ECE 562

Week 1 Lecture 1

Week 1 Lecture 1
Summary

- Section 1
  - Slides 3-9 - Overall expectations and trends
  - Slides 10-18 - Applications
  - Slides 19-27 – Efficiency
  - Slides 28-43 – Circuit elements
  - Slides 43-46 – Wrap-up

Entry Level Engineer Expectations

B.E.E 60K/yr why?
B.A. 30K/yr

	Proficiency
✓ Switching power supply technology	4
✓ Analog circuit design and analysis techniques	3
✓ Understanding of magnetics	3
✓ Simulation skills • Basic understanding	3
✓ Communication skills • Written ← Paper(s) & Powerpoints • Oral ←	5
✓ Teamwork experience and skills } HW, Paper groups!	5

e business

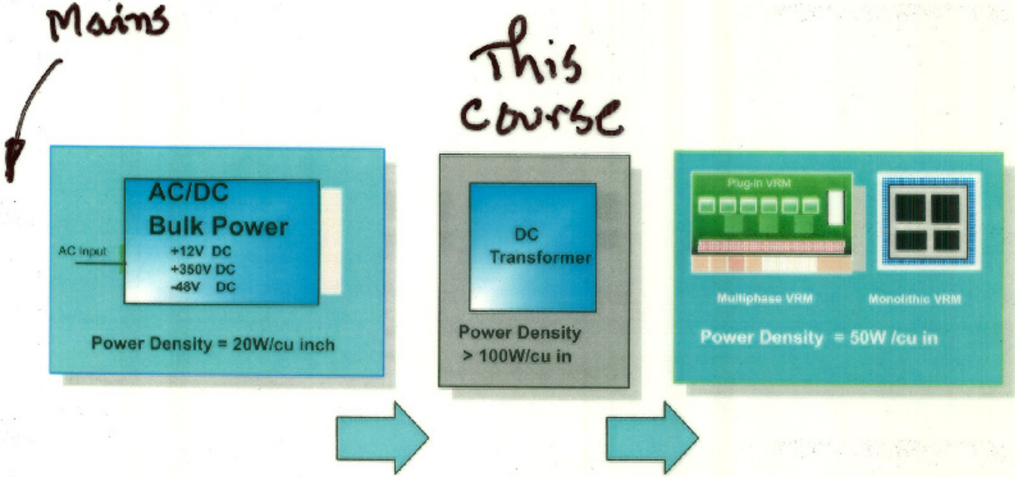
Experienced Engineer Expectations

> 120K/yr

	Proficiency
✓ Power supply design experience	5
✓ Analog circuit design and analysis	5
✓ Magnetic component design and implementation	5
✓ Analog simulation	5
✓ Digital design	4
✓ Digital simulation	3
✓ Verbal communication	5
✓ Written communication	5
✓ Teamwork experience and skills	5

IBM

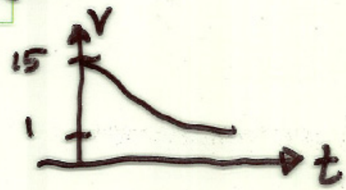
Power Electronics Technology Trend

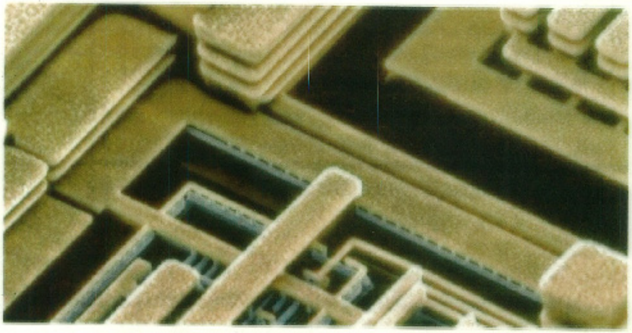


Technology Challenges

- **Faster Semiconductors Require:**

Higher Current
Lower Voltage





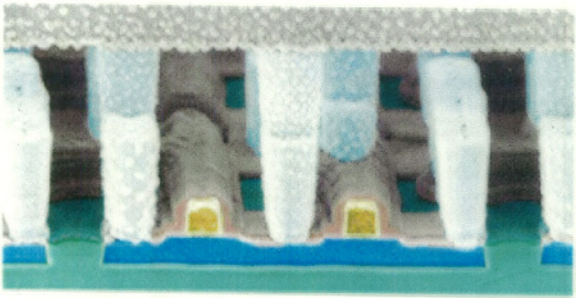
IBM CMOS7S Copper Technology

Technology Challenges

- **Faster Semiconductors Cause:**

High di/dt

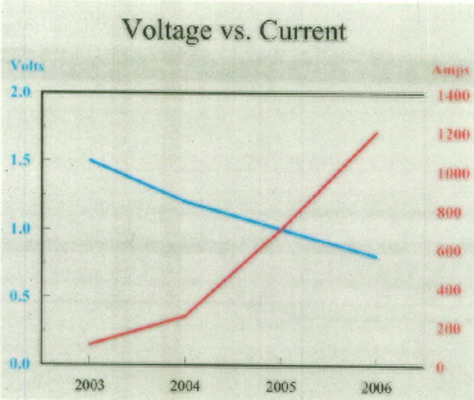
μP: $\frac{50\,A}{10\,ns} \sim \frac{10^{9}\,A}{sec}$



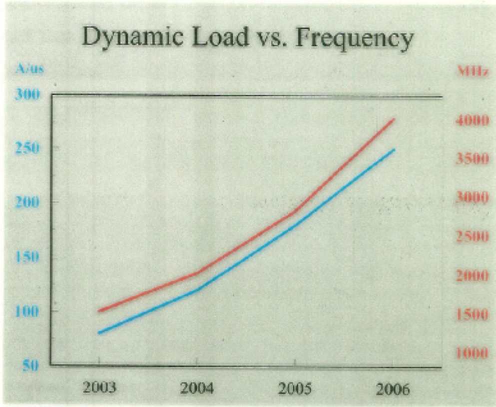
IBM SOI Technology

Technology Challenges

Processor Power Trends



Power per Cell Decreasing
Function Increasing
N-Way Processors



Larger Chips/More Integration
Multi-Chip Modules
Higher Operating Frequencies

Portable Electronics

Power Management Design for Applications Processors

— By Jim Y. Wong, Principal Applications Engineer

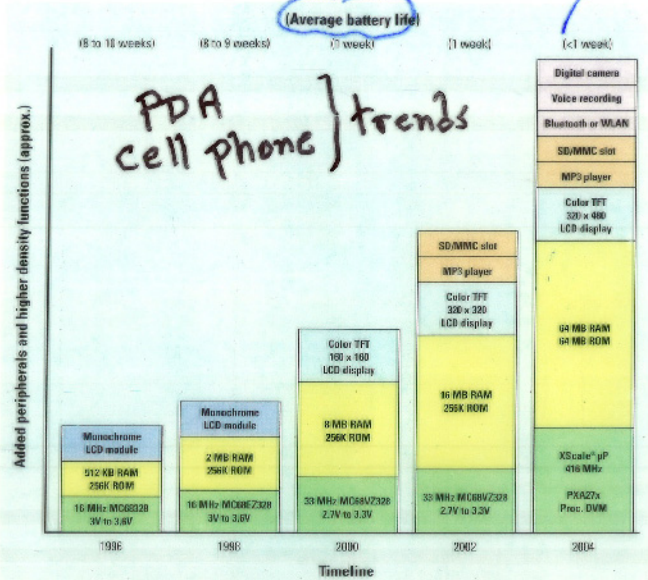


Figure 1. Evolution of PDAs and average battery life

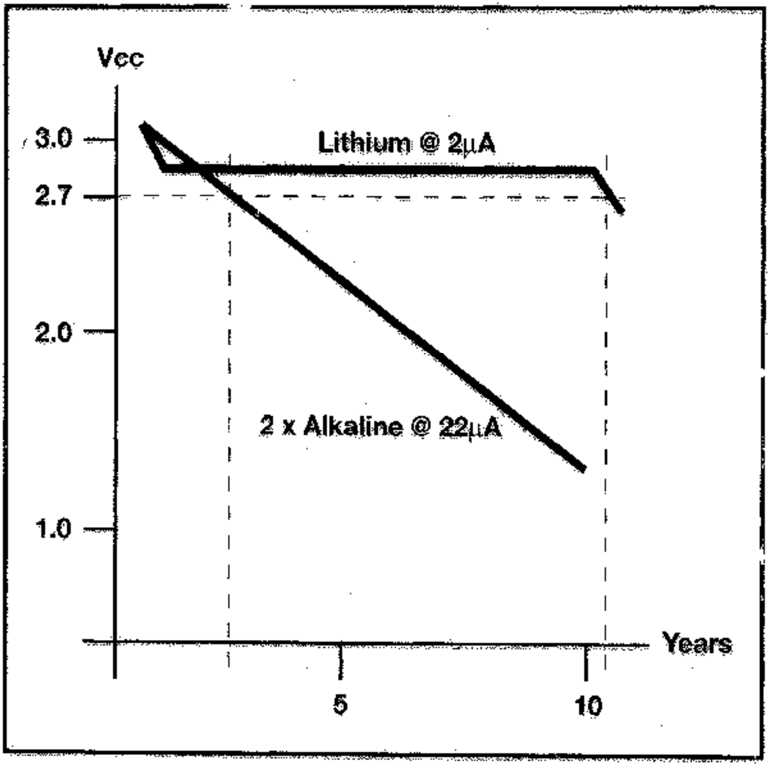


Figure 3: Comparison of alkaline and lithium battery discharge curves.

are trying to minimize lead content most attractive

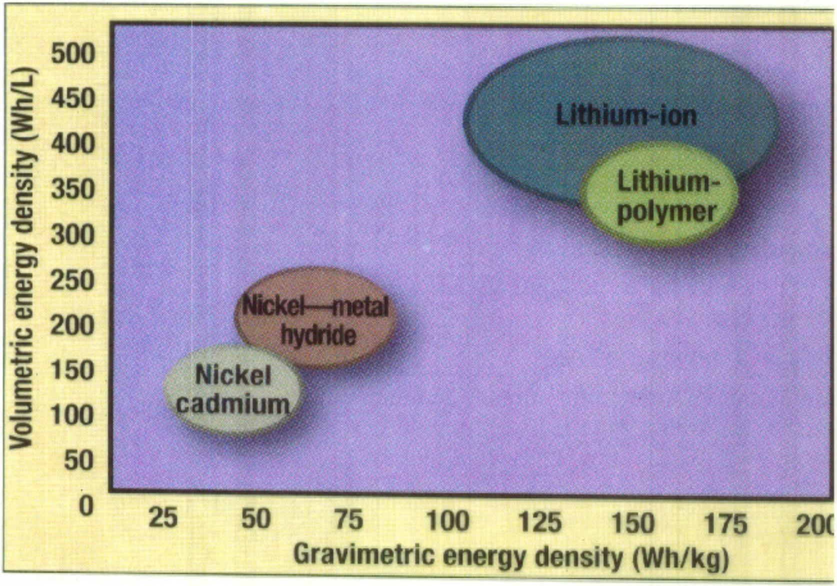
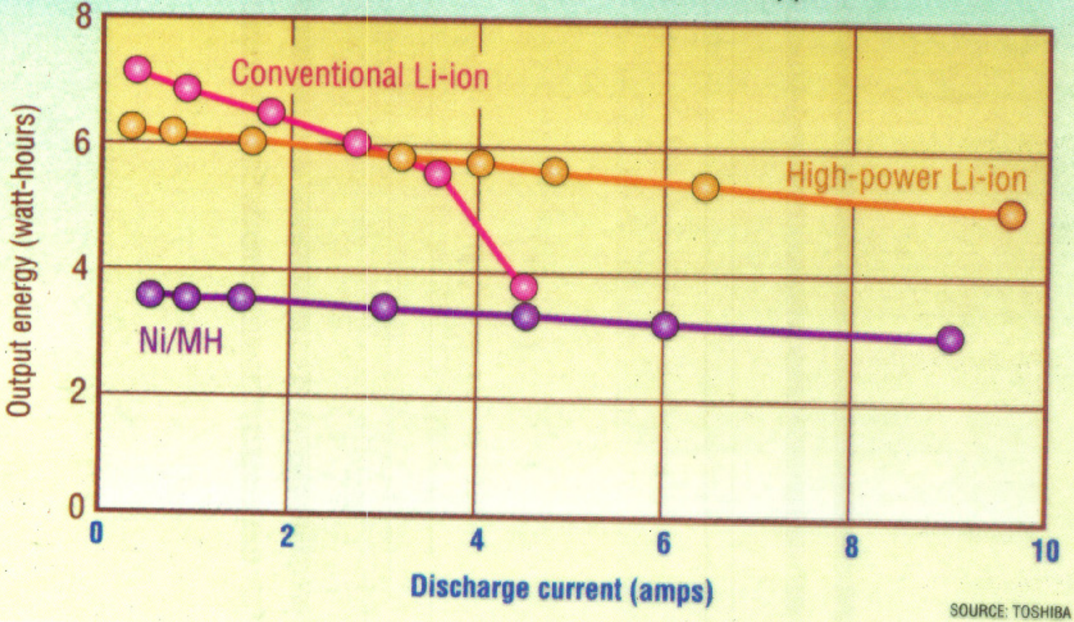


Figure 2. The volumetric and gravimetric energy densities o
principal rechargeable-cell chemistries.

Power e^- extends battery life

TOSHIBA BATTERY TRIPLES DISCHARGE CURRENT

Cell targets robots, power tools, other apps



Pé controls pesky "sleep mode"

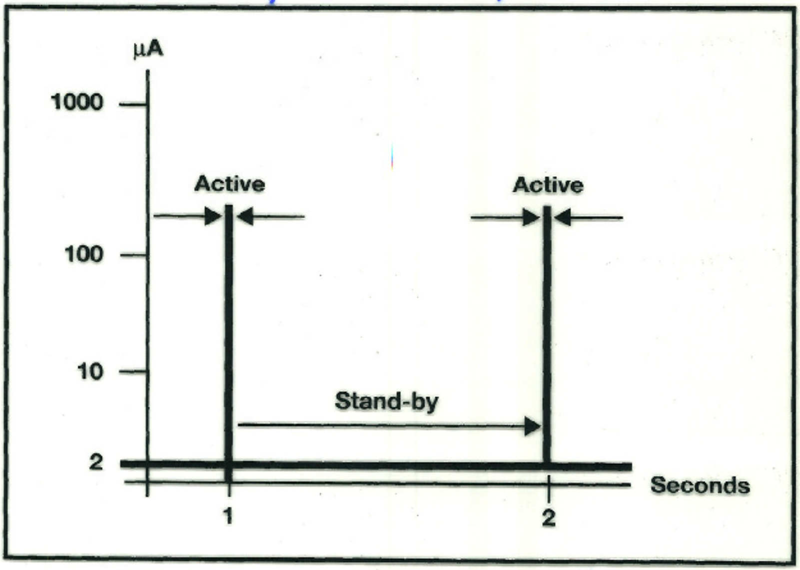


Figure 4: Ultra-low power activity profile maximizes time in standby modes waking the system quickly and only when required.

Power Technology

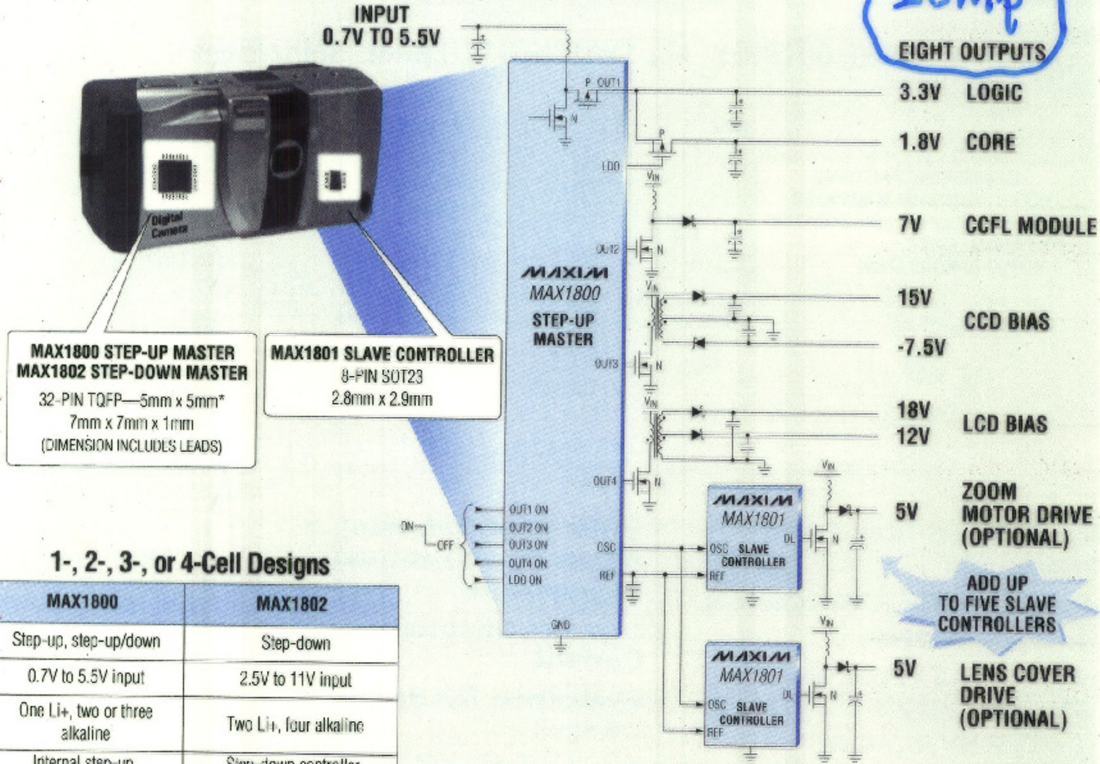
Technology Challenges → di/dt, efficiency

- **High di/dt Requires A Fast Response Converter**
- **di/dt Requirements are up to 250 Amps/uS with Year 2006 Requirements Expected To Reach 1000 Amps/nS (a 4000x increase!!)**
- **Adding Low ESR, Expensive Capacitors Is No Longer Feasible For Future Low And Midrange Systems**
- **System Thermal Requirements Call For High Efficiency Converters**

$$\frac{dv}{dt} = ? \Rightarrow$$

$$\frac{di}{dt} = ? \Rightarrow$$

EXAMPLE OF A COMPLETE DIGITAL CAMERA POWER SUPPLY
(CAN ALSO BE USED IN PDAs)



1-, 2-, 3-, or 4-Cell Designs

MAX1800	MAX1802
Step-up, step-up/down	Step-down
0.7V to 5.5V input	2.5V to 11V input
One Li+, two or three alkaline	Two Li+, four alkaline
Internal step-up, three step-up controllers, LDO controller	Step-down controller, three step-up controllers, internal step-down

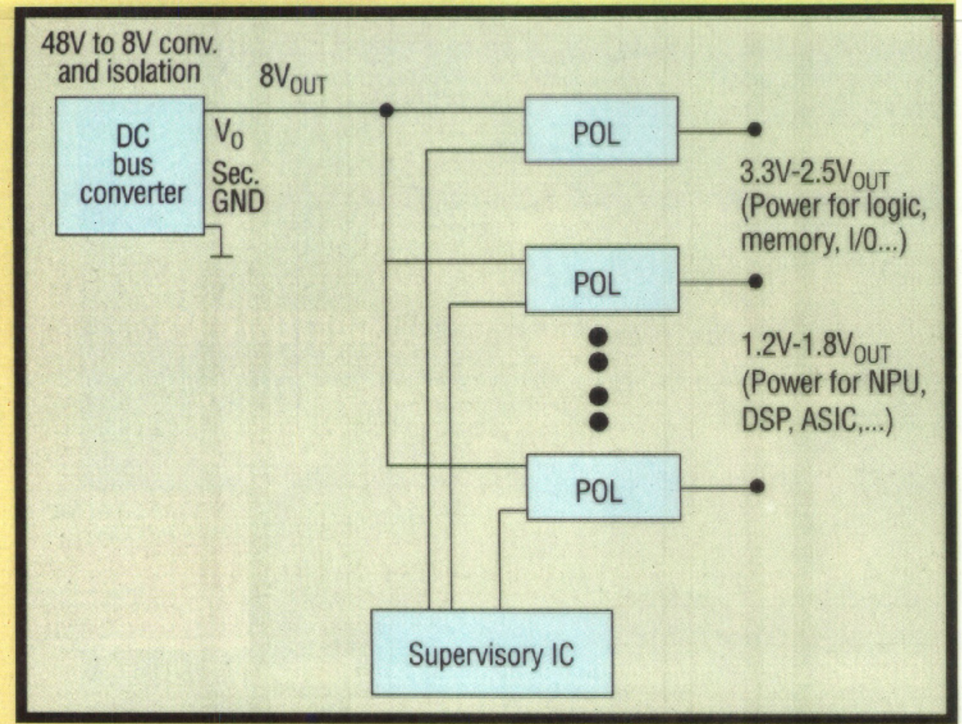
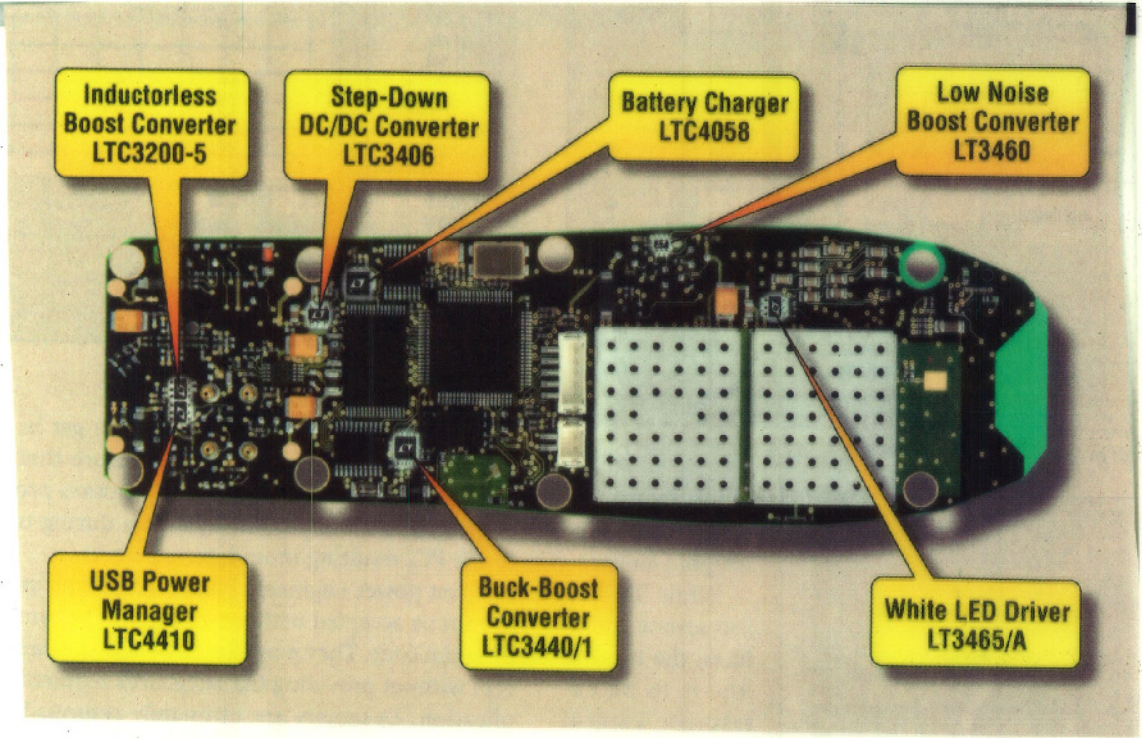


Fig. 1. *An 8V intermediate bus architecture is considered to be optimum for <150W line cards today*

It is not surprising to see the need for multiple operat-
ing voltages on new generation NPU, ASICs, FPGAs or



Tiny & Efficient Power Solutions for Handheld Products

L5 Web

REVIEW OF PULSE-WIDTH MODULATED CONVERTERS AND ASSOCIATED AC WAVEFORMS CAUSED BY SWITCHING

A. UNREGULATED AC MAINS TO DC CONVERTERS:

Linear Electronics Vs Power Electronics

old Approach DC→DC

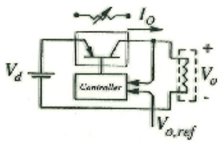
❑ Linear Electronics : Example

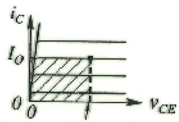
V_d : 20Vdc ± 10%

V_o : 12Vdc (regulated)

$P_{loss} = V_{CE}\ I_O$

low if?





$V_{CE} = V_d - V_o$

❑ Poor efficiency

- cost of wasted energy
- large heatsink

1. Key issues in power electronics are:
   - Energy Efficiency
   - Size/Weight
   - Reliability and Tendency to Instability
   - Cost

On the next page we compare the full on/full off methodology of switch mode methods to supply power more efficiently and the simple trick to achieve bigger efficiency.

Any lossless way?

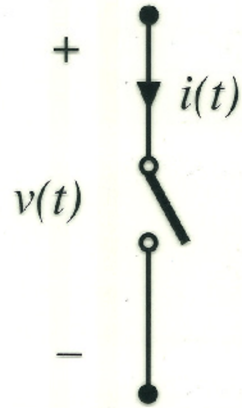
Power loss in an ideal switch

Switch closed: $v(t) = 0$

Switch open: $i(t) = 0$

In either event: $p(t) = v(t)\ i(t) = 0$

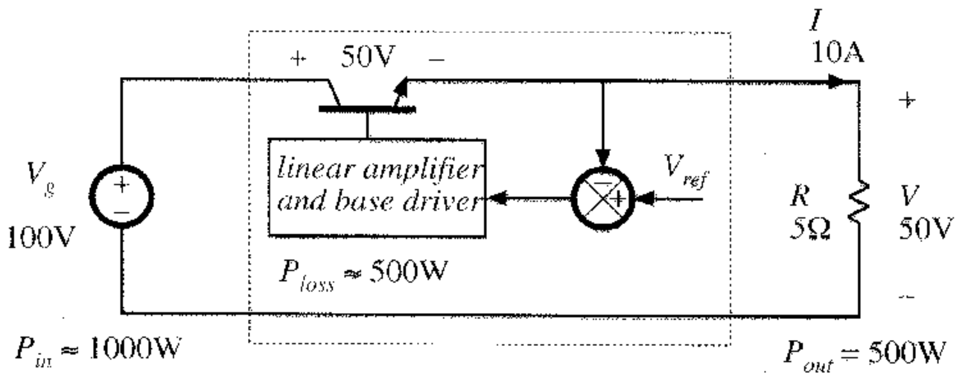
Ideal switch consumes zero power

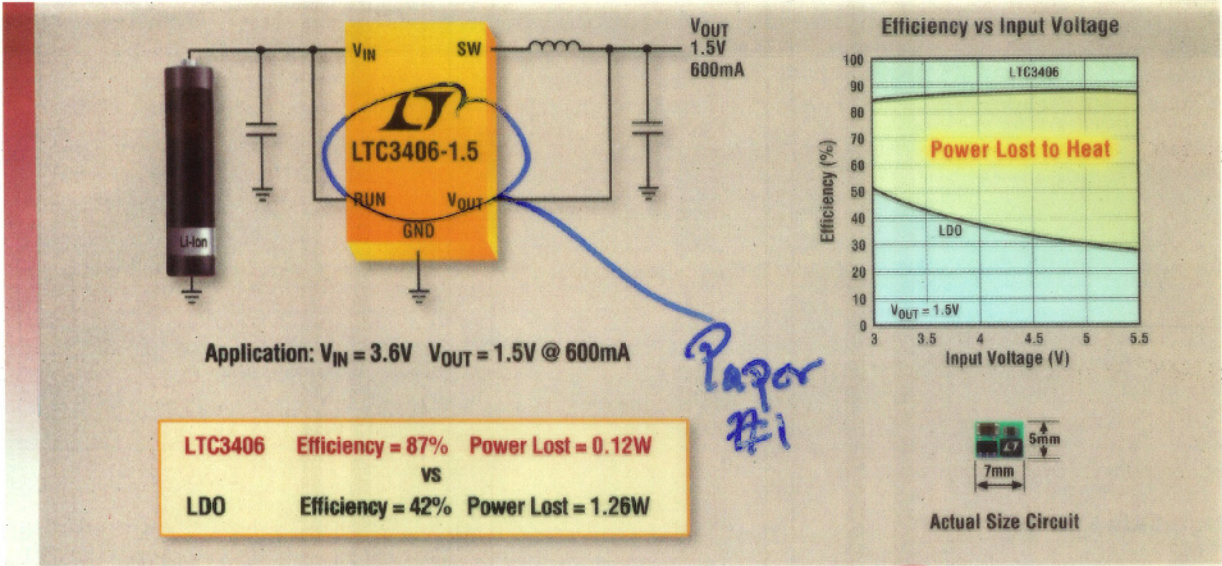


Reality includes more

Dissipative realization

Series pass regulator: transistor operates in active region



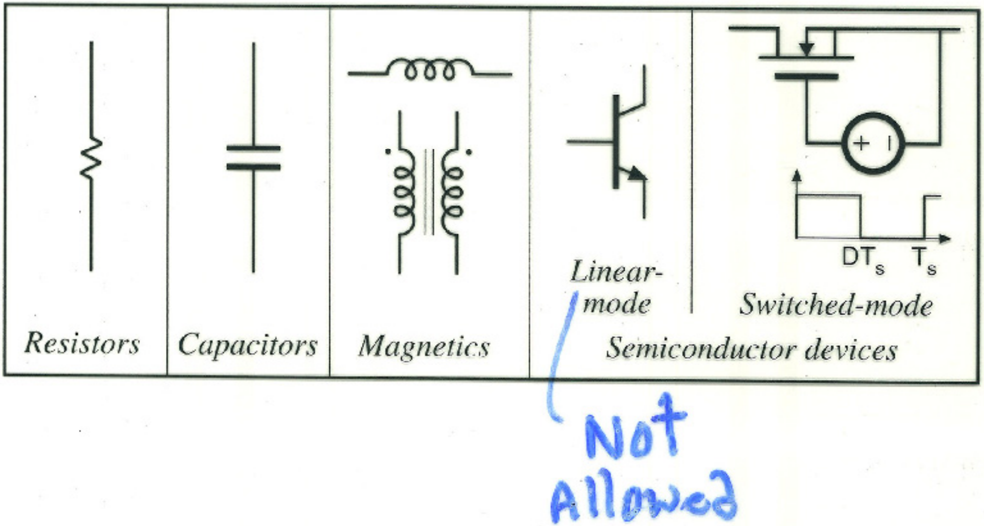


Switchers Reduce Heat by More Than 10 Times vs an LDO

LDO

1V → .9V

Devices available to the circuit designer



Paper Switched "C" Converters

C. THREE GENERAL TECHNOLOGIES

1. Linear Regulators

Employed where weight and heat flow are not crucial because design is fast and cost low. Efficiency is only 50 %

2. Pulsewidth modulated(PWM) converters

Employed in portable equipment or where high power flows demands the highest efficiency power conversion of about 95 %

3.RESONANT SWITCHED CONVERTERS

Utilized to achieve small size supplies and still avoid the electronic noise generated by PWM converters.

681
564

COMPARISION OF THE BIG THREE

power supply properties	LINEAR	PWM	RESONANT
Size and weight	Large	Small	Small
Electrical Efficiency	50%	85%	95%
Multiple Voltage outputs	Not Possible	Easily done	Easily done
NOISE Generated	Low Noise	High EMI	Medium Noise

We choose between the three approaches based upon the criterion for the system such as the four below:

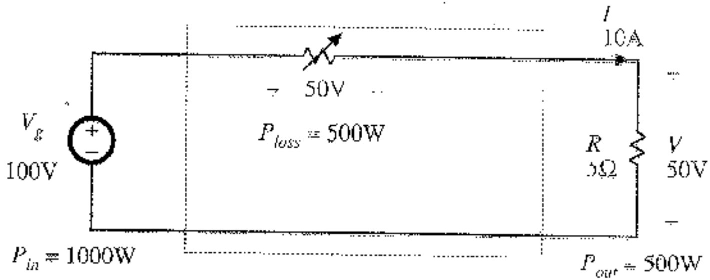
1. Power levels in and out and required operating efficiency to minimize heat generation

% Efficiency = P(out) / P(in)

2. Size and weight lim'ts as well as heat flow limits

Dissipative realization

Resistive voltage divider



High efficiency is essential

Battery

100 kW

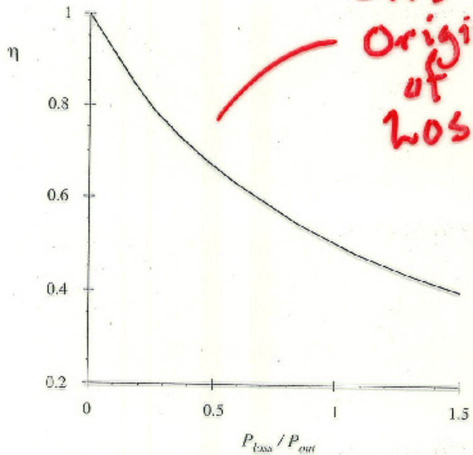
$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_{loss} = P_{in} - P_{out} = P_{out}\left(\frac{1}{\eta} - 1\right)$$

High efficiency leads to low power loss within converter

Small size and reliable operation is then feasible

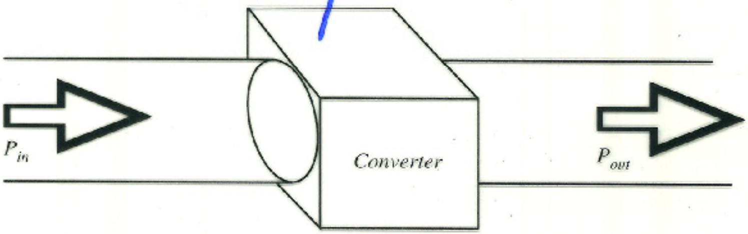
Efficiency is a good measure of converter performance



Ch 3 Origins of Loss

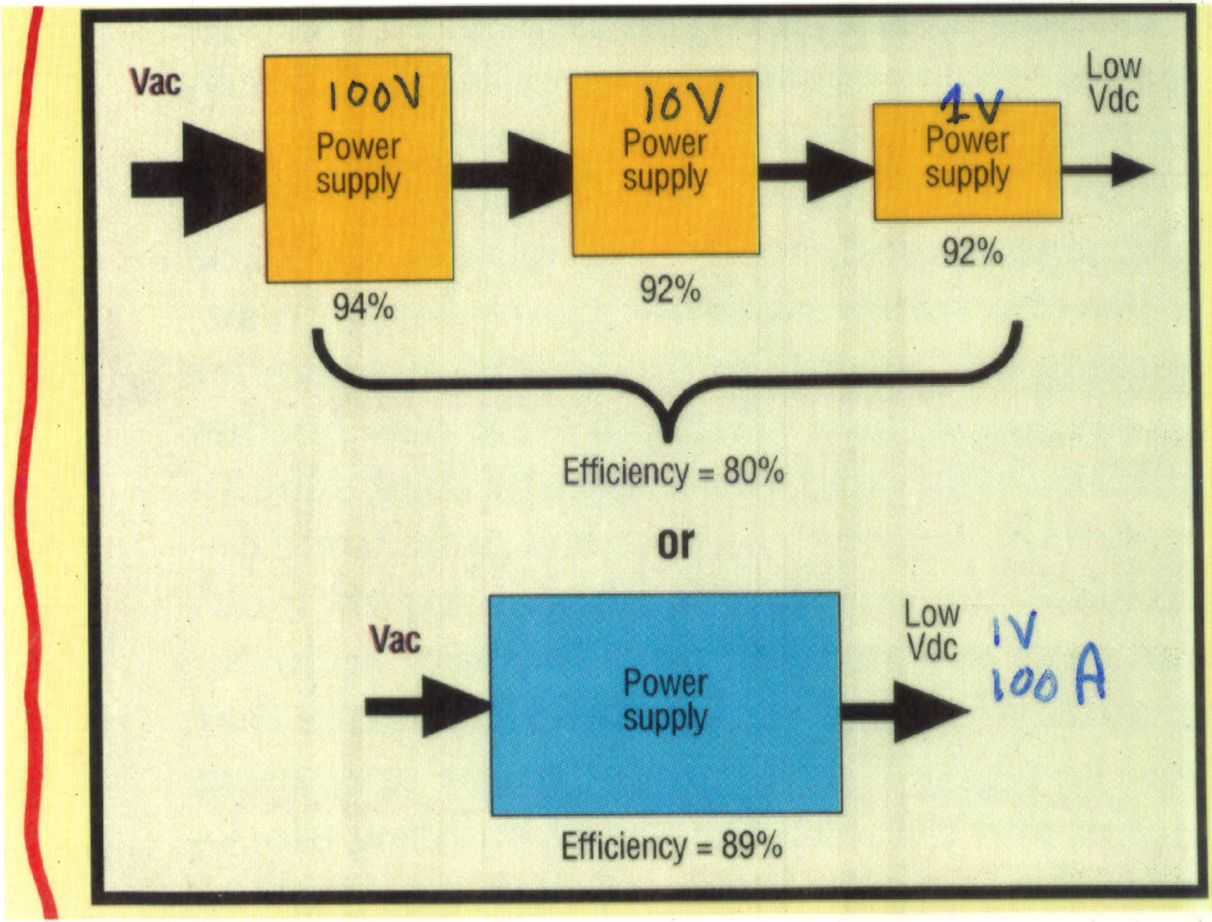
A high-efficiency converter

PWM path
resonant path



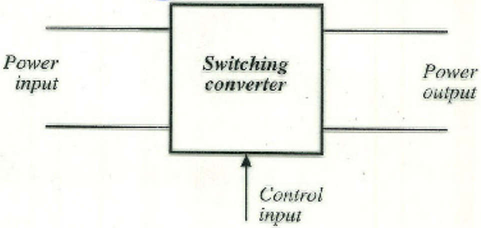
Goal

A goal of current converter technology is to construct converters of small size and weight, which process substantial power at high efficiency


Vac
100V
Power supply
94%
10V
Power supply
92%
1V
Power supply
92%
Low Vdc
Efficiency = 80%
or
Vac
Power supply
Low Vdc
1V
100 A
Efficiency = 89%

1.1 Introduction to Power Processing

10-20KW Conversion @ 95% efficiency



Dc-dc conversion: Change and control voltage magnitude

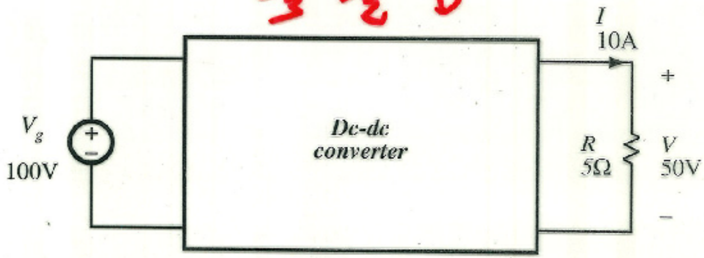
Ac-dc rectification: Possibly control dc voltage, ac current

Dc-ac inversion: Produce sinusoid of controllable magnitude and frequency

Ac-ac cycloconversion: Change and control voltage magnitude and frequency

A simple dc-dc converter example

DC Transformer

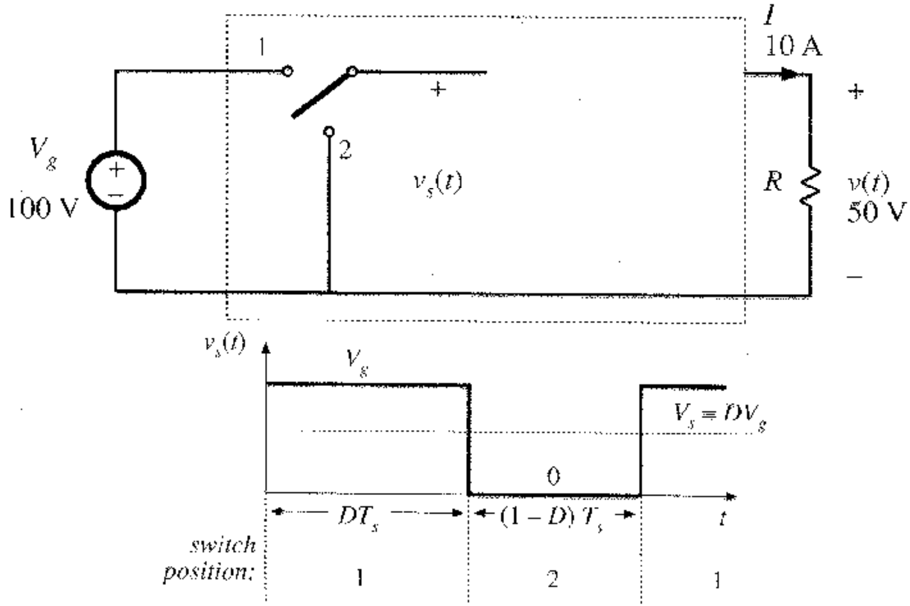


Input source: 100V

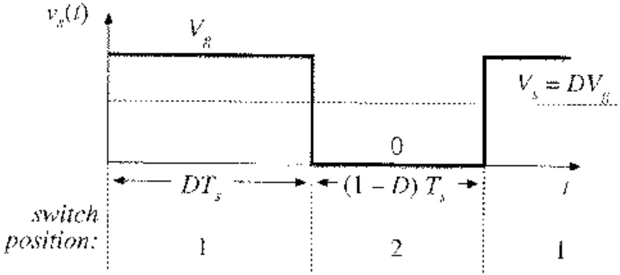
Output load: 50V, 10A, 500W

How can this converter be realized?

Use of a SPDT switch



The switch changes the dc voltage level



D = switch duty cycle

$0 \le D \le 1$

T_s = switching period

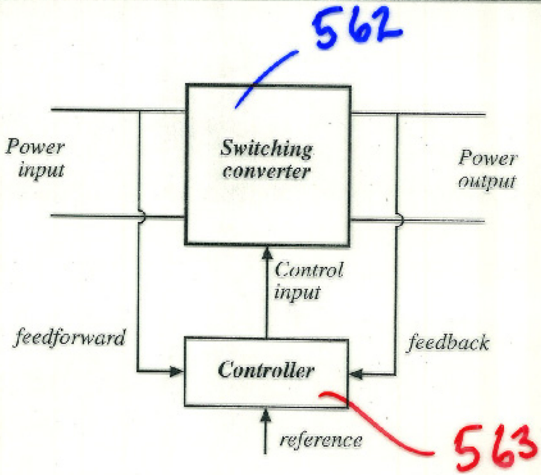
f_s = switching frequency

$= 1 / T_s$

DC component of $v_s(t)$ = average value:

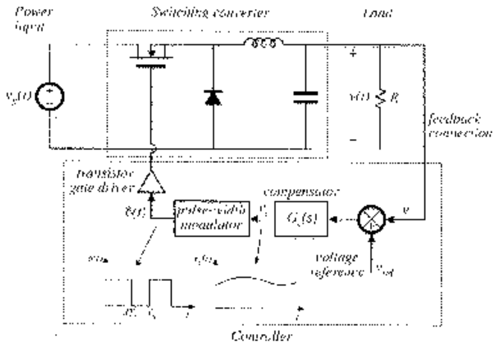
$$V_s = \frac{1}{T_s}\int_0^{T_s} v_s(t)\,dt = DV_g$$

Control is invariably required

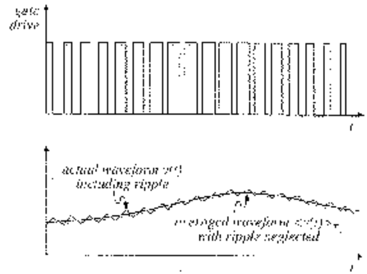


Part II. Converter dynamics and control

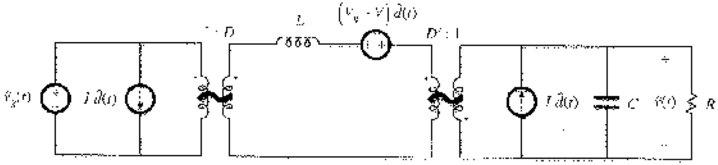
Closed-loop converter system



Averaging the waveforms



Small-signal averaged equivalent circuit



Chapter 1: Introduction

1.1. Introduction to power processing

1.2. Some applications of power electronics

1.3. Elements of power electronics

Summary of the course

Growing 50%/Yr

1Φ
60Hz
AC → DC ——→ Any variable f 3Φ AC

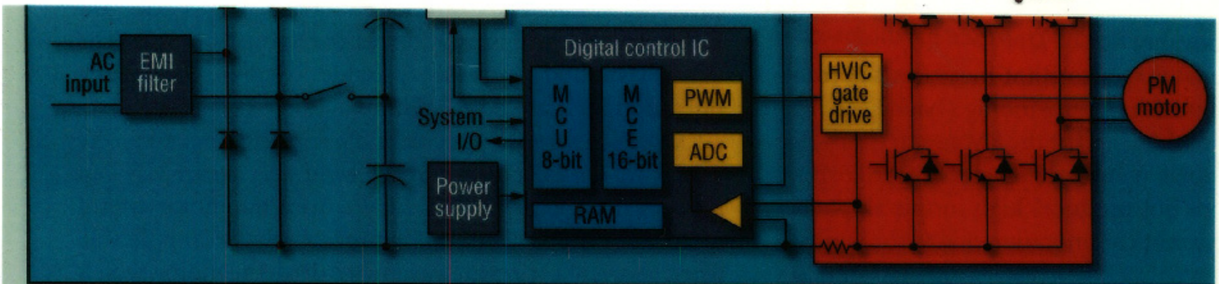


Fig. 4. *The main electronic components of the washing-machine controller are the digital control IC and the integrated power module.*

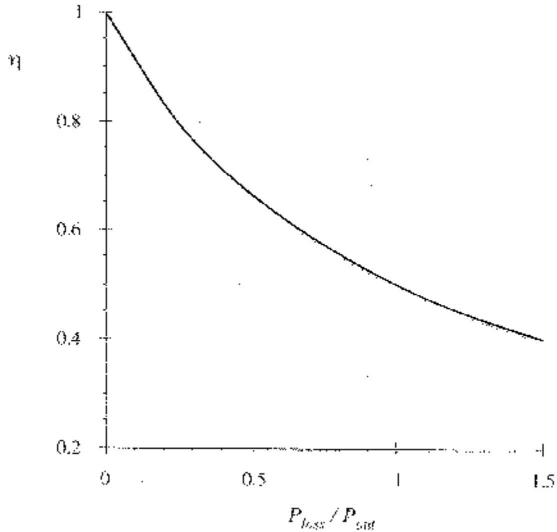
Portable e & High Power

High efficiency is essential

$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_{loss} = P_{in} - P_{out} = P_{out}\left(\frac{1}{\eta} - 1\right)$$

- High efficiency leads to low power loss within converter
- Small size and reliable operation is then feasible
- Efficiency is a good measure of converter performance



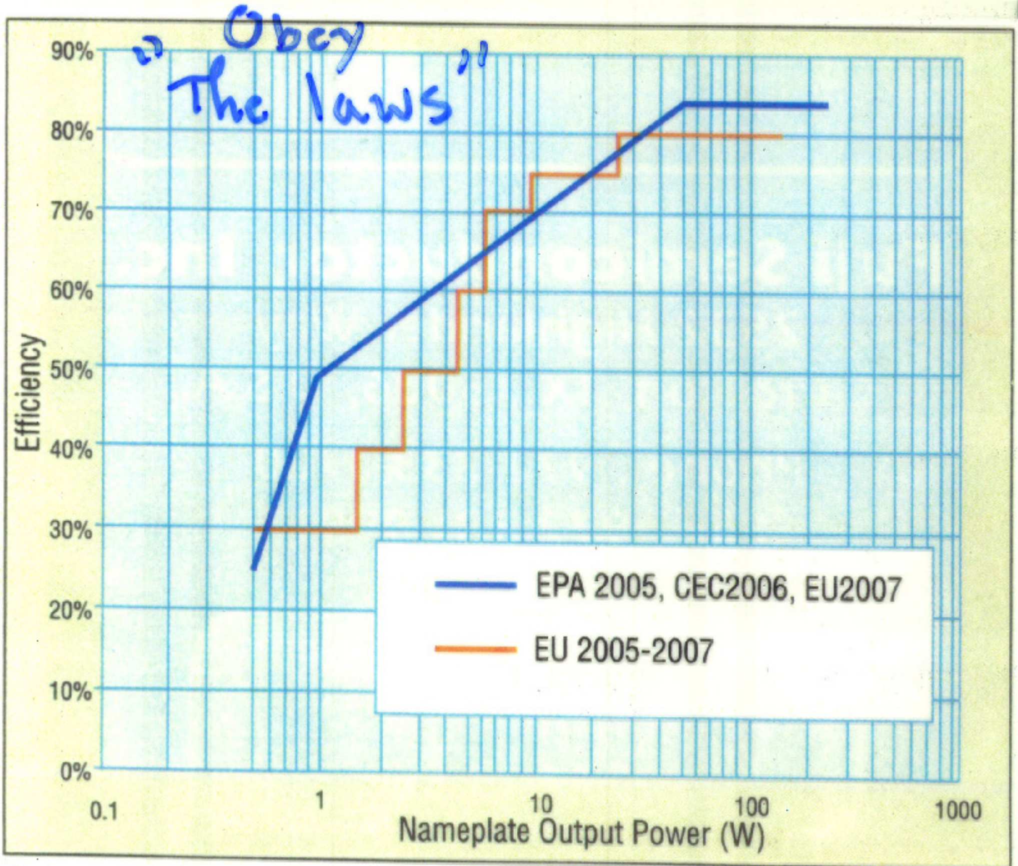


Fig. 1. *Active "ON" mode efficiency curves for the CEC, the EPA and the EU.*

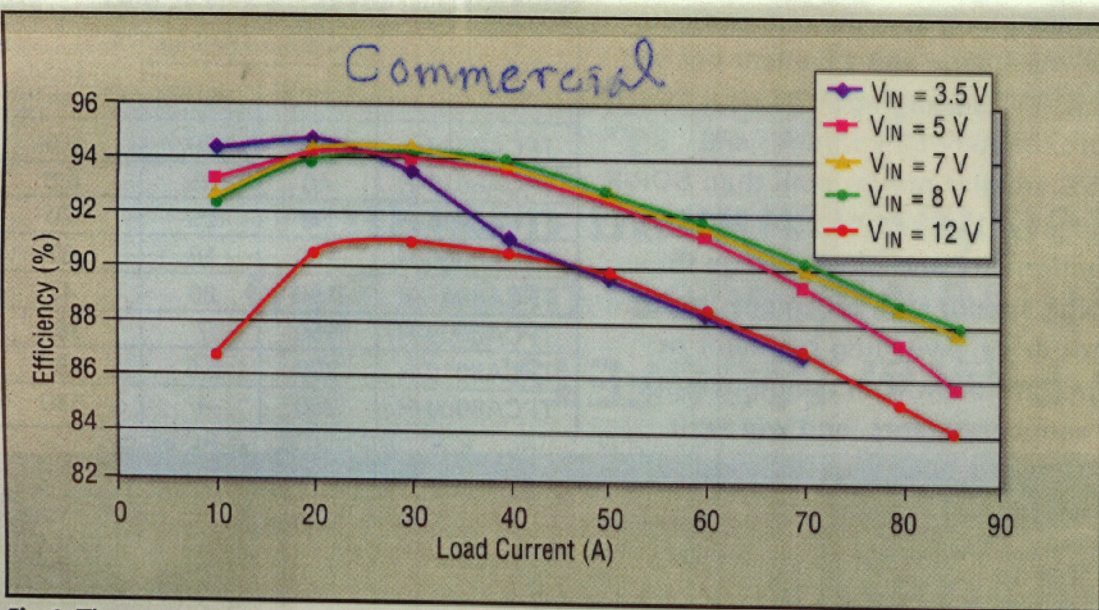
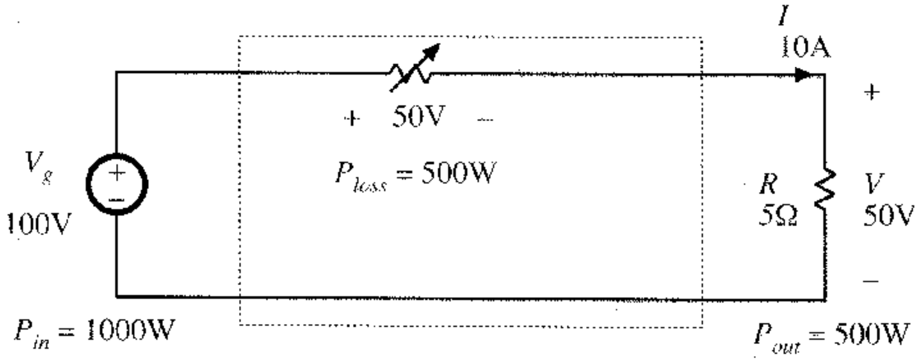


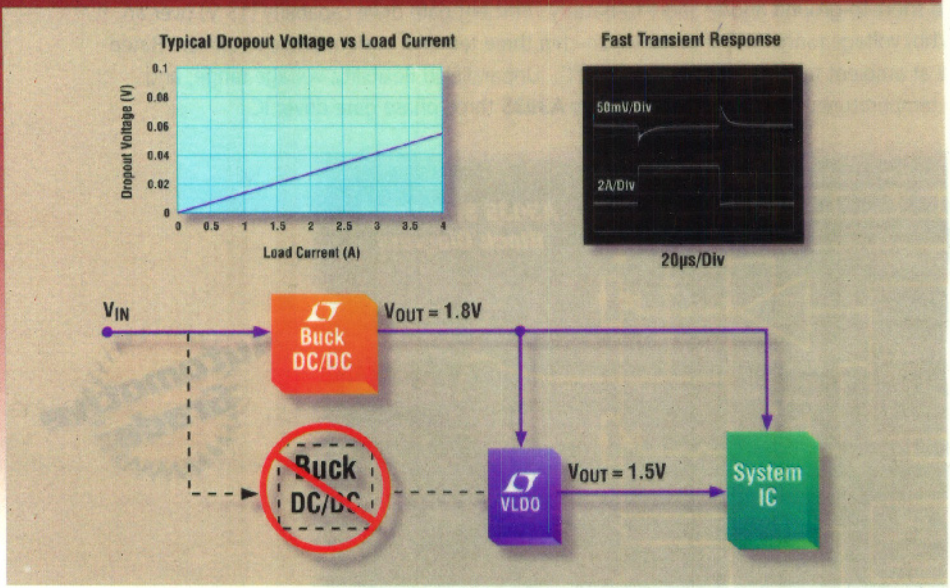
Fig. 1. *The measured converter efficiency of a VRM switching at 1 MHz is plotted as a function of the input voltage over the 3.5-V to 12-V range.*

Dissipative realization

Resistive voltage divider

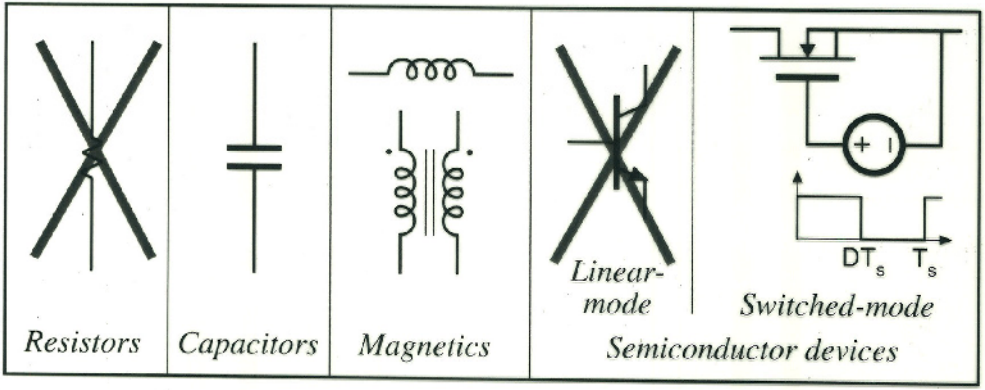


High Efficiency Linear Regulators



VLDO™ Regulators Outperform Switchers in Many Low Voltage Applications

Devices available to the circuit designer



Power processing: avoid lossy elements

Part II. Converter dynamics and control

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7. Ac modeling
8. Converter transfer functions
9. Controller design
10. Input filter design
11. Ac and dc equivalent circuit modeling of the discontinuous conduction mode
12. Current-programmed control

Part III. Magnetics

13. Basic magnetics theory
14. Inductor design
15. Transformer design

Maybe 562
After
Resonant
Converters

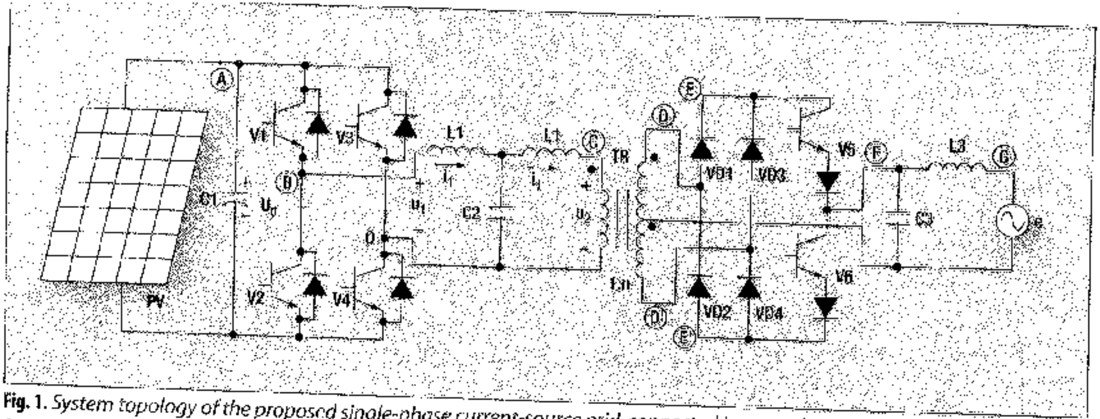
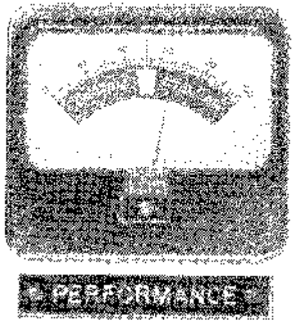
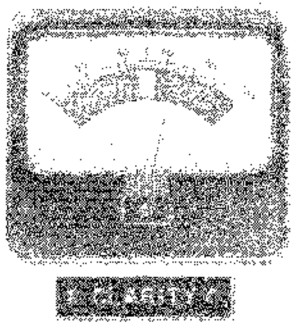
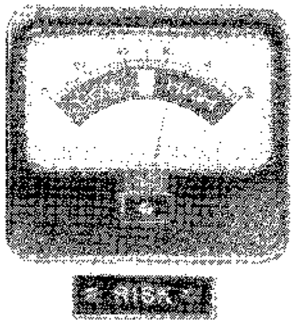
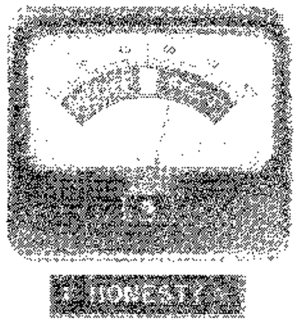


Fig. 1. *System topology of the proposed single-phase current-source grid-connected inverter that consists of a high-frequency, full-bridge inverter, immittance converter, center-tapped transformer, high-frequency bridge rectifier, power-frequency inverter and low-pass filter.*


PERFORMANCE




RISK


HONESTY