# 电源 基础知识

# 一个离不开电的世界

**Our 21st century lives rely on electronics**



**Without it, our day-to-day lives are completely different**



**Electronics require power to operate**

# 什么是电源?


DC POWER SUPPLY HY3005F-3
5.00
30.0
5.00
30.0
AMP
VOLT
AMP
VOLT
CURRENT
VOLTAGE
INDEP
SERIES
PARALLEL
CURRENT
VOLTAGE
SLAVE
TRACKING
MASTER
FIXED 3A
POWER


AC ADAPTER

# 为什么需要电源?

1. *Every* electronic system uses power.
2. What you have never matches what you need.

## What you have

110/220 VAC

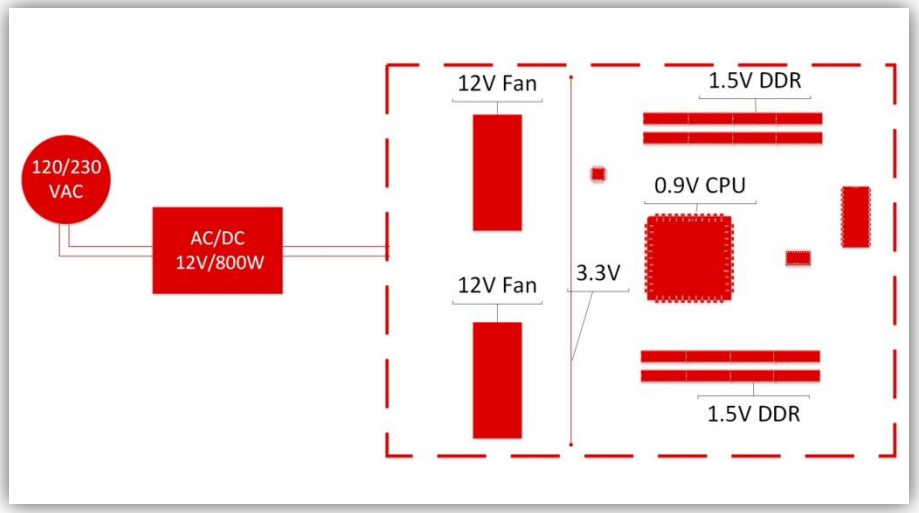
4.2V-3.0V

Power supply gets you from here to there

## What you need

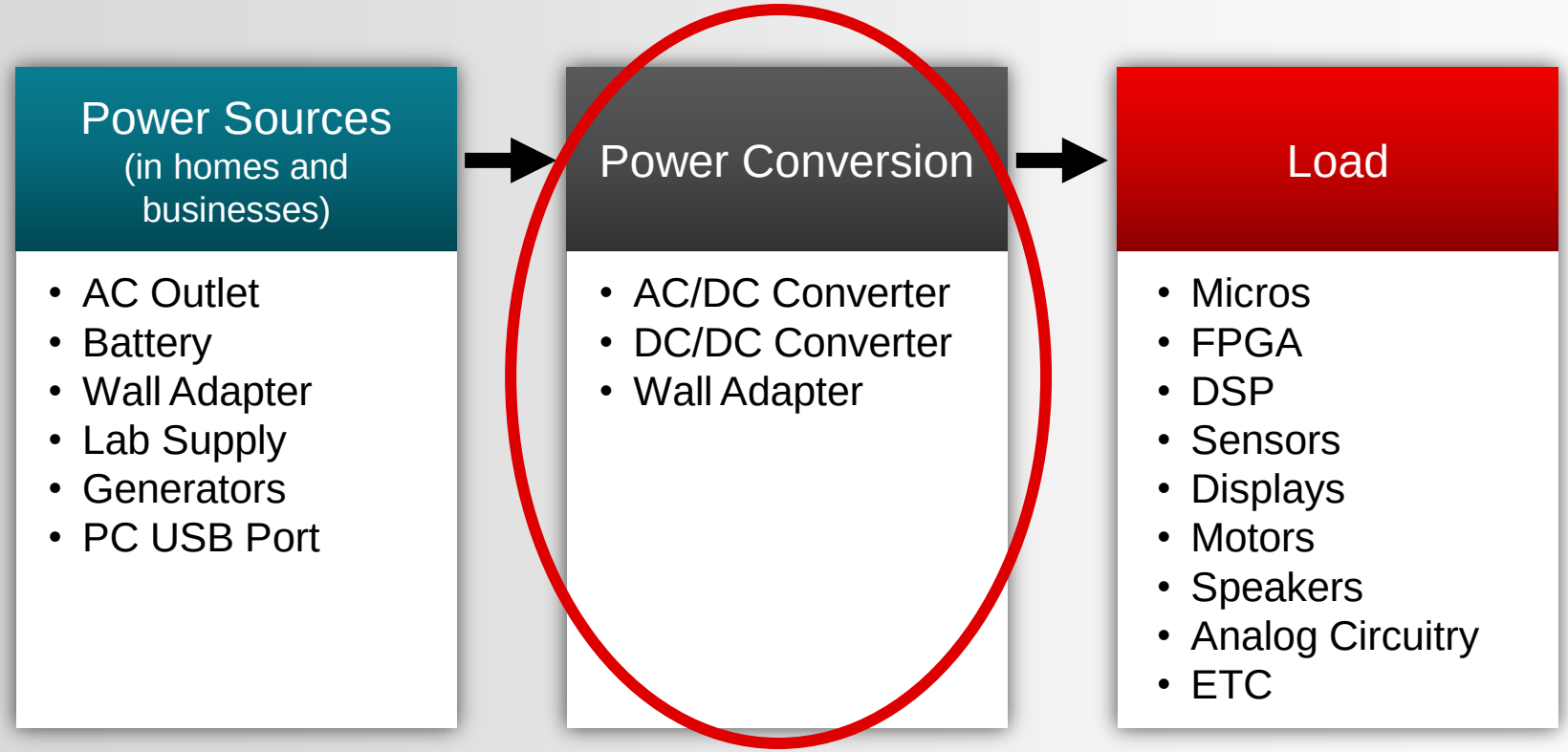
1.2V Core @ 2A
2.5V I/O @ 1.2A
3.3V
5V
+/-12V

# 典型的供电系统




- Due to the high number of unique voltage rails, an intermediate-bus architecture is commonly used – similar to the US Power Grid
  - 12Vdc is distributed throughout a server motherboard
- Voltage is converted from 12Vdc to 1.5Vdc, 0.9Vdc, 3.3Vdc, etc. at the loads
  - Commonly referred to “Point of Load” conversion

# 电源的基本结构


Power Sources
(in homes and businesses)
• AC Outlet
• Battery
• Wall Adapter
• Lab Supply
• Generators
• PC USB Port
Power Conversion
• AC/DC Converter
• DC/DC Converter
• Wall Adapter
Load
• Micros
• FPGA
• DSP
• Sensors
• Displays
• Motors
• Speakers
• Analog Circuitry
• ETC

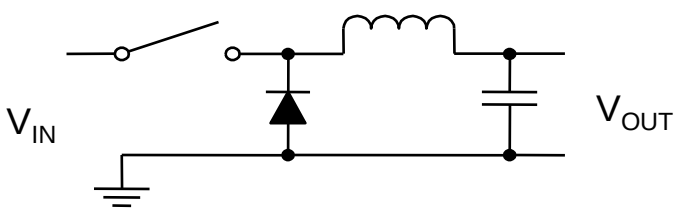
# 当我们谈论电源，我们在谈论什么?

- 拓扑结构
- 功率元器件
- 控制方式
- 布局布线

# 拓扑结构

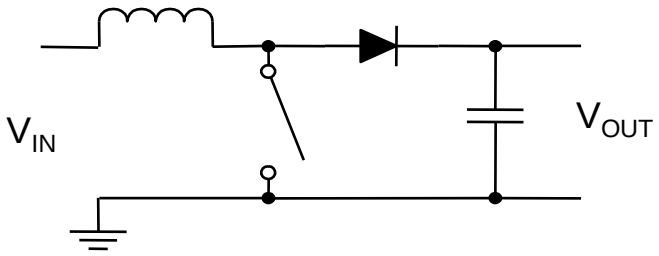
- Three basic types of switching converter topologies: Buck, Boost and Buck-boost

Buck



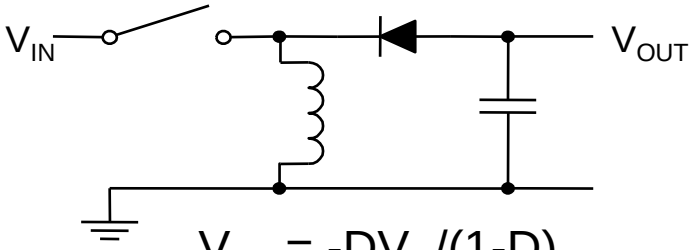

$V_{out} = D*V_{in}$

Boost




$V_{out} = V_{in}/(1-D)$

Buck-boost

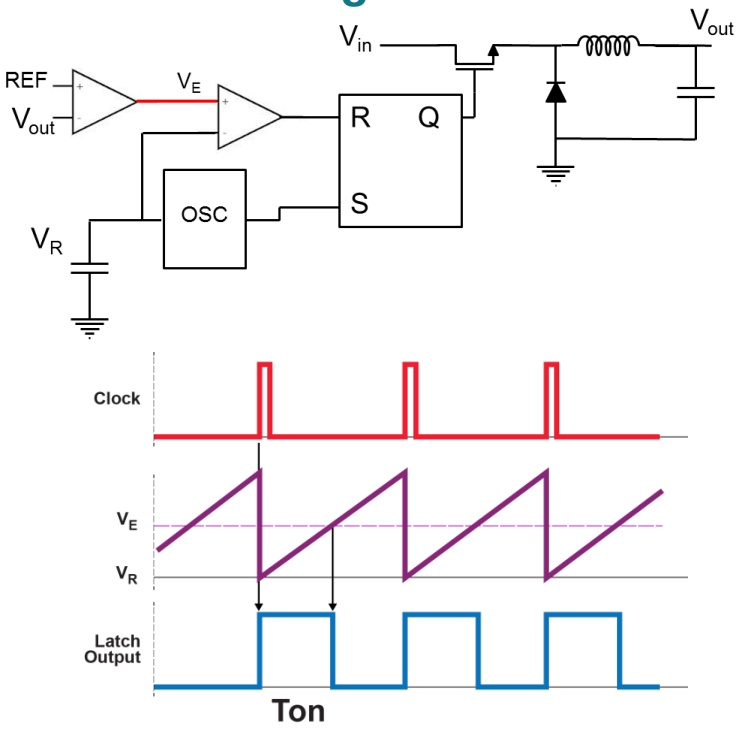



$V_{out} = -DV_{in}/(1-D)$

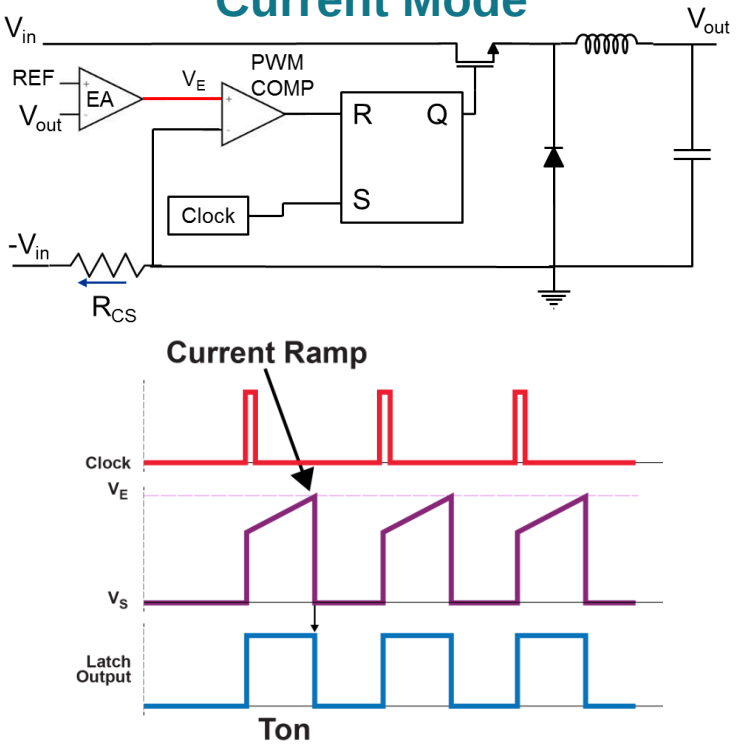
# 功率元器件


# 控制方式

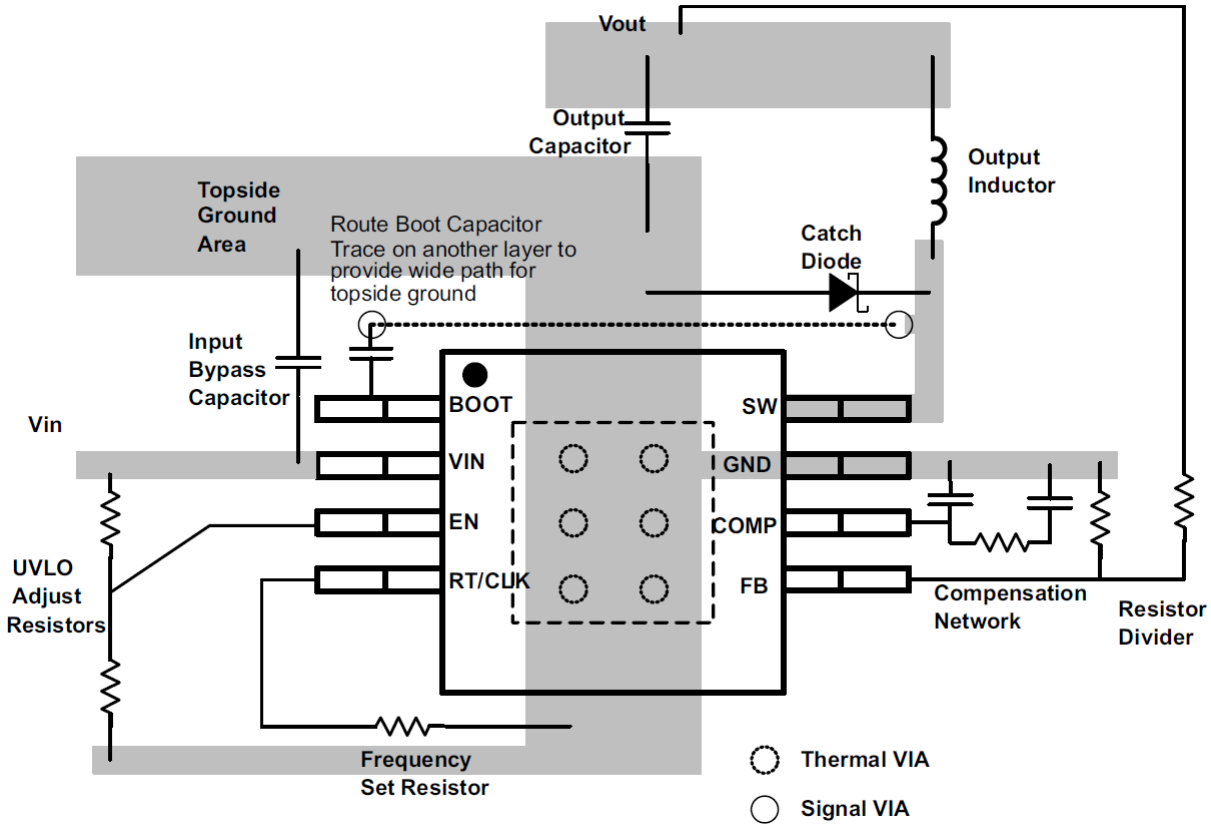
## Voltage Mode




## Current Mode



# 布局布线

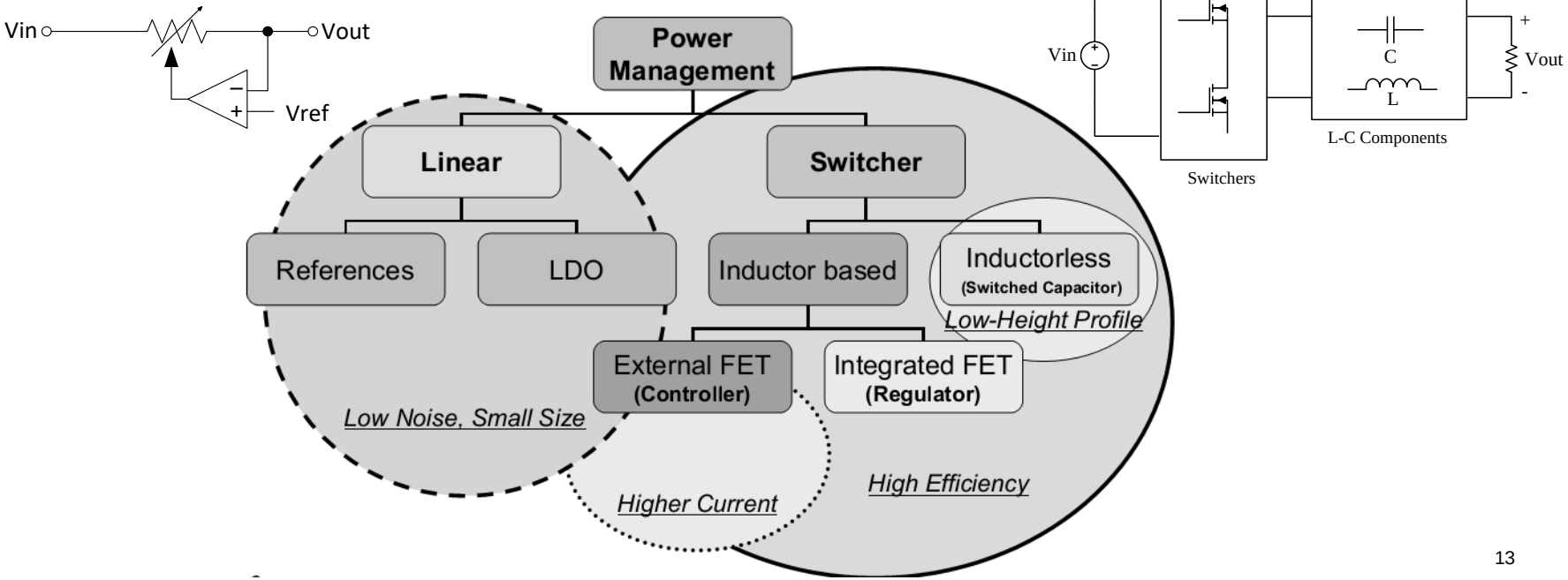

Vout
Output
Capacitor
Output
Inductor
Topside
Ground
Area
Route Boot Capacitor
Trace on another layer to
provide wide path for
topside ground
Catch
Diode
Input
Bypass
Capacitor
Vin
BOOT
SW
VIN
GND
EN
COMP
RT/CLK
FB
UVLO
Adjust
Resistors
Compensation
Network
Resistor
Divider
Frequency
Set Resistor
Thermal VIA
Signal VIA

# 电源转换器的分类

- DC-DC 转换
  - 线性稳压器(Linear Regulator)
  - 降压转换器(Buck Converter)
  - 升压转换器(Boost Converter)
  - 升/降压转换器(Buck/Boost Converter)
- AC-DC 转换
  - 反激变换器(Flyback Converter)
  - 桥式变换器(Half-bridge/Full-bridge Converter)
- DC -AC 转换
  - 逆变器(Inverter)
- AC-AC 转换
  - 变压器(Transformers)

# DC-DC 电源转换器类型

- 线性电源
  - 能量的传输是连续的
  - 通流器件（负责调节能量传输的主要器件）工作在线性状态
- 开关电源
  - 能量的传输是非连续的
  - 通流器件工作在开关状态



# 电源的性能指标

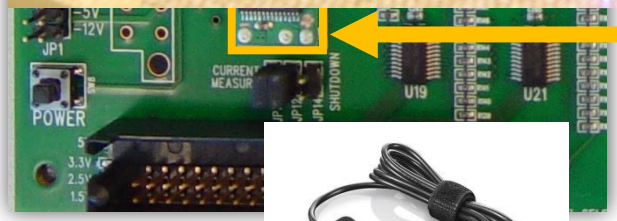
- 输入/输出指标：输出电压、输出电流、输入电压范围
- 效率
- 稳态性能：稳压范围，精度
- 暂态响应：响应速度，稳定性
- 体积，成本，……

# 线性电源 VS 开关电源

| | 线性电源 | 开关电源 |
|---|---|---|
| 效率 | 低 | 高 |
| 纹波 | 很小 | 大 |
| EMI 辐射 | 小 | 大 |
| 外围元件 | 少 | 多 |
| 体积 | 大 | 小 |
| 成本 | 较低 | 较高 |

72W

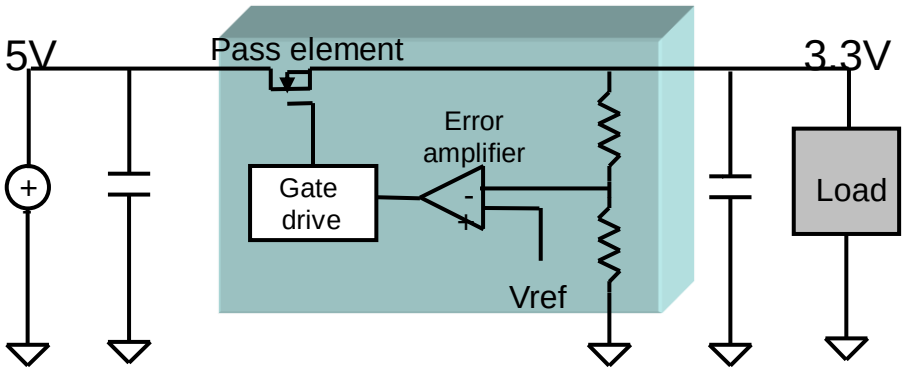

D +
孔




6W 开关电源


65W

# Linear Regulator




## Applications

- Radio frequency or precise analog (measuring very small voltages) circuits that require extremely low ripple & noise
- Applications where $V_{IN} – V_{OUT}$ is very small.
- Applications that require a precisely regulated.
- FPGA or Multi-Core processors that require fast transient response due to fast changes in the load.

## Advantages

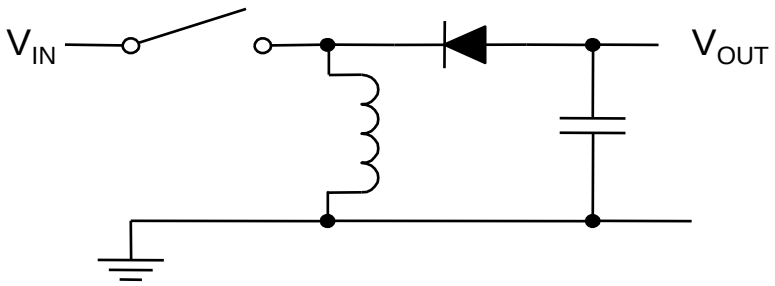
- Low O/P ripple & noise
- Fast transient response at $V_{OUT}$ on large changes of the Load
- Low cost (for low power, at least)
- Few external components make the linear regulator easy to design
- Since linear regulators don't switch current into an inductor there is no EMI to worry about
- Easy to implement short circuit protection

## Disadvantages

- Low efficiency at $V_{IN}>>V_{OUT}$ which requires a larger supply power source
- Power generated from the regulator $(V_{IN} – V_{OUT}) * I_{OUT}$ is dissipated through the Regulator typically requiring a heat-sink
- $V_{OUT}$ will always be less than $V_{IN}$

# Inductive Switcher

## Buck-Boost




## Applications

- Applications where high efficiency ($Power_{IN}$ – $Power_{OUT}$ is very small)
- Applications with extremely high ambient temperatures such as Industrial or Automotive
- Applications where $V_{IN}$ is much larger than $V_{OUT}$
- Applications where the power supply has space constraints (small area)
- Applications requiring High output power

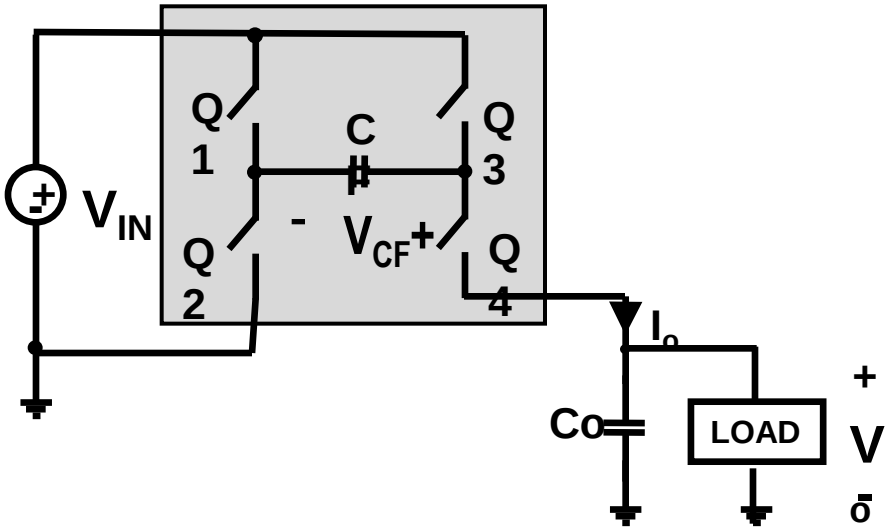
## Advantages

- Since regulation is done by dumping energy into and out of an inductor versus burning power through the regulator
  - Higher efficiencies can be obtained
  - Lower power dissipates through the regulator requiring a smaller heat sink.
  - Topologies of the switching power supply allow $V_{OUT}$>=<$V_{IN}$
  - High Power Density (Watt/cm2)
  - Allows wider input voltage range
- Isolation possible (with transformer)
- Multiple O/Ps possible (with transformer)

## Disadvantages

- Switching current into and out of an inductor:
  - Generates Electromagnetic Interference (EMI)
  - Causes the output to respond slower to transients in load
  - Produces higher output ripple & noise
- More external components and design variables make switching power supplies difficult to design

# Charge Pump




## Applications

- Applications requiring a low output current
- Applications with moderate input to output voltage difference
- Applications that have space constraints

## Advantages

- Moderate Efficiency
- Since charge pumps switch voltages across capacitors in and out of the output:
  - No inductor is needed
  - $V_{OUT}>=<V_{IN}$
- Fewer components make the charge pump easier to design

## Disadvantages

- Switching of the capacitor in and out of the circuit generates EMI
- Since the output of the charge pump is dependent on the charging and discharging of a capacitor, it has limited current capability

# Converter Comparison

The choice of converter type depends on the power design priorities.

| | Linear Regulator | Switching Regulator | |
|---|---|---|---|
| | | Inductive | Charge Pump |
| Efficiency | 20-60% | 90-95% | 75-90% |
| Ripple | Very low | Low | Moderate |
| EMI Noise | Very low | Moderate | Low |
| PCB Area | Very small | Largest | Medium |
| Cost | Lowest | Highest | Medium |

# 思考题：电压源 vs. 电流源

1. 为什么家里的墙插都是电压源？

2. 用5V 2A的充电器给5V 1A的手机充电，会不会充坏手机？