**Koç University**
**College of Engineering**
**Department of Electrical & Electronics Engineering**

**ELEC 390 - Independent Study**
**Meeting – 3: Power Electronics**
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## *1: Introduction*

The term power electronics refer to the usage of electronic circuits to achive manipulation of electrical power in terms of magnitude, direction and type. These circuits allows engineers to create electronic devices that operate on variety of voltage levels from a single unified electrical source such as the mains power grid. While many types and methods for creating power electronics exists, they can be classified under one of 4 main groups which are:

- AC to DC Rectifiers
- DC to AC Inverters
- DC to DC Converters
- AC to AC Converters

## *2: Power Electronics*

### *2.1: Buck Converter*

Buck converters refer to the circuits that exhibit the behaviour of switch-mode, step-down, DC to DC power converters. Meaning that the circuit switches between its on and off states using either diodes or more commonly transistors at high frequencies to achieve a pulse-width-modulated square wave of DC voltage that has the magnitude of its input power, when averaged, this square wave equals the desired output power of the converter. The averaging of the output square wave is often done by creating an inductor-capacitor or LC filter on the output side of the filter that resists, or as its namesake “bucks”, to the change of the voltage magnitude to create a linear output. Buck converters are often favored for their high efficiency rates at low voltage applications such as consumer electronics where various sub-circuits at common voltage levels such as 3.3V, 5V, 9V are all powered by a main 12V power line.

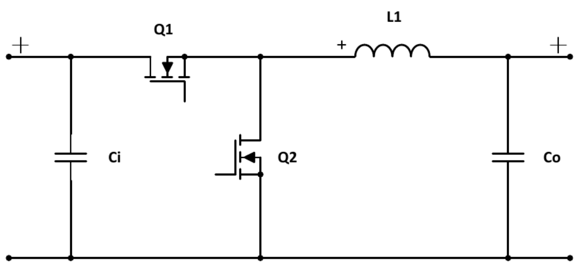


Figure 3.0.2. **Schematic of a synchronous Buck converter**

### *2.2: Boost Converter*

Boost converters are the step-up version of the buck converter where a transistor is used to switch the polarity of an inductor relative to a capacitor to increase the output voltage, at its on state the inductor is charged by the power input to store power as induced magnetic field, when the inductor is charged the circuit switched to the off state where the polarity of the inductor, this allows the inductor to supply power to the output side of the converter in pulses, a capacitor placed at the output side of the converter not only smooths out the pulses from the inductor it also continues supplying power to the output while the converter is at off state, which results in steady output at desired step-up voltage.

As the output voltage is determined by the circuit boost converters can accept wide range of input voltages to function, this property makes boost converters a common sight in battery powered devices where not only devices can be powered by higher voltages than a standard battery can provide, they also enable more energy to be extracted by the battery as its voltage decreases during usage.

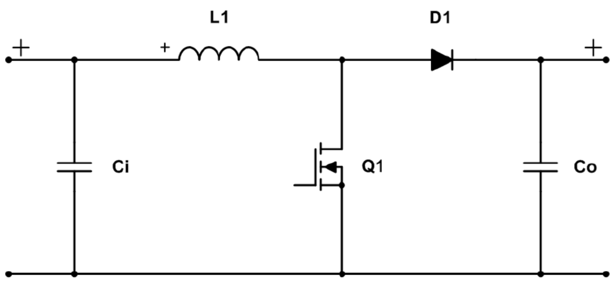


Figure 4.0.1. **Schematic of a Boost converter**

### *2.3: Buck-Boost Converter*

The buck-boost converters combine both power topologies in a single cascaded circuit to achieve a virtually limitless range of power output both greater and lesser than the input voltage. The output voltage is controlled by the pulse width of the input voltage. However, due to its cascading nature, the polarity of the output is reversed relative to the input.

The finely controllable behaviour of this topology makes it a common sight in self-regulating power supplies along with power amplifiers and in consumer electronics that require multiple voltages at different states.

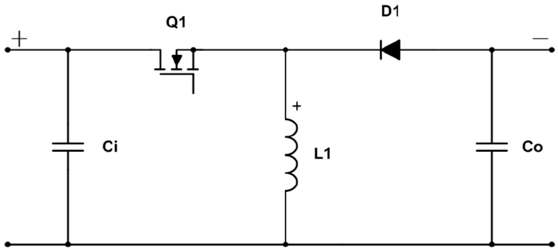


Figure 5.0.1. **Schematic of an Inverting Buck-Boost converter**

## *2.4: SEPICs*

SEPICs or Single-Ended Primary-Ended Converters are a variant of Buck-Boost Converters where a second boost converter is cascaded in front of an Buck-Boost Converter. This adds the advantages of non-inverted polarity of output along with coupling of input and output sides of the circuit allowing safer reactions to short circuits.

Due to their similarity SEPICs are used in similar places to buck-boost converters especially so when short-circuit protection is needed. However, due to its capacitor layout SEPICs not only require high performance capacitors they are also difficult to control due to the high-order nature of the layout, making SEPICs only viable for slow varying applications.

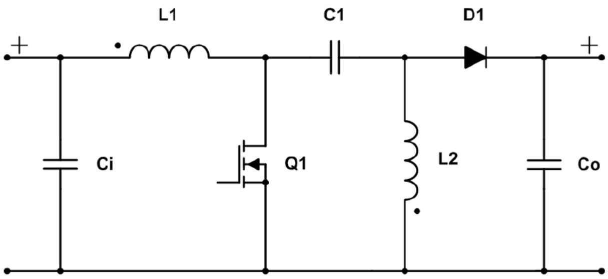


Figure 6.0.1. **Schematic of a SEPIC converter**

## *2.5: Ćuk Converter*

Ćuk converter at is base is an inverted SEPIC, this inversion is caused by the addition of LC filters at both the input and the output sides of the converter. However, this addition allows the inductors to carry current continously so that the current is not pulsed at either ends of the converter resulting in minimal amounts of ripple, this feature makes Ćuk converters a common sight in ripple sensitive applications such as measurement devices.

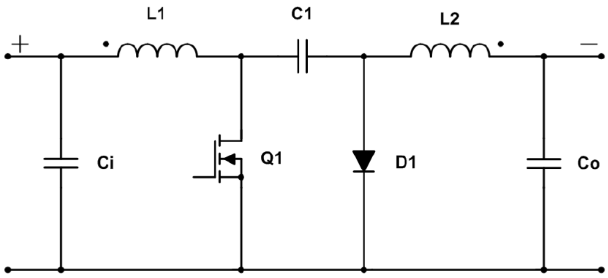


Figure 7.0.1. **Schematic of a Cuk converter**

## *2.5: Zeta Converter*

Zeta converters are also closely related to the SEPICs but with an added LC filter at the output end of the converter, this allows Zeta converters to have the best responsiveness to dynamic loads compared to SEPICs and Ćuk converters. However, Zeta converters experience high input ripple.

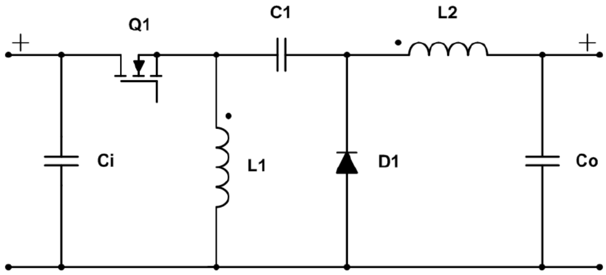


Figure 8.0.1. **Schematic of a Zeta converter**

## *2.6: Flyback Converter & Transformer*

The Flyback topology is very similart to the SEPIC, Zeta and Ćuk topologies. However, unlike those topologies the flyback features a galvanically seperated input and output sides, this is achieved by replacing the inductor of the aforementioned topologies with an dual inductor transformer, this allows flyback topology to be used in both DC to DC and AC to DC applications. Storage of energy in the transformer also allows flyback topologies to be used in multi-output circuitry.

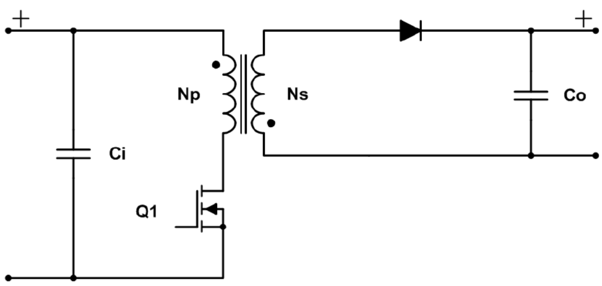


Figure 9.0.1. **Schematic of a Flyback converter**

## 2.7: Forward Converter

A forward converter is a DC/DC converter topology that uses a transformer to increase or decrease the output voltage to galvanically isolate the load. Multiple output windings can be used to provide both high and low voltage outputs at the same time.

Although on the surface they look like flyback converters, they operate fundamentally differently and are generally more energy efficient. A flyback converter stores energy in the magnetic field of the coil air gap while the transistor of the converter is conducting. When the switch is turned off, the stored magnetic field collapses and the energy is transferred as a current to the output of the flyback converter.

A flyback converter can be thought of as two inductors sharing a common core with opposite polarity windings. In contrast, a forward converterstores no energy during the conduction time of the switching elements. A transformer cannot store a significant amount of energy. Contrast with inductors. Instead, energy is conducted directly to the output of the forward converter by the action of the transformer during the switching conduction phase.

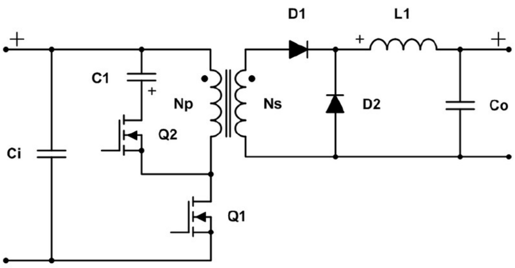


Figure 11.0.1. **Schematic of an Active Clamp Forward converter**

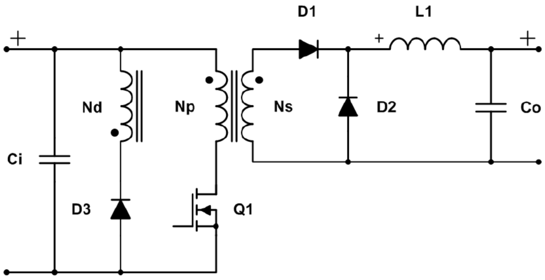


Figure 12.0.1. **Schematic of a Single Switch Forward converter**

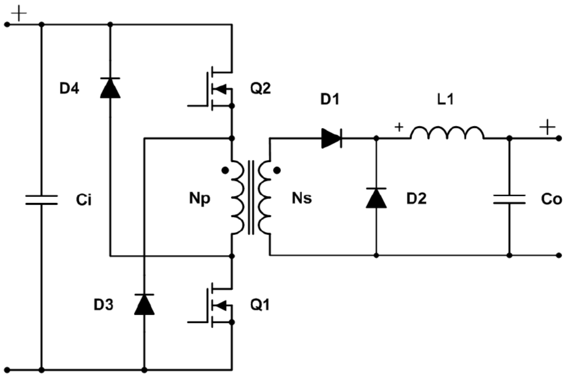


Figure 13.0.1. **Schematic of a Two Switch Forward converter**

## 2.8: Push-Pull Converter

Push-Pull converters use transformers to perform DC to DC conversion much like forward or flyback converters. However push-pull topology features two push-pull circuits oriented symmetrically at the input side of the converter. This allows push-pull converters to achive continous and steady current draw from the input side, resulting in minimal noise and high efficiency in high power applications.

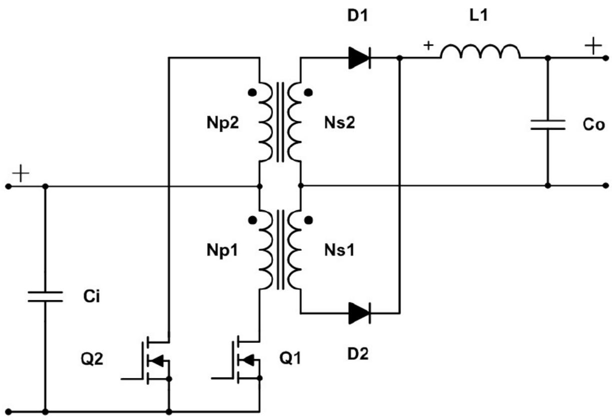


Figure 14.0.1. **Schematic of a Push-Pull converter**