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This application brief highlights the half-bridge and the push-pull converter. The output power range of these topologies is typically between 250 W and 500 W. For output power above this level, a better design is possible using a hard-switched full-bridge, a phase-shifted full-bridge or an LLC half- or full-bridge topology for increased efficiency. These topologies will be the topic of the next installations in this series.

Push-Pull Converters

The push-pull topology can step its input voltage up and down, generating an isolated output voltage that can be positive or negative. When either of the switches Q1 and Q2 is conducting, energy is transferred from the primary to the secondary. Also, diodes D1 and D2 provide a freewheeling path when both switches are not conducting. The following figure is a schematic of a nonsynchronous push-pull converter.

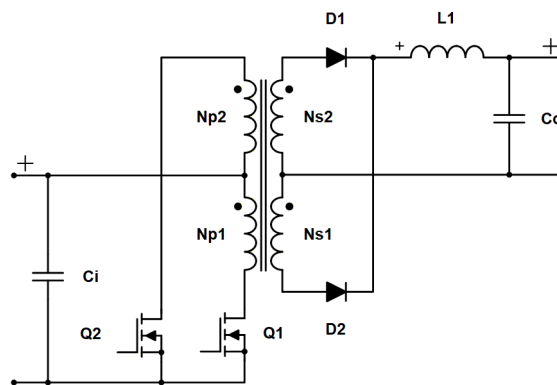


Figure 1. Schematic of a Nonsynchronous Push-Pull Converter

Equation 1 calculates the duty cycle in continuous conduction mode (CCM) as:

$$D = \frac{1}{2} \times \frac{V_{out} + V_f}{V_{in} \times \frac{n_s}{n_p}} \quad (1)$$

where V_{in} is the input voltage, V_{out} is the output voltage, V_f is the diode forward voltage and n_p/n_s is the turns ratio between the primary winding and the secondary winding. The maximum duty cycle per metal-oxide semiconductor field-effect transistor (MOSFET) leg is limited to 50%.

Equation 2 calculates the maximum MOSFET stress as:

$$V_{Q1/2} = 2 \times V_{in} \quad (2)$$

where V_{in} is the input voltage. Push-pull converters are preferably used with lower input voltages, because of the large voltage stress across the primary MOSFETs. Also, the transformer structure with center tap will lead to larger overshoot and ringing compared to other topologies, which requires the designer to leave reasonable margin when selecting the MOSFETs.

Equation 3 gives the maximum rectifier diode stress as:

$$V_{D1/2} = 2 \times V_{in} \times \frac{n_s}{n_p} - V_f \quad (3)$$

where V_{in} is the input voltage, V_f is the diode forward voltage and n_p/n_s is the turns ratio between the primary winding and the secondary winding.

Since any forward topology is essentially an isolated buck converter, this converter family has a continuous current due to the output LC-filter and the freewheeling path through either diode on the secondary side. Like a buck converter, the forward converter has a pulsed current at the input. This fact leads to rather high voltage ripple at the converter input. For electromagnetic compatibility, additional input filtering will likely be necessary. If the converter needs to supply a very sensitive load, a second-stage filter at the output could help damp the output voltage ripple.

You can build a push-pull converter by using a general-purpose pulse-width modulation (PWM) controller integrated circuit (IC) which supports two alternating gate drive signals. The same controller can often also be used for the half-bridge topology.

In terms of dynamic behavior, an optocoupler in the isolated feedback path is the primary limiting factor for the push-pull converter's achievable regulation bandwidth. If a high regulation bandwidth is required, it can be an option to place the PWM controller on the secondary side of the converter.

The following figures show voltage and current waveforms in CCM for FET Q1, primary transformer winding N_p , rectifier diode D1 and inductor L1 in a nonsynchronous push-pull converter.

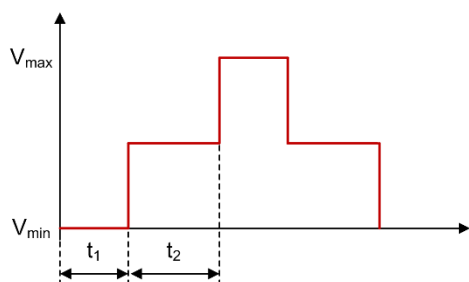


Figure 2. Push-Pull FET Q1 Voltage Waveform in CCM

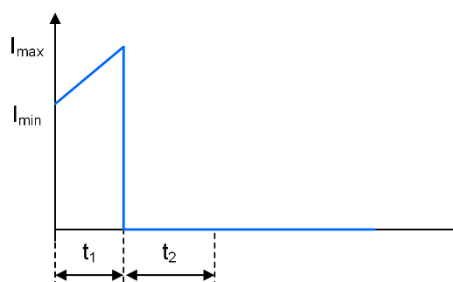


Figure 3. Push-Pull FET Q1 Current Waveform in CCM

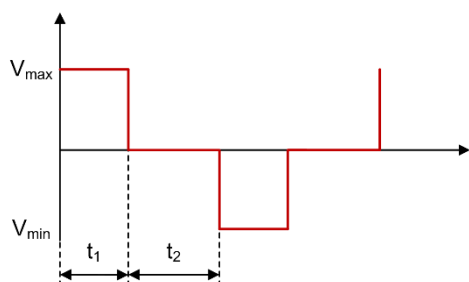


Figure 4. Push-Pull Primary Transformer Winding N_{p1} Voltage Waveform in CCM

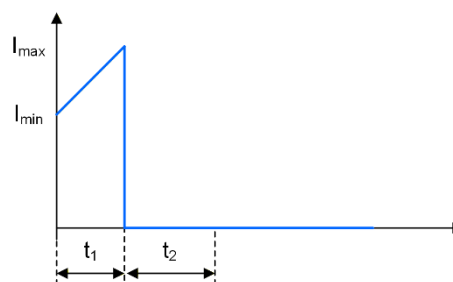


Figure 5. Push-Pull Primary Transformer Winding N_{p1} Current Waveform in CCM

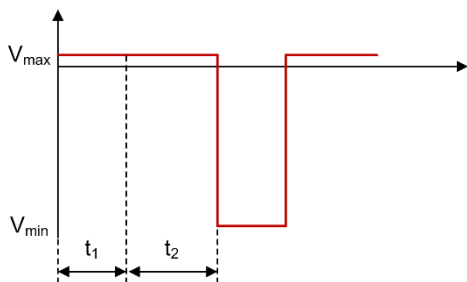


Figure 6. Push-Pull Rectifier Diode D1 Voltage Waveform in CCM

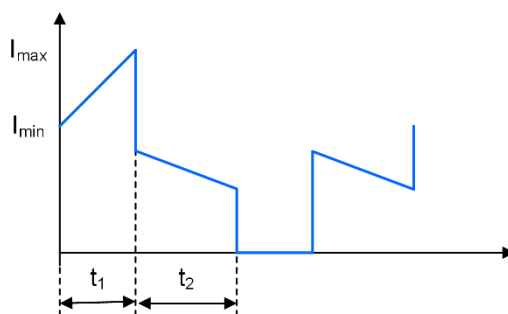


Figure 7. Push-Pull Rectifier Diode D1 Current Waveform in CCM

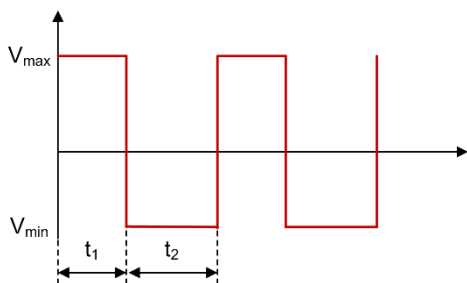


Figure 8. Push-Pull Inductor L1 Voltage Waveform in CCM

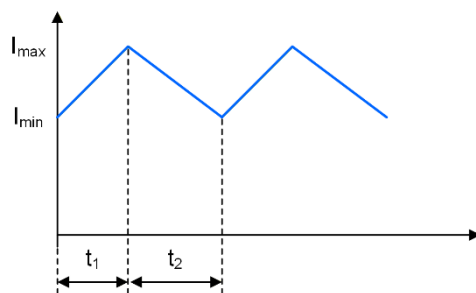


Figure 9. Push-Pull Inductor L1 Current Waveform in CCM

Half-Bridge Converters

For higher input voltage levels, it is preferable to use a half-bridge converter over a push-pull converter, which enables the use of MOSFETs with a lower breakdown voltage and better performance parameters since they will have only half the overall voltage stress compared to a push-pull converter.

Like the push-pull converter, the half-bridge converter can step its input voltage up and down, generating an isolated output voltage that can be positive or negative. When either of the switches Q1 and Q2 is conducting, energy is transferred from the primary to the secondary. Also, diodes D1 and D2 provide a freewheeling path when both switches are not conducting. The schematic of a half-bridge converter is shown in the following figure.

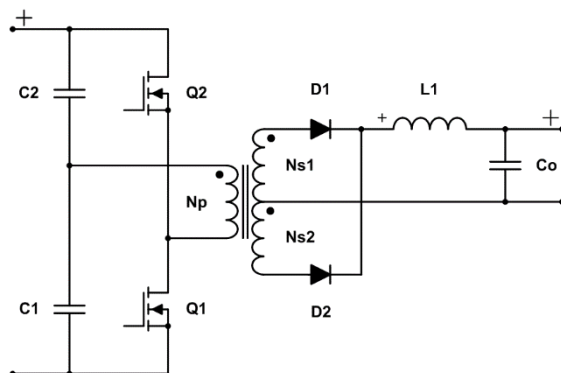


Figure 10. Schematic of a Nonsynchronous Half-Bridge Converter

Equation 5 calculates the duty cycle in continuous conduction mode (CCM) as:

$$D = \frac{V_{out} + V_f}{V_{in} \times \frac{n_s}{n_p}} \quad (5)$$

Equation 6 calculates the maximum MOSFET stress in a half-bridge converter as:

$$V_{Q1/2} = V_{in} \quad (6)$$

where V_{in} is the input voltage.

Equation 6 gives the maximum rectifier diode stress as:

$$V_{D1/2} = V_{in} \times \frac{n_s}{n_p} - V_f \quad (6)$$

Also with a half-bridge configuration, the maximum MOSFET leg duty cycle is limited to 50%.

The following figures show voltage and current waveforms in CCM for FET Q1, primary transformer winding N_p , rectifier diode D1 and inductor L1 in a nonsynchronous half-bridge converter.

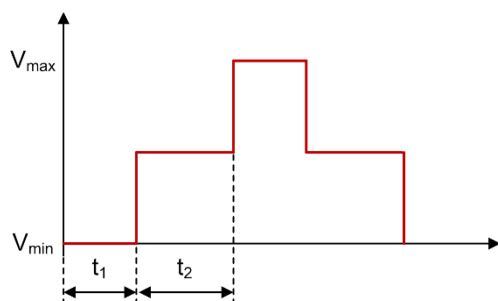


Figure 11. Half-Bridge FET Q1 Voltage Waveform in CCM

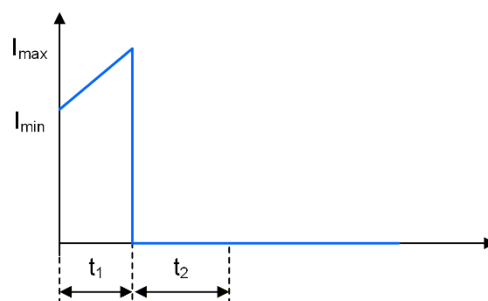


Figure 12. Half-Bridge FET Q1 Current Waveform in CCM

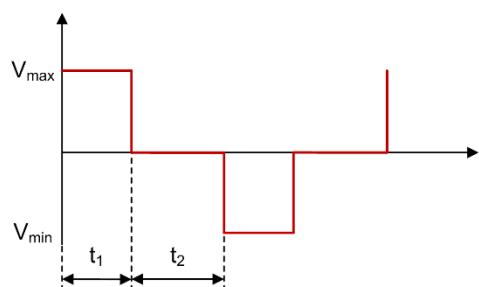


Figure 13. Half-Bridge Primary Transformer Winding N_p Voltage Waveform in CCM

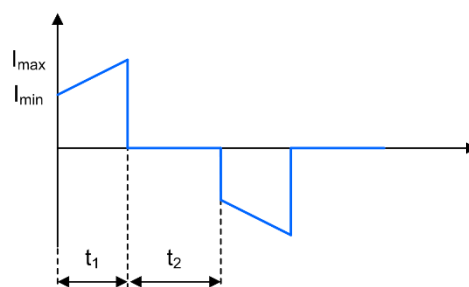


Figure 14. Half-Bridge Primary Transformer Winding N_p Current Waveform in CCM

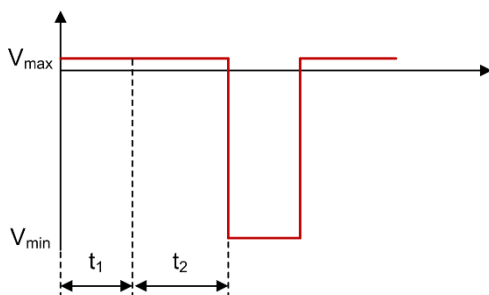


Figure 15. Half-Bridge Rectifier Diode D1 Voltage Waveform in CCM

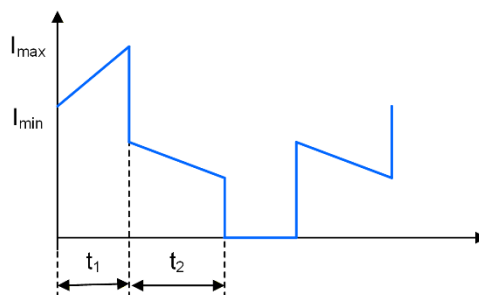


Figure 16. Half-Bridge Rectifier Diode D1 Current Waveform in CCM

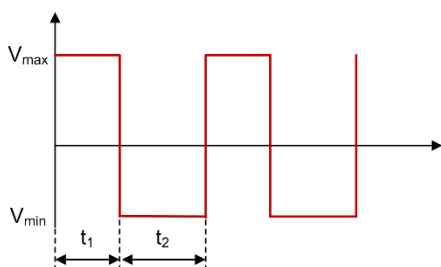


Figure 17. Half-Bridge Inductor L1 Voltage Waveform in CCM

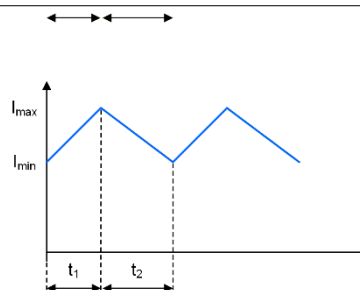


Figure 18. Half-Bridge Inductor L1 Current Waveform in CCM

Half-bridge converters are typically operated in voltage-mode control because of the capacitive divider on the converter input: If operated in peak current-mode control, a small imbalance in charge on this capacitive divider will lead to the gap between the two charges increasing, making things worse with every switching cycle since there is often no mechanism implemented that provides Volt-seconds balance for the two switching legs based on the sensed current information. As a result the energy transferred for each leg will drift apart more and more and can ultimately lead to transformer core saturation since the core is not properly reset with every switching cycle.

Output Voltage Regulation Concepts

Depending on the application, there are two different options to feed back the isolated output voltage to the controller:

- Secondary-side regulation (SSR) typically uses an optocoupler to transfer feedback information from the secondary to the primary side. Optocouplers have a limited bandwidth, which can affect the maximum achievable regulation bandwidth. Aging effects of the glass passivation in the optocoupler can be detrimental in certain applications. These applications then need to employ an optocoupler replacement, such as an isolated amplifier circuit or opto-emulator.
- Placing the controller on the secondary side can help achieve higher regulation bandwidths by eliminating the optocoupler in the feedback loop. However, an auxiliary power supply for start-up and short-circuit conditions is required to supply the PWM controller on the secondary. In addition, the MOSFET(s) on the primary side need to be driven with an isolated gate drive circuit, which can be implemented either with a dedicated isolated gate drive IC or with a discrete circuit leveraging a gate drive transformer and a non-isolated driver.

A third option is to not regulate the output:

- Open loop push-pull operation with a constant duty cycle of 50% is a common implementation for low-power isolated bias supplies. These bias supplies often do not use an LC filter on the output since the output ripple is negligibly small. Devices which can support this kind of application are [SN6505B](#) or [SN6507](#).

Using synchronous rectification for larger load currents is advisable, especially when efficiency needs to be high or when external heat sinks need to be avoided. The synchronous rectifier can either be controlled from the primary side or use a self-driven concept, with the latter typically the more cost-effective option.

Additional Resources

- [Watch the video, "Topology Tutorial: What is a Push Pull?"](#)
- [Watch the video, "Topology Tutorial: What is a Half Bridge?"](#)
- Design your power stage with [Power Stage Designer](#).
- Download the [Power Topologies Handbook](#) and [Power Topologies Quick Reference Guide](#).

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