Texas Instruments System Power Solution
德州仪器系统电源解决方案

Power Management

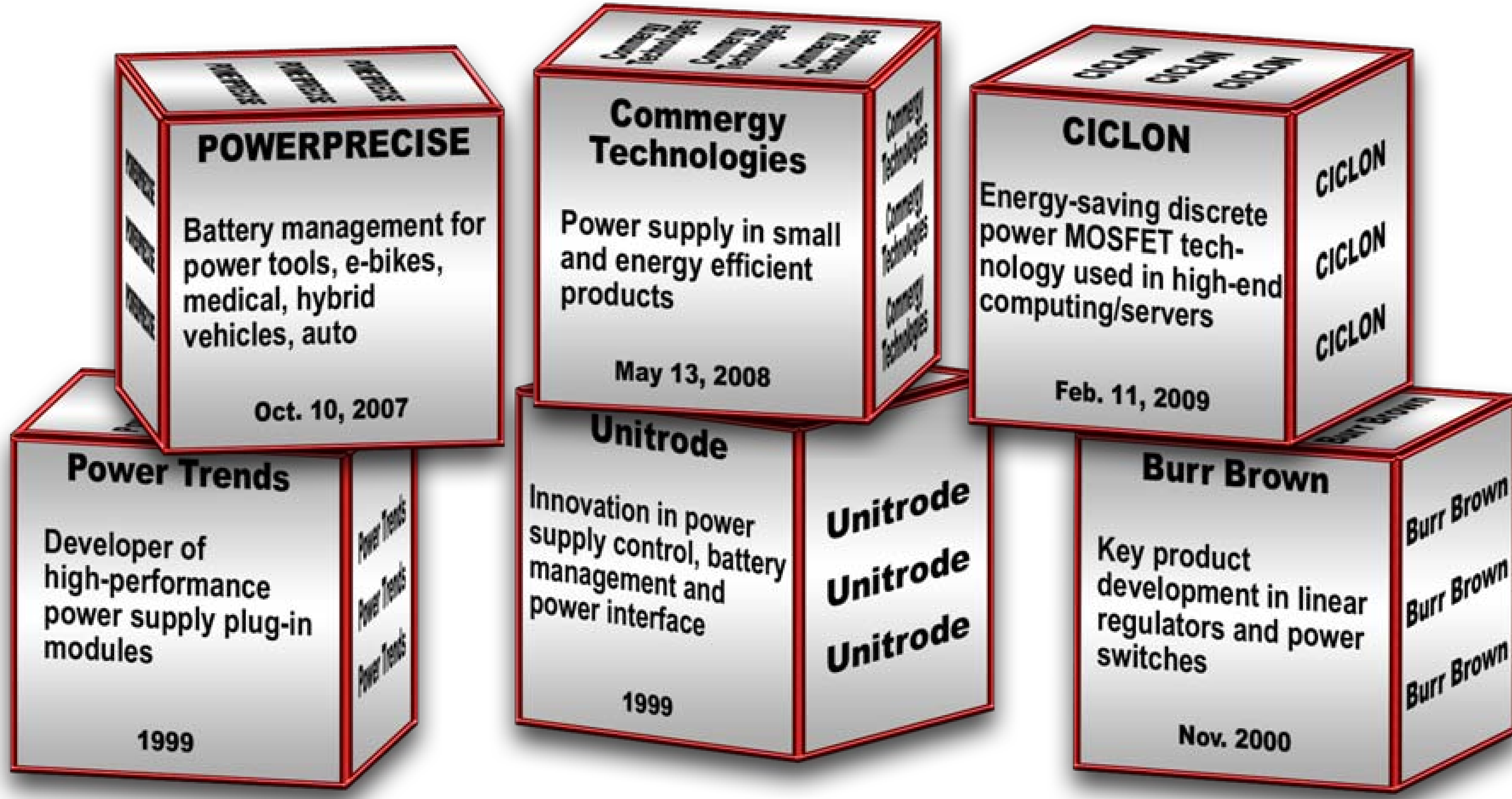
Nov 2009

Outline

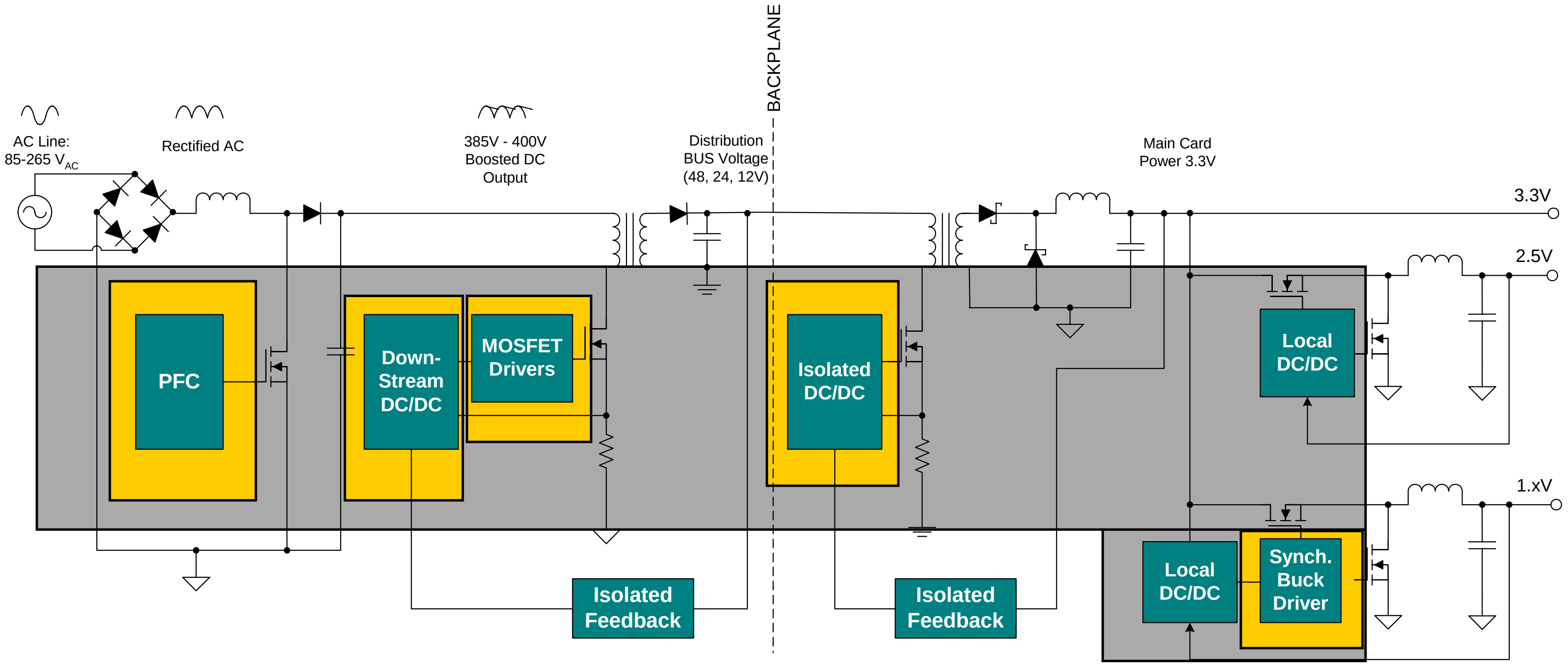
- TI Power Management Focus
- TI System Power Supply Update (PFC, PWM, etc.)
- TI Design Tools

TI Power History

TI has built the leading power management business



TI Total System Power Solutions



Boost	**Flyback**	Flyback	**Synchronous Buck**	**MOSFET**
Interleaved Boost	Forward	**Forward**	Boost	Ciclon MOSFET
Flyback	2-switch Forward	2-switch Forward	Multiphase Sync Bucks	
	Half-Bridge	Push-Pull	Push-Pull	
	Phase-Shifted Full-Bridge	Half-Bridge		
	Resonant Mode	Phase-Shifted Full-Bridge		

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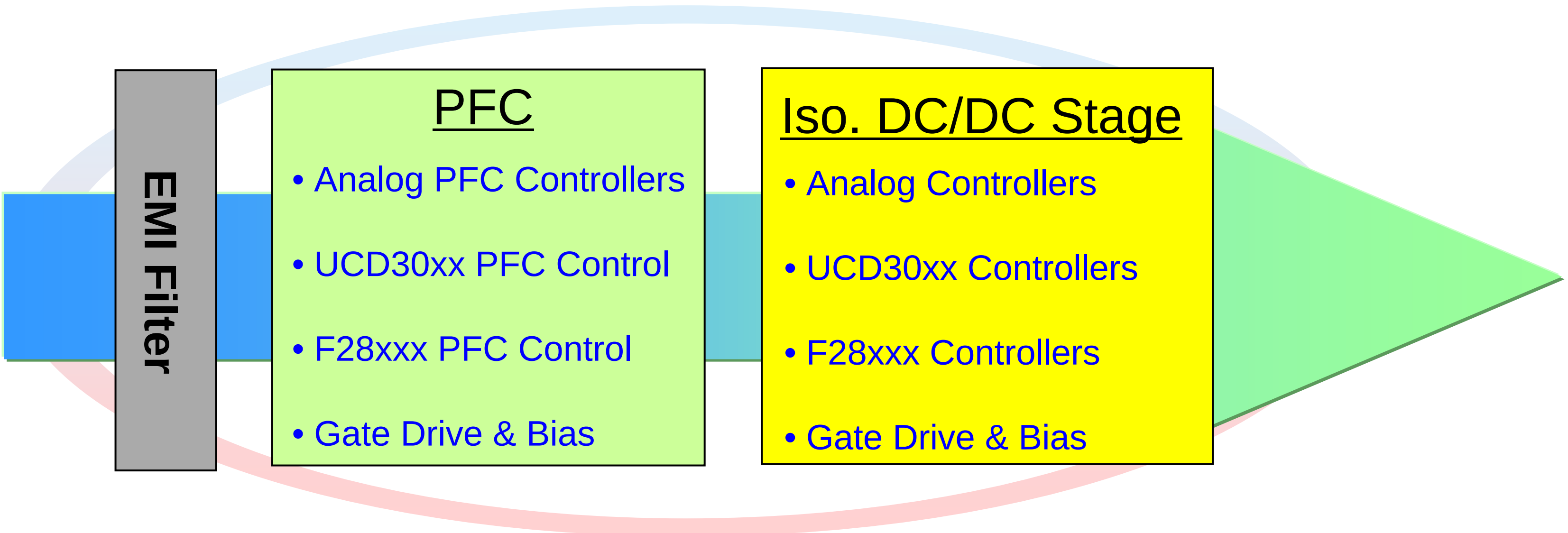
Complete System Power Solutions from TI

UCCxxxx – **High Performance Analog Solutions**

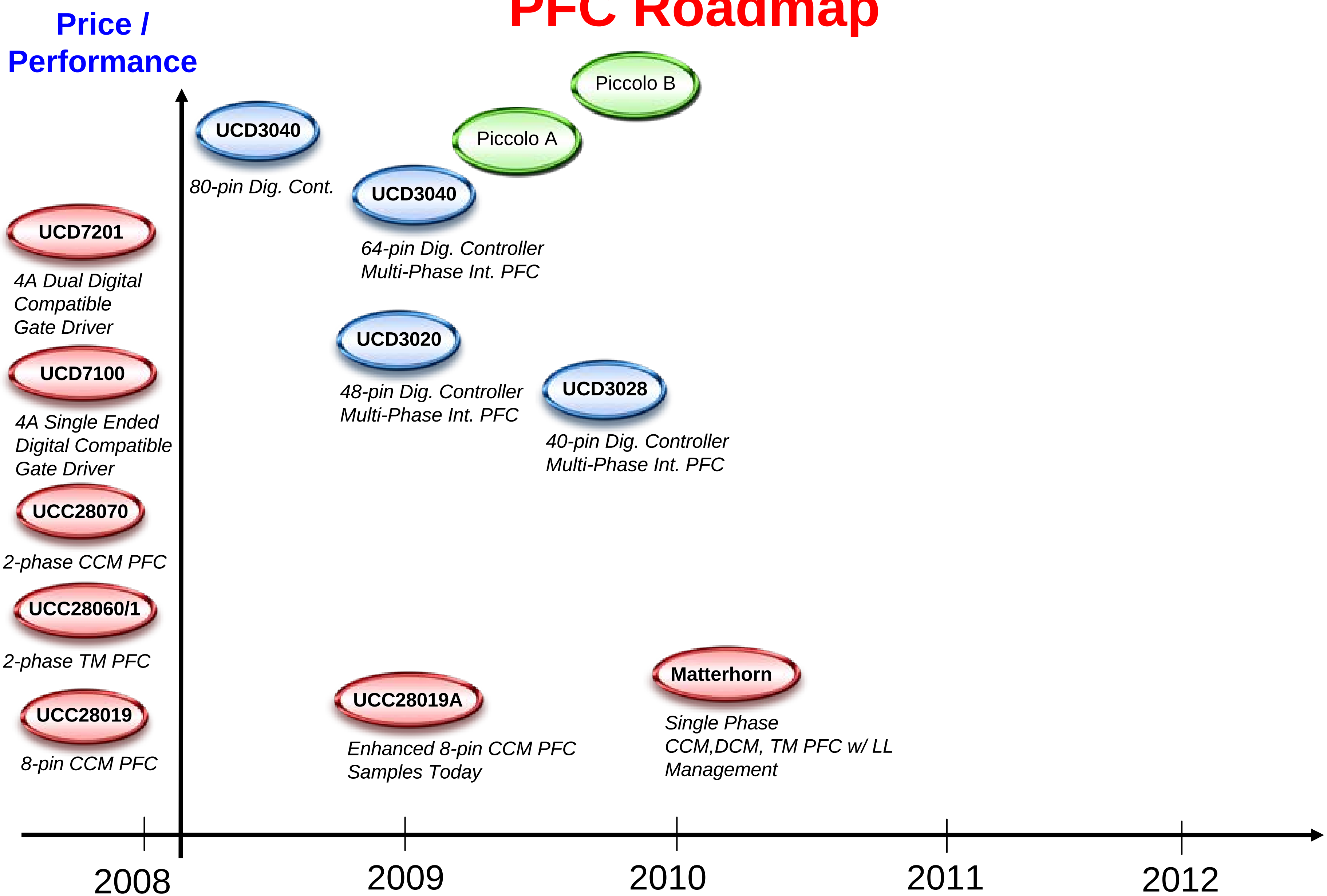
UCD30xx – **Power-Optimized Digital Controllers**

F28xxx – **Fully Programmable Digital Controllers**



TI Solutions Cover the Spectrum of Power Applications

PFC Roadmap



Price /
Performance
UCD3040
80-pin Dig. Cont.
Piccolo B
Piccolo A
UCD3040
64-pin Dig. Controller
Multi-Phase Int. PFC
UCD7201
4A Dual Digital
Compatible
Gate Driver
UCD3020
48-pin Dig. Controller
Multi-Phase Int. PFC
UCD3028
40-pin Dig. Controller
Multi-Phase Int. PFC
UCD7100
4A Single Ended
Digital Compatible
Gate Driver
UCC28070
2-phase CCM PFC
UCC28060/1
2-phase TM PFC
UCC28019
8-pin CCM PFC
UCC28019A
Enhanced 8-pin CCM PFC
Samples Today
Matterhorn
Single Phase
CCM,DCM, TM PFC w/ LL
Management
2008
2009
2010
2011
2012

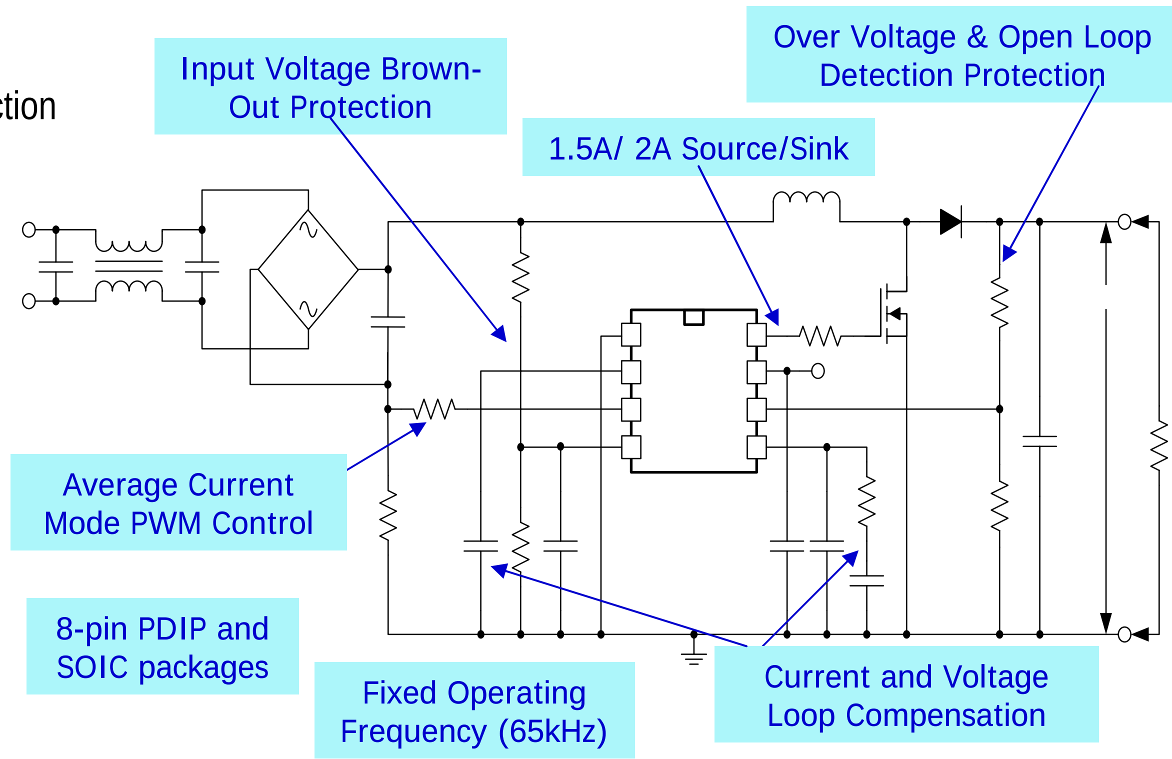
UCC28019A 8-Pin CCM (ACM) PFC Controller

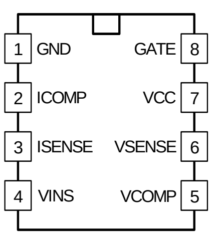
Features

- Complete 8-pin Power Factor Solution using Few External Components
- Average Current Mode PWM Control
- External Current and Voltage Loop Compensation
- Fixed Operating Frequency (65kHz)
- Cycle-by-Cycle Peak Current Limiting
- VCC Under-Voltage Lockout
- Open Loop Detection; Over-Voltage Protection
- Output Under-Voltage Detection
- Input Voltage Brown-Out Protection
- Enhanced Dynamic Response
- Soft-Start to Limit Start Up Current
- 8-pin PDIP (P) and SOIC (D) packages

Applications

- Desktop and Server P/S
- LCD-TV and PDP-TV
- Hi-Power Adapters

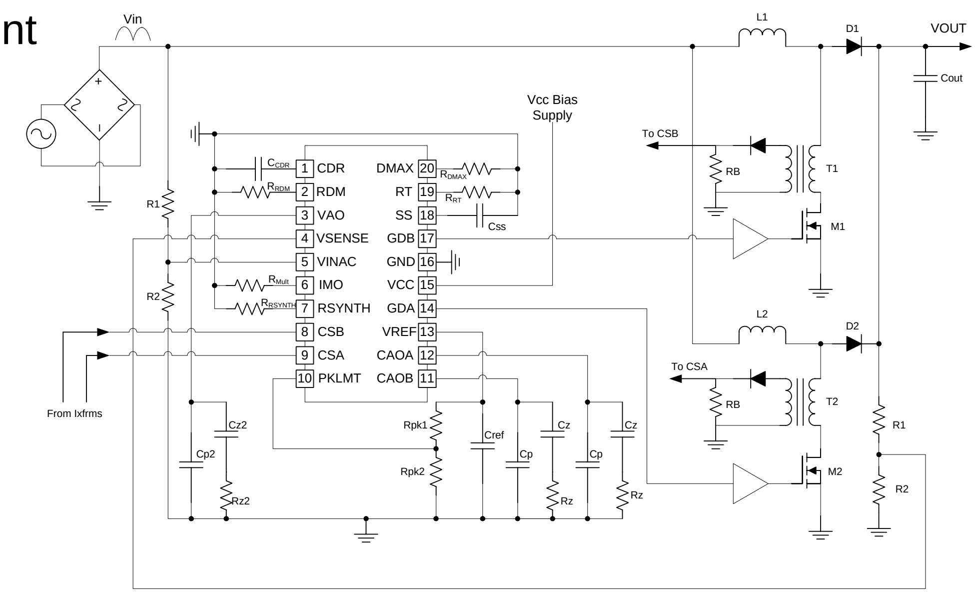




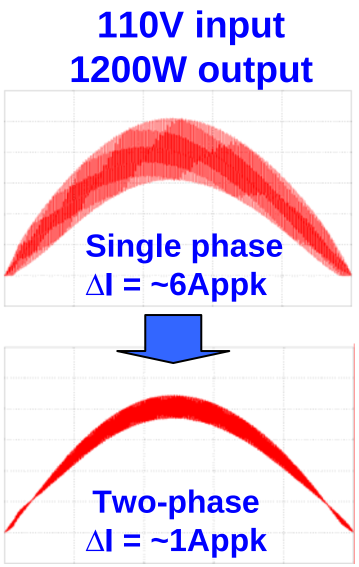
UCC28070 Interleaved-CCM PFC

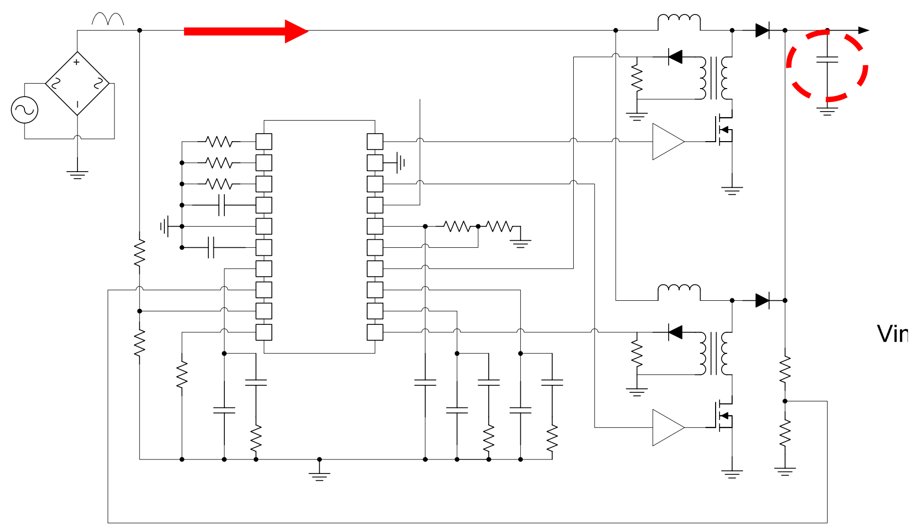
UCC28070 enables the benefits of a 2-phase interleaved CCM architecture and more in a single-chip Power Factor Correction (PFC) IC solution

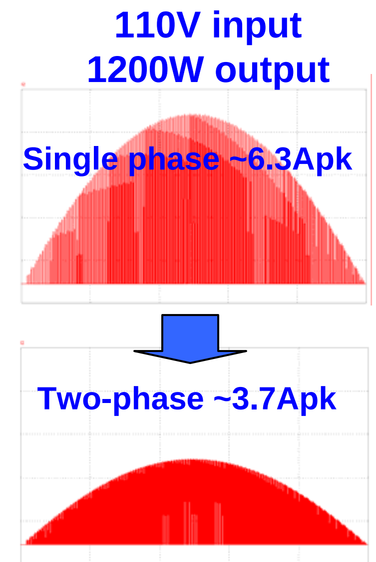
- Current ripple cancellation on input filter and reduction on output capacitor
- Current Synthesis eliminates 2 current sense transformers and improves efficiency
- Frequency dithering reduces EMI
- Improved transient response
- Complete system-level protection
  - IC protection
    - Under-Voltage Lockout
    - Thermal Shutdown
  - Output protection (non-latched)
    - Soft-Start
    - Over-Voltage
    - Open-Loop
    - Peak Current Limit
    - Power Limit

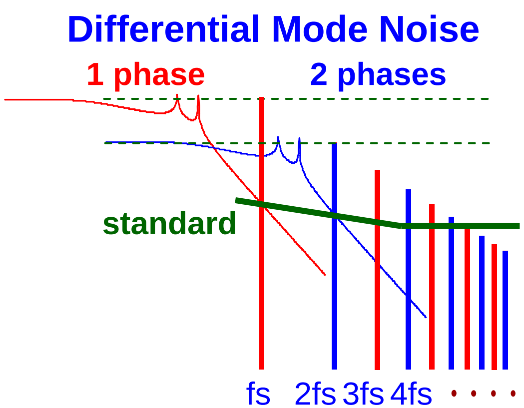


UCC28070 180° Interleaved-PFC Benefits

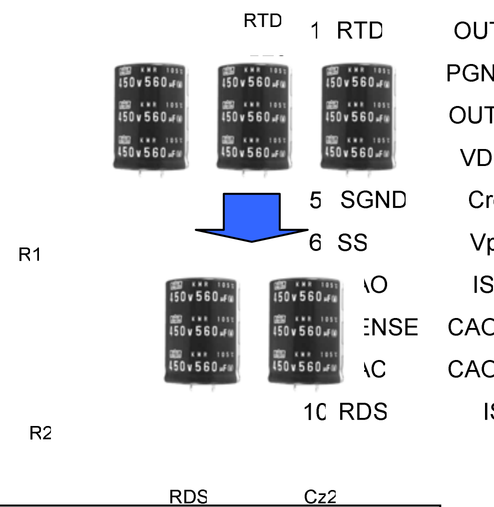




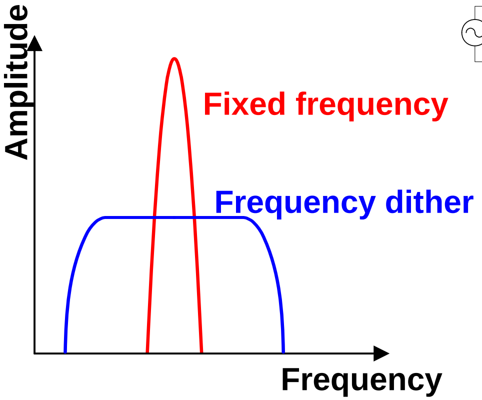


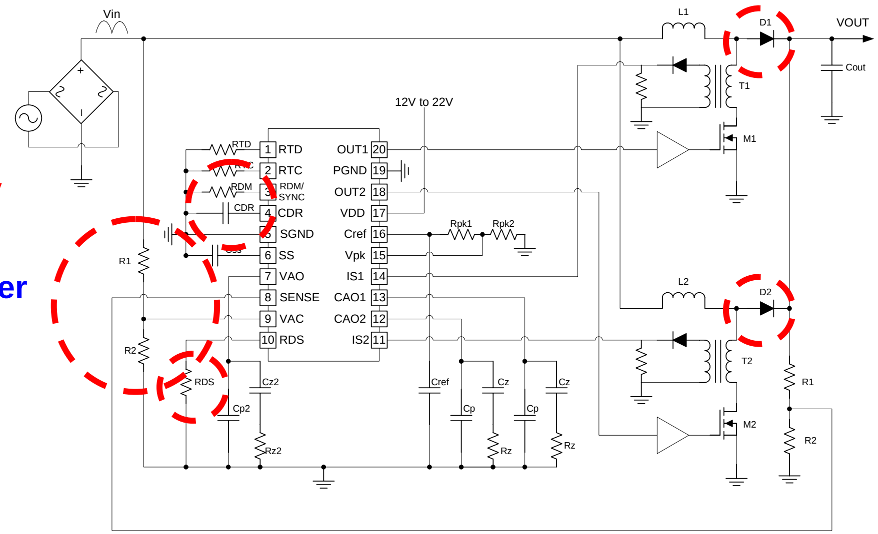


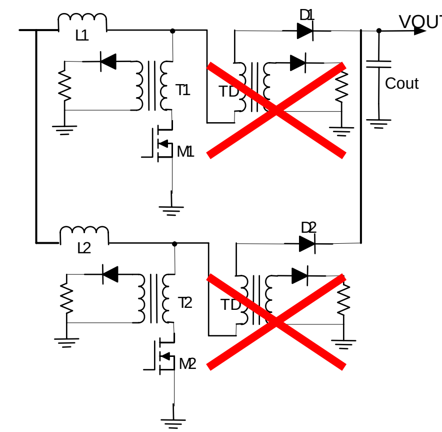
- Cancellation Effects by Interleaving reduces input current ripple dramatically.
- Reduced ripple allows smaller EMi filter design.
- Interleaving also reduces rms current in output capacitor.
- Lower rms current allows smaller, fewer or cheaper caps and higher reliability.

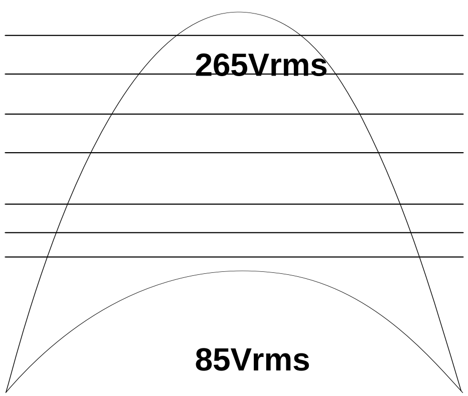


UCC28070 Innovations and Benefits

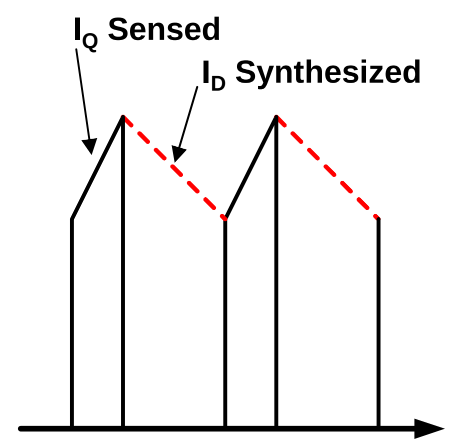




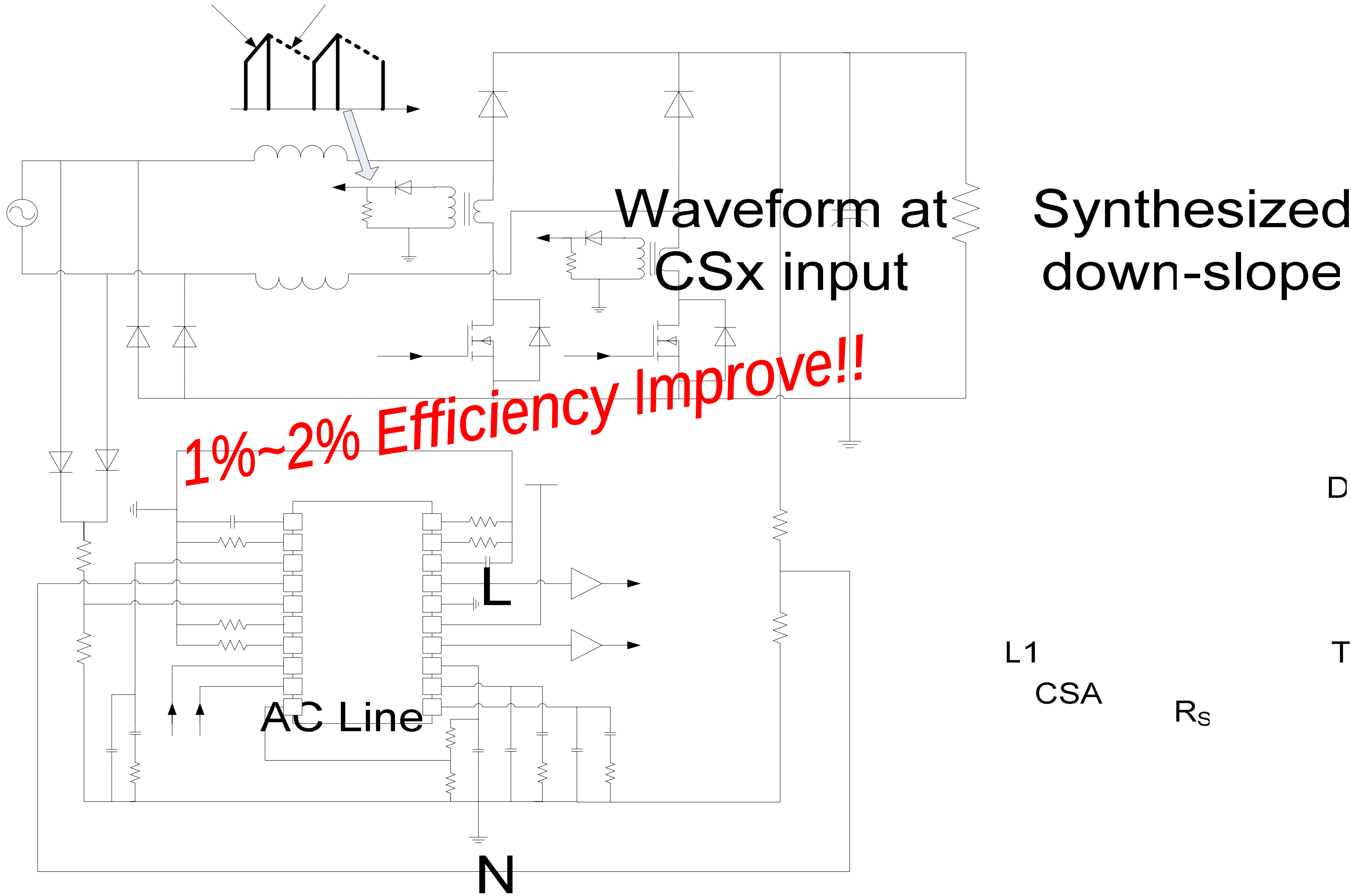




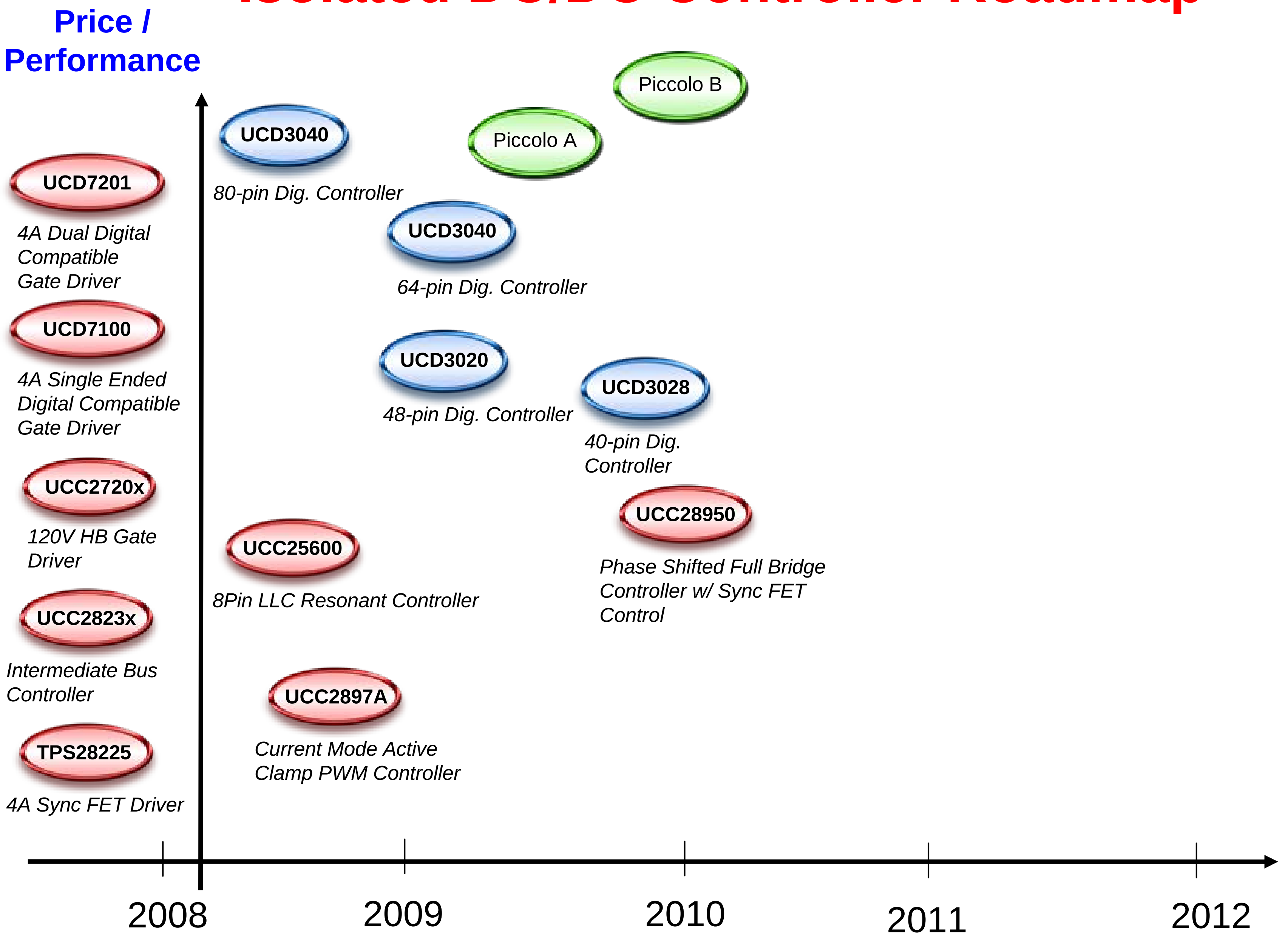
- •Frequency dithering reduces EMI peak signatures, allowing smaller filter design.
- •Discrete Vrms detection levels eliminate THD contribution and increase response to line changes with minimized gain variations.
- •Current synthesis eliminates 3 lossy resistors or 2 of 4 sense transformers.
- •Higher efficiency, smaller volume, less complexity, lower cost.



UCC28070 Implement Bridgeless PFC



Isolated DC/DC Controller Roadmap



Texas Instruments

TI UCC25600
8 Pin Resonant Half Bridge Controller

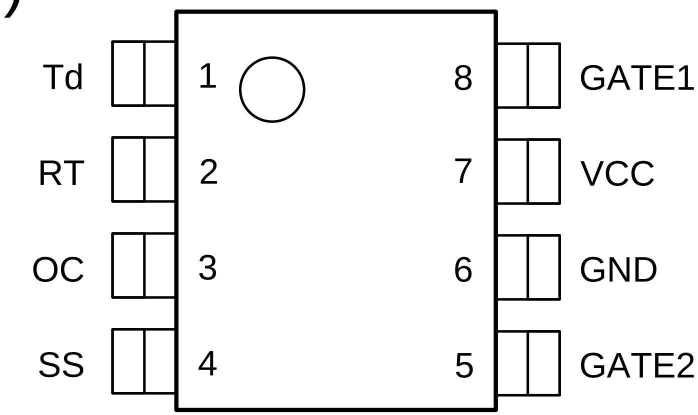
Features

- Adjustable Soft start (1ms to 500ms)
- Adjustable dead time
- Adjustable F_{swmax} & F_{swmin} (3% accuracy)
- Io = +1A /-1.5A
- Enable (ON/OFF control)

Protection functions

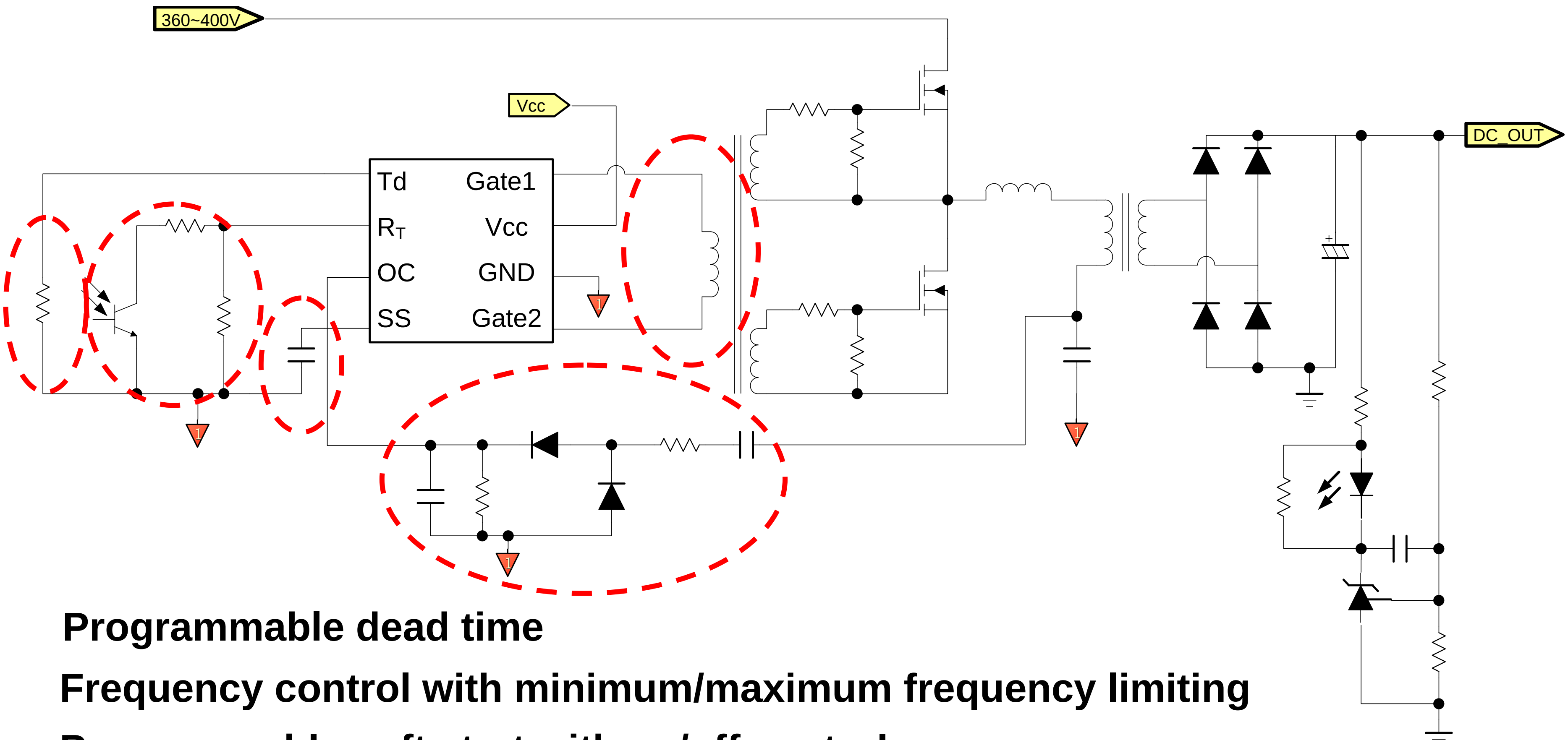
- Two levels over current protection
  - auto recovery
  - latch
- Bias voltage UV and OV protection
- Over temperature protection
- Soft start after all fault conditions

SOT 8 pin package= Easy design and layout



Ready to Order

Application Circuit



Programmable dead time

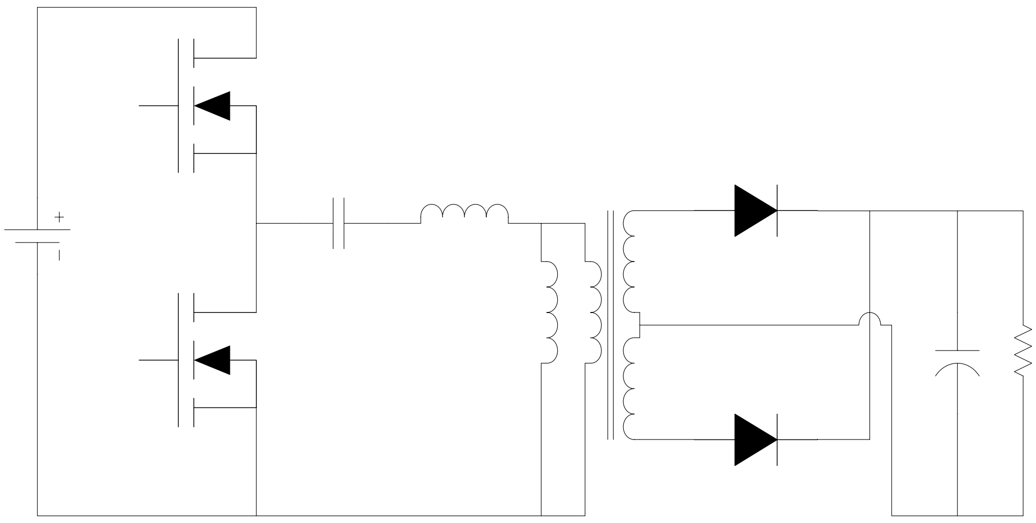
Frequency control with minimum/maximum frequency limiting

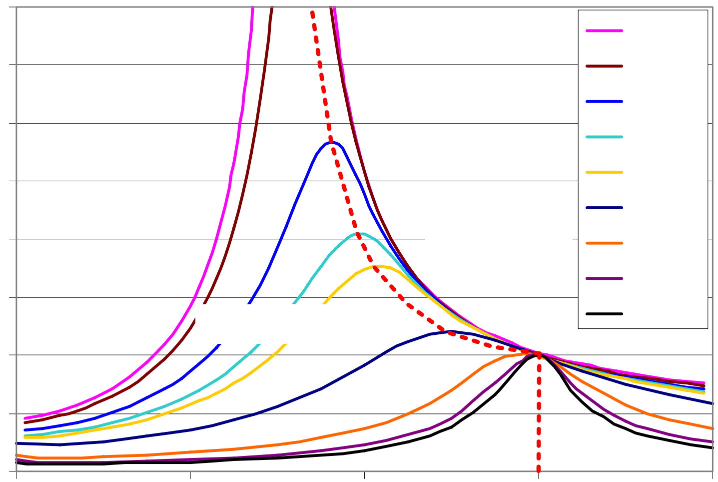
Programmable soft start with on/off control

Two level over current protection, auto-recovery and latch up

Matching output with 50ns tolerance

LLC Resonant Converter with Wide Operation Range





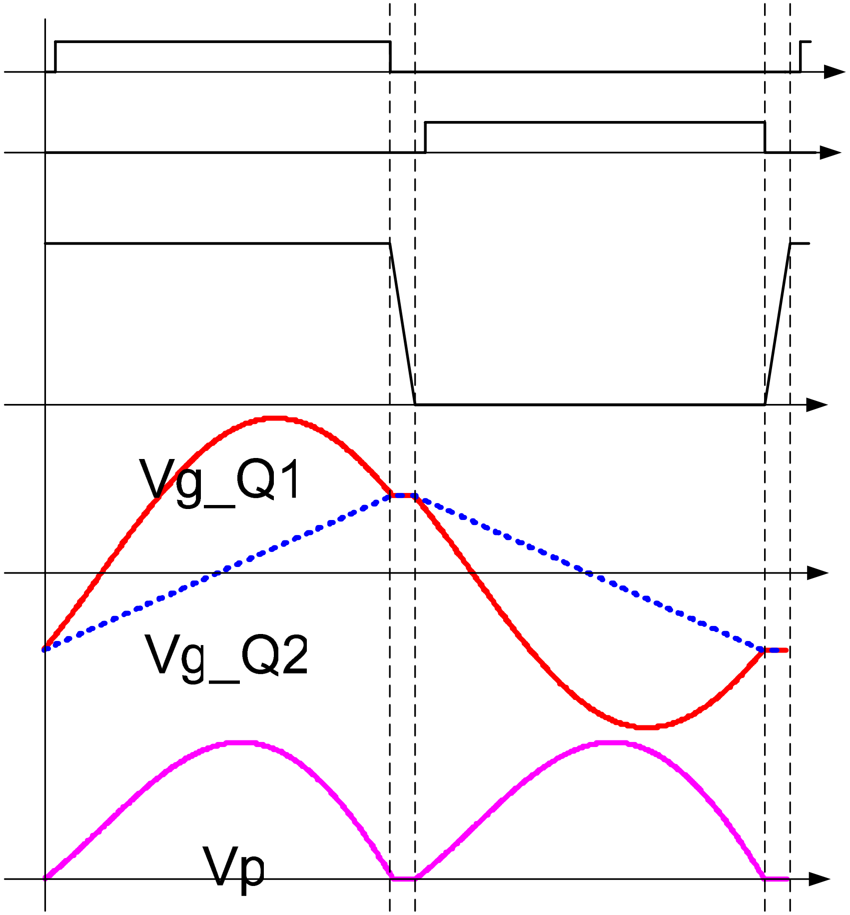
Resonant frequency $$f_0 = \frac{1}{2\pi\sqrt{L_r C_r}}$$

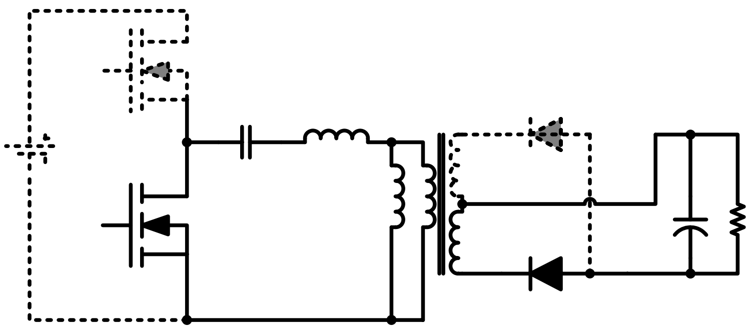
Transformer turns-ratio $$n = \frac{V_{in}/2}{V_o}$$

- **At 400V input, switching frequency is resonant frequency**
- **During holdup time, switching frequency is reduced**

Operation Principles

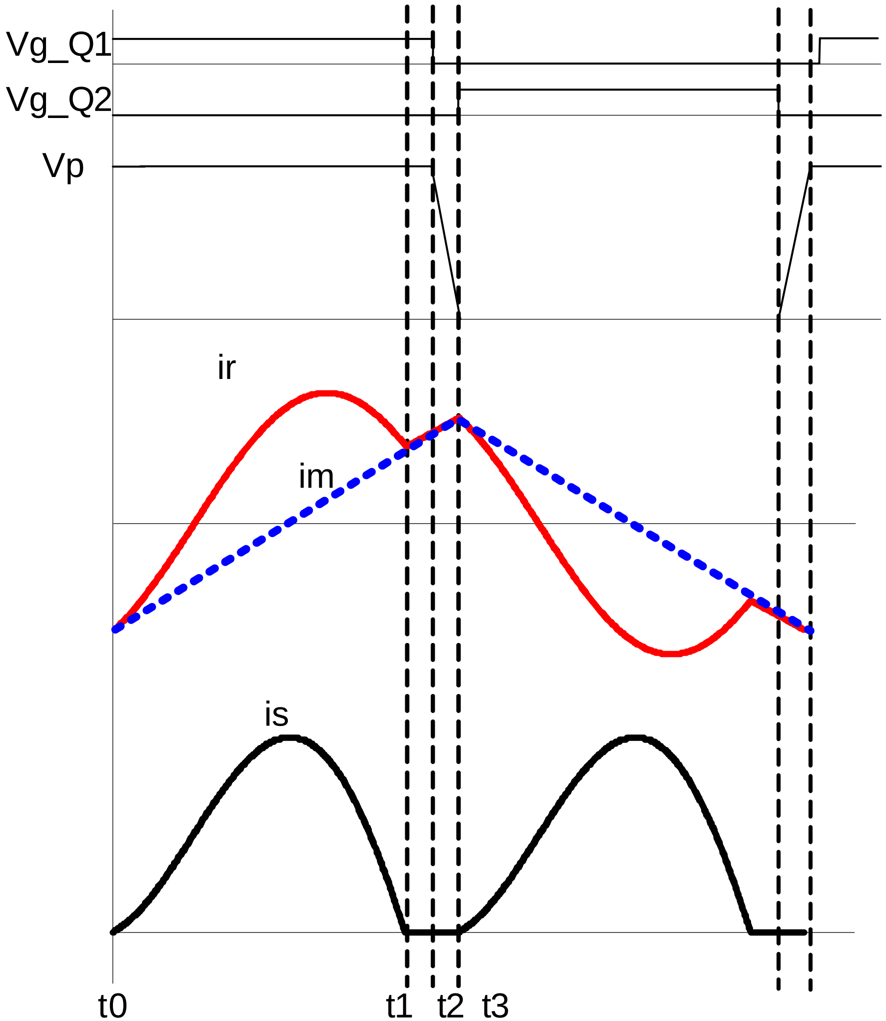
At Resonant Frequency

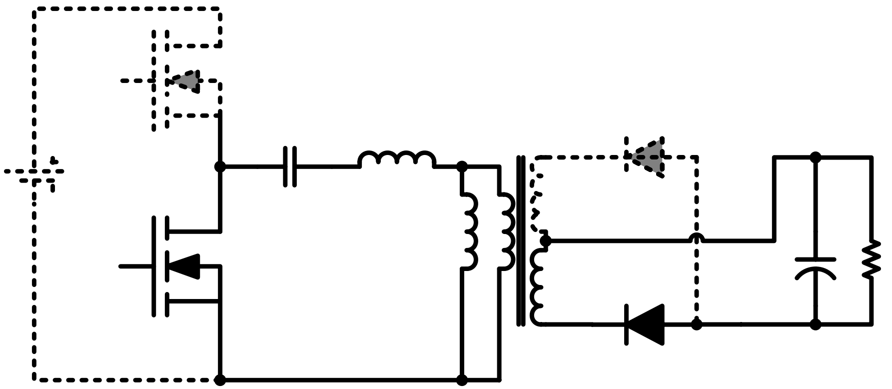




➢At resonant frequency, maximum efficiency is expected

Operation Principle
Below Resonant Frequency

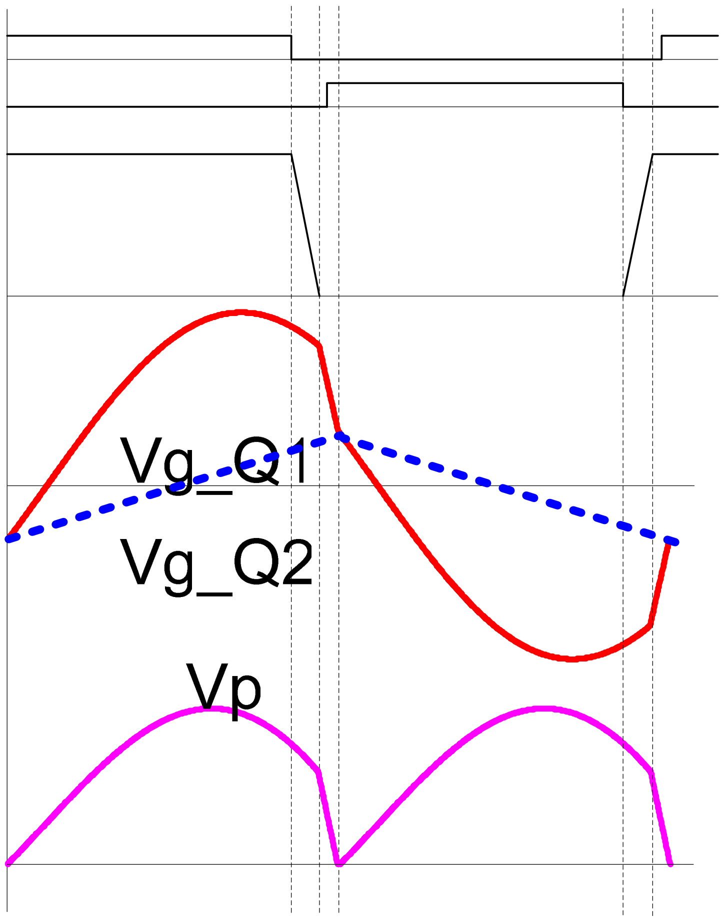


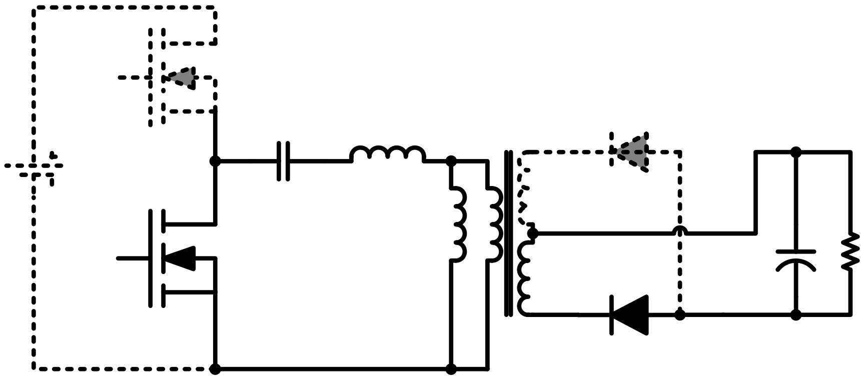


- When switching frequency is below resonant frequency, magnetizing inductor begins to participate in resonant and increase voltage gain
- Secondary diode becomes discontinuous

Operation Principle

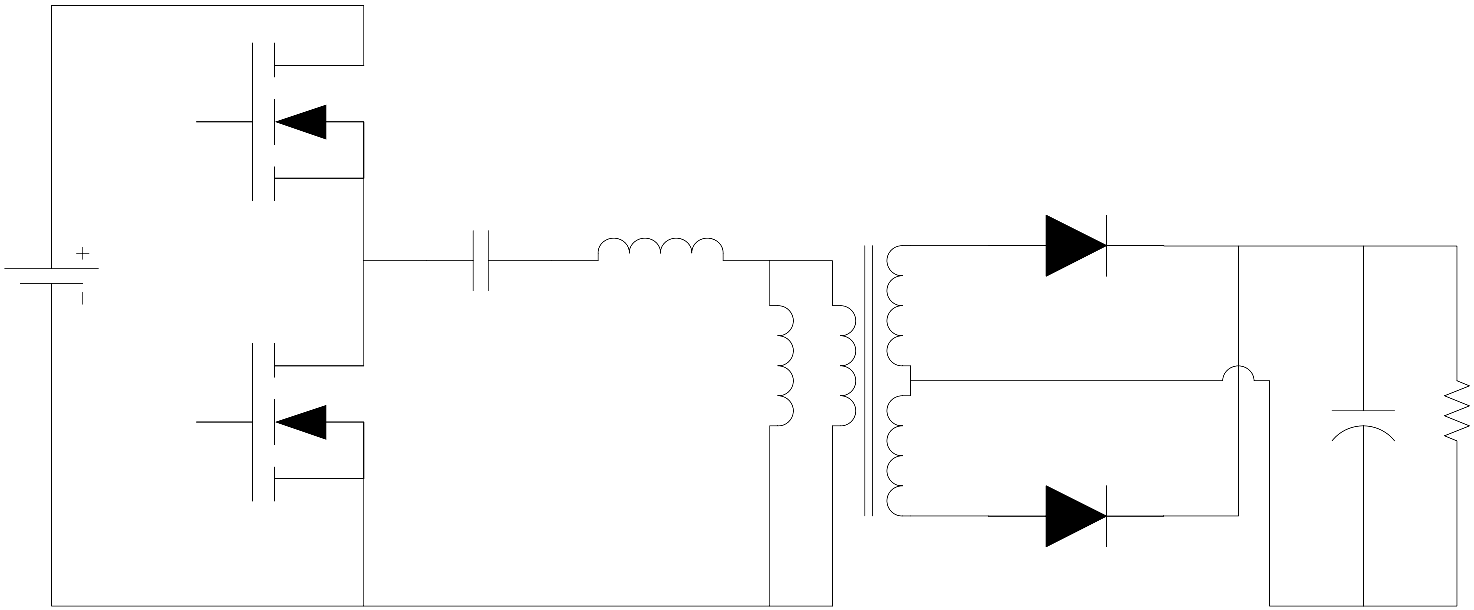
Above Resonant Frequency





- When switching frequency is above resonant frequency, circuit behaves as SRC
- Secondary current becomes CCM, reverse recovery loss increases

Benefits of LLC Resonant Converter



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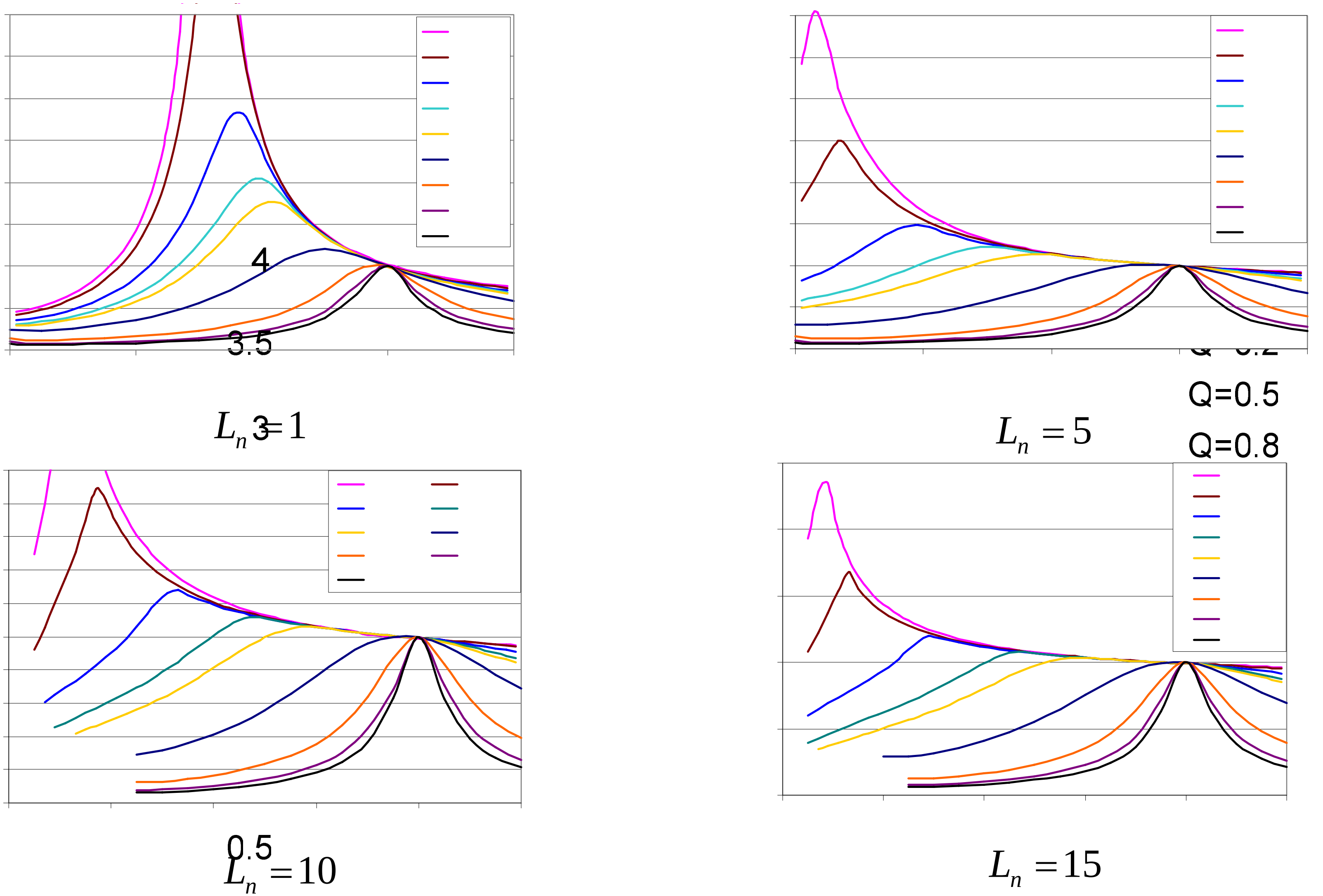
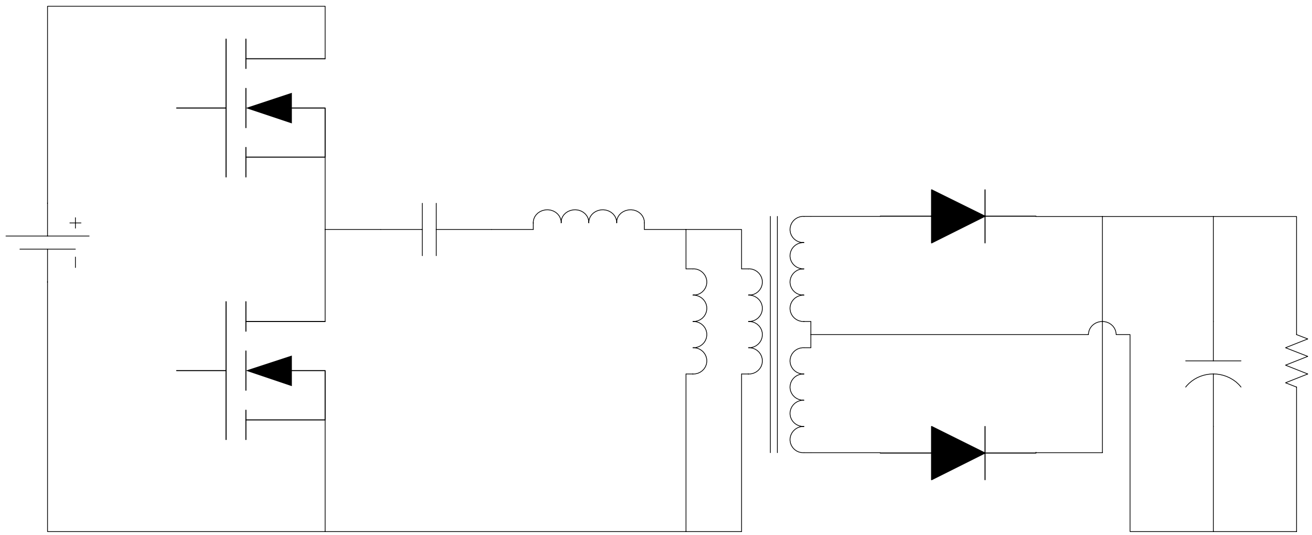
- ZVS can be achieved by utilizing transformer magnetizing inductor
- Capacitor filter, less voltage stress on rectifiers
- Smaller switching loss due to small turn off current
- Variable switching frequency control, not sensitive to load change
- Wide operation range without reducing normal operation efficiency

Impacts of Circuit Parameters



Design Goals for LLC Resonant Converter



Inductor Ratio

$$L_n = \frac{L_m}{L_r}$$

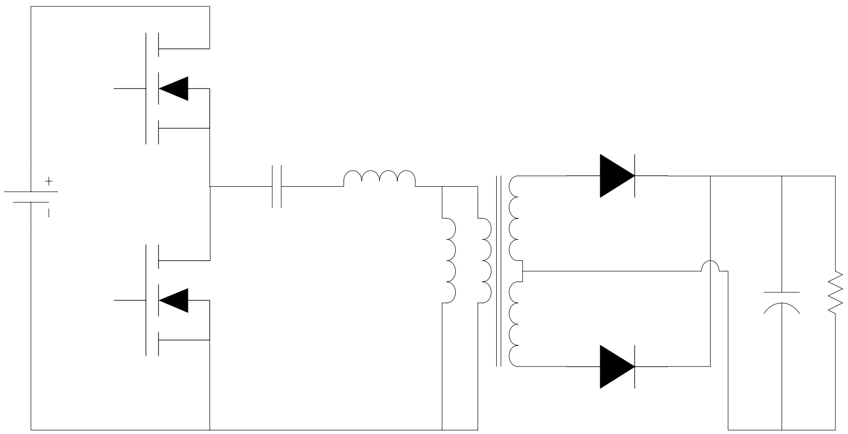
Quality factor

$$Q = \frac{\sqrt{L_r / C_r}}{n^2 R_L}$$

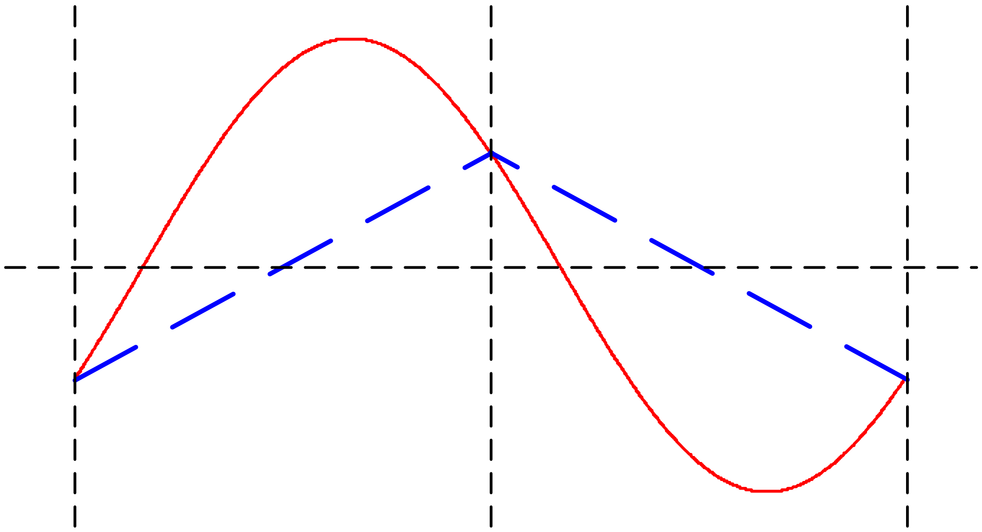
- Minimize RMS current under normal operation condition
- Ensure ZVS operation
- Ensure desired operation range

Choice of Lm

Criteria 1: Primary RMS Current at Normal Operation



$$I_{RMS\_P} = \frac{1}{4\sqrt{2}} \frac{V_O}{nR_L} \sqrt{\frac{n^4 R_L{}^2 T^2}{L_m{}^2} + 4\pi^2}$$



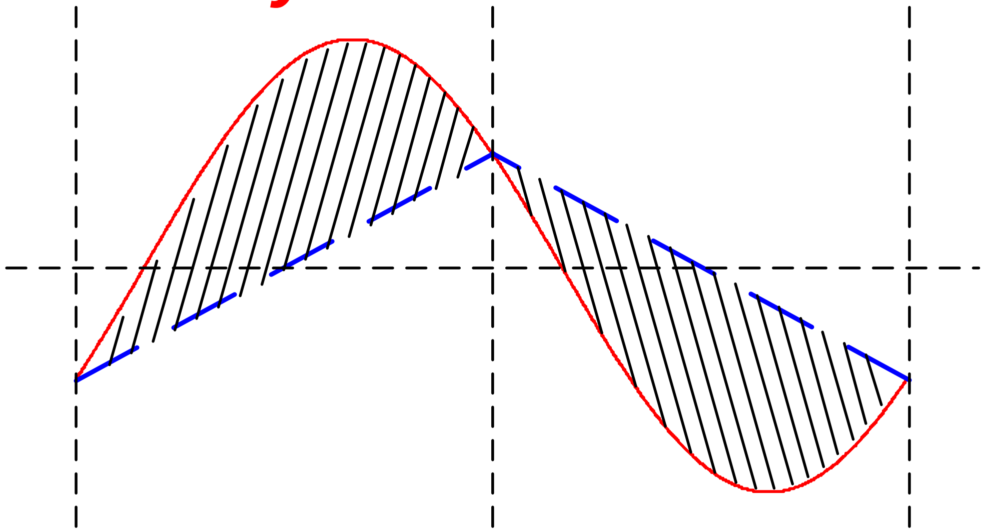
n:1:1

m

- Primary side RMS current is determined by magnetizing inductor
- Larger Lm the better

Choice of Lm

Criteria 2: Secondary RMS Current



Primary side current

$$I_{RMS\_S} = \frac{1}{4}\frac{V_O}{nR_L}\sqrt{\frac{5\pi^2 - 48}{12\pi^2}\frac{n^4 R_L{}^2 T^2}{L_m{}^2} + 1}$$

- Secondary side current is the difference between resonant tank current and magnetizing current
- Larger Lm the better

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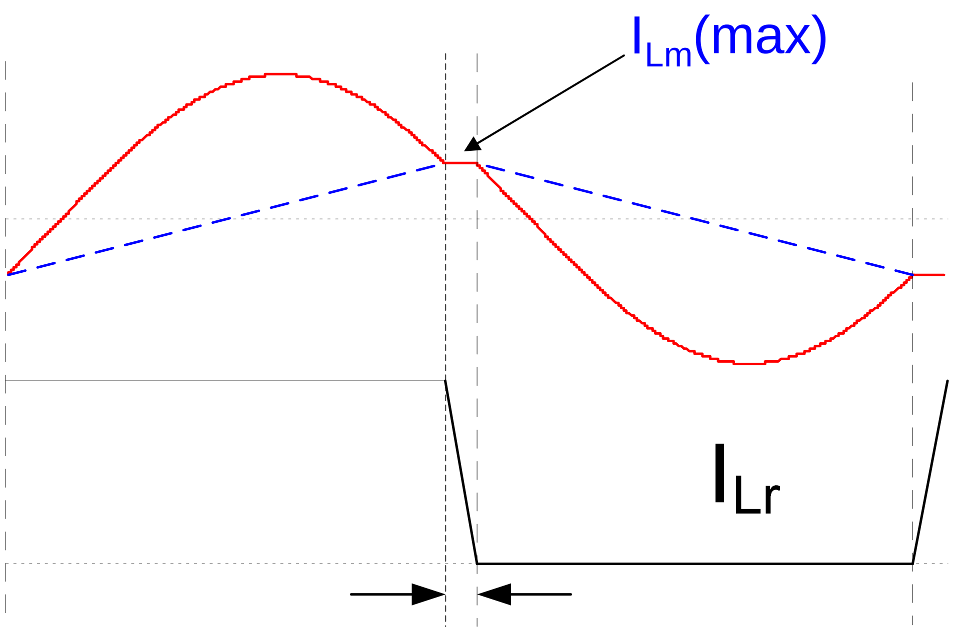
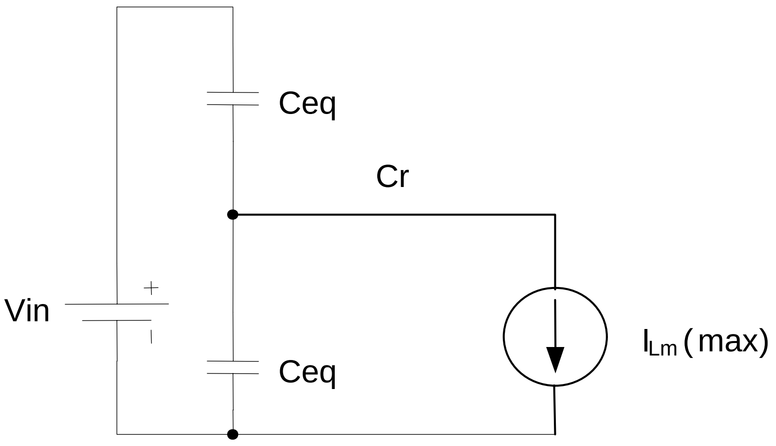
inductor curre

Choice of Lm

Criteria 3: Zero Voltage Switching





$$I_{Lm}(\max) = \frac{nV_o}{L_m}\frac{T}{4}$$

- Turn off current should be able to discharge junction caps during dead-time

$$L_m \le \frac{T \cdot t_{dead}}{16C_{eq}}$$

Trade-off Design of Dead Time

$t_{dead} \uparrow$

$L_m \uparrow$

- Smaller turn off current
- Smaller magnetizing current

- Increase RMS current due to duty cycle loss

$t_{dead} \downarrow$

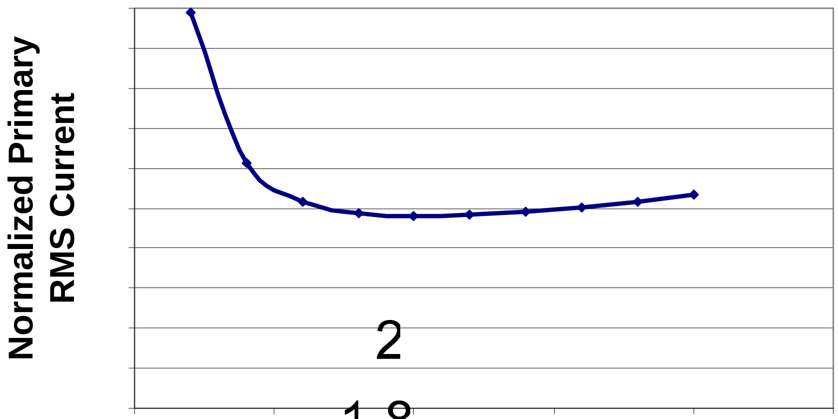
$L_m \downarrow$

- Smaller duty cycle loss

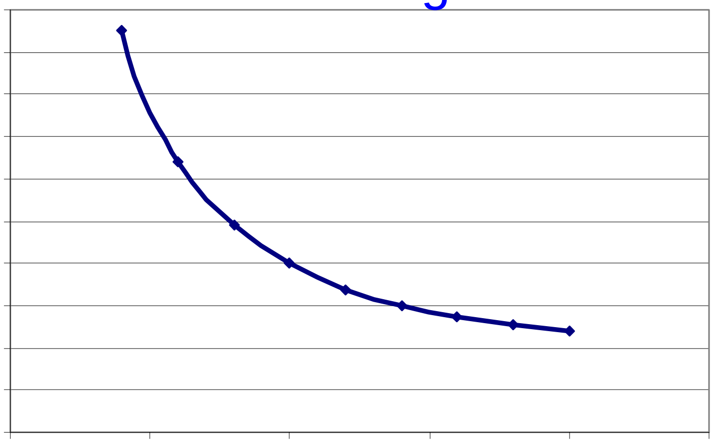
- Larger magnetizing current
- Larger turn off loss

Trade-off Design of Dead Time

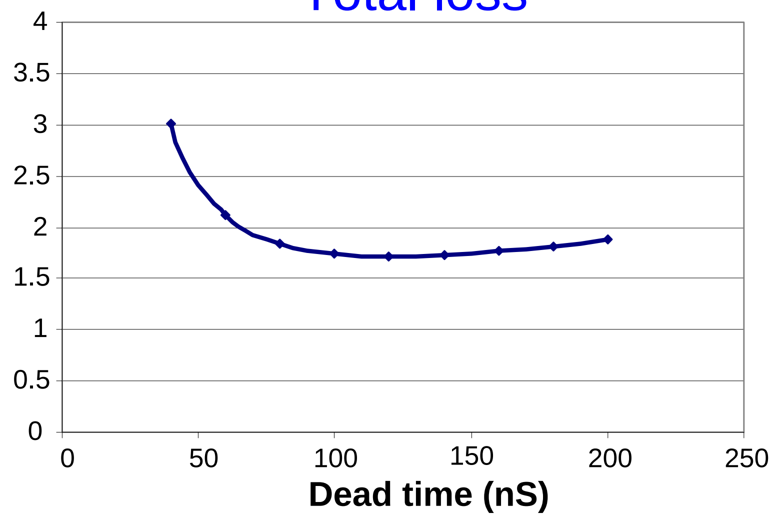
Conduction loss



Switching loss

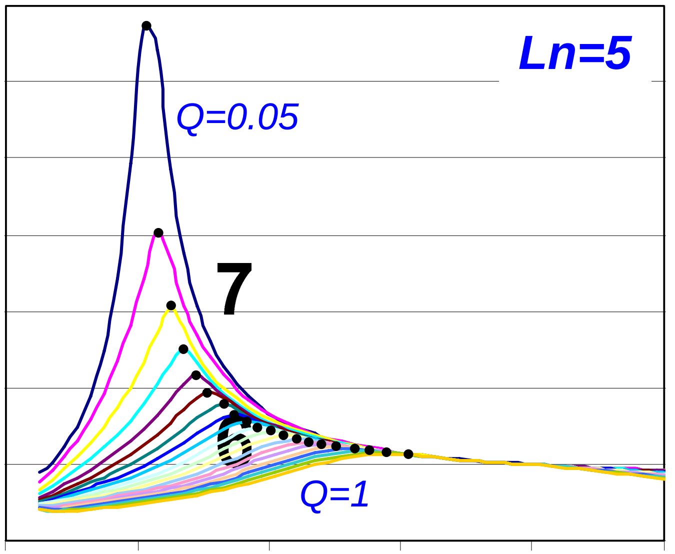


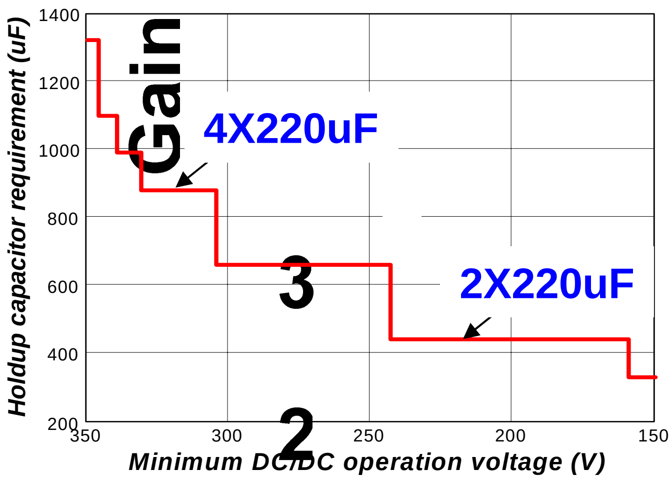
Total loss

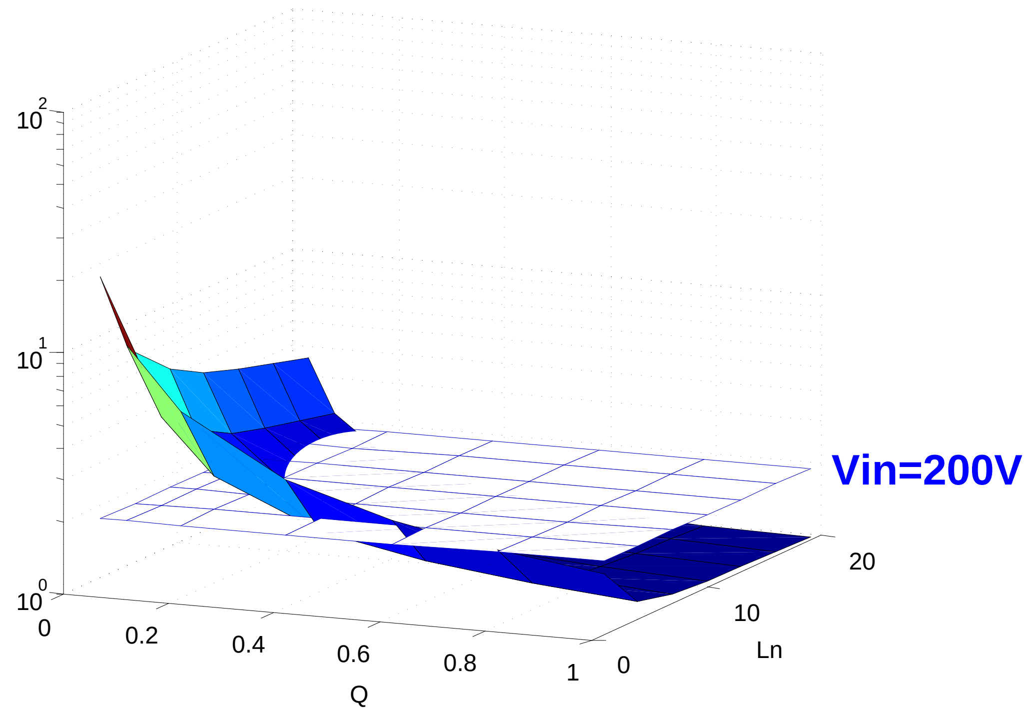


- ➢ 100nS shows the trade-off between the switching loss and conduction loss

Achievable Peak Gain for Different Ln and Q



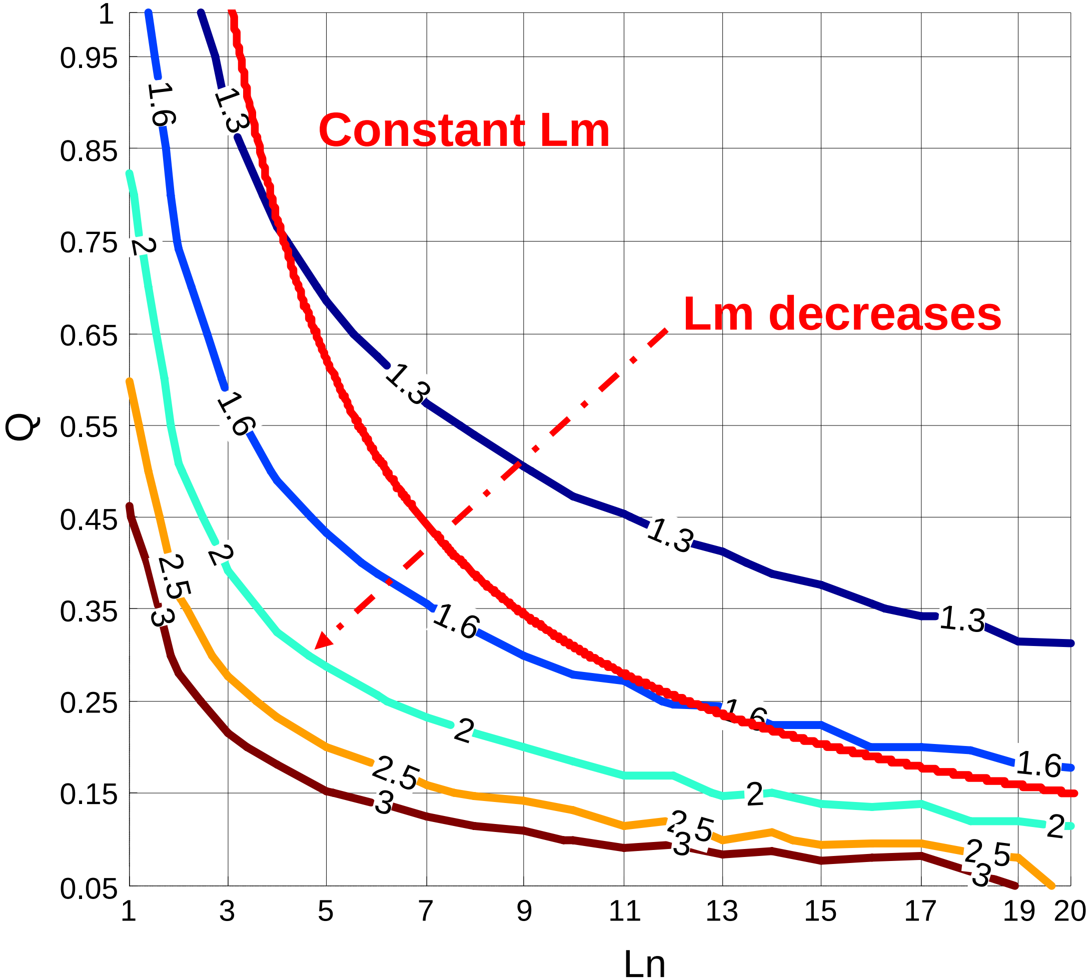




- For each Ln and Q combination, the maximum gain can be achieved is determined
- Colored surface represent the maximum gain for different Ln and Q combinations
- Only certain Ln and Q region can meet gain requirement

Gain

Peak Gains for Different Designs



$$Q = \frac{\sqrt{Lr/Cr}}{n^2 R} \qquad L_n = \frac{L_m}{L_r}$$

$$L_m = \frac{n^2 R}{2\pi f_0} L_n Q$$

- ➢ **To keep Lm constant and achieve low conduction loss and switching loss at normal operation, product of Ln and Q is expected to be constant**
- ➢ **Reduce Lm can help achieve higher peak gain**

Start Up Current Consideration

$$Ip^* = \begin{cases} \dfrac{\pi^2}{4\cdot Q} & 1 < \Omega_S \le 2 \\ \dfrac{\pi^2}{4\cdot Q}\cdot\sin(\dfrac{\pi}{\Omega_S}) & \Omega_S > 2 \end{cases}$$

$$\Omega_S = \frac{f_{s-startup}}{f_0}$$

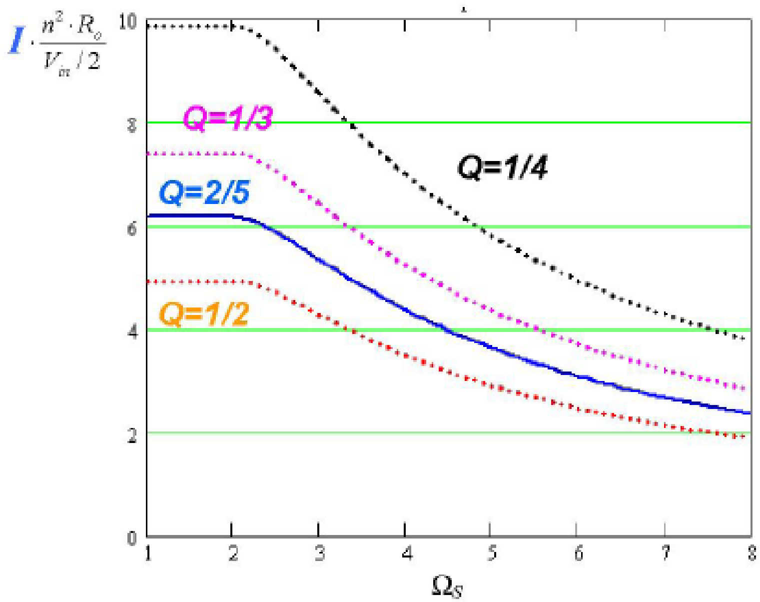


Fig.9 Normalized start-up first peak current

- Larger Q value gives smaller start up current with less frequency range

"A Novel Precise Design Method for LLC Series Resonant Converter", Teng liu, etc., INTELEC '06

Design Flow Chart for LLC Resonant Converter

Converter Specification

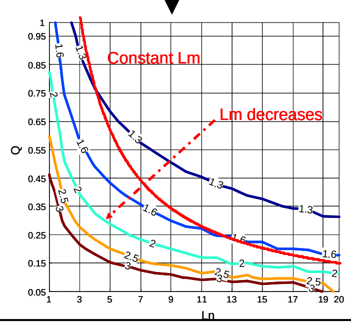
$$n = \frac{V_{in}}{2V_O}$$

Primary switching Device

$$L_m = \frac{T \cdot t_{dead}}{16C_j}$$

Magnetizing inductor

$$L_n Q = \frac{L_m}{n^2 R} 2\pi f_0$$



Peak gain enough?

No

Reduce Lm

Yes

Choose cross section of required gain and constant Lm

$$L_r = \frac{L_m}{L_n}$$

Resonant inductor

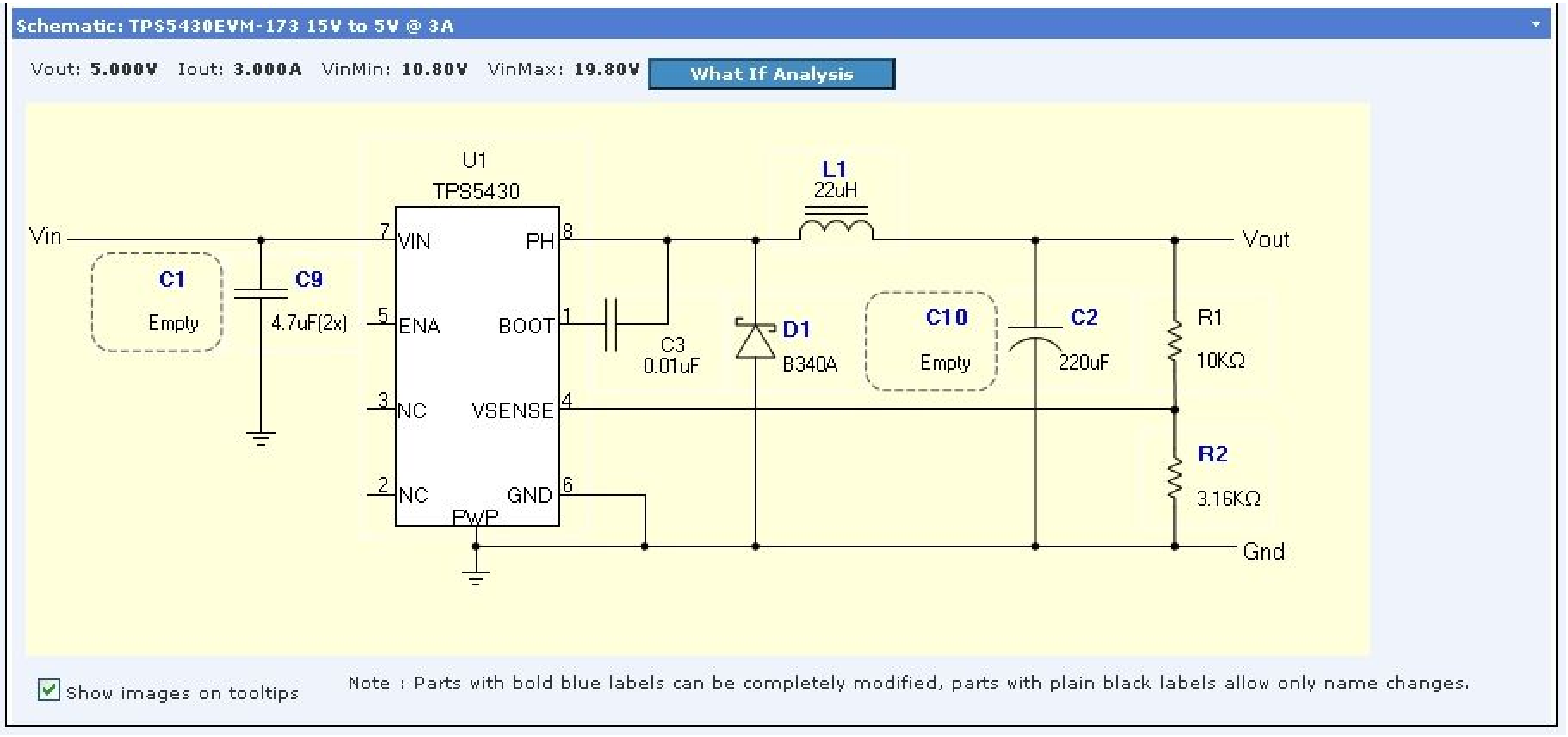
$$f_0 = \frac{1}{2\pi\sqrt{L_r C_r}}$$

Resonant capacitor

Outline

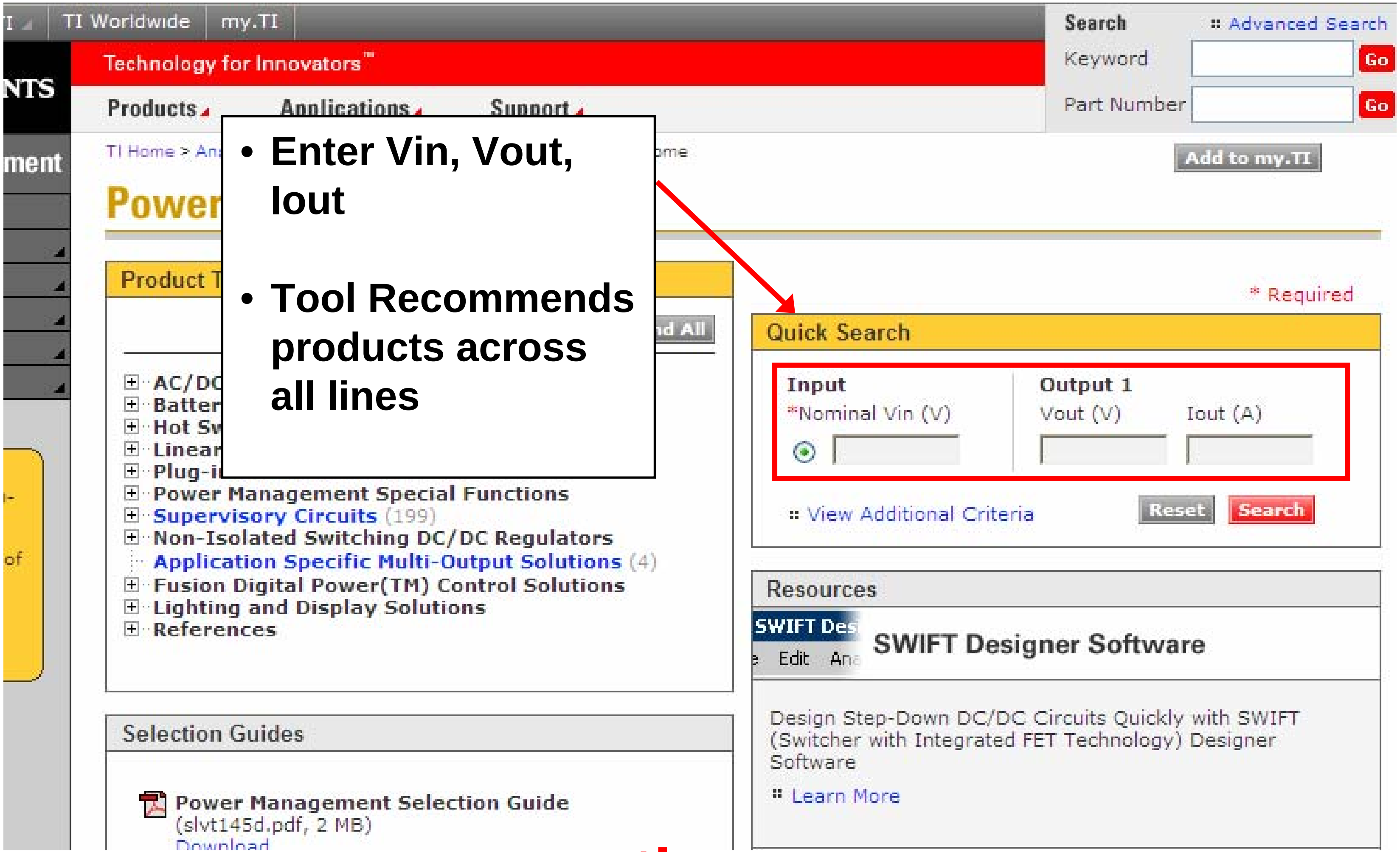
- TI Power Management Focus
- TI System Power Supply Update (PFC, PWM, etc.)
- <u>TI Design Tools</u>

Switcher Pro Design Software



On-Line Beta Version Available at www.ti.com/analogelab

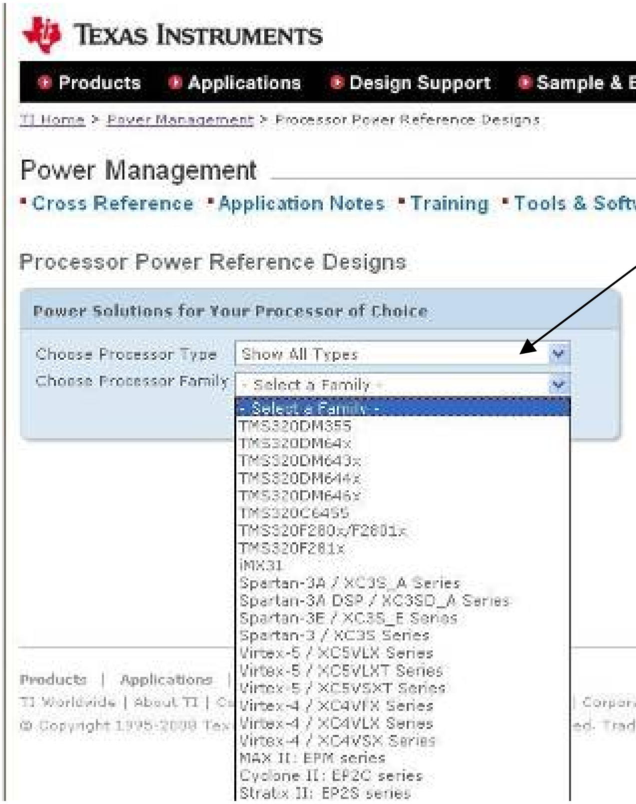
Power Quick Search Tool



- **Enter Vin, Vout, Iout**
- **Tool Recommends products across all lines**

power.ti.com

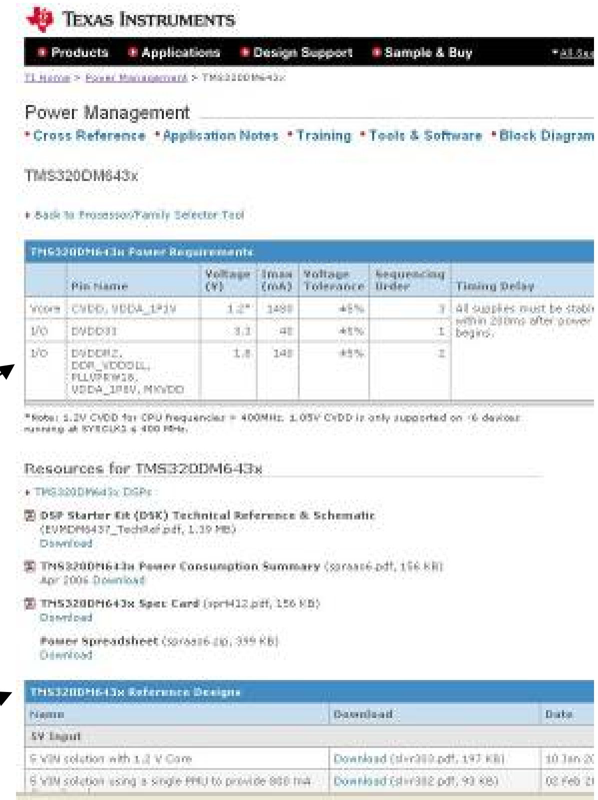
Processor Power Web Page



Many Processors Supported

Specific Details Provided

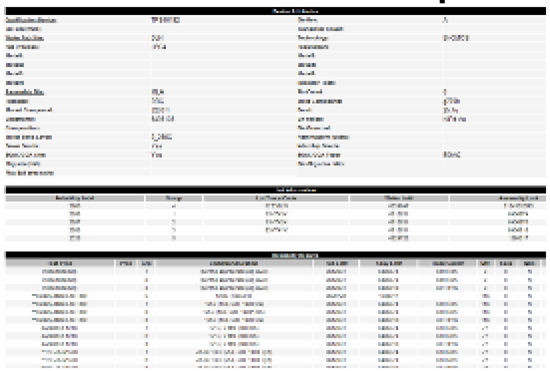
Download Reference Designs



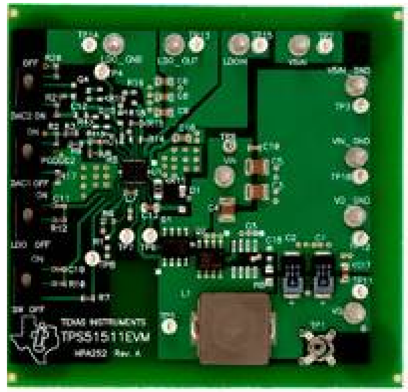
Find power requirements and reference designs at www.ti.com/processorpower

TI Power Management Service and Support

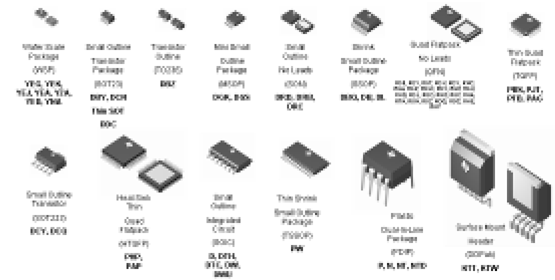
Qualification Reports and Documentation on Request



Free Samples and EVMs

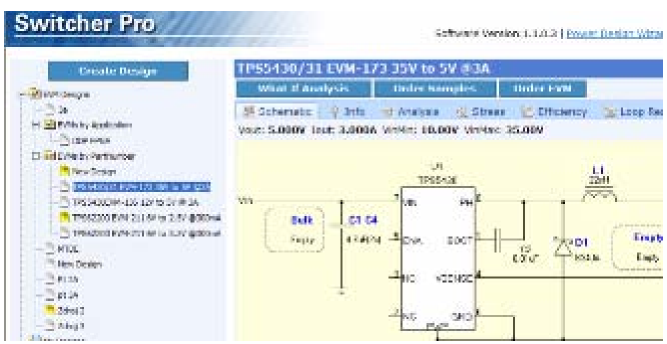


Broad Power Portfolio



Wide Sales Network

Software Tools



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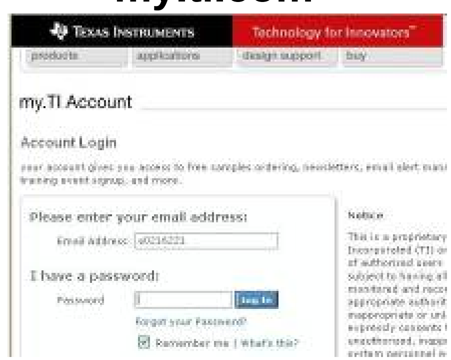
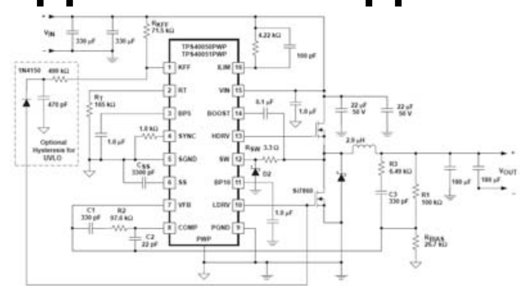
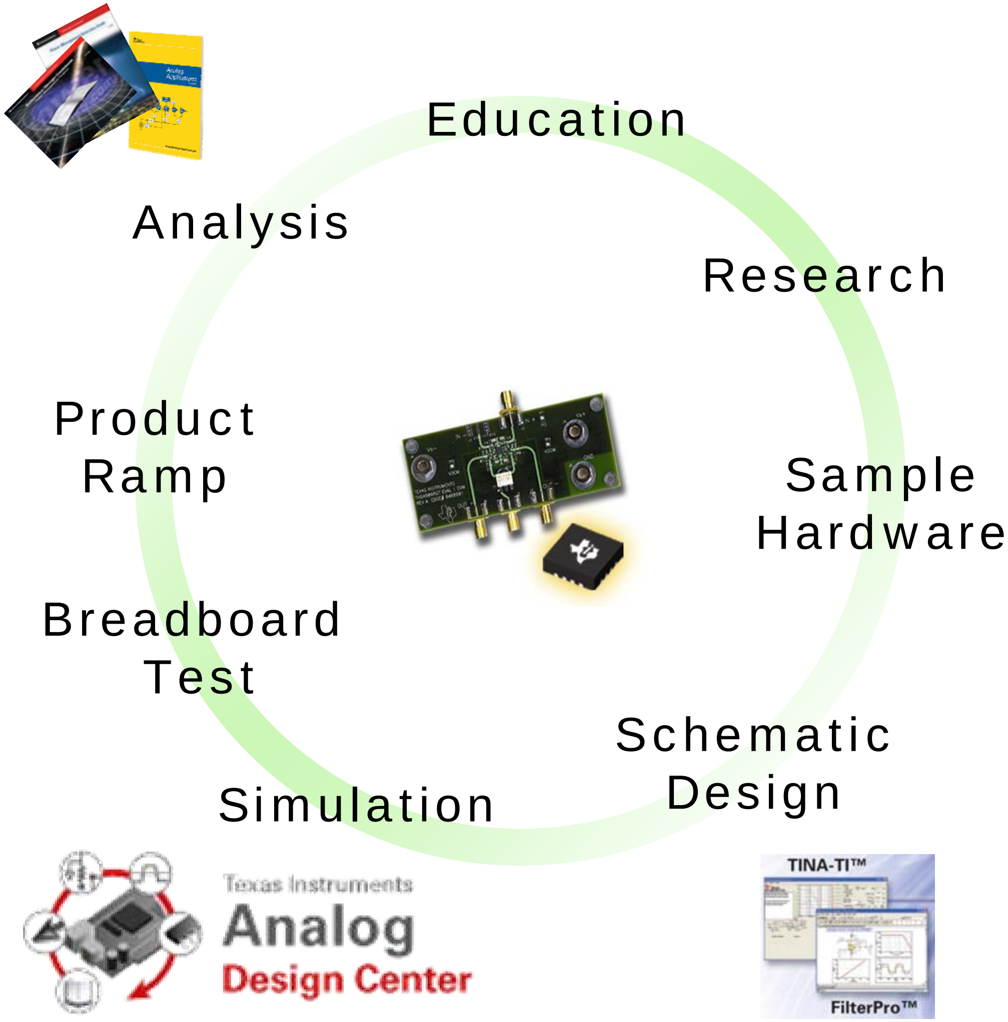


Register Today!

Applications Support



Complete Design/Product Cycle Support



- **Seminars, webcasts, collateral and design notes**
- **Selection guides, web search tools, industry brochures, application notes, datasheets, ACAT**
- **Rapid delivery samples, EVMs**
- **Reference designs, Cookbook I and II and design services, design software**
- **TINA - spice based simulation**
- **AFAs, ACAT and FAQs**
- **Distributor partners, Mfg capacity**
- **AFAs, distributor FAEs and internal support teams**

Thank You