New Legislation from Bush on Energy Conservation Requirements**
    - **New Florida Building Code will Require Variable Speed Air Handlers**
  - **Industrial Process Control and Automation is BOOMING with new/refined motor drive applications**
    - **HVAC (VAV, Chilled Water Flow, Chiller)**
    - **Elevator Drives (DC Drives)**

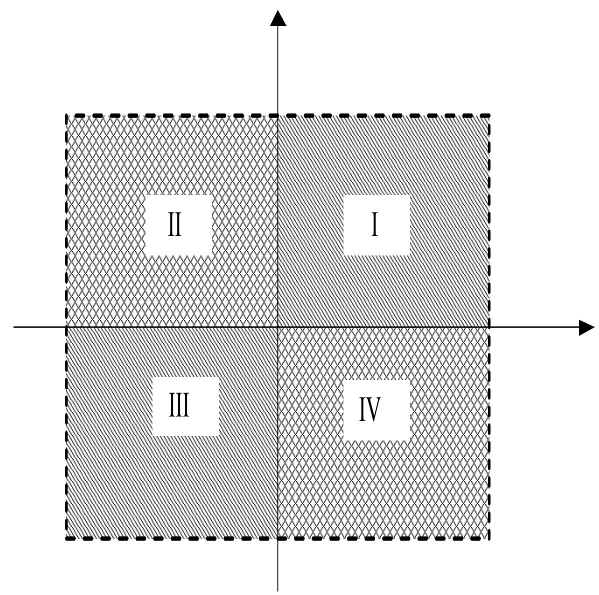
Power Flow
Unidirectional: input-to-output





Power Flow – Bi-directional





Power Conversion Dictates
Change in Current and/or Voltage:

- **Voltage/Current form *ac* or *dc***
- **Voltage/Current level (magnitude)**
- **Voltage frequency (line or otherwise)**
- **Voltage/Current waveshape (sinusoidal or nonsinusoidal such as square, triangle, sawtooth, etc.)**
- **Voltage phase(single or three-phase).**

Conversion Type Description

- Power Electronic systems perform one or more of the following conversion functions:

a)Rectification (*ac*-to-*dc*)

b) Inversion (*dc*-to-*ac*)

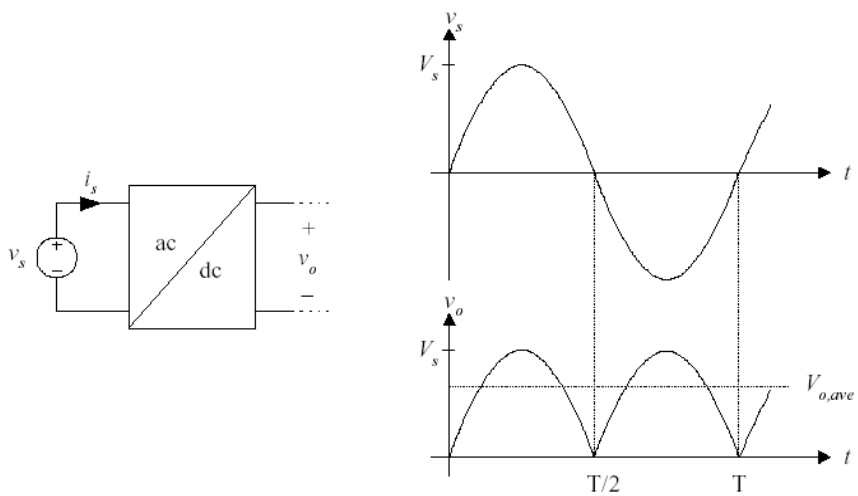
c) Cycloconversion

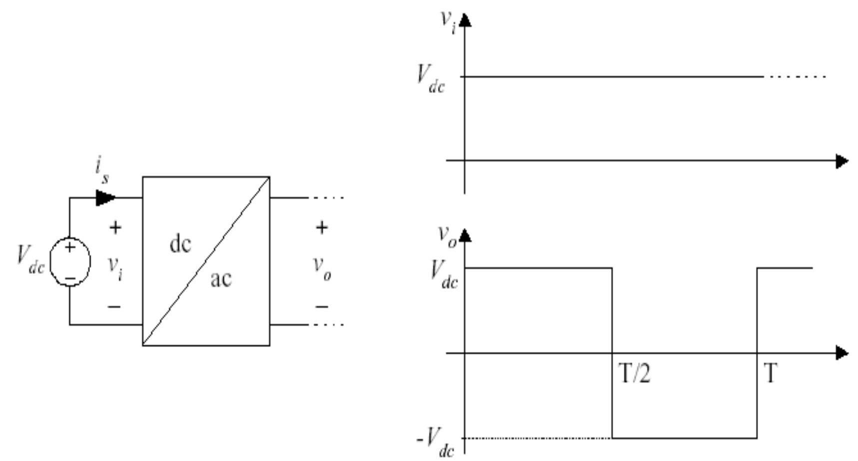
(*ac*-to-*ac* different frequencies) or

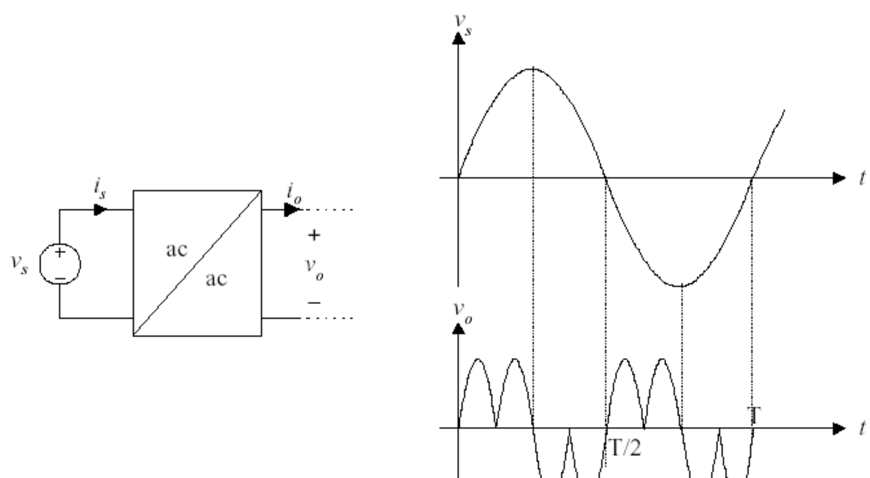
(*ac*-to-*ac* same frequency)

d) Conversion (*dc*-to-*dc*)

Types Of Power Conversion







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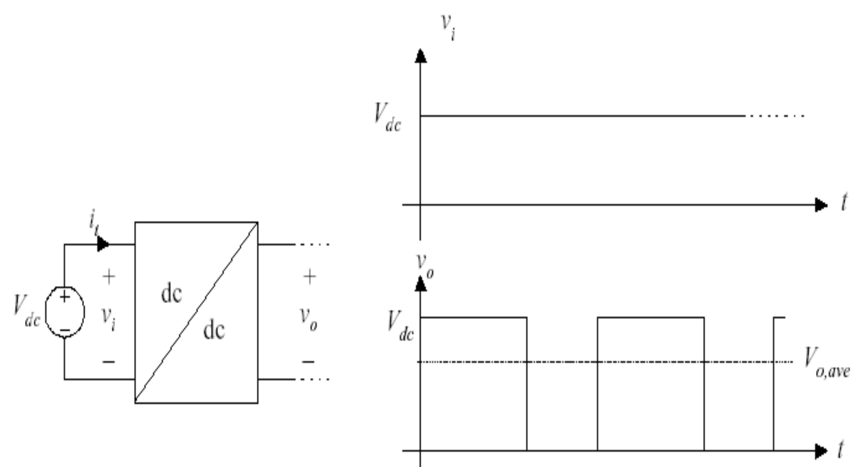


(a)

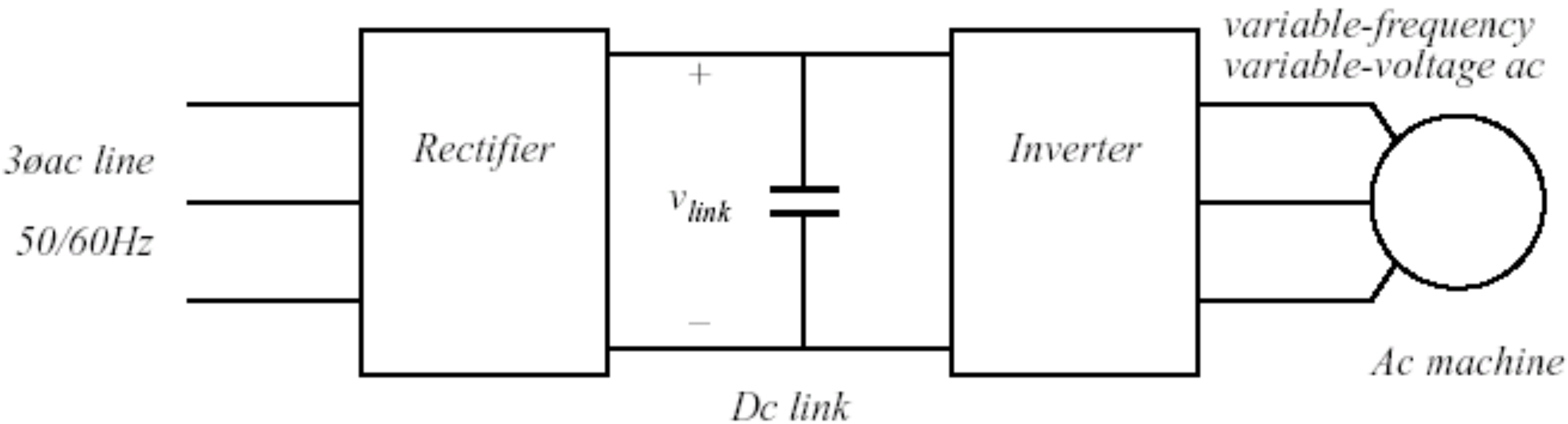
Figures of Merit for Power Electronic Converters

- **What is the objective?**
  - **Overall goal: To produce a converter that performs well in these areas:**
    - **Efficiency**
    - **Transient Response**
    - **Load and Line Regulation**
    - **Power Density**
    - **Input/Output Distortion (Input Power Factor)**
    - **Reliability (MTBF)**
    - **Cost**
  - **In the final analysis, the job is to process and control the flow of electric energy by supplying currents/ voltages in a form most suited to both the load and energy source**

Industrial Applications

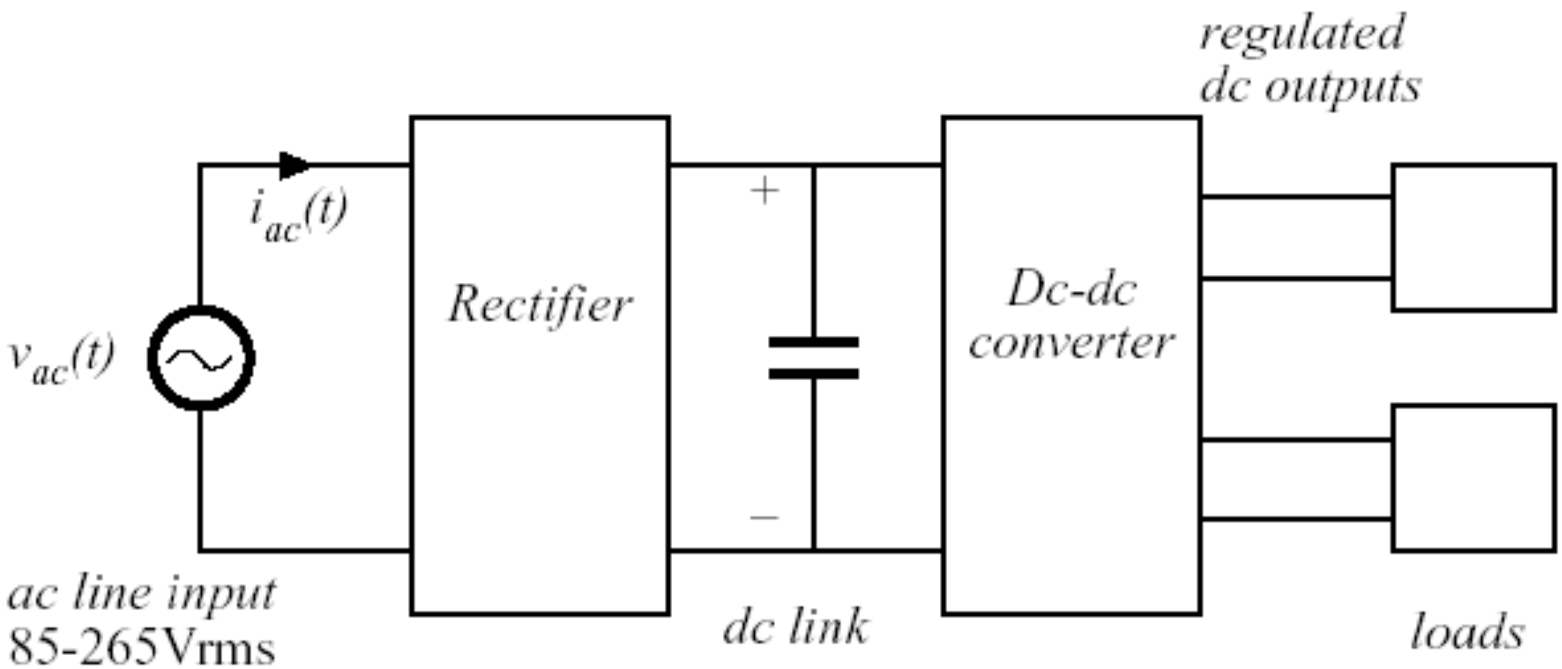
- SMPS
  - PFC
  - Universal Input
  - Soft-Switching
- Uninterruptible Power Supplies
  - Hot-Sync Paralleling
- Process Control
  - Motor Drives (DC Drives-VSDs, VFD)

Motor Drive

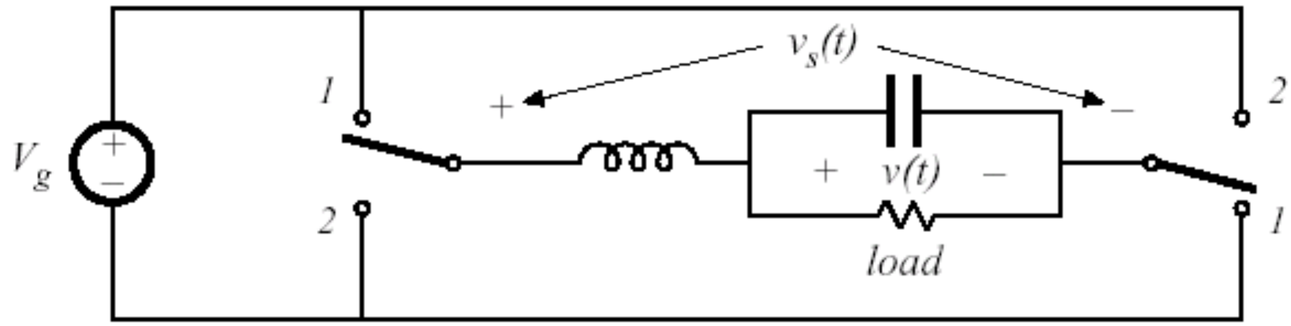


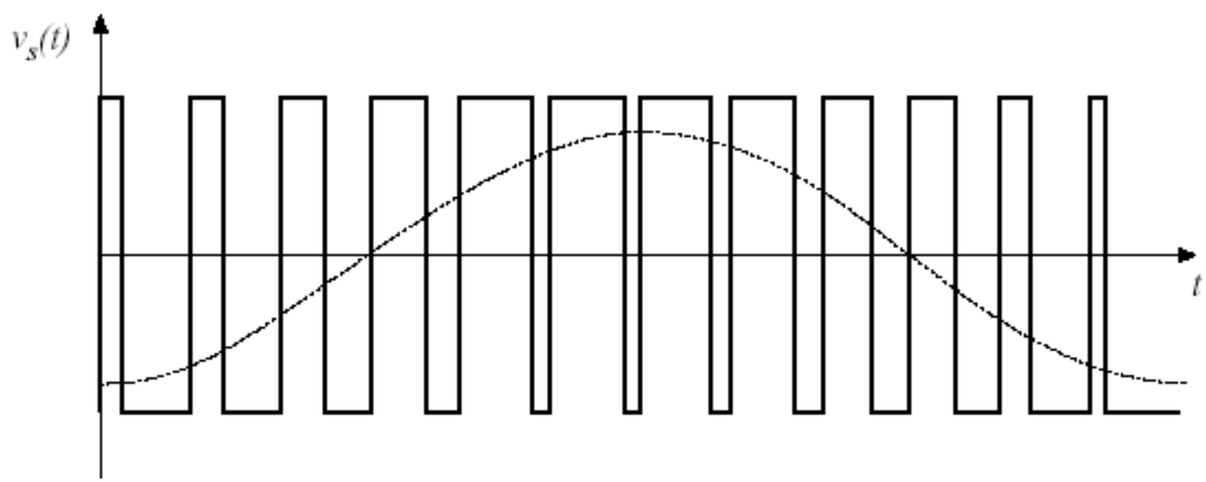
3øac line
50/60Hz
Rectifier
+
v_{link}
–
Dc link
Inverter
variable-frequency
variable-voltage ac
Ac machine

Typical PC Power Supply



Classic Inverter Scheme





Typical Commercial Power Supply-Univ. PFC 600V

INPUT CHARACTERISTICS					
Parameter	PFC Mini	PFC Micro	PFC MicroS	Units	Notes
AC Input					
Voltage		85-264		Vac	
Frequency		47-500		Hz	
DC Input	100-380	100-300		Vdc	
Line Regulation		0.4		%	From low line to high line
Inrush Current					
@ 115Vac	30	5		A rms	
@ 230Vac	60	10		A rms	
Ride Through Time		>20		ms	
@ load	1,200	500		W	
Conducted EMI/RFI	FCC Class A	FCC Class A			PFC Mini with 1st Gen units
	EN55022 Class A	EN55022 Class A *(consult factory)*			meets FCC & EN Class B
Power Factor		>0.98			>75% load
Harmonic Current Limits		EN61000-3-2/A14			Class A

OUTPUT CHARACTERISTICS					
Parameter	PFC Mini	PFC Micro	PFC MicroS	Units	Notes
Setpoint Accuracy		0.5		%	of Vnom
Load Regulation		0.05		%	10% to full load
		0.2		%	No load to full load
Temperature Regulation		0.005		%/°C	-20° to +65°C
Long Term Drift		0.02		%/khr	
Output Ripple & Noise					
≤10Vout		100		mV	20 MHz bandwidth
>10Vout		1.0		% Vout	20 MHz bandwidth
Voltage Trim Range					
1st Gen *Slots*		50-110		% Vout	±10% on 10-15 Vout
2nd Gen *Slots*		10-110		% Vout	Preload may be required
Remote Sense Compensation		0.5		Vdc	Autosense (See page 2)
OVP Set Point		125		% Vout	Not available on 1st Gen Minis
Current Limit		115		% Imax	Auto recovery

Typical Commercial Power Supply-Universal PFC 150W

OUTPUT SPECIFICATIONS		
Total regulation (Line and load)	Main output Auxiliary outputs	±2.0% ±5.0%
Rise time	At turn-on	1.5s, max.
Transient response	Main output 75% to 100% step at 0.1A/µs	5.0% or 250mV max. dev., 1ms max. recovery to 1%
Temperature coefficient		±0.02%/°C
Overvoltage protection	Main outputs	125%, ±10%
Short circuit protection	Cyclic operation	Continuous
Minimum output current	Single and multiple	See table

INPUT SPECIFICATIONS		
Input voltage range	Universal input	90 to 264VAC
Input frequency range		47Hz to 63Hz
Input surge current	264VAC (cold start)	40A max.
Safety ground leakage current	264VAC, 60Hz	0.99mA
Input current	120VAC @ 150W 230VAC @ 150W	1.95A rms 1.10A rms
Input fuse	UL/IEC127	F3.15A H, 250VAC

ELECTROMAGNETIC COMPATIBILITY SPECIFICATIONS (10)		
Conducted emissions	EN55022, FCC part 15	Level B
Radiated emissions	EN55022, FCC part 15	Level A
Harmonic current emission correction	EN61000-3-2	Compliant
ESD air	EN61000-4-2	Level 3
ESD contact	EN61000-4-2	Level 3

ELECTROMAGNETIC COMPATIBILITY SPECIFICATIONS (11)		
Surge	EN61000-4-5	Level 3
Fast transients	EN61000-4-4	Level 3
Radiated immunity	EN61000-4-3	Level 3
Conducted immunity	EN61000-4-6	Level 3

GENERAL SPECIFICATIONS		
Hold-up time	120VAC @ 60Hz	20ms @ 150W
Efficiency	120VAC @ 150W	73% typical
Isolation voltage	Input/output Input/chassis	3000VAC 1500VAC
Approvals and standards pending		EN60950, VDE0805, IEC950 UL1950, CSA C22.2 No. 950
Weight		540g (19oz)
MTBF (@ 25°C)	MIL-HDBK-217F Bellcore	350,000 hours min. 800,000 hours min.

ENVIRONMENTAL SPECIFICATIONS (8)		
Thermal performance	Operating ambient, (See derating curve)	0°C to +50°C
	Non-operating	-40°C to +85°C
	50°C to 70°C ambient, convection cooled	Derate to 50% load
	0°C to 50°C ambient, convection cooled	110W
	0°C to 50°C ambient, 300LFM forced air	150W
	Peak (0°C to +50°C)	
Relative humidity	Non-condensing	5% to 95% RH
Altitude	Operating Non-operating	10,000 feet max. 30,000 feet max.
Vibration (See Note 6)	5Hz to 500Hz	2.4G rms peak
Shock	per MIL-STD-810E	516.4 Part IV

Future Trends

- Continue in the technological improvement of high power and high frequency semiconductor devices.
- Attempts to improve energy density with increased efficiency and performance
- Improvement in the design of driver circuits for switching devices (DSP)
- Improvement in control techniques including optimal and adaptive control.
- Integration of power and control circuitry on a single IC
- Distributed Power Systems (DPS).
- Power factor correction techniques and EMI reduction.
- New Power Transmission Concepts

UCF Power Electronics
FloridaPEC

Florida Power Electronics Center

Director: Dr. Batarseh

http://apec.engr.ucf.edu

- **Power Factor Correction (PFC) circuits**
- **Soft-Switching DC-DC Converters**
- **Low Voltage AC-DC and DC-DC converters**
- **Low Voltage high-current fast-transient VRMs**
- **Dynamic Modeling and Control**
- **Electromagnetic Interference and Compatibility (EMI/EMC)**
- **Modeling of Power Devices**
- **Solar/Wind Source Converters**