MEFTRONICS

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APPLICATION NOTE

Catalog of Power Electronic Topologies: A Menagerie

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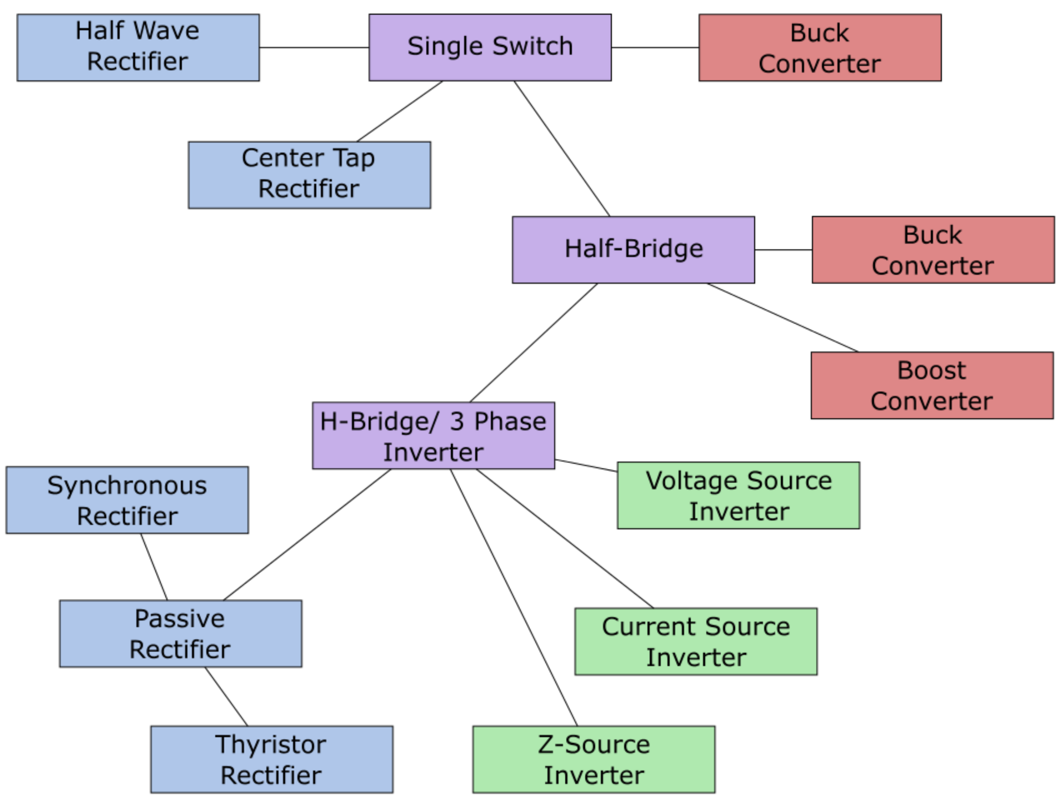
There are a dizzying number of topologies and special cases in power electronics that perform one particular power conversion function or another, so in the effort to help navigate the maze that we engineers have erected over the last century, below is a list of common topologies and a family tree for the most commonly encountered topologies. There are undoubtedly more than what is shown here, particularly if one wants to include those that exist only to publish a paper, but in terms of practicality and ubiquity, this captures a great deal. That said, this is an ongoing work and over time surely more will be added. Most useful circuits are derived from the half-bridge, either being a special case of it by replacing an active switch with a diode, as with a passive rectifier, or by utilizing multiple half-bridges, as with the single-phase and three-phase inverters. First, let us start with a family tree of all the topologies derived from the half-bridge, including its primordial predecessor, the single switch.



And here is a more general table of topologies with some useful attributes.

	Converter Type	Function and Power Flow	Polyphase Capable	Voltage Range
Half Bridge Derivatives	Buck Converter	DC<-->DC	No*	Vo < Vi
	Boost Converter	DC<-->DC	No*	Vo > Vi
	Passive Rectifier	AC-->DC	Yes	VAC > VDC
	Synchronous Rectifier	AC<-->DC	Yes	VAC > VDC
	GTO Rectifier	AC-->DC	Yes	VAC > VDC
	SCR Rectifier	AC-->DC	Yes	VAC > VDC
	Voltage Source Inverter	DC<-->AC	Yes	VAC < VDC/2
	Current Source Inverter	DC<-->AC	Yes	VAC > VDC/2
	Z-Source Inverter	DC<-->AC	Yes	0-->∞
More Exotic Topologies	Half-Wave Rectifier	AC-->DC	No	VDC < VAC
	Center-Tap Rectifier	AC-->DC	No	VDC < VAC
	Voltage Multiplier	AC-->DC	No	VDC > VAC
	Fly-Back Converter	DC-->DC	No	0-->∞
	Buck-Boost Converter	DC-->DC	No	0-->∞
	Cuk Converter	DC-->DC	No	0-->∞
	Cycloconverter	AC<-->AC	Yes	

*Can be "interleaved"

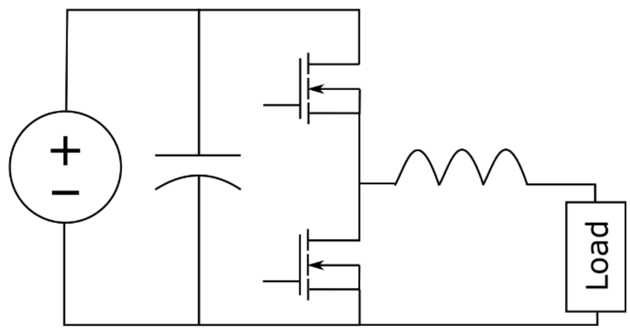
There are also modified versions of many of these topologies known as "multi-level" which replaces a single switch in a phase-leg with multiple stacked switches, reducing the voltage strain on individual switches and allowing for more output voltage levels than the typical binary output. These are not something typically encountered in the wild, but worth knowing about.

In addition to these core topologies, certain combinations are common. Given that an engineer often has the AC line as a supply, a rectifier of some kind often provides the DC source for an inverter which then gives broad flexibility in the output. Additionally, a passive rectifier's power factor and line harmonics can be improved with the addition of a boost converter stage immediately after the diode bridge, "shaping" the current and operating the diode bridge in a continuous mode. Alternatively, a configuration known as "back-to-back inverters" can be constructed where the DC buses of two inverters are linked, thus allowing power to be transferred in either direction between the line and load with low distortion and high power factor.

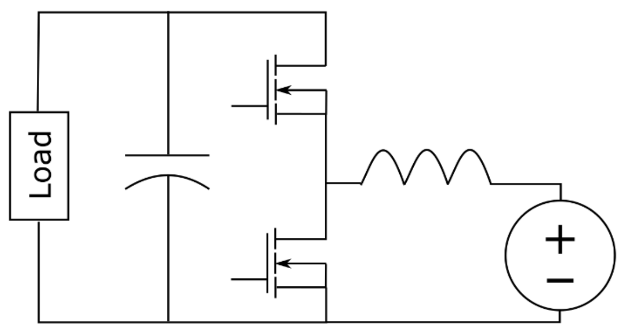
Descriptions

Each of the converters in the table have motivations for use, advantages, disadvantages, and limits to their usefulness. We shall try to briefly cover each of these below accompanied with schematics of the topologies in their most general form.

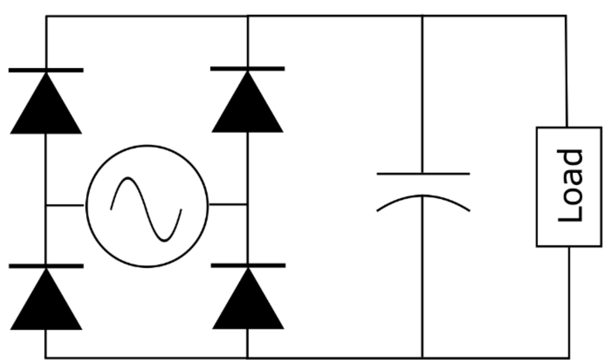
Buck Converter: Straightforward topology that efficiently reduces the voltage of a source proportional to duty ratio. Output is unipolar. Can be built with one active switch and one passive switch, or two active switches. If two active switches are used, power flow can be bidirectional. The load and source share a reference.



Boost Converter: Variation on the buck converter where the source and load are swapped. Output has an inverse relationship to the duty ratio and is always greater than the source. Output is unipolar. Can be built with one active switch and one passive switch, or two active switches. If two active switches are used, power flow can be bidirectional. The load and source share a reference.



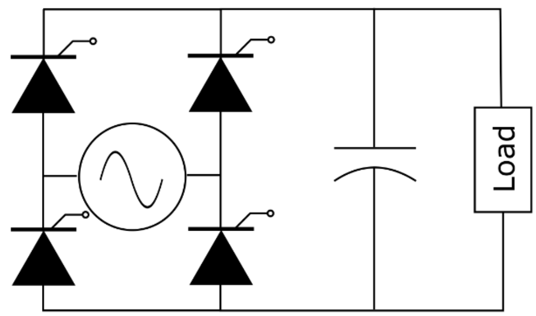
Passive Bridge Rectifier: Self-commutated system (diode switches) to convert an AC source into a DC source. Extremely simple in principle so it is easy to implement. The typical single-phase application operates in discontinuous current mode producing high peak currents and line harmonics. It also requires a large capacitor bank to mitigate voltage ripple resulting from the discontinuous current. Usually less than 1kW. The three-phase variant avoids much of the ripple and harmonics problem,



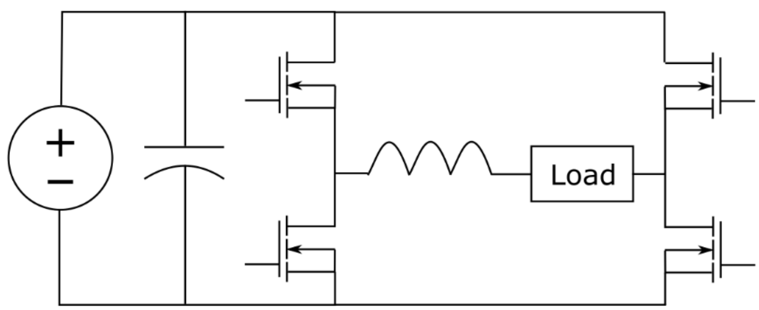
making it useful in larger systems. Maximum output is the peak of the AC waveform; average output decreases with load while ripple increases. Output is “floating” and so cannot be referenced to either line of the AC supply.

Synchronous Rectifier: Replaces passive switches with MOSFETs to achieve higher efficiency in cases where the forward drop of a diode is greater than the voltage drop due to on-resistance.

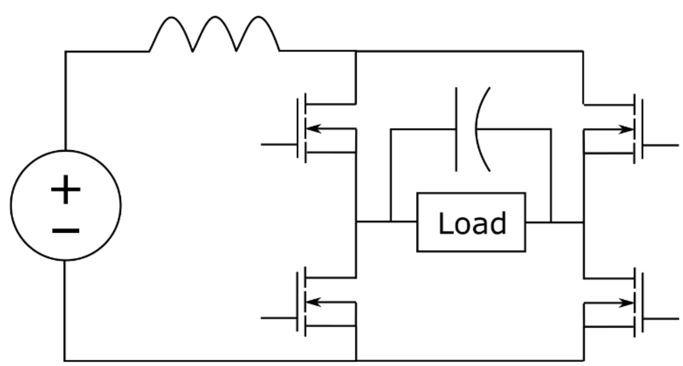
SCR/GTO Rectifier: A modified diode rectifier where the diode's turn-on time can be delayed, thereby reducing the average voltage produced at the DC output. The GTO thyristor allows for both turn-on and turn-off to be varied, utilizing waveform symmetry and outperforming its SCR cousin in harmonic distortion and power factor. Polyphase capable.



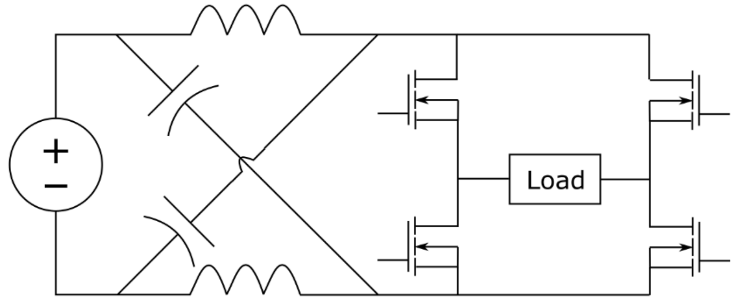
Voltage Source Inverter: Perhaps the most versatile power electronics circuit, the most common manifestations are the H-bridge and three-phase inverter. Can be used to convert a DC source to a "bipolar" DC output, or from a different perspective, convert DC to AC, hence its name. Power can flow in both directions so that the VSI can also perform both passive and active rectification, or with motors, braking. Each phase-leg can produce a maximum of VDC/2 as an output.



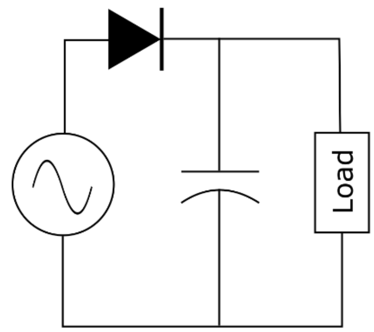
Current Source Inverter: An older topology used to convert a DC source to AC, where the DC bus is an approximate current source. Can be implemented with controlled diodes rather than bidirectional switches. Needs a load and suffers from control stability problems. Each phase-leg must produce a minimum voltage of VDC/2.



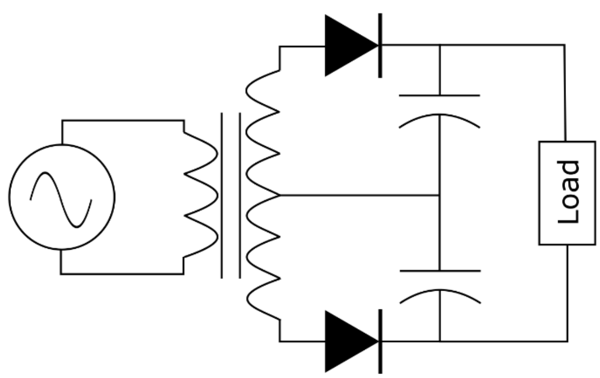
Z-Source Inverter: A relatively new entrant to power electronics, the Z-source inverter attempts to overcome the output limitations imposed on the voltage and current source inverters through the use of a capacitor-inductor network in the DC bus, hence its name. The output voltage can in principle be less than or greater than the DC bus voltage.



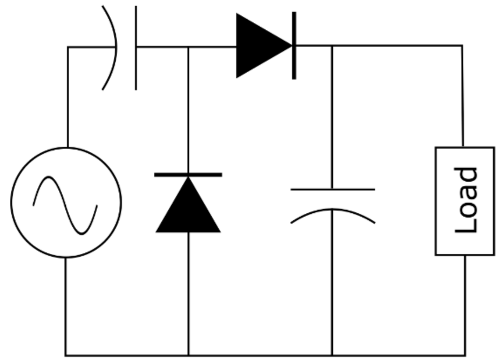
Half-Wave Rectifier: Crude, but arguably the simplest power electronics circuit. A single diode is used to cut off half of the line supply waveform, thus creating a DC source. Offensively low power factor and high harmonic content. Appears only in low power applications such as a digital circuit supply. Can be referenced to the AC supply.



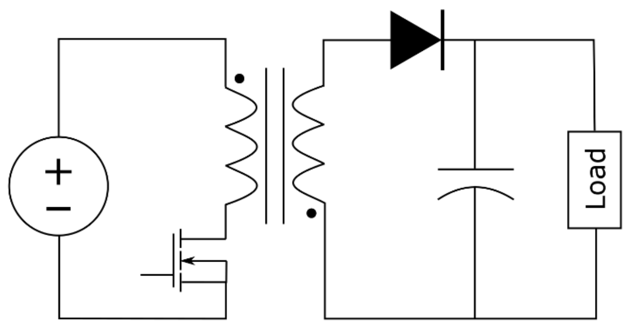
Center-Tap Rectifier: Variation on the Half-Wave Rectifier, exploiting a center-tap transformer to use both sides of the supply waveform. Common in low-power applications requiring positive and negative supplies. Galvanically isolated and output can be referenced to any node.



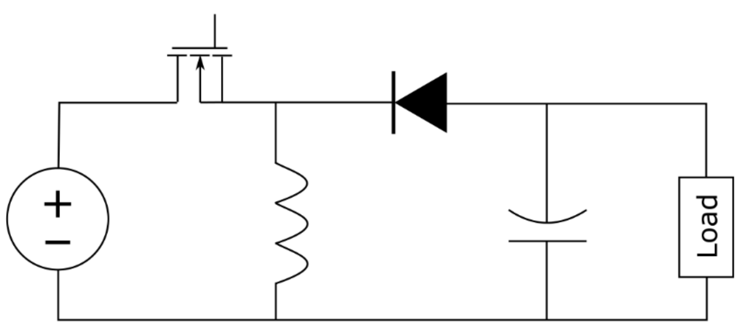
Voltage Multiplier: An arrangement of half-wave rectifiers used to convert an AC source to a higher voltage DC source, where the maximum output is the number of stages multiplied by the input peak.



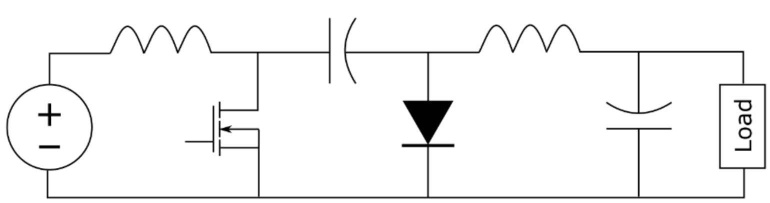
Fly-Back Converter: A galvanically isolated DC-DC converter using only one active switch. Its simplicity and isolation make it desirable in cost-sensitive applications, but it requires robust part ratings and lacks efficiency due to high peak currents, limiting it to low voltage and low power applications.



Buck-Boost Converter: DC-DC converter enabling the output voltage magnitude to be less than or greater than the input voltage. Built using one active switch, one passive switch, and an inductor and capacitor. The output is negative and source current discontinuous. Typically limited to low power applications.



Cuk Converter: Alternative to the buck-boost converter enabling the output voltage magnitude to be less than or greater than the input voltage. Built using one active switch, one passive switch, but two inductors and two



capacitors. The input current is continuous, unlike the vanilla buck-boost converter, but its output is also negative and it is typically limited to low power applications.

Cycloconverter: Category of topologies used to convert an AC source directly into another AC source, thereby eliminating the AC-to-DC-to-AC conversion that is often used to perform the same task. Requires bi-directionally controlled (four quadrant) switches.

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