High VOLT Interactive

Where power supply design meets collaboration

The First Step to Success – Selecting the Optimal Topology

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What will I get out of this session?

- Purpose:

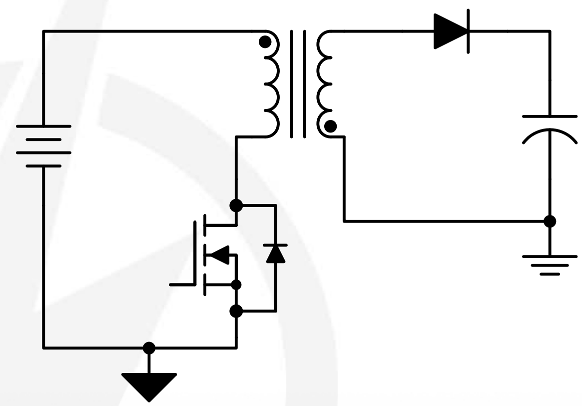
Inside the Box: General Characteristics of Common Topologies

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

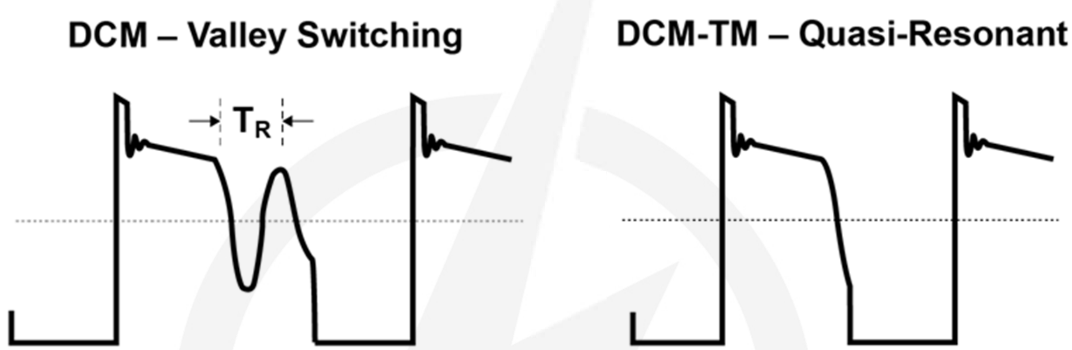


When to consider:
- Low cost
- Wide input range
- Multiple outputs
- High output voltage

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)**
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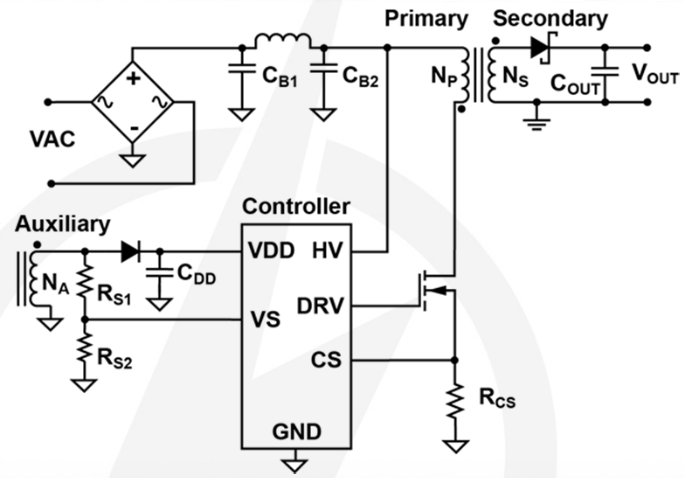
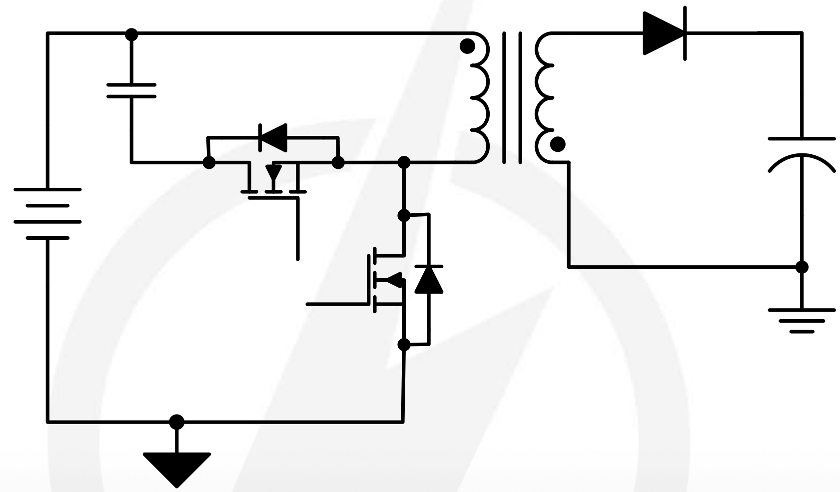


Regulation achieved by sampling auxiliary winding eliminates the need for an error amplifier and optocoupler.

- 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

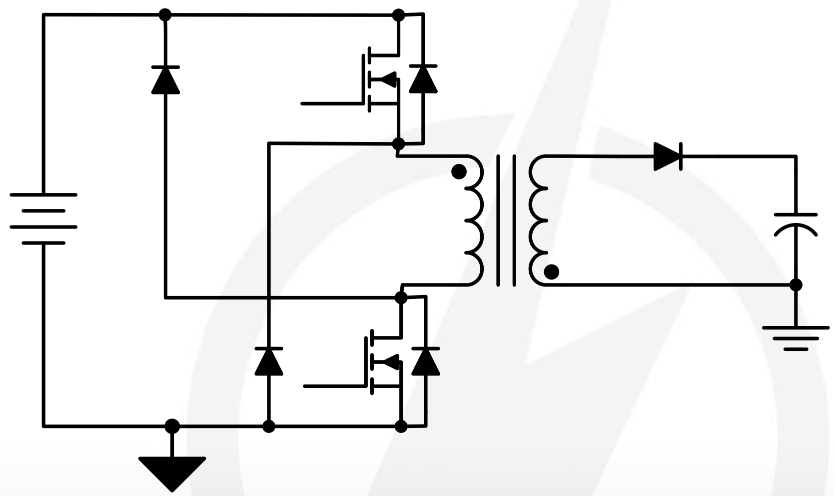


Dissipative clamp is replaced with a lossless clamp, reclaiming energy stored in leakage inductance.

- 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

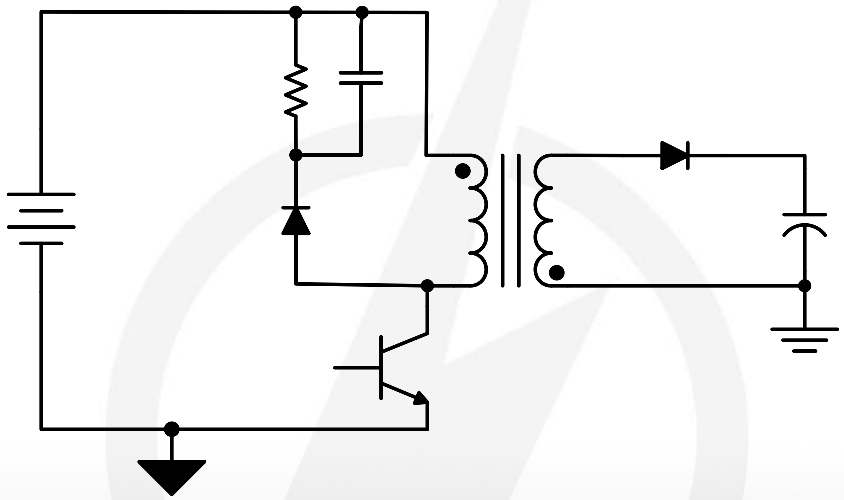


Both switches conduct simultaneously. Leakage energy is recycled back to the input via diodes on primary.

- 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**
- SiC switch
- Interleaved

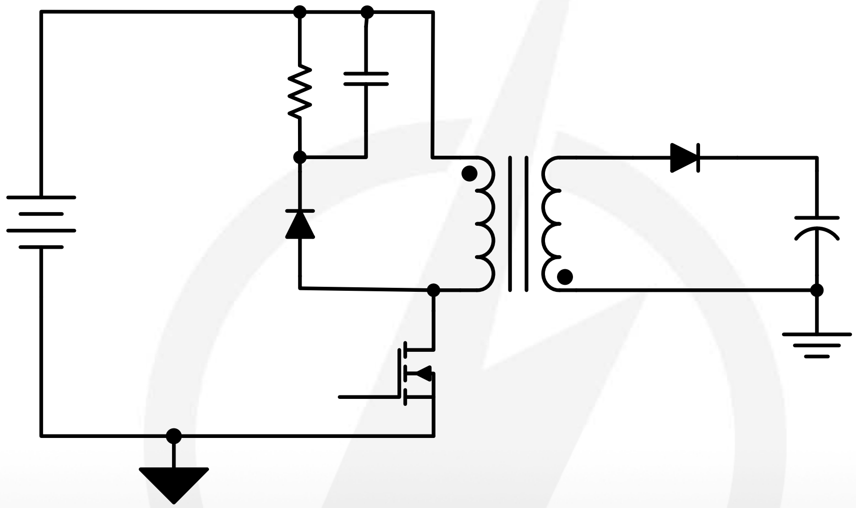


Main switch is replaced by a NPN bipolar junction transistor.

- Low cost
- Higher voltage rating
- Limited to ~10W

Flyback Variants

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

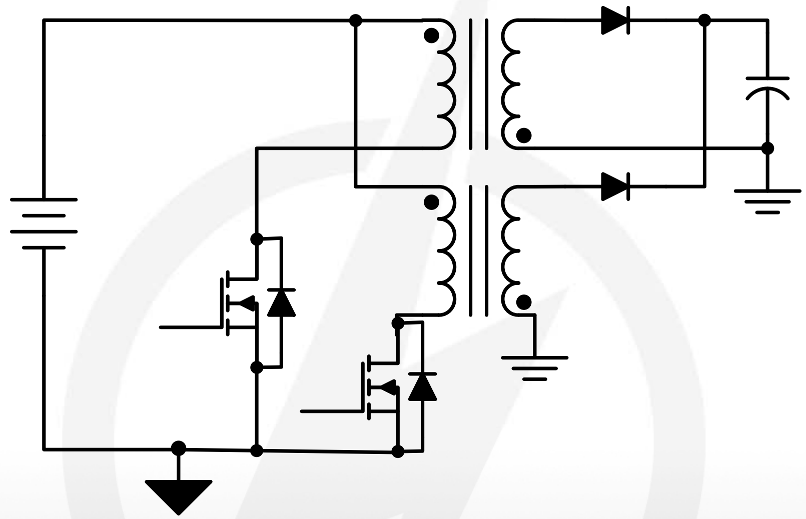


Main switch is replaced by a silicon carbide transistor.

- 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**

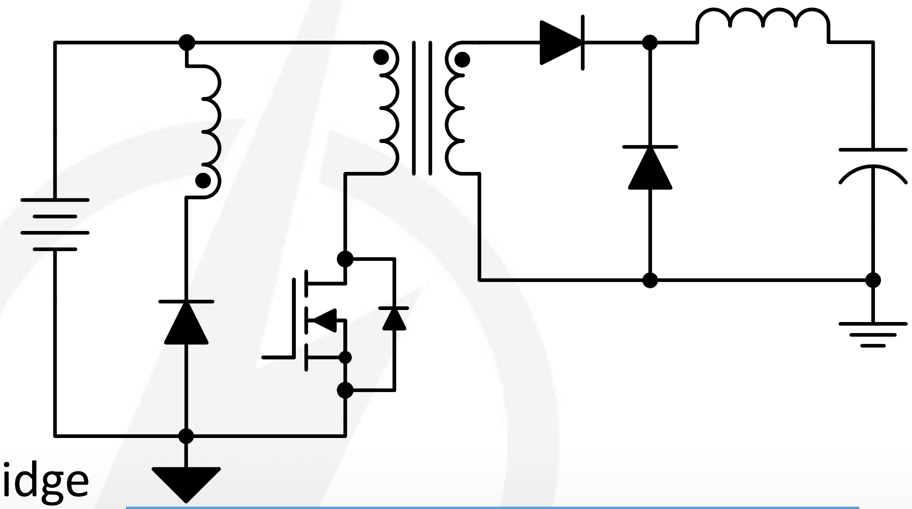


A single controller drives two paralleled flyback power stages.

- 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

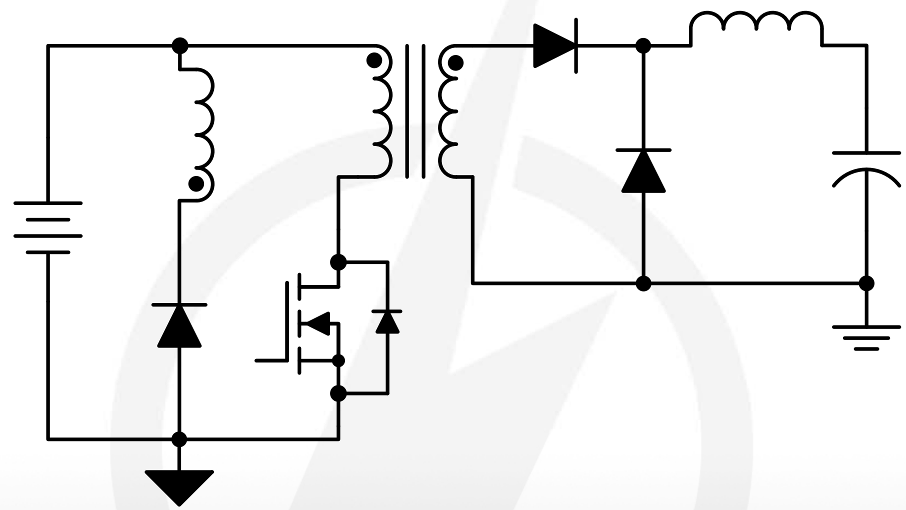


When to consider:
- 100W-500W
- Load currents up to 40A
- Moderate input range (< 4:1)

When to avoid:
- High output voltage
- Multiple outputs

Forward Variants

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

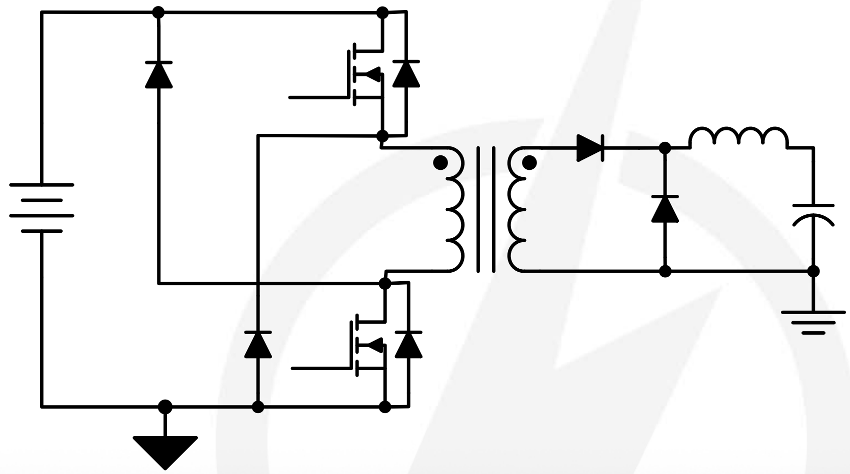


Magnetizing energy is recycled back to the input via a reset winding.

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

Forward Variants

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

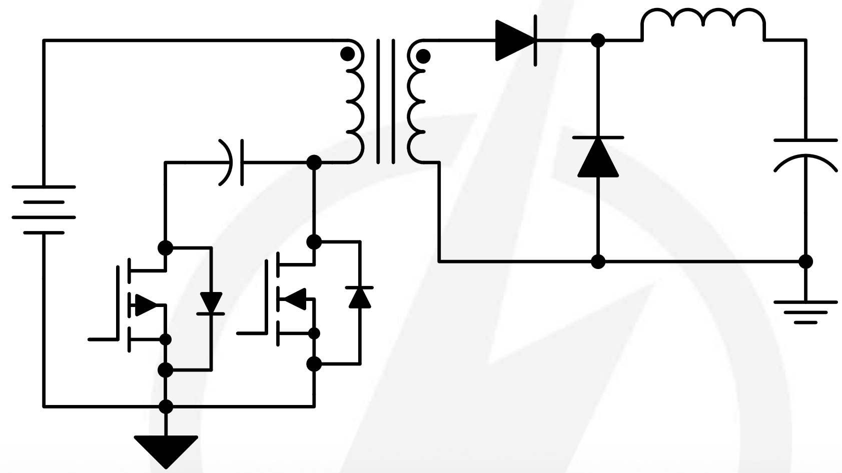


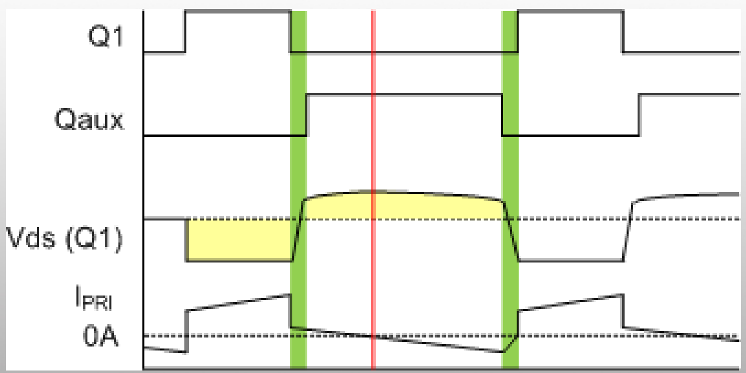
Magnetizing and leakage energy is recycled back to the input via diodes.

- 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



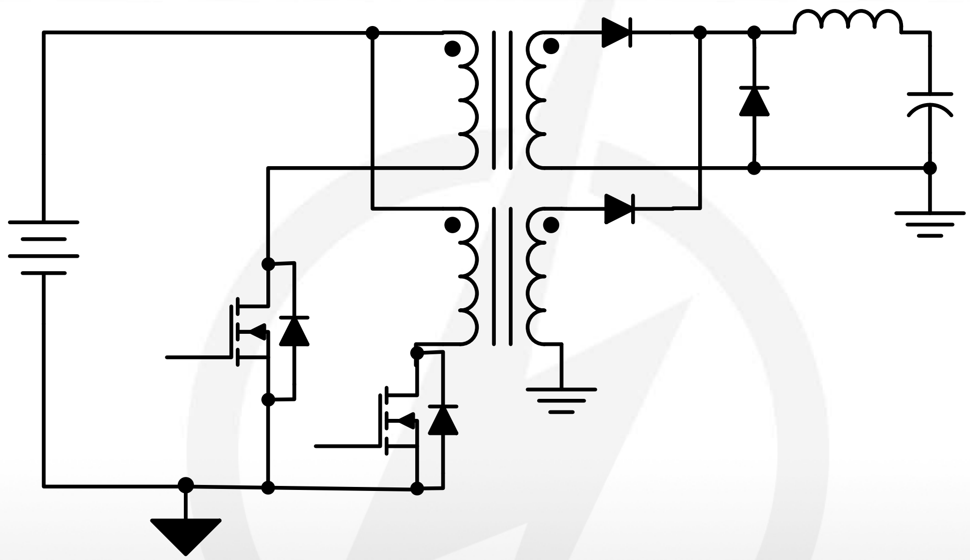


Magnetizing and leakage energy is recycled in the clamp capacitor.

- 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**

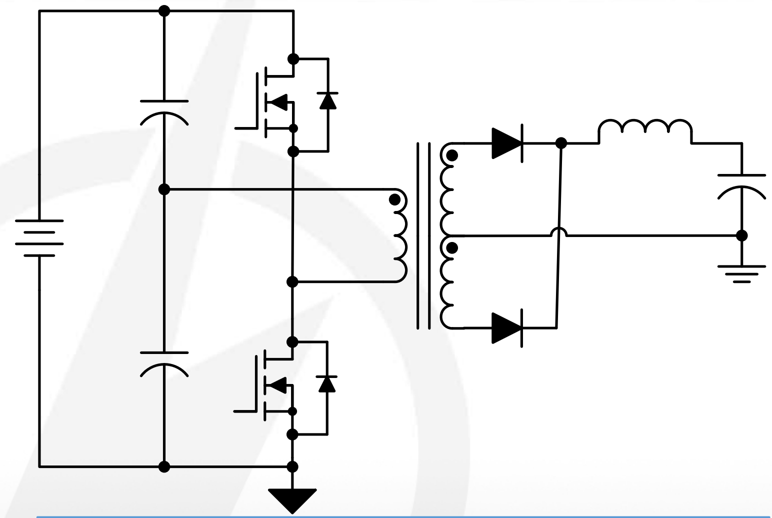


A single controller drives two paralleled forward power stages.

- 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

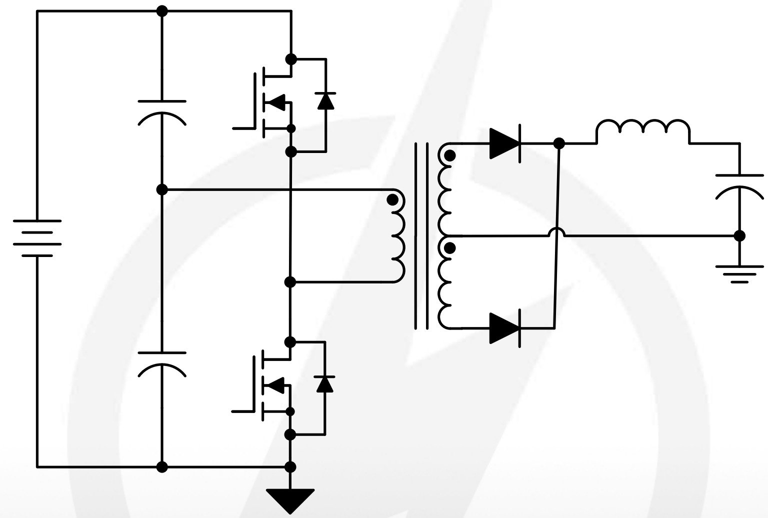


When to consider:
- 100W-1kW
- LLC for multiple outputs
- Radiated EMI concerns

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

Half-Bridge Variants

- **Hard switched**
- Resonant LLC
- Bus converter

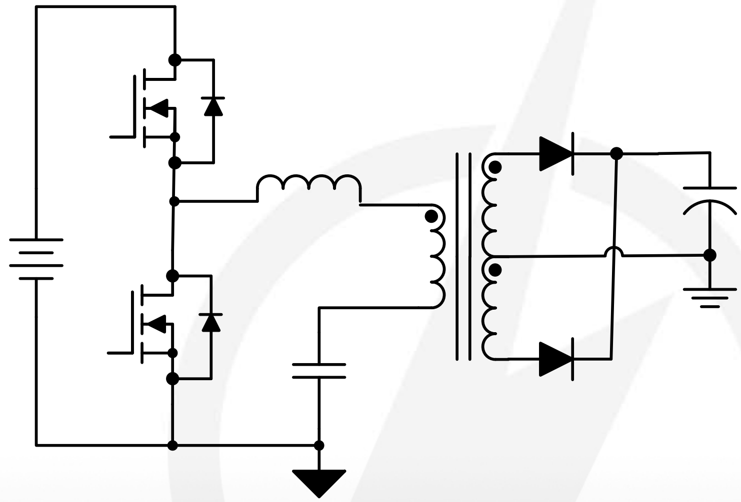


Basic form of half-bridge, where transformer primary sees ½ of the input voltage.

- 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

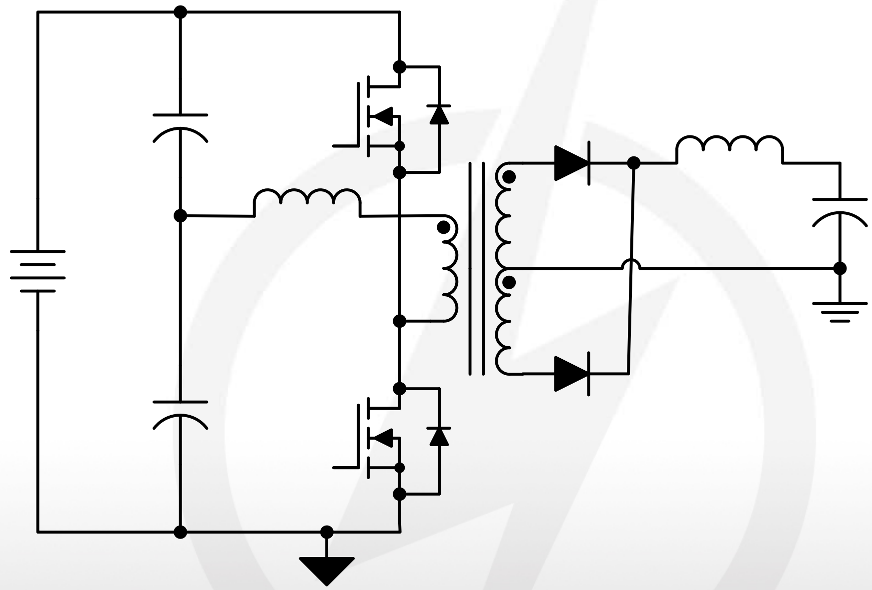


Operates at fixed 50% duty cycle with variable frequency control using gain curves of resonant power stage.

- 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**

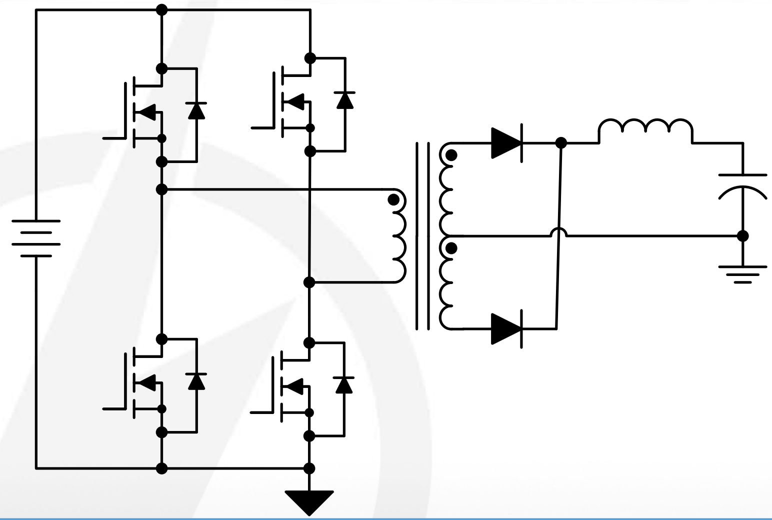


Operates at fixed 50% duty cycle, open loop.

- 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

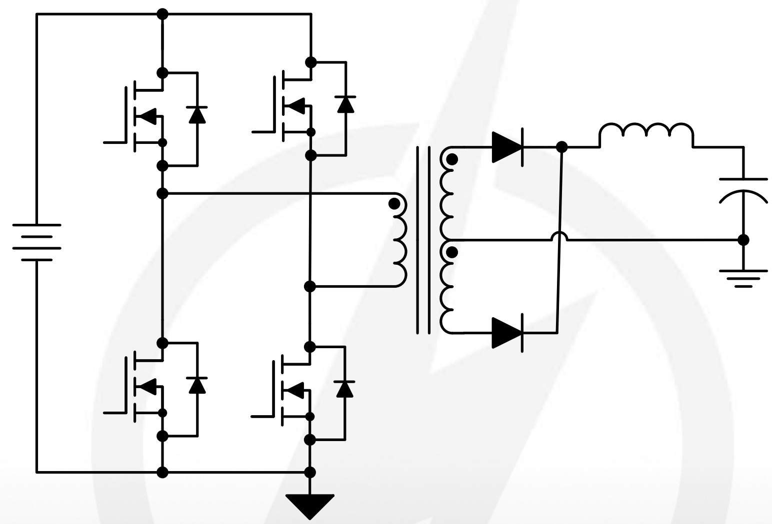


When to consider:
- > 500W
- Bus converters
- Controllable output to 0V, chargers

When to avoid:
- < 500W
- Multiple outputs

Full-Bridge Variants

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

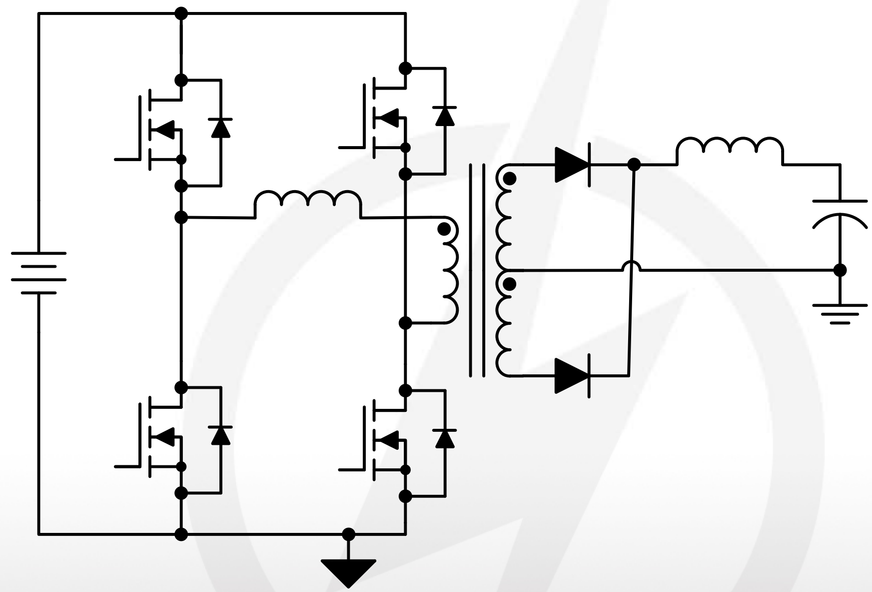


Basic form of full-bridge, where primary FETs are controlled by PWM at a fixed frequency.

- 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

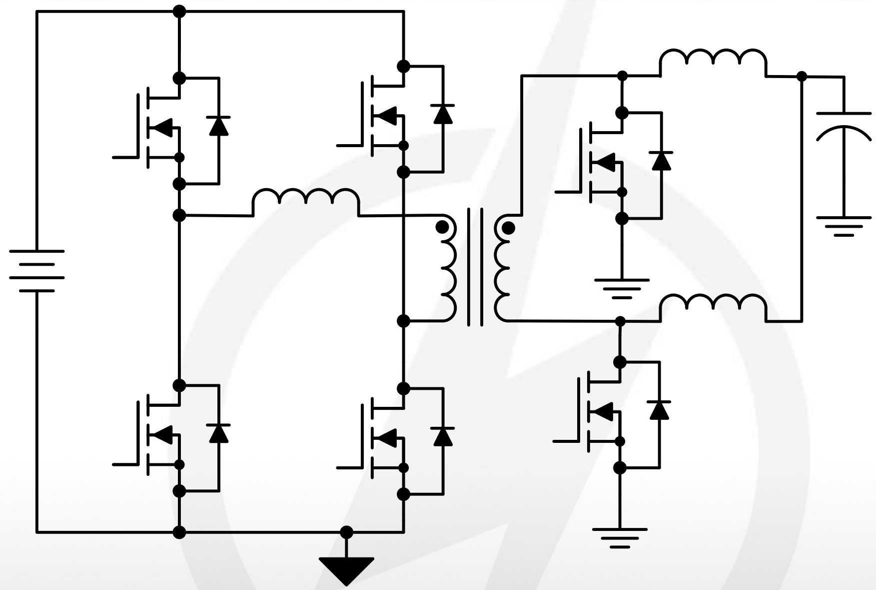


Popular form of full-bridge, where primary FETs are controlled by phase-shift at a fixed frequency.

- 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

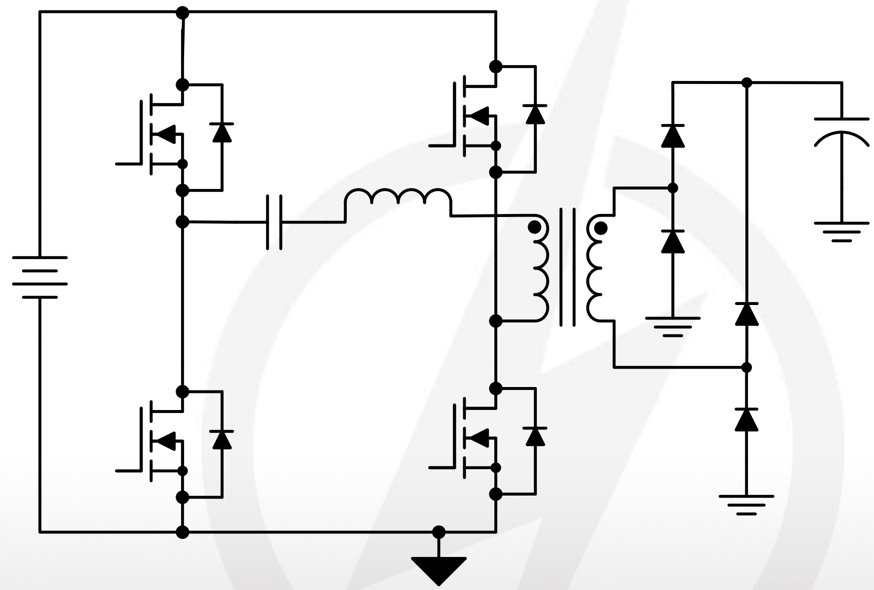


Single winding used for secondary, splitting the current between two output inductors.

- 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 the ½ bridge LLC

Example #1: 2kW Modular Power Supply / Battery Charger

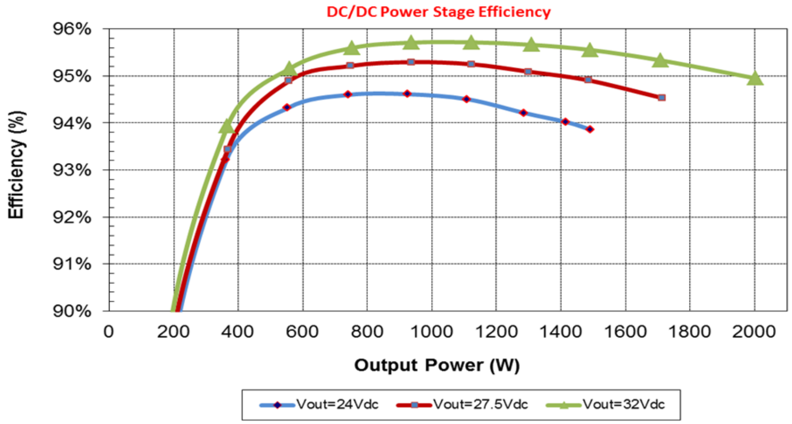
- Working AC voltage: 90 VAC…265VAC
- Output voltage: 20 V…32 V @ 62.5 A; 0 V to 32V (as charger)
- Harmonic limits: EN61000-3-2 Class A
- Output power: 2 kW
- Minimum plug-to-plug efficiency: 90% (better than “80 Plus Silver”)
- User interface: LCD display, 4 pushbuttons
- Modularity: Parallel with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

Example #1: Solution

Flyback Forward

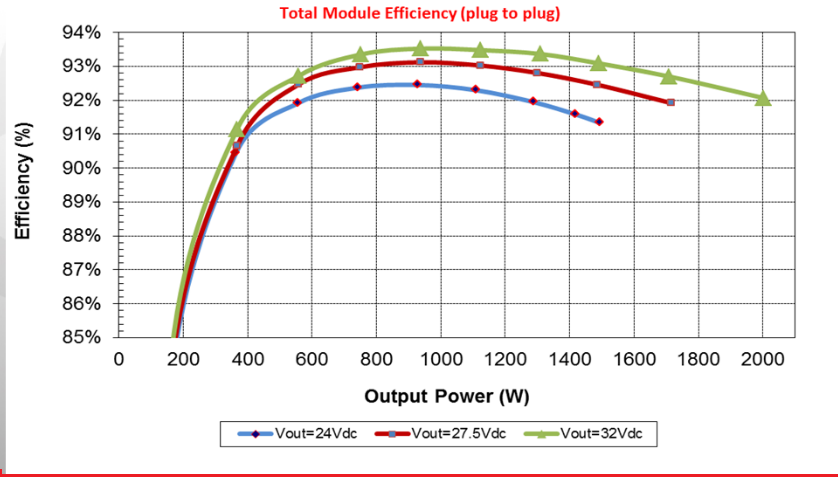
Half-bridge - LLC

- 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 "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

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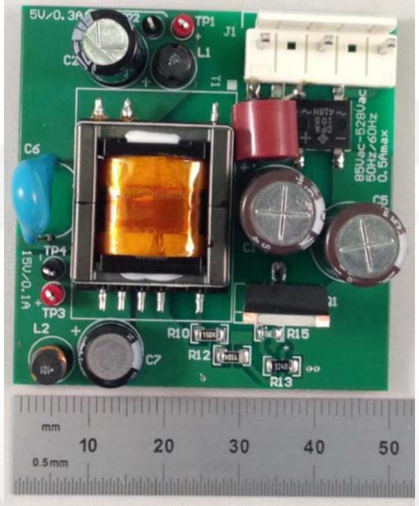
Example #2: Solution

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



$Iout_{5V}$ (A)	$Iout_{15V}$ (A)	$5V_{measured}$ (V)	$15V_{measured}$ (V)
0.05	0	5.102	17.42
0.3	0.1	4.998	16.58
0.3	0	5.029	18.72
0.05	0.1	5.912	16.64

Example #3: 300W Television Power Supply

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

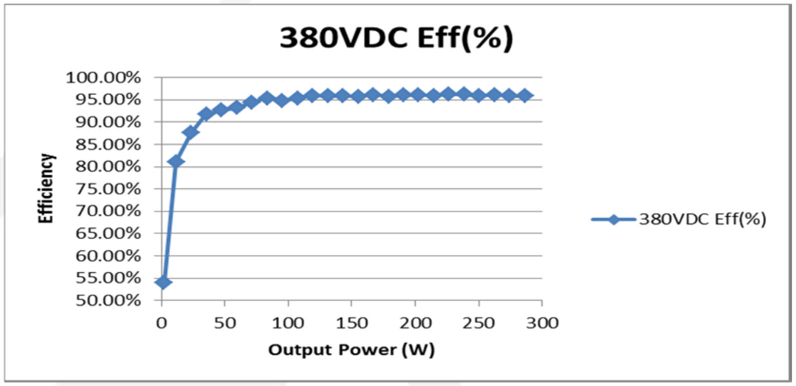
Example #3: Solution

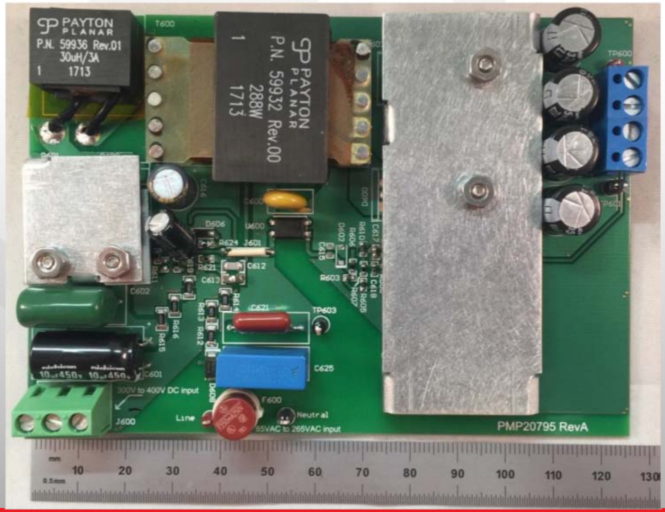
Flyback
- Transformer would be too large

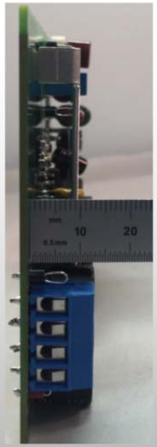
Full-Bridge
- Over-kill – too expensive

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
- http://www.ti.com/tool/PMP20795







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