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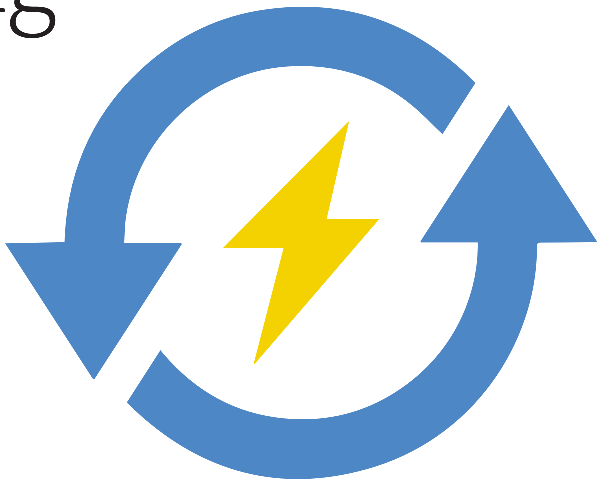
# Understanding **Power Conversion** and the Popular Topologies



By Mark Patrick (Mouser Electronics)

For many pieces of electronic equipment, whether it's a complex infotainment system or a simple battery-power IIoT sensor, some form of power conversion is required. However, several types of switching mode topologies are available to choose from for DC/DC and AC/DC power conversion. Selecting the type largely depends on the required voltage levels and the amount of power needed. This article covers the basic concepts of power conversion, including isolation and voltage regulation. It also investigates some of the most popular topologies available for use in discrete and module-based designs.

Power conversion is taking place in most of the technology we use today. For instance, your smartphone is likely to run off a Li-ion battery with a nominal output voltage of 3.7 V. However, the devices inside are likely to operate at higher or lower voltages levels. The most popular ones are 1.8 V, 3.3 V and 5.0 V. Power conversion techniques are employed to convert the battery's nominal output voltage into the necessary voltage level. Even the modest USB power bank — used in their millions to re-charge smartphones, earbuds, and other portable devices while on the move — has power conversion going on inside. Again, it uses a Li-ion pouch cell that provides a nominal output of 3.7 V; power conversion techniques raise the voltage supply to the required 5.0 V.

For larger electronic goods like a smart speaker, TV, or other domestic appliances, there is a need to convert the mains voltage down to a suitable voltage level. Here, AC/DC power adapters and DC/DC conversion methods are used. The linear method was used in the past, but it required large components and was relatively inefficient. Although this method is still in use for a few DC/DC power conversion tasks, most of today's applications now employ a switching regulator.

Switching power conversion techniques store energy in an inductor or capacitor. This stored energy enables the switching regulator to provide an output voltage above or below the nominal input voltage, see **Figure 1**.

To drive the switch within the converter, a PWM signal is applied to a semiconductor device. The duty cycle, which is the mark to space ratio, and the frequency of the PWM signal, directly impact the efficiency, load regulation, and output voltage. In essence, the PWM and switching device form a charge pump circuit to store energy in the inductor or capacitor during the 'on' cycle. During the 'off' period, this stored energy is released and rectified. Output voltage regulation is applied to the PWM signal. To achieve input to output isolation, a transformer is used as the inductive element with a capacitor.

Several DC/DC converter topologies have become popular, over the years, with the main ones being:

- step-down (buck)
- step-up (boost)
- isolated flyback

This article also highlights three other switching topologies in regular use — the push-pull, half-bridge, and full-bridge.

## Popular Power Conversion Topologies

**Step-down (buck)**

As the name suggests, a step-down buck converter lowers the output voltage. For example, if the nominal input is 5 Vdc, it would convert the voltage down to 3.3 Vdc.

If we look at **Figure 2**, SW1 is usually a transistor driven with a PWM signal. SW2 represents a diode. When SW1 is closed, or switched 'on', current flows through and energy is stored in the inductor. Conversely, when SW1 is 'off', energy is released with current flowing through the diode and providing the required output voltage. Remember, the step-down buck converter's output voltage depends on the duty cycle of the PWM signal, see **Figure 3**.

In a synchronous buck topology, the diode is replaced by a FET and is fed from an out of phase signal. As FETs lower the forward resistance, they are widely adopted to reduce losses, thereby increasing efficiency.

**Step-up (boost)**

With boost converters, the output voltage is higher than the input voltage. The amount by which the voltage level rises depends on various factors. For most implementations, the maximum boost is by a factor of five, but it is more common to employ a 3x boost to optimize output voltage regulation, **Figure 4**.

Compared to the buck converter topology illustrated in Figure 2, S1 (switching transistor), L1 (inductor), and D1 (diode) are placed in slightly different positions. When S1 is 'on', the energy is stored in L1. When switched 'off', the energy is added to the input voltage across the input capacitor and added to the output capacitor.

As the buck and boost converter topologies described above are not isolated, any input voltage can appear at the output. For instance, if the DC/DC converter is powered from an AC power line, a failure could cause this voltage to appear at the output, which may lead to potentially fatal consequences depending on the end application. For medical and healthcare applications, galvanic isolation between the input and output eliminates this risk. Where the ground connection

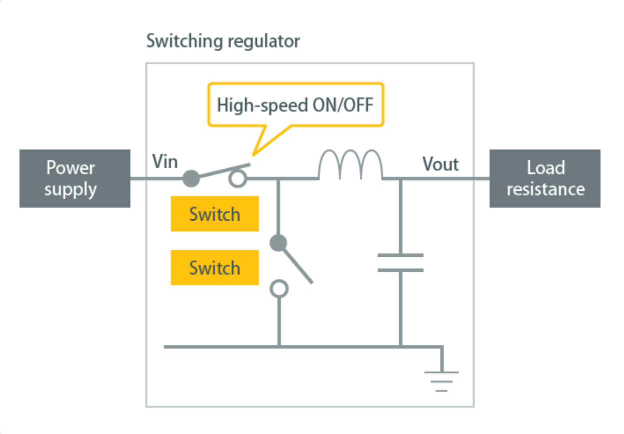



*Figure 1: Functional block diagram of a typical DC/DC converter (Source: Murata)*

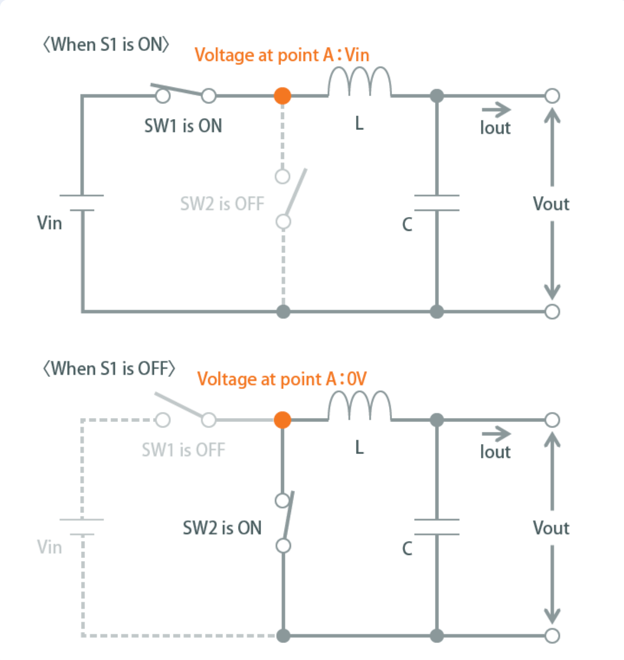



*Figure 2: Functional block diagram of an asynchronous step-down buck converter (Source: Murata)*

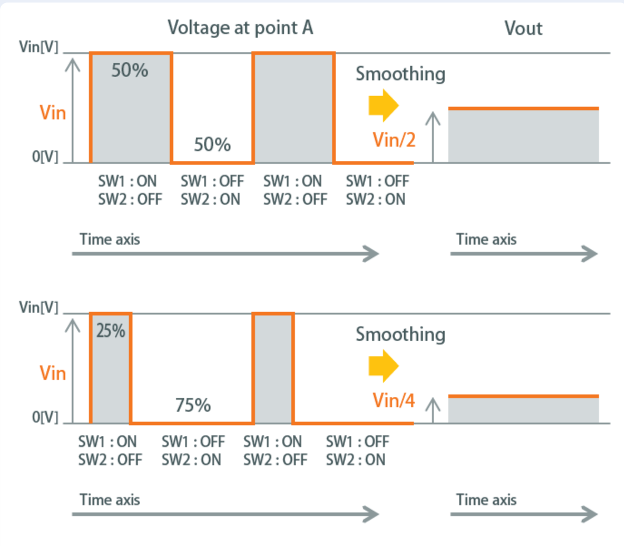



*Figure 3: The PWM signal's duty cycle affects the output voltage of the buck controller. (Source: Murata)*

is not common, one way of achieving galvanic isolation is to use a transformer.

### Isolated flyback

In an isolated flyback topology, the transformer has two functions – storing energy and providing isolation. Perhaps the simplest of all DC/DC power conversion topologies, it requires relatively few components, see **Figure 5**.

Isolated flyback converter applications are typically for power applications below 50 W, and those that can withstand relatively high ripple currents. As the transformer creates primary to secondary losses, most flyback converters rarely achieve an efficiency above 90 %. Nevertheless, a broader range of potential output voltages is available by increasing or reducing the transformer's turns ratio. Moreover, adding more secondary windings can deliver multiple output voltages.

### Other common topologies

Push-pull, half-bridge and full-bridge converters are also isolated switching topologies that are in regular use. Suited to higher power applications, the push-pull topology uses two switching devices, which share the current. This arrangement uses split centre-tapped primary and secondary windings and therefore requires a more expensive transformer. Like the push-pull, the half-bridge and full-bridge topologies only require a single primary winding. The half-bridge uses two switching devices, while the full-bridge uses four (see **Figure 6**).

## Voltage Regulation Options

Aside from choosing a specific topology for your DC/DC converter design, another important consideration is how to regulate the output voltage. It is essential for processors with varying compute workloads to ensure tight regulation across all load conditions. Here, feedback of the output voltage to the PWM switching function to change the duty cycle must be fast and precise. Most DC/DC converter control ICs now include this function and, therefore, for non-isolated topologies, this task is achieved easily.

However, maintaining input to output isolation requires extra components, such as a transformer or an optocoupler, which adds to the BOM cost and PCB space requirements. Using more components also adds complexity to the design which may impact the end product's overall reliability.

A much simpler way of regulating the voltage is to use primary-side sensing. Here, the controller IC senses the secondary output via the transformer during the flyback 'off' phase. The Maxim MAX17687, 'no opto' flyback controller IC is a good example (see **Figure 7**). It has two on-chip MOSFETs that can drive a primary peak current of 3.2 A.

By using this sensing method, output voltage regulation is to within ±1.2 %. The PWM frequency of the IC is also programmable (100 kHz to 500 kHz) and can typically achieve a conversion efficiency of over 90%.

An attractive alternative to using a discrete DC/DC converter is to use a module. Modules ease the overall design effort, thereby saving engineering time. Choosing a pre-certified module for EMC/EMI compliance and conformance to the required safety standards also simplifies product approvals.

The Murata UWS-Q12 open-frame, isolated flyback DC/DC converter module is a good example (**Figure 8**). Modules within the series cover the popular nominal single output voltages from 3.3 V to 24 V, delivering up to 54 W from a 9 V to 36 V input with an efficiency of up to 91 %. It also comes with a broad set of protection features, including input under-voltage and over-temperature circuity, and is certified to UL/EN60950-1 safety approvals.

If you need to replace the inefficient linear regulator within an existing design, the Traco TSR 1.5E series is a convenient 1.5 A part. It uses a step-down non-isolated topology to achieve efficiency up to 97 % and accommodates a wide 7 V to 36 V input operating range. The compact SIP 3 open-frame module offers three output options 3.3 V, 5.0 V and 12 V.

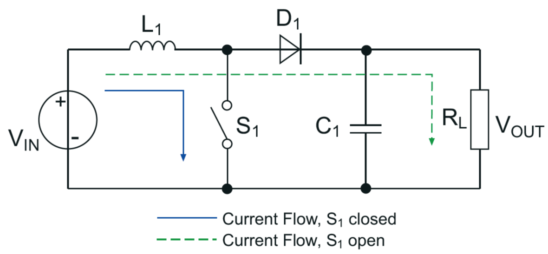



*Figure 4: Block diagram shows the basic function of a boost converter (Source: Recom)*

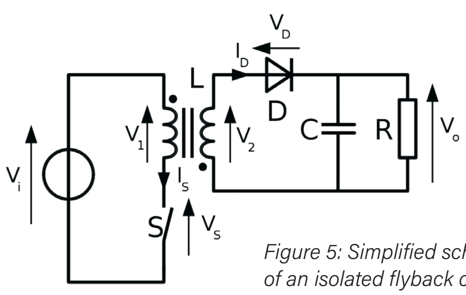



*Figure 5: Simplified schematic of an isolated flyback converter (Source: Wikipedia, https://commons.wikimedia.org/wiki/File:Flyback_conventions.svg)*

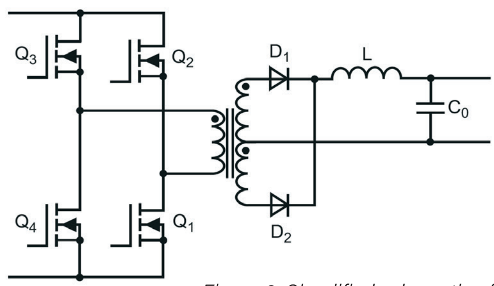



*Figure 6: Simplified schematic of a full-bridge isolated DC/DC converter (Source: Mouser)*

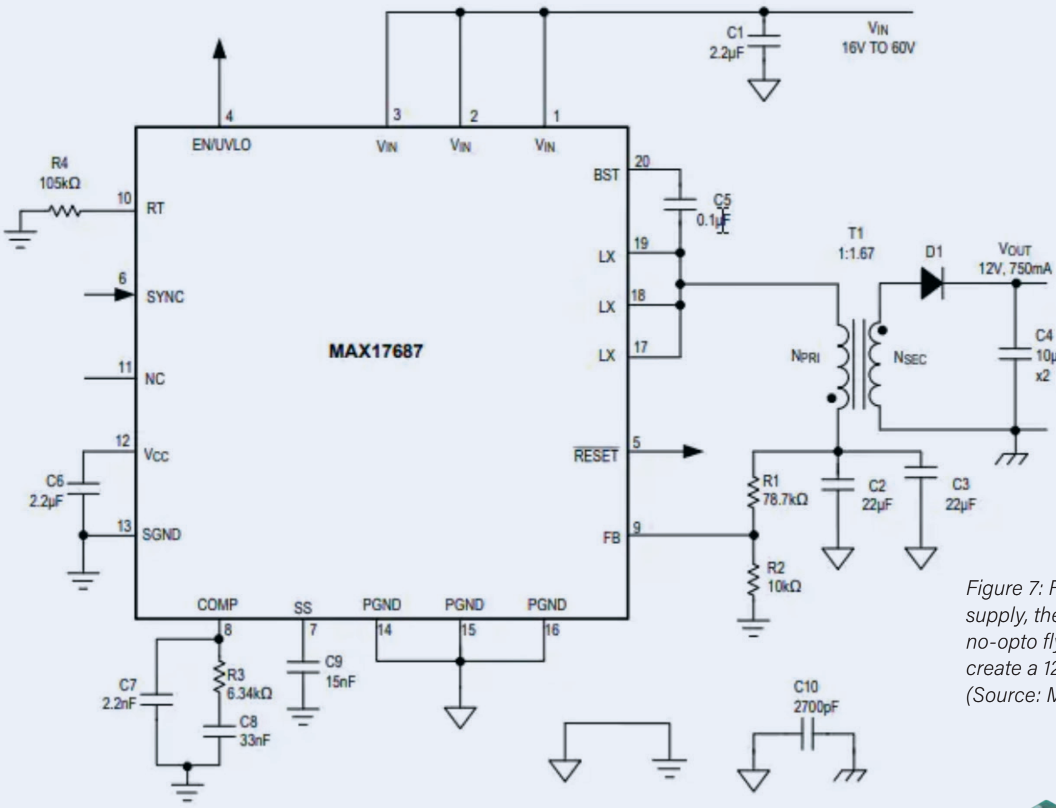



*Figure 7: From a 16 V to 60 V supply, the Maxim MAX17687 no-opto flyback converter IC can create a 12 V / 750 mA output (Source: Maxim)*

The DCS-Control technology from TI achieves a significantly faster transient response with better regulation and ripple characteristics than the standard synchronous buck approach. The converter is available both as a device, the TPS6282x, and a module with an integrated inductor, the TPSM8282x (see **Figure 9**).

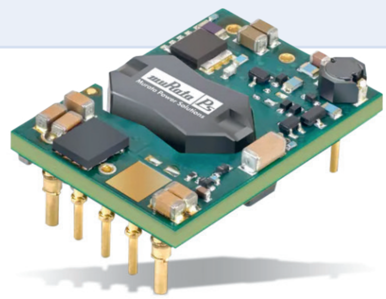


*Figure 8: The Murata UWS-Q12 series of isolated DC/DC converters (Source: Murata)*

## Simple Power Conversion

This article has investigated the three most popular DC/DC power conversion topologies with highlights of some product examples. For DC/DC power conversion, converter ICs are the preferred option to save space and reduce BOM costs. Low power converter ICs, which integrate switching transistors or FETs, are widely used in many industrial, commercial, and consumer product applications. However, DC/DC converter modules with an integrated inductor are an attractive alternative to ease integration and procurement. ◀

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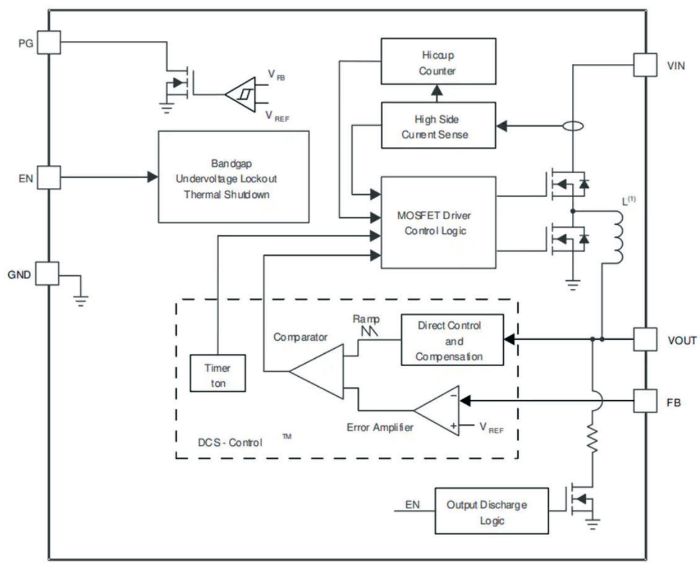


*Figure 9: The TPSM82821 step-down buck converter module from TI integrates the TPS6282x controller IC. (Source: TI)*


## About the Author

As Mouser Electronics' Technical Marketing Manager for EMEA, Mark Patrick is responsible for the creation and circulation of technical content within the region — content that is key to Mouser's strategy to support, inform and inspire its engineering audience. Prior to leading the Technical Marketing team, Patrick was part of the EMEA Supplier Marketing team and played a vital role in establishing and developing relationships with key manufacturing partners. In addition to a variety of technical and marketing positions, Patrick's previous roles include eight years at Texas Instruments in Applications Support and Technical Sales.