The First Step to Success – Selecting the Optimal Topology
Brian King
What will I get out of this session?

• Purpose:

  **Inside the Box:** General Characteristics of Common Topologies

  **Outside the Box:** Unique Characteristics and Variations of Common Topologies

• Part numbers mentioned:
  - UCC28950, UCC28722
  - UCC25630

• Reference designs mentioned:
  - PMP8740, PMP10397
  - PMP20795

• Relevant End Equipments:
  - Everything
Flyback

• Cost: Lowest
• Size: Scales with Power
  • < 50W – hard to beat
  • > 100W transformer becomes excessively large
• Efficiency: 83%-94%
  • Highly dependent on output voltage
  • Sometimes improved with synchronous rectifiers

When to consider:
  • Low cost
  • Wide input range
  • Multiple outputs
  • High output voltage

When to avoid:
  • Output power > 100W
  • Load current > 5A
Flyback Variants

- Quasi-resonant (QR)
- Primary-side regulated (PSR)
- Active clamp flyback (ACF)
- 2-switch
- BJT switch
- SiC switch
- Interleaved

**DCM flyback with valley switching**, where the primary FET turns on during the first valley at maximum load.

- Optimized for consumer supplies < 60W
- Good efficiency
- Ultra-low standby
Flyback Variants

- Quasi-resonant (QR)
- Primary-side regulated (PSR)
- Active clamp flyback (ACF)
- 2-switch
- BJT switch
- SiC switch
- Interleaved

Regulation achieved by sampling auxiliary winding eliminates the need for an error amplifier and optocoupler.

- Ultra-low cost
- Usually operates in QR mode
- +/-5% regulation
- Not recommend for multiple outputs
Flyback Variants

- Quasi-resonant (QR)
- Primary-side regulated (PSR)
- Active clamp flyback (ACF)
- 2-switch
- BJT switch
- SiC switch
- Interleaved

*Dissipative clamp is replaced with a lossless clamp, reclaiming energy stored in leakage inductance.*

- Best efficiency, highest power density
- Optimized for GaN and high frequency
- ZVS Possible
Flyback Variants

- Quasi-resonant (QR)
- Primary-side regulated (PSR)
- Active clamp flyback (ACF)
- 2-switch
  - BJT switch
  - SiC switch
  - Interleaved

Both switches conduct simultaneously. Leakage energy is recycled back to the input via diodes on primary.

- Higher efficiency, but higher cost
- Lower voltage stress on FETs
- Limited to 50% duty cycle
Flyback Variants

- Quasi-resonant (QR)
- Primary-side regulated (PSR)
- Active clamp flyback (ACF)
- 2-switch
- **BJT switch**
  - Low cost
  - Higher voltage rating
  - Limited to ~10W
- SiC switch
- Interleaved

*Main switch is replaced by a NPN bipolar junction transistor.*
Flyback Variants

- Quasi-resonant (QR)
- Primary-side regulated (PSR)
- Active clamp flyback (ACF)
- 2-switch
- BJT switch
- **SiC switch**
- Interleaved

*Main switch is replaced by a silicon carbide transistor.*

- Higher voltage rating
- Higher performance vs. BJT or Si
- Higher cost
Flyback Variants

- Quasi-resonant (QR)
- Primary-side regulated (PSR)
- Active clamp flyback (ACF)
- 2-switch
- BJT switch
- SiC switch
- Interleaved

A single controller drives two paralleled flyback power stages.

- Extended power range of flyback
- Can be realized with a push-pull controller
Forward

- Cost: Moderate
- Size: Scales with Power
  - < 100W – flyback wins as power decreases
  - 100W to 500W – sweet spot
  - > 500W xfmr size and # of FETs favor full-bridge
- Efficiency: 85%-96%
  - Can be improved with synchronous rectifiers

When to consider:
- 100W-500W
- Load currents up to 40A
- Moderate input range (< 4:1)

When to avoid:
- High output voltage
- Multiple outputs
Forward Variants

- Single switch
- 2-switch
- Active clamp forward
- Interleaved

*Magnetizing energy is recycled back to the input via a reset winding.*

- High voltage stress on FET, unclamped
- 50% duty cycle limit
- Leakage energy is lost
Forward Variants

- Single switch
- 2-switch
- Active clamp forward
- Interleaved

Magnetizing and leakage energy is recycled back to the input via diodes.

- Higher cost – due to high-side FET
- FET voltage clamped to Vin
- Higher efficiency than single switch
- 50% duty cycle limit
Forward Variants

- Single switch
- 2-switch
- Active clamp forward
- Interleaved

Magnetizing and leakage energy is recycled in the clamp capacitor.

- Self-driven synchronous rectifiers
- FET voltage clamped to VIN / (1−D)
- Better transformer utilization
- Higher cost – due to clamp FET
Forward Variants

- Single switch
- 2-switch
- Active clamp forward
- Interleaved

A single controller drives two paralleled forward power stages.

- Extended power range of forward
- Can be realized with a push-pull controller
- Output inductance is decreased
Half-Bridge

- Cost: Moderate
- Size: Scales with Power
  - < 100W – flyback wins as power decreases
  - 100W to 500W – sweet spot
  - > 500W xfmr size and # of FETs favor full-bridge
- Efficiency: 88%-96%
  - Can be improved with synchronous rectifiers

When to consider:
- 100W-1kW
- LLC for multiple outputs
- Radiated EMI concerns

When to avoid:
- Low input voltages
- Wide input ranges (> 2:1)
Half-Bridge Variants

- Hard switched
- Resonant LLC
- Bus converter

Basic form of half-bridge, where transformer primary sees $\frac{1}{2}$ of the input voltage.

- Good transformer utilization
- 2 X primary current in FETs
- Difficult to implement synchronous rectifiers
- Sees limited use
Half-Bridge Variants

- Hard switched
- Resonant LLC
- Bus converter

Operates at fixed 50% duty cycle with variable frequency control using gain curves of resonant power stage.

- Popular topology for 100W-500W range
- ZVS - high efficiency
- Narrow input/output range
- Ultra-low standby possible
Half-Bridge Variants

- Hard switched
- Resonant LLC
- Bus converter

Operates at fixed 50% duty cycle, open loop.

- Shim inductor for ZVS - high efficiency
- Not regulated
- Minimal output inductance
Full-Bridge

- Cost: High
- Size: Scales with Power
  - < 500W – # of FETs and inductor favor LLC
  - > 500W – usually smallest solution
- Efficiency: 90%-98%
  - Can be improved with synchronous rectifiers
  - Ultra-high when used as bus converter

When to consider:
- > 500W
- Bus converters
- Controllable output to 0V, chargers

When to avoid:
- < 500W
- Multiple outputs
Full-Bridge Variants

- Hard switched
- Phase-shifted
- Current doubler
- Resonant LLC

Basic form of full-bridge, where primary FETs are controlled by PWM at a fixed frequency.

- Good transformer utilization
- Lower primary current than ½ bridge
- Difficult to implement synchronous rectifiers
- Sees limited use above 48V
Full-Bridge Variants

- Hard switched
- Phase-shifted
- Current doubler
- Resonant LLC

Popular form of full-bridge, where primary FETs are controlled by phase-shift at a fixed frequency.

- Shim inductor for ZVS – very high efficiency
- Eliminates/reduces switching loss
- Difficult to implement synchronous rectifiers
Full-Bridge Variants

- Hard switched
- Phase-shifted
- **Current doubler**
- Resonant LLC

*Single winding used for secondary, splitting the current between two output inductors.*

- Better for higher output currents
- Complex timing of synchronous rectifiers
- Higher flux per inductor
Full-Bridge Variants

- Hard switched
- Phase-shifted
- Current doubler
- Resonant LLC

Similar to half-bridge LLC, but resonant tank is driven bi-directionally.

- Lower primary current
- Better for lower input voltages
- Less common than the ½ bridge LLC
Example #1: 2kW Modular Power Supply / Battery Charger

- Working AC voltage: 90 VAC...265VAC
- Output voltage: 20 V...32 V @ 62.5 A; 0 V to 32V (as charger)
- Harmonic limits: EN61000-3-2 Class A
- Output power: 2 kW
- Minimum plug-to-plug efficiency: 90% (better than “80 Plus Silver”)
- User interface: LCD display, 4 pushbuttons
- Modularity: Parallel with master/slave architecture
- Parallel function: CAN (non-standard) communications bus
Example #1: Solution

Flyback  ✔  Forward  ❌
Half-bridge - LLC
  • 2kW is stretch, but possible
  • Output range is too wide

Full-bridge
  • UCC28950 Phase-shifted for higher efficiency
  • PMP8740 reference design
  • [www.ti.com/powerseminars](http://www.ti.com/powerseminars) “Design review of a 2-kW parallelable power-supply module”
Example #2: Power Meter Bias Supply

- **Vin:** 85VAC to 528VAC
- **Vout:**
  - 5V (+/-250mV) at 300mA
  - 15V (+4V/-3V) at 100mA
- Very Low Cost
Example #2: Solution

Forward  Half-bridge  Full-bridge

• Over-kill – too expensive

Flyback

• Obvious choice due to power level
• UCC28722 PSR flyback controller with BJT drive
  • PSR for ultra low cost
  • BJT main switch (further cost savings, voltage rating)
• PMP10397 reference design
• http://www.ti.com/tool/PMP10397
Example #3: 300W Television Power Supply

- Vin: 390V ±15V (from PFC)
- Vout: 24V/12A
- Switching frequency: 200kHz typ.
- Preferred height < 15mm
Example #3: Solution

**Flyback**
- Transformer would be too large

**Full-Bridge**
- Over-kill – too expensive

**Forward**
- Possible, might be an OK solution
- Output inductor might be large at 24V/12A
- Lower efficiency vs. LLC

**Half-bridge LLC**
- UCC25630 LLC controller with integrated drivers
- PMP20795 reference design
Conclusions

- Less than 100W think flyback
- 100W to 500W think forward or half-bridge
- Over 500W think full bridge
- Many other factors can skew your choice
  - Input voltage range
  - Output voltage range
  - Size
  - Cost
  - Efficiency
- Learn the finer details of topology variations
- Often there is more than “acceptable” answer