Efficiency and density (Watts/Volume) have long been the metrics used to compare the performance of isolated DC-DC power converters. When designing an isolated dc-dc power converter, the first and most critical choice is selection of the topology. Historically, topology selection was based upon the desired output power level. For the basic topologies, the order from lower power to higher power was usually Flyback, Forward, Push-Pull, Half-Bridge and Full-Bridge. While this basic power order still remains true, for designers to push to new heights in power density, topologies that were once used in much higher power applications are now finding their way into relatively lower power, small form factor high density power converters. Power management IC manufacturers are enabling this trend by adding not only more features but also by integrating high voltage gate drivers within the controllers.

While clearly subjective, historically, the output power range has often been used as the primary guide when selecting a topology. However, there are many other factors that play into the topology selection for an isolated dc-dc power converter such as cost, size, electrical stress, output noise and input voltage range. The size of an isolated power converter primarily depends on the transformer size and the number of active switches employed. The utilization of the power transformer affects the size of the power converter. Isolated power converter topologies can be classified as either single-ended or double-ended depending on the usage of the B-H curve. During the operation, if the flux swings in only one quadrant of the B-H curve, then the topology is classified as single-ended. If the flux swings in two quadrants of the B-H curve, then the topology is classified as double-ended. For a given set of requirements, a double-ended topology requires a smaller core than a single-ended topology and does not need an additional reset winding. Table 1 lists several of the most popular isolated topologies and the power range these topologies had been historically employed.

**CONVENTIONAL USE OF VARIOUS ISOLATED TOPOLOGIES**

The Flyback may be the most commonly used isolated topology. It is generally found in low cost, low power applications. Flyback topology requires only a single active switch and does not require a separate output inductor in addition to the transformer. This makes the topology easy to use and low cost. The disadvantages of the flyback topology are poor transformer utilization, as it is a single-ended topology, and extra capacitors are required at both the input and the output due to the high input and output ripple currents.

The Forward and Active Clamp Forward topologies are
often employed in medium power applications. The Forward topology also suffers from poor transformer utilization due to the limited duty cycle and as it is also single-ended topology. The active clamp forward transformer does operate in two quadrants during steady state operation however peak flux can reach high levels during startup and transient conditions. In order to reset the transformer the maximum duty cycle is limited in both the forward topology and the active clamp forward topology.

The remaining three topologies; Push-Pull, Half-Bridge and Full-Bridge are true double-ended topologies whereby power transfer occurs in two quadrants of the BH curve and does not require special provisions to reset the transformer. These double-ended topologies are the best choice for applications where the highest power density is desired, since the transformer core can be fully utilized. Another advantage of double-ended topologies is the transformer can be further optimized because of the larger available duty cycle range. Double-ended topologies can operate at a maximum duty cycle of

<table>
<thead>
<tr>
<th>TOPOLOGY</th>
<th>POWER RANGE HISTORICALLY USED</th>
<th>TRANSFORMER UTILIZATION</th>
<th>NUMBER OF ACTIVE SWITCHES</th>
<th>VOLTAGE STRESS ON THE ACTIVE SWITCH</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flyback</td>
<td>&lt; 100W</td>
<td>Single ended</td>
<td>1</td>
<td>&gt;VIN+N×VOUT</td>
<td>Lowest</td>
</tr>
<tr>
<td>Forward</td>
<td>50W - 200W</td>
<td>Single ended</td>
<td>1</td>
<td>&gt;VIN×2 (For DMax=0.5)</td>
<td>&gt;Flyback</td>
</tr>
<tr>
<td>Active Clamp</td>
<td>50W-300W</td>
<td>Double ended *</td>
<td>2</td>
<td>VIN/ (1-D)</td>
<td>Flyback&lt;ACF&lt;Forward</td>
</tr>
<tr>
<td>Push-Pull (P-P)</td>
<td>100W - 500W</td>
<td>Double ended</td>
<td>2</td>
<td>&gt;VIN×2</td>
<td>&gt;ACF</td>
</tr>
<tr>
<td>Half-Bridge</td>
<td>100W - 500W</td>
<td>Double ended</td>
<td>2</td>
<td>&gt;=VIN/2</td>
<td>&gt;P-P</td>
</tr>
<tr>
<td>Full-Bridge</td>
<td>&gt;500W</td>
<td>Double ended</td>
<td>4</td>
<td>&gt;=VIN</td>
<td>&gt;Half-Bridge</td>
</tr>
</tbody>
</table>

Pearson Electronics is pleased to introduce a new line of Wide Band Clamp-on Current Monitors. The new design features a ½ inch or 1 inch aperture with a hinged type opening for easy operation. The new design incorporates Pearson’s wide band frequency response in a demountable configuration for use on fixed conductors.

The model 411C, typical of the group, has a sensitivity of 0.1 V/A, a 3dB bandwidth from 25 Hz to 20 MHz, and a 5,000 amp peak current rating. Pulse rise times down to 20 nanoseconds can be viewed. Accuracy of 1%, or better, is obtainable across the mid-band.

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almost 50% per side which equates to an effective maximum duty cycle of nearly 100% at the output filter inductor. Designing the transformer turns ratio to maximize the effective duty cycle greatly reduces the RMS current in the transformer and reduces the size of the output filter.

Fig. 1 shows a Push-Pull topology configuration. Diodes D1 and D2 are shown for simplicity however most modern, high efficiency power converters use synchronous MOSFETs as secondary rectifiers. The Push-Pull topology has the advantage of being double-ended however the peak voltage stress placed upon the primary switches during the off state is very high, well over two times the input voltage.

Fig. 2 shows a Half-Bridge topology configuration. The Half-Bridge is a double-ended topology configuration. The advantage of the Half-Bridge over the push-pull is the primary switch voltage stress does not exceed the input voltage.

Fig. 4. This 100W isolated Full-Bridge power converter has a 36V to 100V input range and a 30A, 3.3 V output.
for the Half-Bridge. Another advantage is there is only one primary winding, allowing the transformer core window to be better utilized. The Half-Bridge topology is only compatible with voltage-mode control. The $\frac{1}{2}$ Vin voltage balance at the midpoint between C1 and C2 is not maintained with current-mode control or when operating in cycle-by-cycle current limiting. Active midpoint balancing circuits can be added to allow a Half-Bridge to operate with current-mode control; however these circuits can be fairly complex.

**FULL BRIDGE TOPOLOGIES**

Fig. 3 shows a Full-Bridge topology configuration. The Full-Bridge topology has all of the double-ended benefits. The primary switch voltage does not exceed the input voltage. Transformer window utilization is very good since there is only a single primary winding. When one of the primary switches is active for the Half-Bridge topology the voltage across the primary winding is $\frac{1}{2}$ Vin. For the Full-Bridge topology, the switches are activated as diagonal pairs. When a pair of diagonal switches is active, the voltage across the primary winding is the full value of Vin. For a given power, the primary current will be half as much for the Full-Bridge as compared to the Half-Bridge. The reduced current enables higher efficiency as compared to a Half-Bridge especially at high load currents. The disadvantage of the Full-Bridge topology is the added complexity of driving four primary switches and the cost of the additional switches. Relative to the Half-Bridge, part of this additional cost is offset with reduction of input capacitors.

Another Full-Bridge configuration, which is used in high input voltage and high power applications, is the phase-shifted Full-Bridge. This topology is similar to the conventional Full-Bridge. However, the control methodology is different; the phase-shifted Full-Bridge (PSFB) results in zero-volt switching of the primary switches while keeping the switching frequency constant. Zero-volt switching is especially beneficial at high input voltage applications.
Often this topology needs an extra commutating inductor in series with primary of the power transformer to ensure zero-volt switching at light load conditions. A disadvantage of this topology is increased conduction losses in the primary during the free-wheeling time.

The LM5045 is a new controller that integrates the control and gate drive allowing the Full-Bridge topology to be used in lower power, small form factor applications. The LM5045 has a total of six control outputs, four 2 Amp gate drivers that can directly drive the primary switches and two control outputs for the secondary side synchronous switches. The LM5045 can operate directly with input voltages up to 100V and can be configured for either voltage-mode or current-mode control.

Shown in Fig. 4 is the schematic of a 100W isolated dc-dc power converter based on the Full-Bridge topology. The input range is 36V to 100V with an output capability of 30A at 3.3V.

Shown in Fig. 5 is the efficiency curve of the evaluation board for the schematic shown in Fig. 4. Also shown is the efficiency curve of a similar Half-Bridge converter (LM5035 evaluation board). It can be seen that the Full-Bridge design has a flatter efficiency curve and exceeds the Half-Bridge efficiency at higher output currents. At lower output current, the Full-Bridge efficiency is lower due to gate drive losses.

**SMALL BRICK POWER SOLUTIONS**

An emerging trend to improve power density in isolated DC-DC power converters is to employ more efficient, high power topologies into lower power applications. This allows designers to achieve higher power density solutions. Several power module vendors already have quarter and eighth brick solutions, on the market, based upon the Full-Bridge topology. The LM5045 converter will further this trend by integrating high voltage level shifted gate drivers synchronous FET controls and integrating the additional logic circuitry required to turn-on the power converter linearly into pre-biased loads. This integration trend will continue in the future at all power levels and in not-too-distant future, the primary and secondary controls along with galvanic isolation will be integrated into a single IC package.