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

PMIC: 6mm x 6mm, 225 pins

Samsung Galaxy S4
Source: chipworks
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**

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

**DC-DC Converter Types**

Switching
- Inductive or Capacitive
  - Can generate output voltage less, greater, inverting or equal to input voltage.

Linear
- Low Drop-Out (LDO) Regulators
  - Can generate output voltage only less or equal to input voltage.
**DC-DC Converter Types**

![Diagram of 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

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

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

Switching Vs Linear Regulator

- For \( V_{IN} = 5V, V_O = 1V \) and \( I_{Load} = 1A \)
  - 80% power loss in the Linear regulator as compared to 10% in switching regulator
- For \( V_{IN} = 5V, V_O = 4V \) and \( I_{Load} = 1A \)
  - 20% power loss in linear regulator as compared to 2.5% in switching regulator

Efficiency (\( \eta \)) = \( \frac{\text{Output Power}}{\text{Input Power}} \)
Switching vs Linear Regulator

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**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 ($V_{out}/V_{in}$)**
  - Efficiency of linear regulators is comparable to switching for higher $V_{out}/V_{in}$ (>0.9)
  - Switching regulators are preferred when $V_{out}/V_{in}$ 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