Lecture-1

EE5325 Power Management Integrated Circuits

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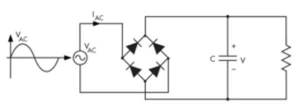
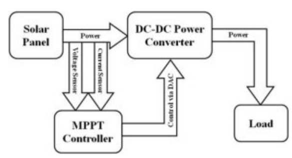
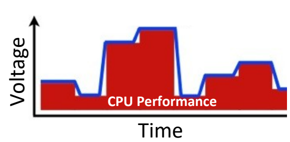
What is Power Management?

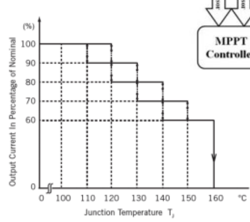
Deals with Efficient and Reliable Power Delivery to a system

- **Voltage conversion from one power domain to other**
  - DC-DC Conversion (Regulators)
  - AC-DC/DC-AC Conversion (Rectifiers/Inverters)
- **Voltage/Current Measurement**
  - Voltage and Current Sensing
- **Managing Losses or Heat**
  - Current de-rating
  - Dynamic Voltage Scaling (DVS)









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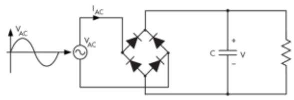

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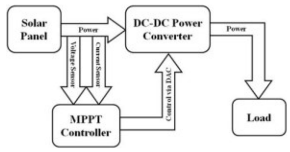

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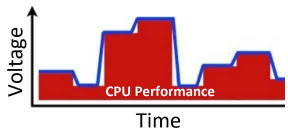
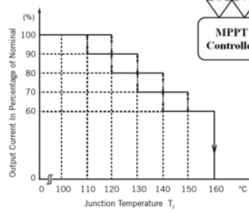
  - Current de-rating
  - Dynamic Voltage Scaling (DVS)





Achieved by controlling or managing power delivered to load

Types of Power Management

High Power:

- 100s to KWatts range powered by direct AC
- Discrete semiconductor devices (FETs, BJTs, diodes) and large passives

Low/Mid Power:

- mWatts to 10s of Watts powered from battery
- Integrated controller & power FETs with few small external passives

Source: ST Microelectronics

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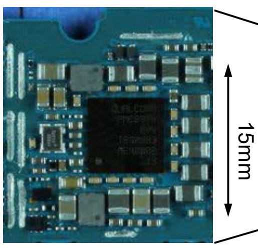
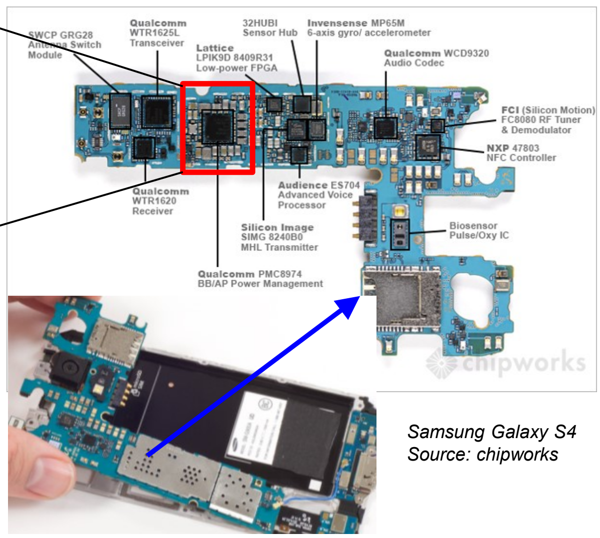
VLSI Power Management deals with mainly Low/Mid power applications

Need of Integrated Power Management



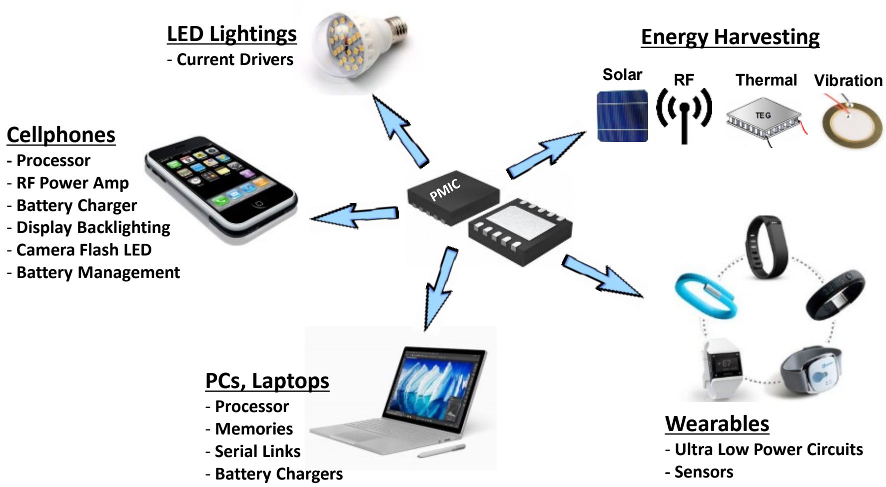
PMIC: 6mm x 6mm, 225 pins

- **Power demand is increasing while board space is shrinking**



Samsung Galaxy S4
Source: chipworks

Application of DC-DC Converters



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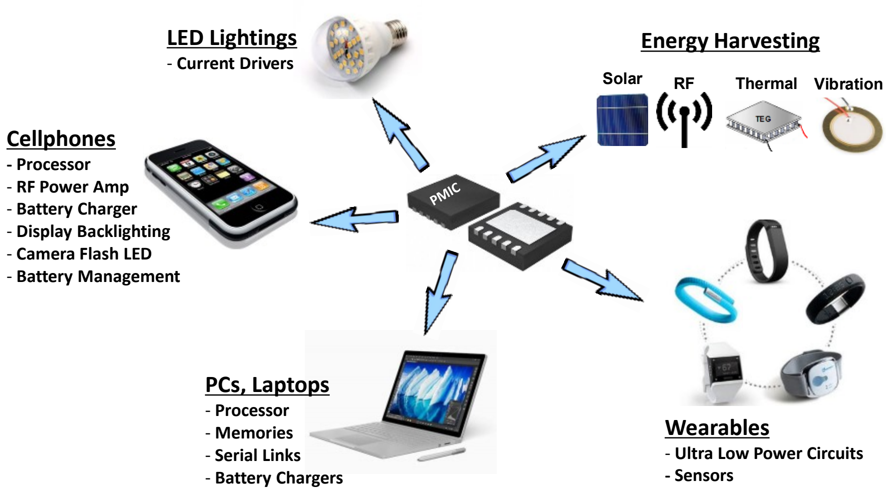


Power delivery for these applications is mostly met by DC-DC Converters

Applications in Self Powered Sensors

- Targeted for ultra low power applications – IoT
- Highly efficient, miniaturized low power converters
- Energy is harvested from freely available sources such as light, vibration, heat, RF

Structural Health Monitoring

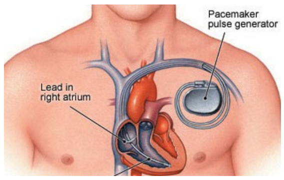
→ Powering Sensors from Mechanical Vibration

→ Wireless Charging

Implantable Biomedical

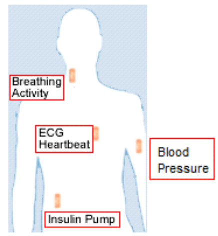
→ Charging Battery from Heart Beat

→ Wireless Charging



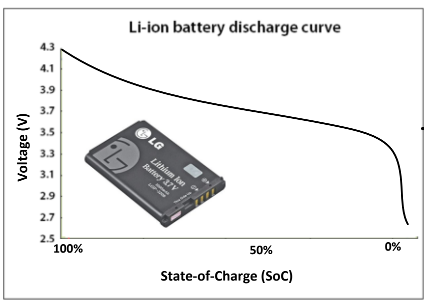
Health Monitoring Systems

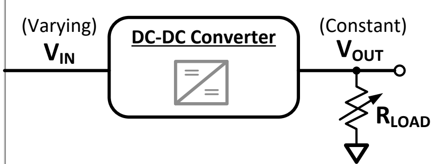
→ Powering Sensors from Body Heat



DC-DC Power Converter

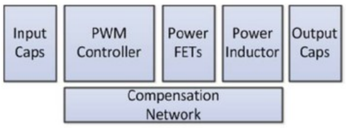
- Converts voltage from one domain to other
- Provides regulated output voltage
  - Under varying conditions (input voltage, output current)



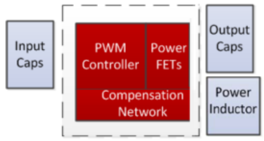


Discrete Vs. Integrated Power Converters

Discrete

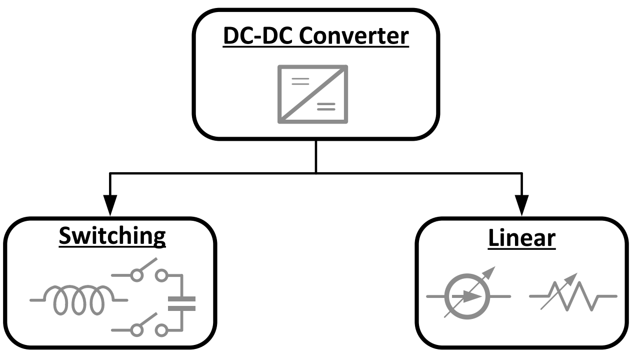


Integrated



VLSI Systems mostly use Integrated DC-DC Converters due to limited board space

DC-DC Converter Types



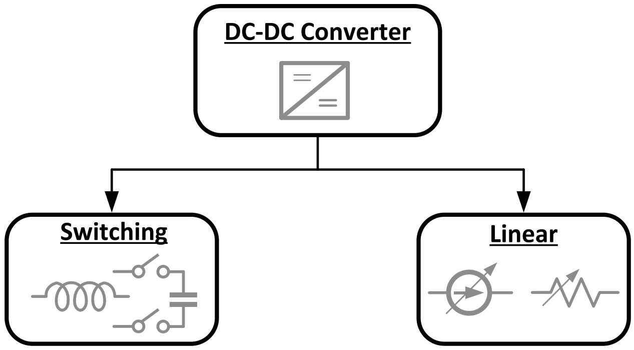
Inductive or Capacitive

Can generate output voltage less, greater, inverting or equal to input voltage .

Low Drop-Out (LDO) Regulators

Can generate output voltage only less or equal to input voltage.

DC-DC Converter Types



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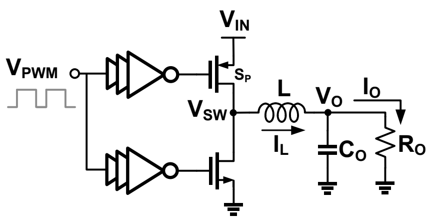
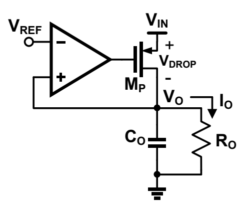
Switching vs Linear Regulator

Switching Regulator



- Regulation achieved by changing on/off time
- Switches are in either linear or cutoff → reduced losses
- High efficiency over wide range of V_O/V_{IN}

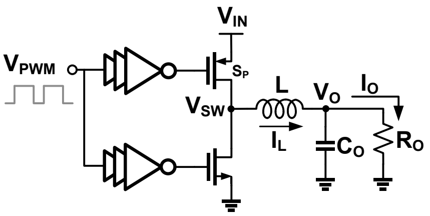
Linear Regulator



- Regulation achieved by dropping voltage
- Switches are in saturation → higher losses
- Poor efficiency when V_O/V_{IN} ratio is low

Switching vs Linear Regulator

Switching Regulator



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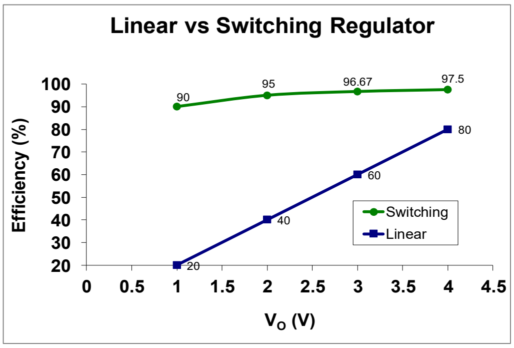
More than 90% of power requirement is met by Switching Converters

Switching Vs Linear Regulator

- For Vin = 5V, Vo = 1V and I_{Load} = 1A
  - 80% power loss in the Linear regulator as compared to 10% in switching regulator
- For Vin = 5V, Vo = 4V and I_{Load} = 1A
  - 20% power loss in linear regulator as compared to 2.5% in switching regulator

$$Efficiency\,(\eta) = \frac{Output\ Power}{Input\ Power}$$



Recent Trends in Power Management ICs for VLSI Systems

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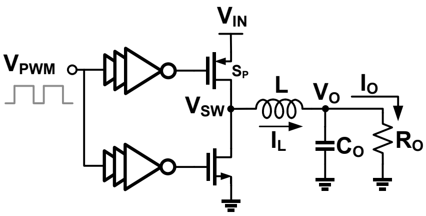
Switching vs Linear Regulator

Switching Regulator



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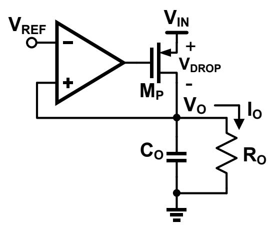
Linear Regulator



- Regulation achieved by dropping voltage
- Switches are in saturation → higher losses
- Poor efficiency when V_O/V_{IN} ratio is low

How to Choose Between Linear Vs Switching

- Cost
  - Linear Regulators are cheaper compared to switching
- Power
  - In a multi-power domain, linear regulator are preferred over switching regulators for low power domains
  - Switching regulators are preferred for high power applications
- Conversion Ratio (Vout/Vin)
  - Efficiency of linear regulators is comparable to switching for higher Vout/Vin (>0.9)
  - Switching regulators are preferred when Vout/Vin is less
- Noise
  - Linear regulators are quiet compared to switching hence preferred over switching for noise sensitive applications such as RF, sensors and other analog circuitries