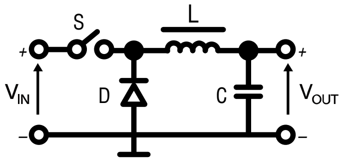
Reference Guide to Switched DC/DC Conversion

DC/DC converters convert one DC voltage level to another. Switched-mode DC/DC converters use a FET switch and a storage element to first store energy, then release it to achieve the desired output voltage. The common arrangements of switches and storage elements, or topologies, are shown below.

Non-isolated, non-inverting topologies, output voltage at same polarity as input.



Step-down or Buck converter

$0 \leq V_{OUT} \leq V_{IN}$ $V_{OUT} = d*V_{IN}$

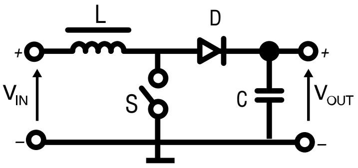
Simple step down circuit with single switch (FET) and storage element (Inductor). The output capacitor C is needed to remove significant output ripple. Synchronous version replaces D with second FET.

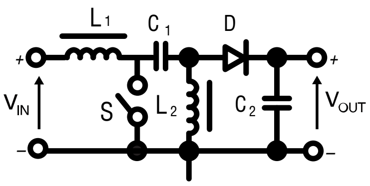
Ref: https://www.mouser.com/applications/power-supply-topology-buck/

Step-up or Boost converter

$V_{OUT} \geq V_{IN}$ $V_{OUT} = V_{IN}/(1\text{-}d)$

Simple step up circuit with single switch and storage element. The output capacitor C is needed to remove significant output ripple. Synchronous version replaces D with second FET





SEPIC (Single-ended primary-inductor converter)

$V_{OUT} = d*V_{IN}/(1\text{-}d)$

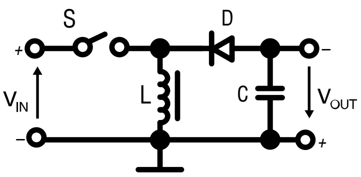
Can step-up or step down as required to maintain a fixed output voltage. Vout is fixed by the switching duty cycle. Can use coupled inductors to save PCB space.

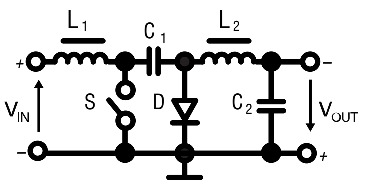
Non-isolated, inverting topologies – output voltage polarity reversed vs input

Inverting (buck-boost)

$V_{OUT} = \text{-}d*V_{IN}/(1\text{-}d)$

Simple single switch and inductor topology. Maintains a stable but inverted output voltage, with varying input voltage. The output capacitor C is needed to remove significant output ripple.





Čuk (Pronounced 'Chook')

$V_{OUT} = \text{-}d*V_{IN}/(1\text{-}d)$

A buck-dboost topology with Inverted output voltage and very low ripple current. Can use coupled inductors to save PCB space. Ideal for applications needing stable smooth output from varying input source.

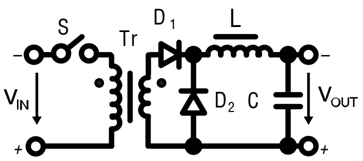
Note: The output current is continuous and ripple-free

Isolated Topologies

Forward converter

$V_{OUT} = V_{IN}*d*(Ns/Np)$

Can provide Vout higher or lower than Vin and electrical isolation via a transformer. Higher output power (generally up to 200W) along with higher energy efficiency than Flyback topology.

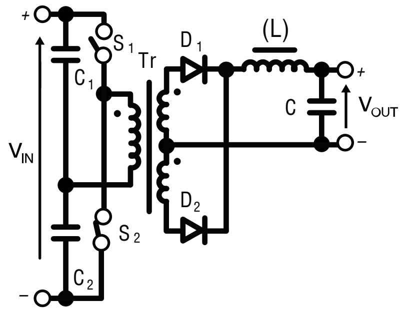


Ref: https://www.mouser.com/applications/power-supply-topology-forward/

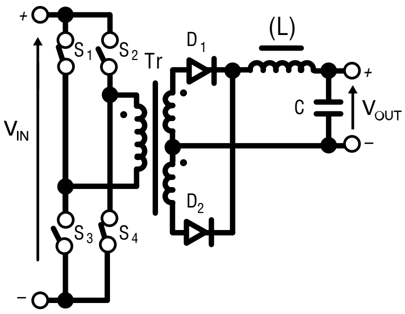
Push-pull (Half Bridge)

$V_{OUT} = 2*V_{IN}*d*(Ns/Np)$

Can provide Vout higher or lower than Vin, gives electrical isolation via a transformer, output power up to 500W along with higher energy efficiency than Flyback topology.



https://www.mouser.com/applications/power-supply-topology-half/



Full bridge

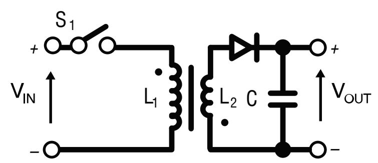
$V_{OUT} = 2*V_{IN}*d*(Ns/Np)$

A robust buck converter topology, similar to half-bridge, can provide Vout higher or lower than Vin. Often used in higher power applications such as EV charging and renewable energy systems.

Flyback

$V_{OUT} = V_{IN}/(1\text{-}d)$

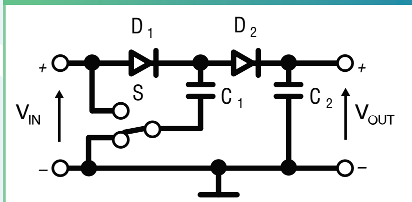
Simple single transistor topology, typically used for offline, low output power (<100W) applications such as cellphone chargers. Fixed Vout determined by transformer.



Ref: https://www.mouser.com/applications/power-supply-topology-flyback/

Charge Pumps

Charge Pumps DC/DC converters that use capacitors as the storage element are known as Charge Pumps. Suitable for low-power applications, they are typically used to boost or invert Input voltage. They may be cascaded in order to obtain even-numbered multiples or fractions.



Voltage doubling charge pump

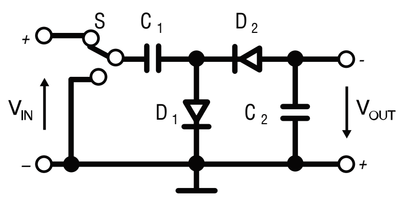
$V_{out} = 2*V_{in} - 2*V_D$

(Where V_d is the voltage drop across the diodes)

Inverting charge pump

$V_{OUT} = \text{-}V_{IN} + 2*V_D$

(Where V_d is the voltage drop across the diodes)



Disclaimer: These diagrams are for reference only and not intended to be implemented as complete working designs. The simplified equations shown are for ideal converters and do not account for losses that may occur within components.

Legend

Circuits

- S = Switch, usually a FET or IGBT
- D = Diode
- C = Capacitor
- L = Inductor
- TR = Transformer
- V_{IN} = Input voltage
- V_{OUT} = Output Voltage

Equations

- d = PWM Duty Cycle
- Np = Number of turns, primary side
- Ns = Number of turns, secondary side

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