Platinum Rated 720W AC/DC Reference Design

Universal Single Phase Input, Single Phase Output

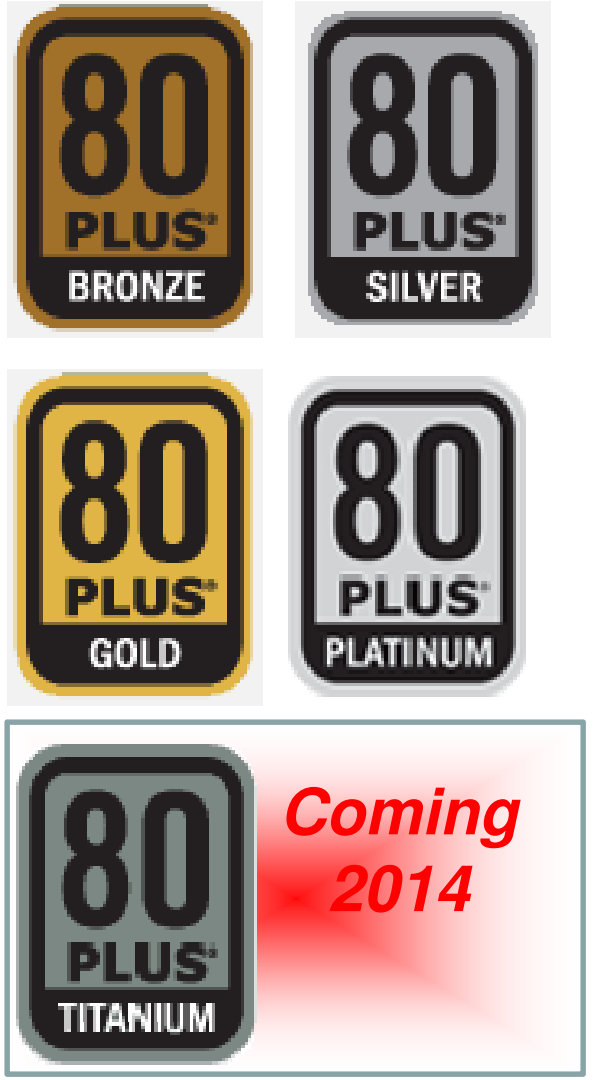
Agenda

- CSCI and ENERGY STAR Standards
- System Overview
- Hardware Information
- System Software
- Advanced Features
- Additional Resources

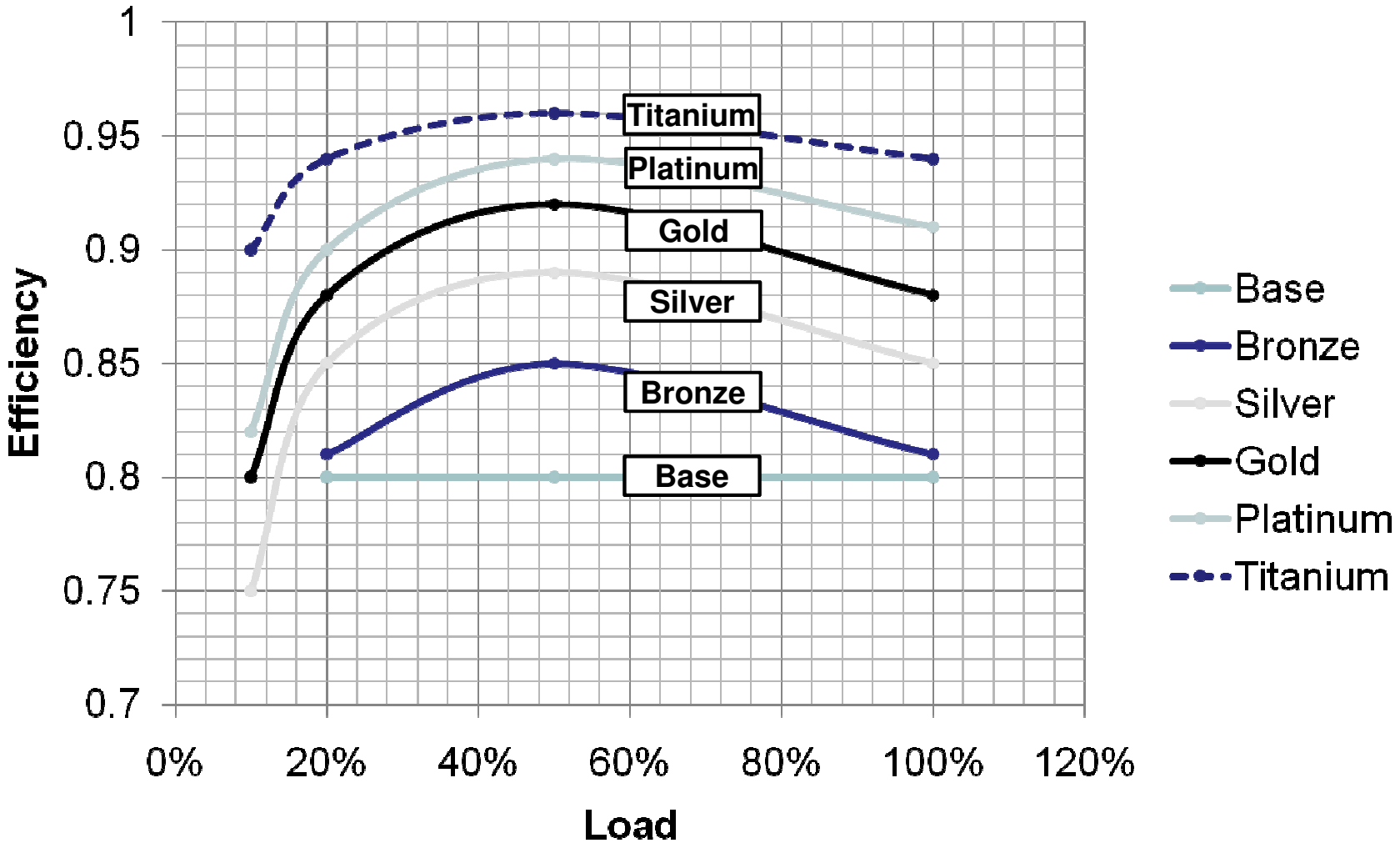
CSCI Efficiency Standards

The Climate Saving Computing Initiative (CSCI) adds Platinum Efficiency standard as part of the ENERGY STAR specifications

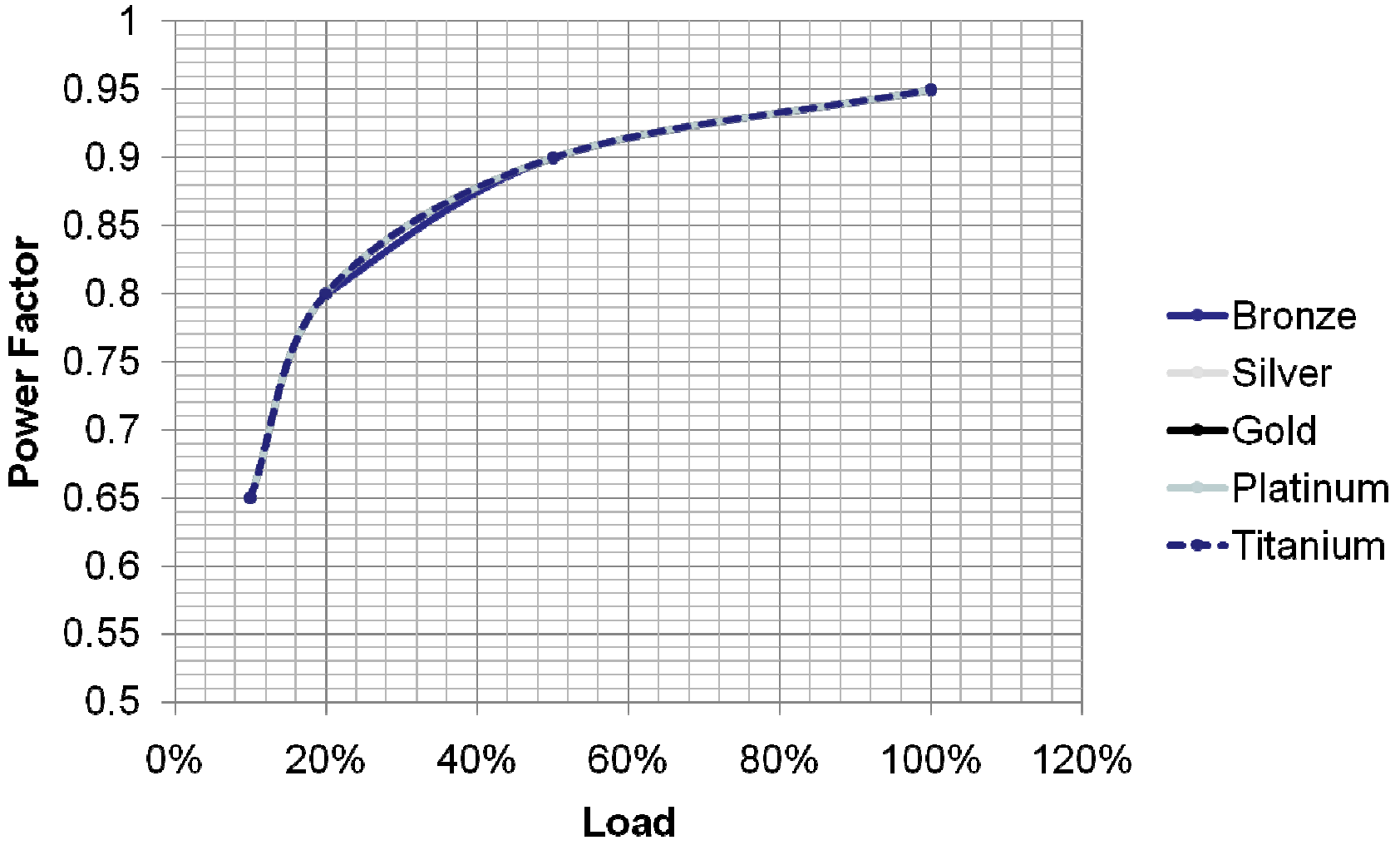
- Dedicated to blade and volume server applications
- 500-1,000W Single Phase 90-264V AC-Input, 12V Single DC-Output
- Specification defines minimum efficiencies and power factors for certain load conditions
- ENERGY STAR members have to meet Platinum Specification by July 2013



CSCI Efficiency Levels



CSCI Efficiency Levels



Platinum-Rated AC/DC Reference Design

Input:

- 90~264Vac, 45-65 Hz
- Active PFC (PF up to 0.99)

Output:

- 12V DC / 60A (720W max)
- Load Regulation: ± 1.5%
- Line Regulation: ± 0.5%

Efficiency:

- **Peak Efficiency:** 94.1%
- Meets ENERGY STAR CSCI Platinum Level

Dimensions:

- 5U x 5U x 1U
- (222 x 222 x 44.45) mm

Platinum-Rated AC/DC Reference Design

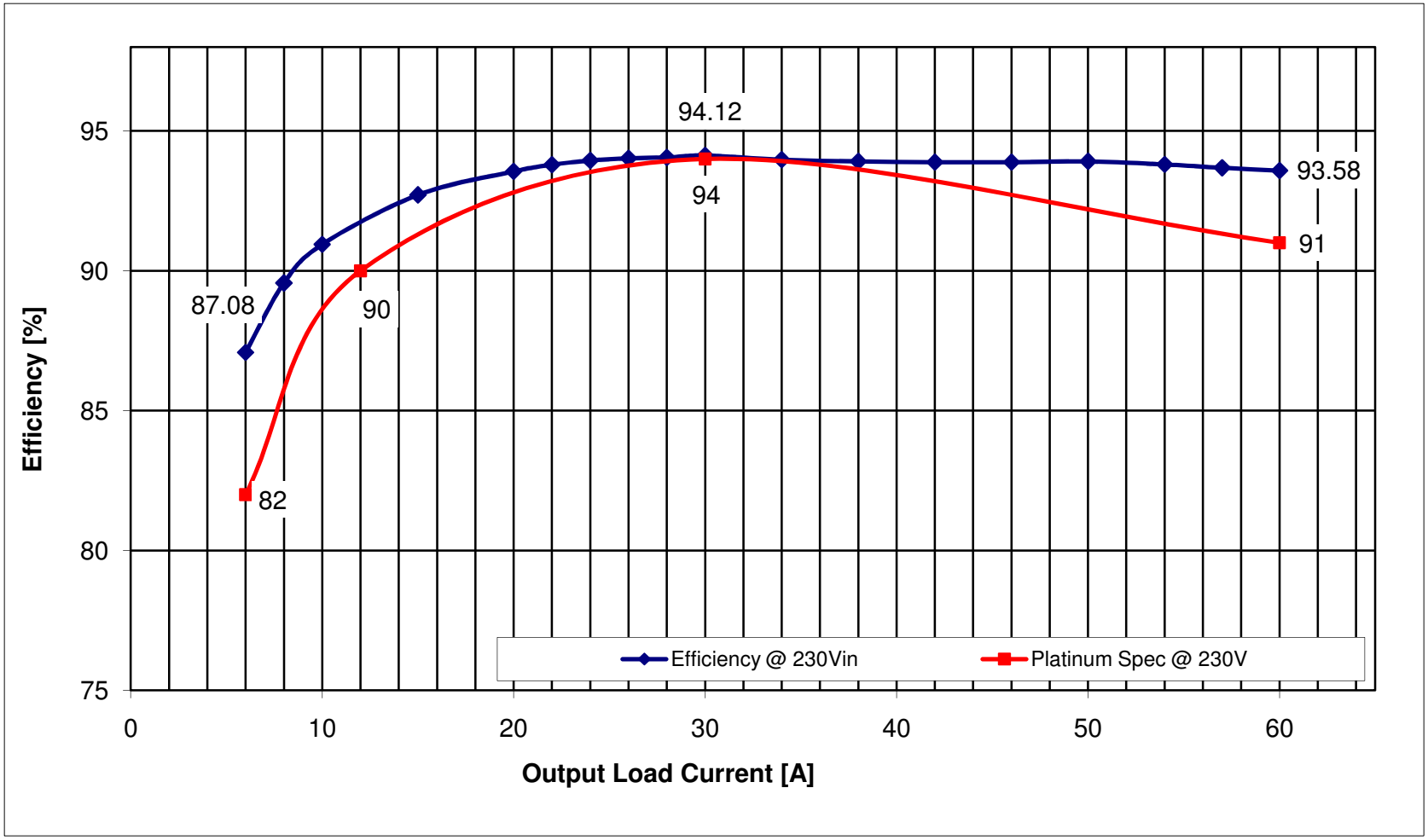
Special Features:

- Full digital control
- Enhanced system monitoring & fault handling
- Load share bus for N+1 Redundancy

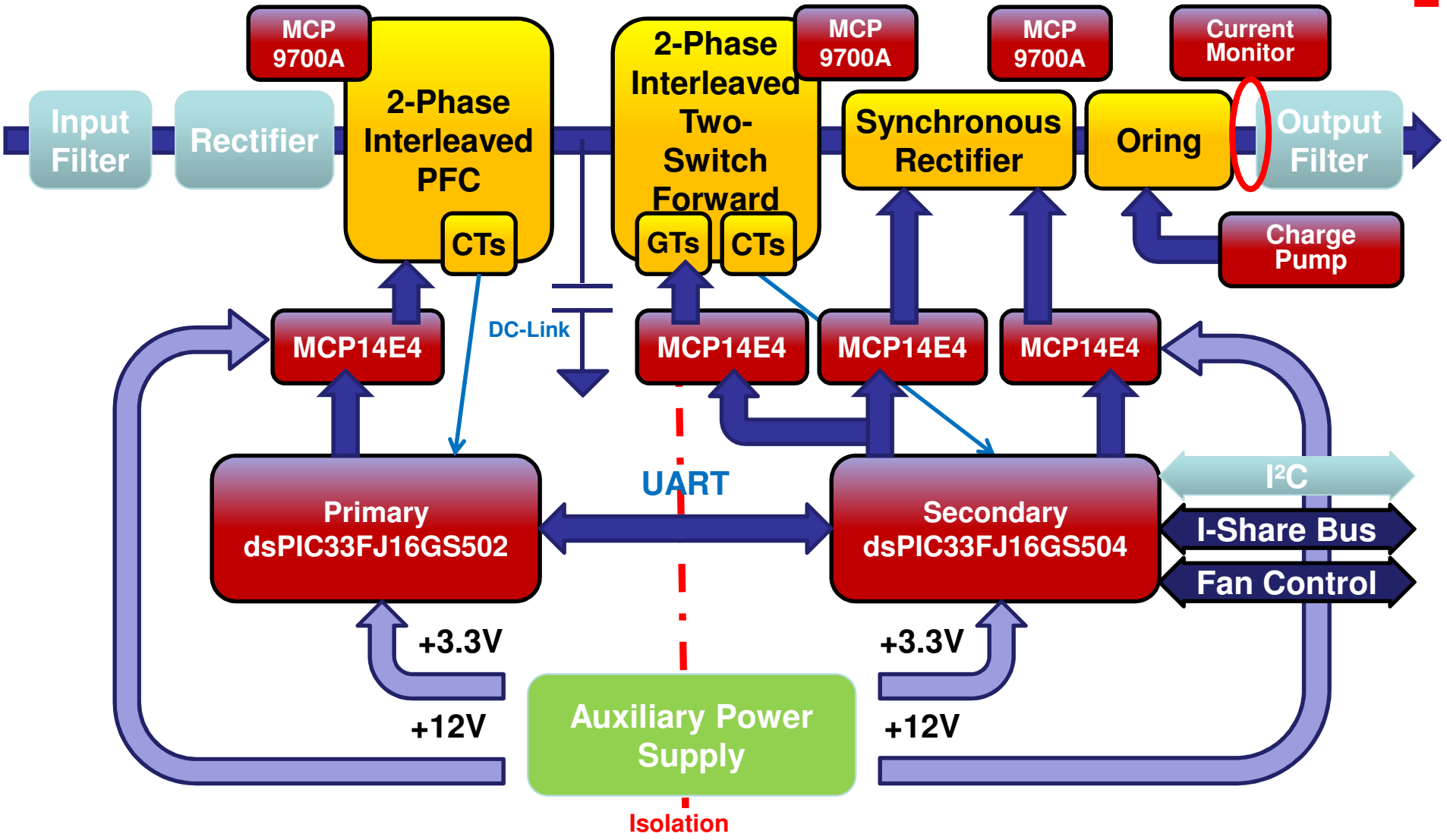
Efficiency Optimization:

- Switching Frequency Adaption
- Dynamic Bulk Voltage Adjustment
- Enhanced Sync Rectifier Control

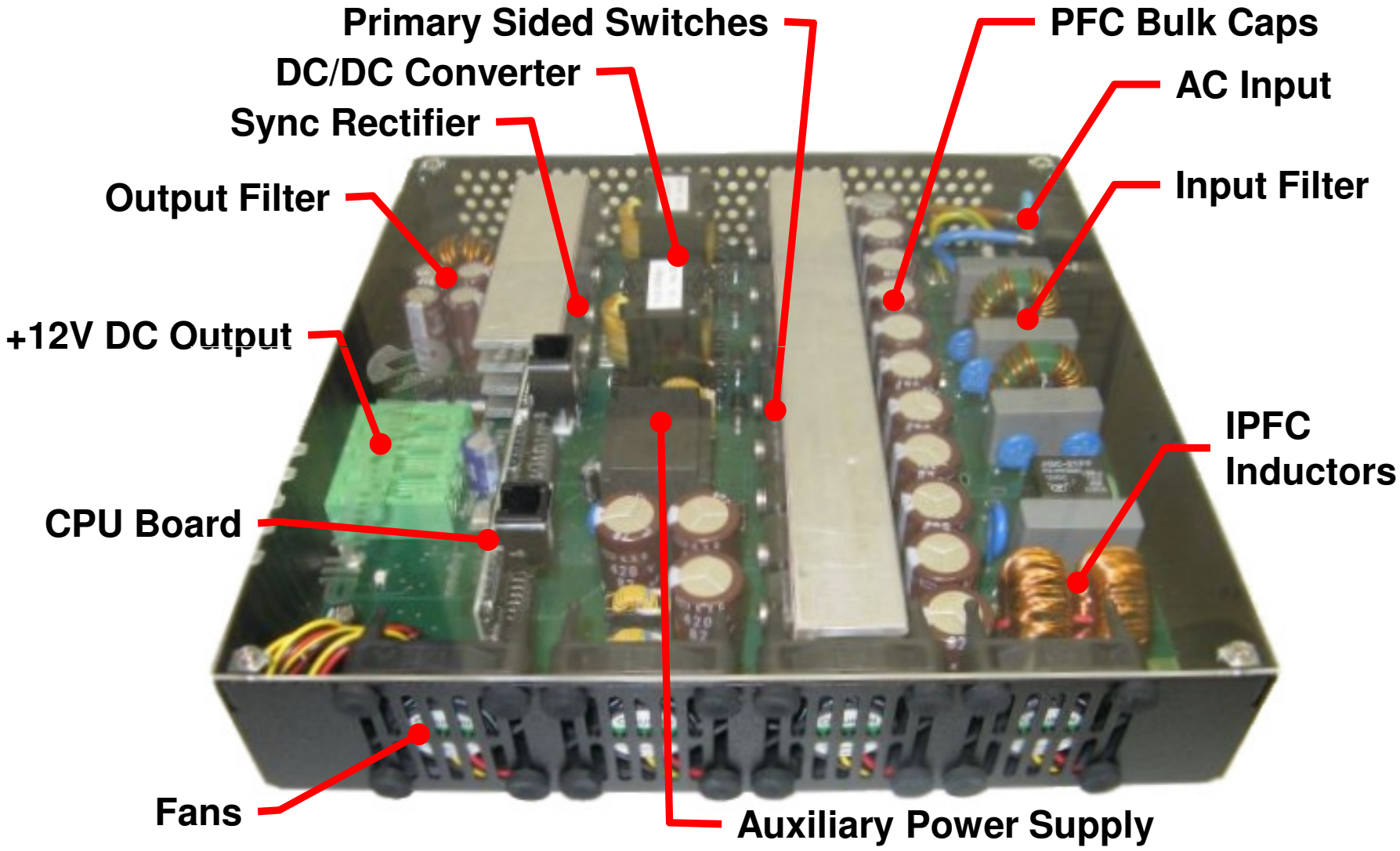
Efficiency vs. Output Load



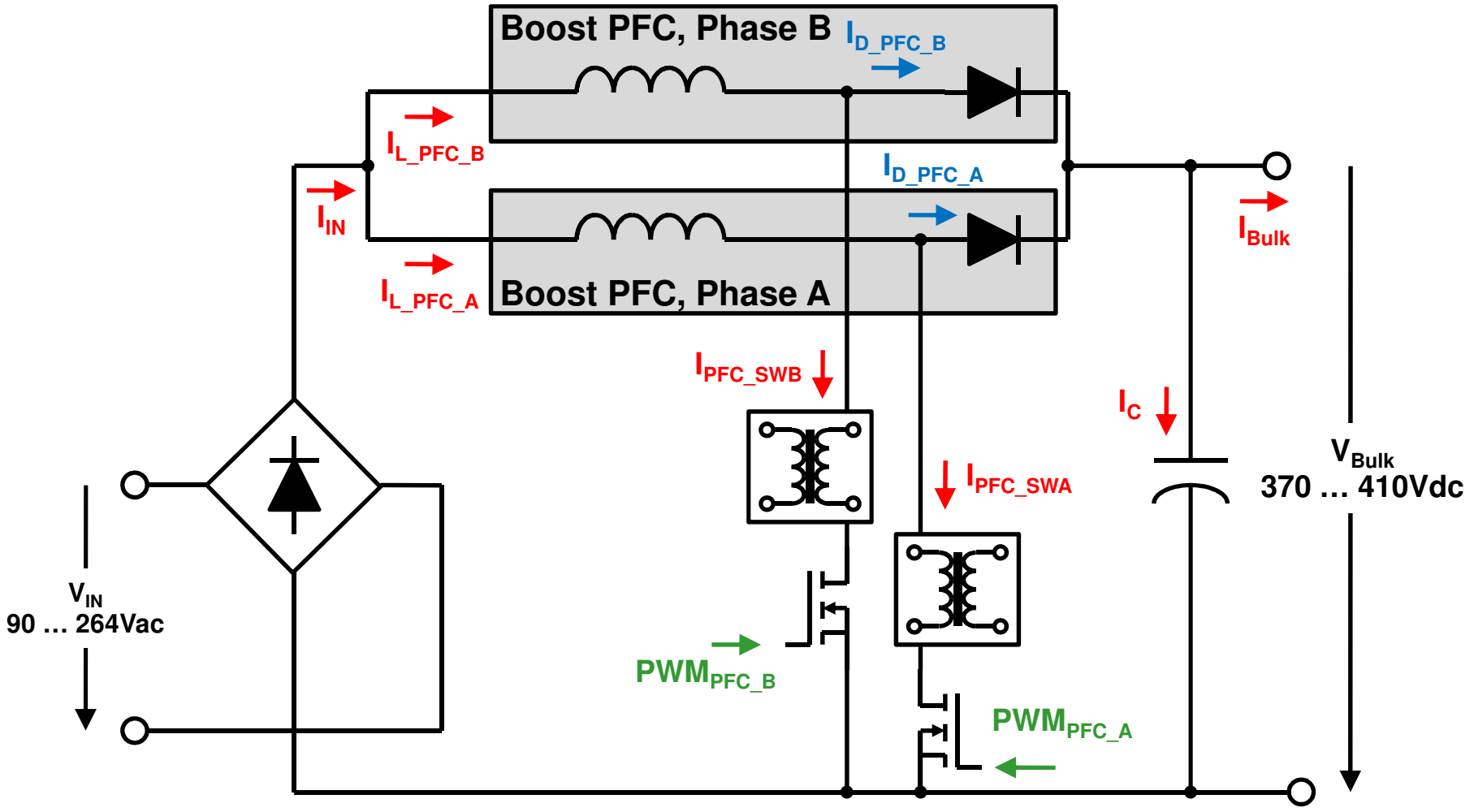
High-Level Block Diagram



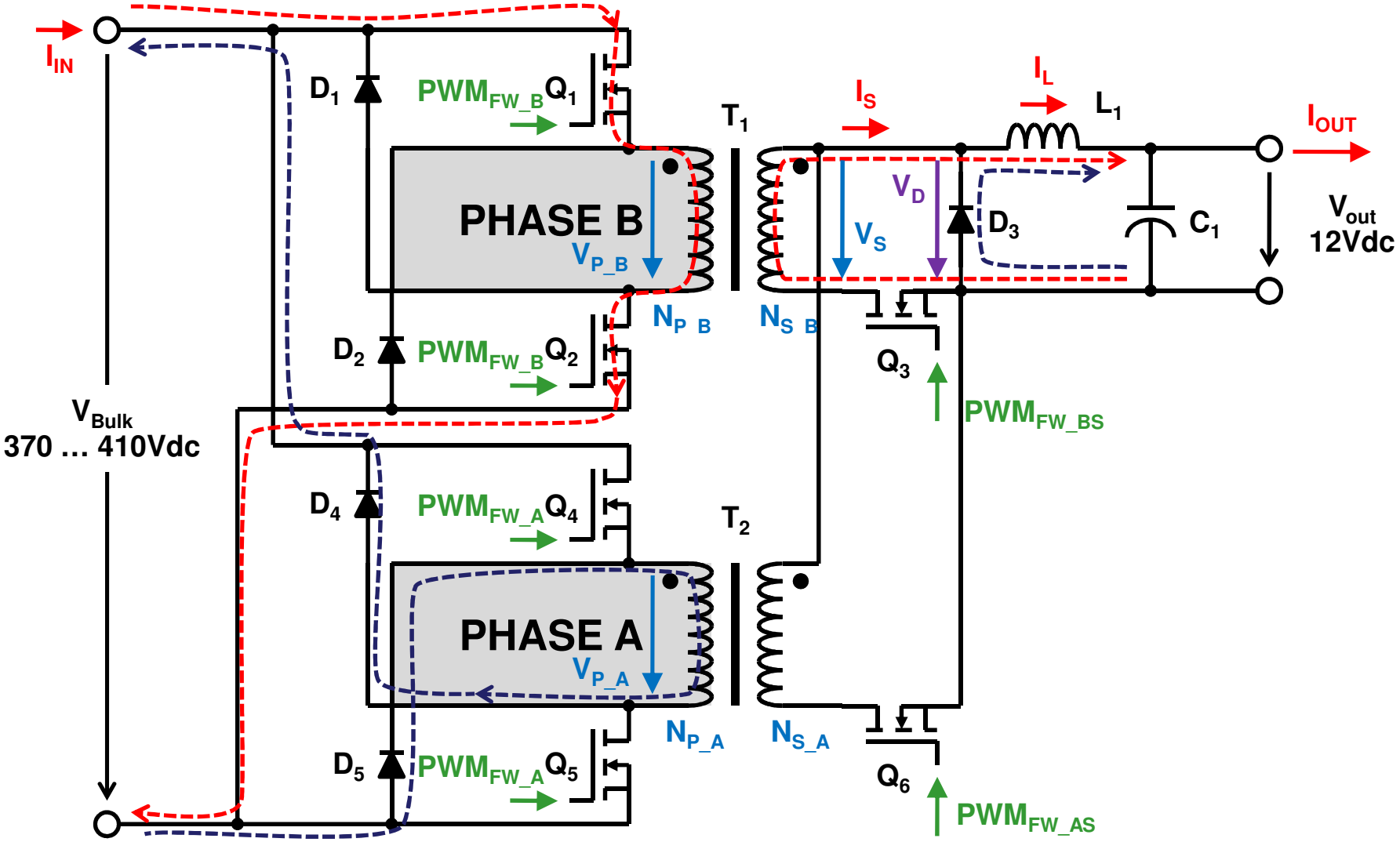
Design Architecture



Interleaved PFC Stage



Interleaved 2-Switch Forward



Software Overview

Two independent software projects

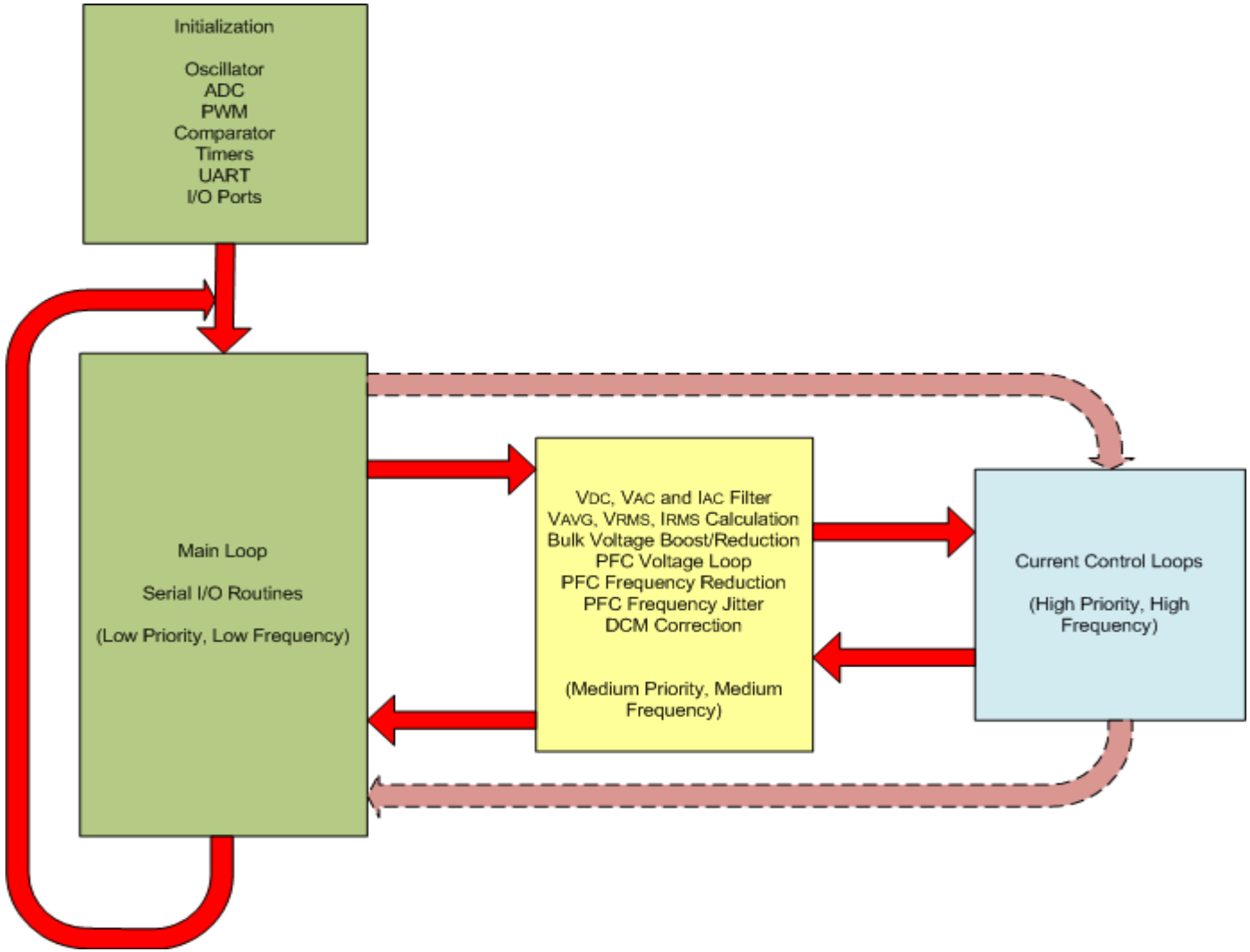
- Primary Side (PFC)
- Secondary Side (DC-DC)

Interrupt based priority scheme

- High Priority – Critical Power Control algorithms
- Medium priority – Advanced algorithms
- Low priority – Communications

UART Communication between primary and secondary for exchange of system information

System Software - Primary



Primary Control Loop

Primary Side Control Loop consists of three sub-sections

- Voltage Control Loop
- Current Control Loop
- Sine modulation of current and input feed-forward

Current Control Loops (x2)

- High speed PI algorithm
- Executed in ADC ISR (Highest priority)
- Independent control loops for each interleaved phase

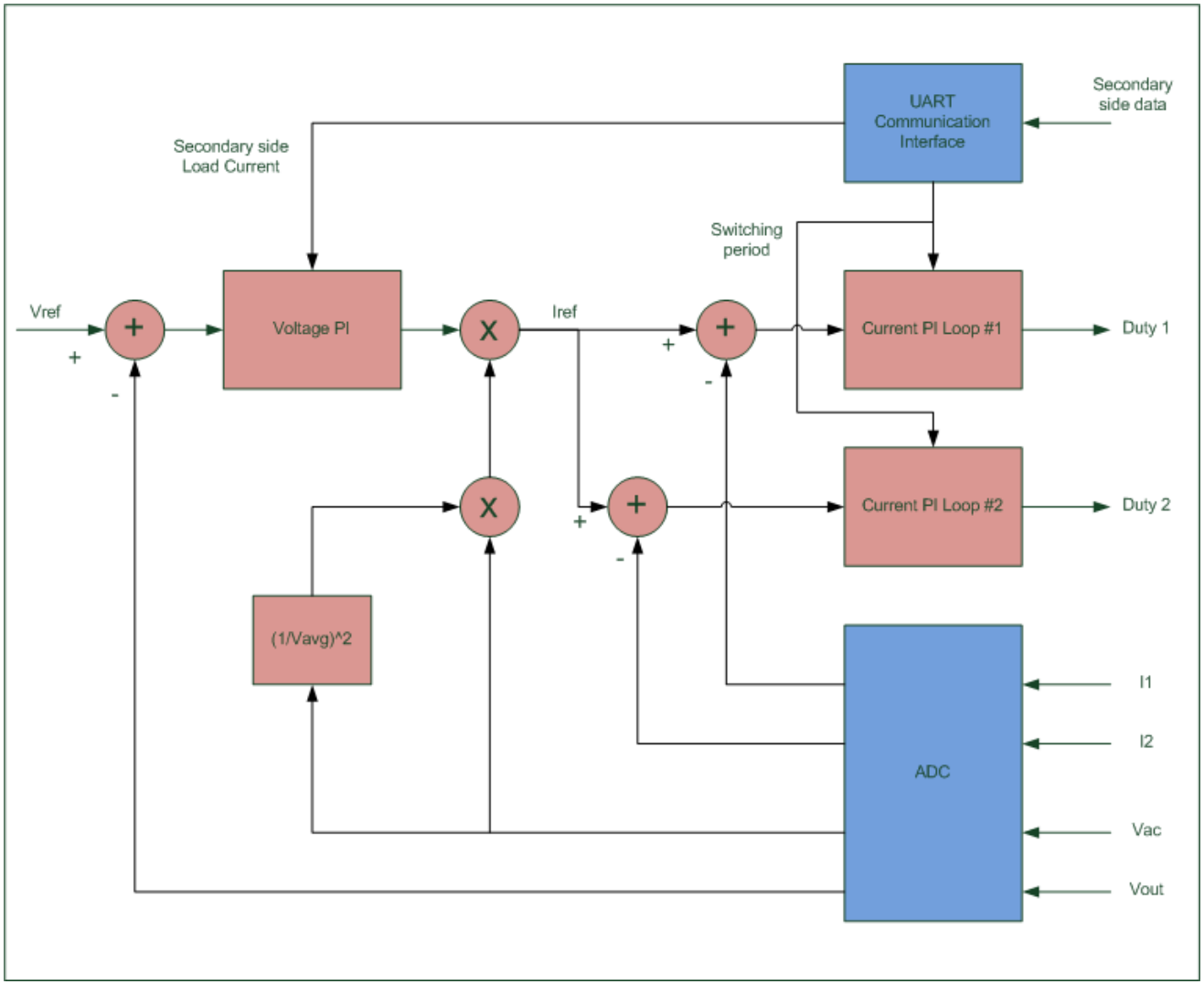
Sine Modulation

- Modulates output of voltage loop into a sinusoidal shape
- Adds input voltage feed-forward
- Executed in Timer2 ISR (Medium priority)

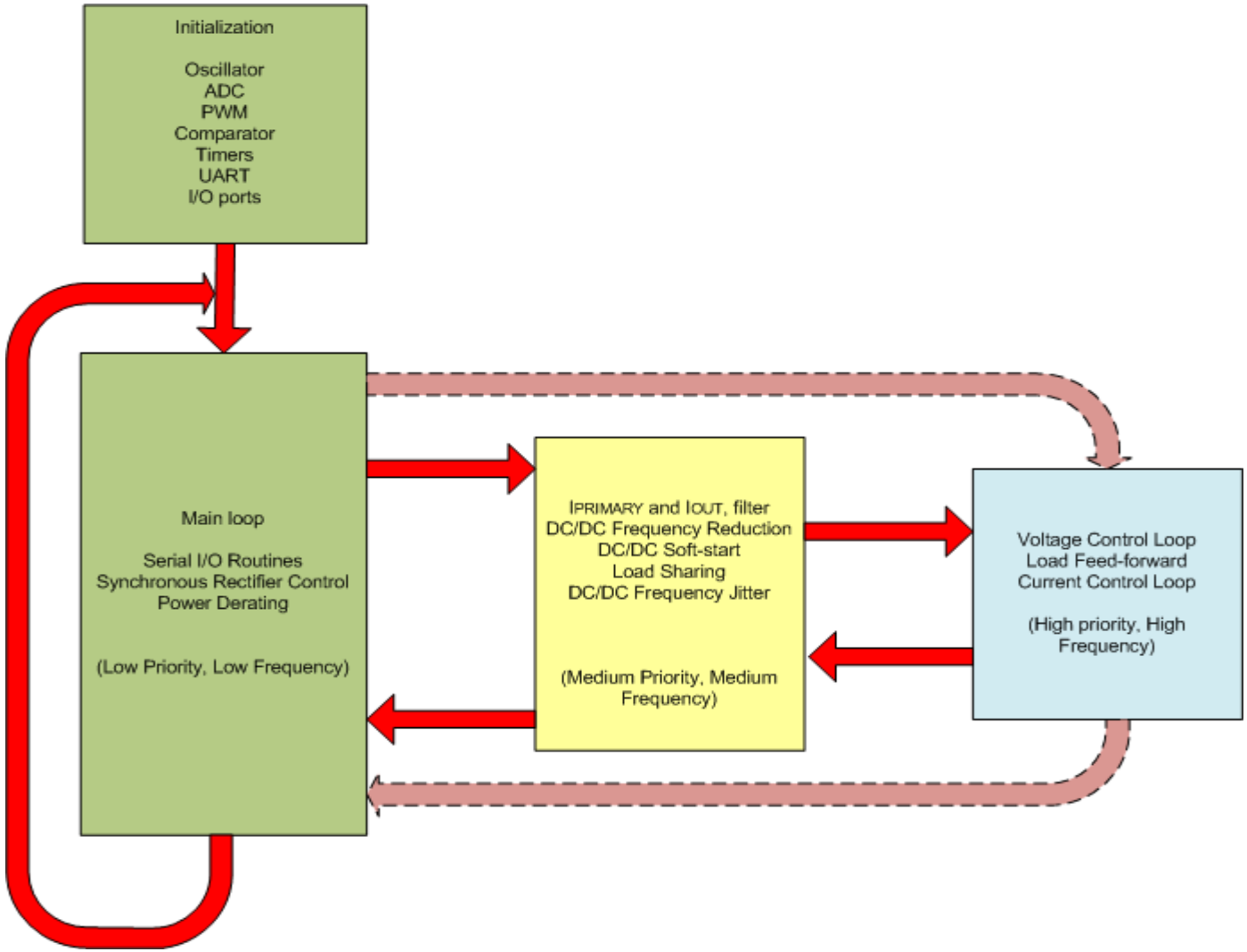
Voltage Loop

- Controls output voltage using PI algorithm
- Executed in INT2 ISR (Medium priority) once every four Timer2 ISRs

Primary Control Loop



System Software - Secondary



Secondary Control Loop

Secondary Side Control Loop consists of three subsections

- Voltage Control Loop
- Current Control Loop
- Load Feed-forward

Current Control Loop

- High speed PI algorithm
- Executed in every other PWM Special Event ISR (High priority)

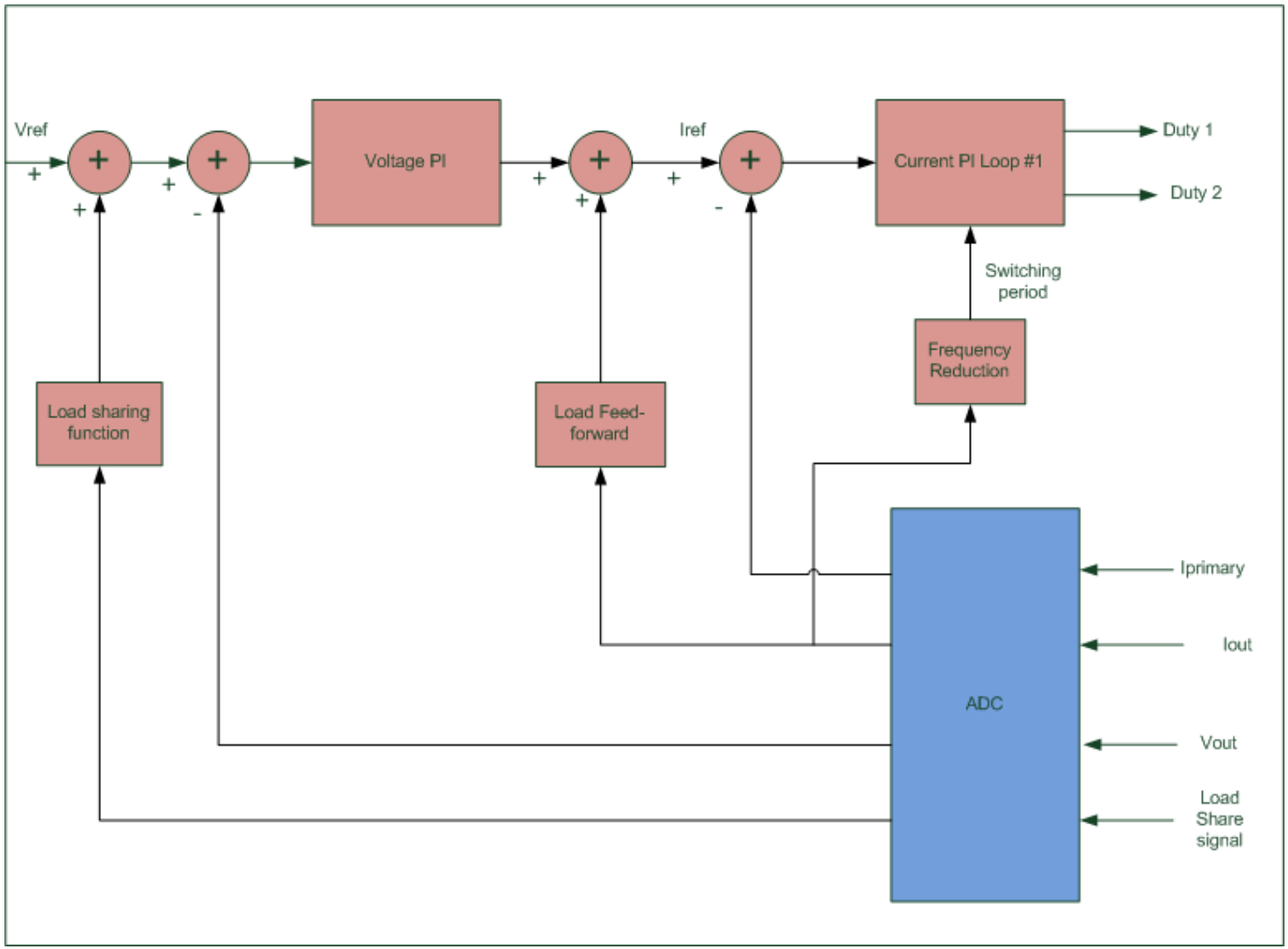
Voltage Loop

- High Speed PI algorithm
- Executed in every other PWM Special Event ISR (High priority)

Load Feed-Forward

- Executed in every other PWM Special Event ISR (High priority)
- Improves response to load transients

Secondary Control Loop



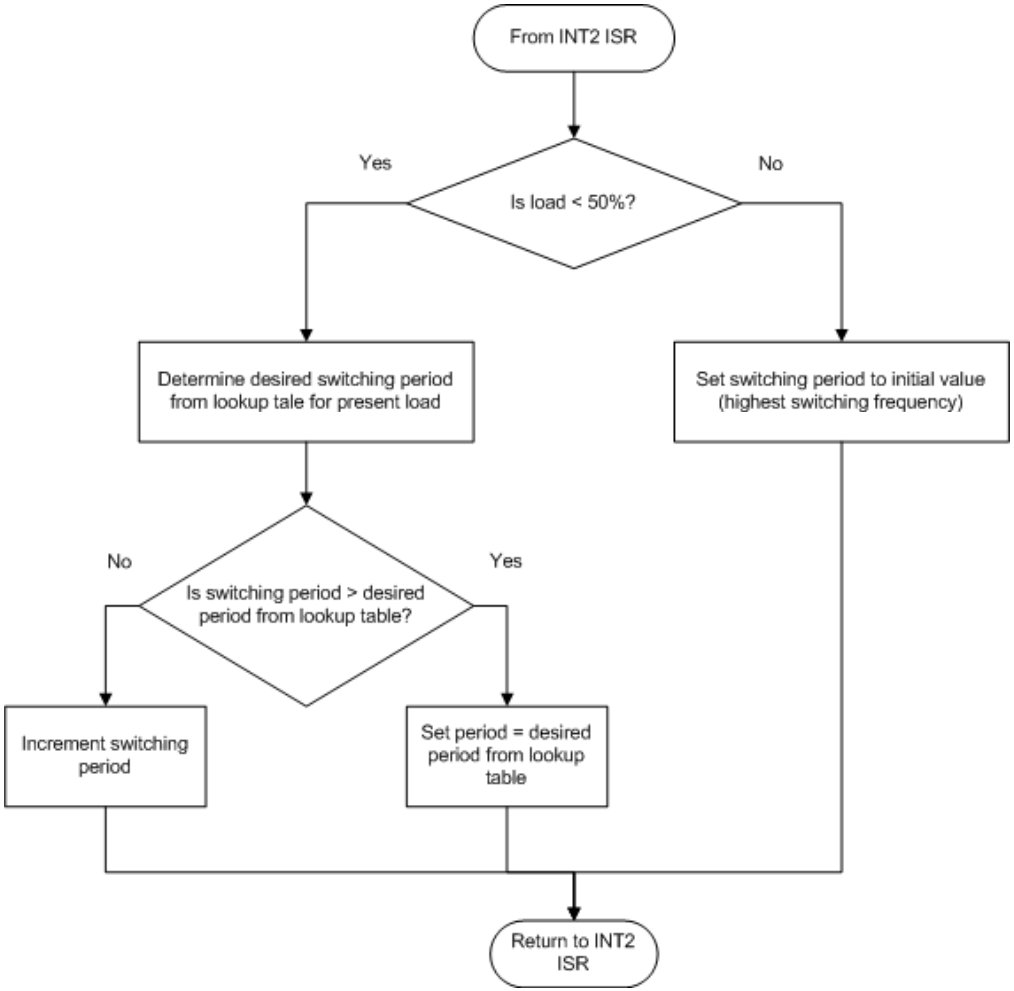
Advanced Features

Algorithm	Primary	Secondary
Frequency Reduction	X	X
Frequency Jitter	X	X
DCM Correction	X	
Bulk Voltage Reduction/Boost	X	
Synchronous Rectifier Control		X
Power Derating		X
Load Sharing		X

Frequency Reduction

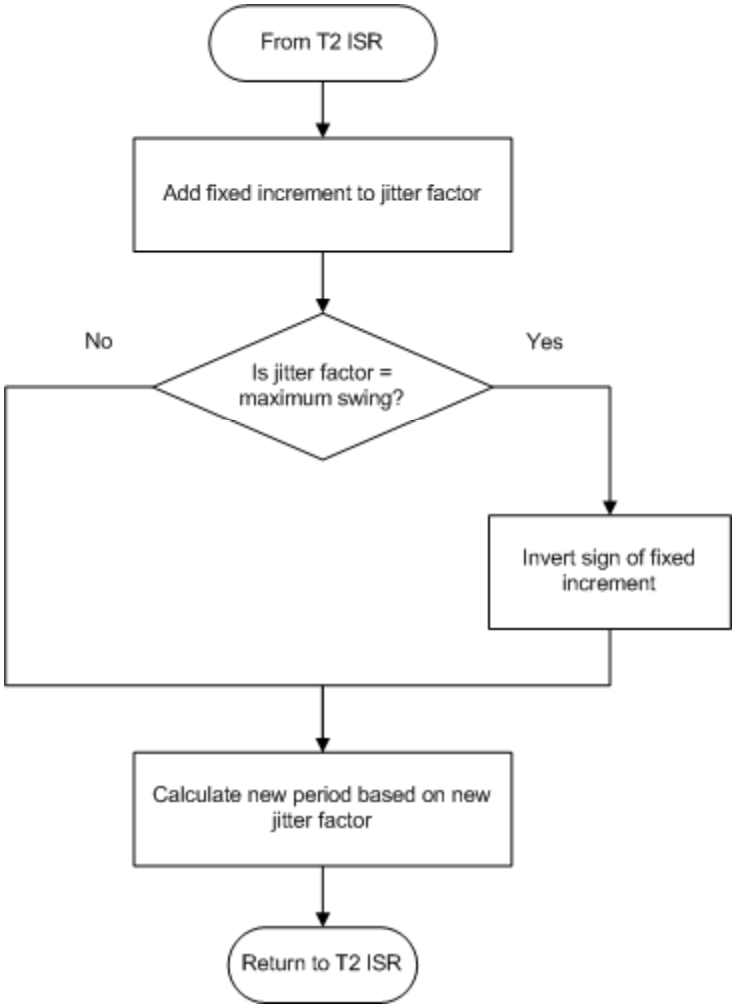
- Improved efficiency at light loads
- Frequency is reduced gradually in small steps until optimum frequency is reached
- When a load transient is detected, frequency is instantly increased to maximum to maintain good response

PRIMARY SIDE	X
SECONDARY SIDE	X



Frequency Jitter

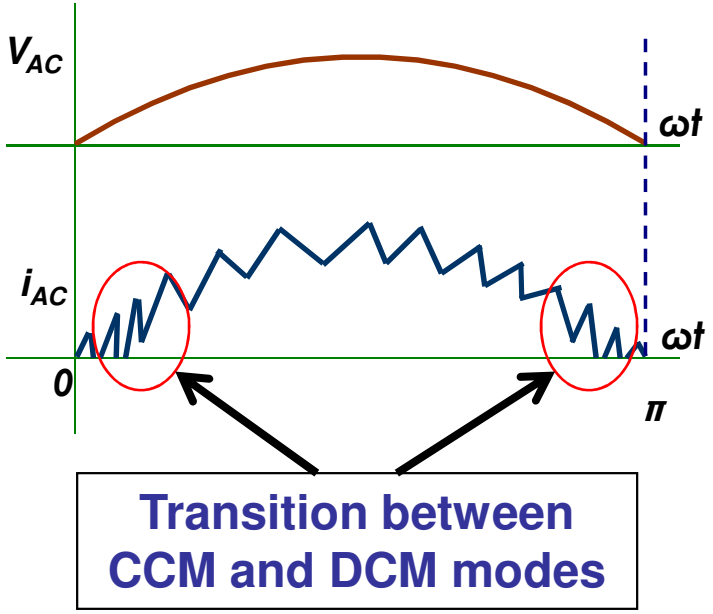
- **Improves EMI performance of the system**
- **Jitter is applied to switching frequency at a slow rate after frequency reduction algorithm**

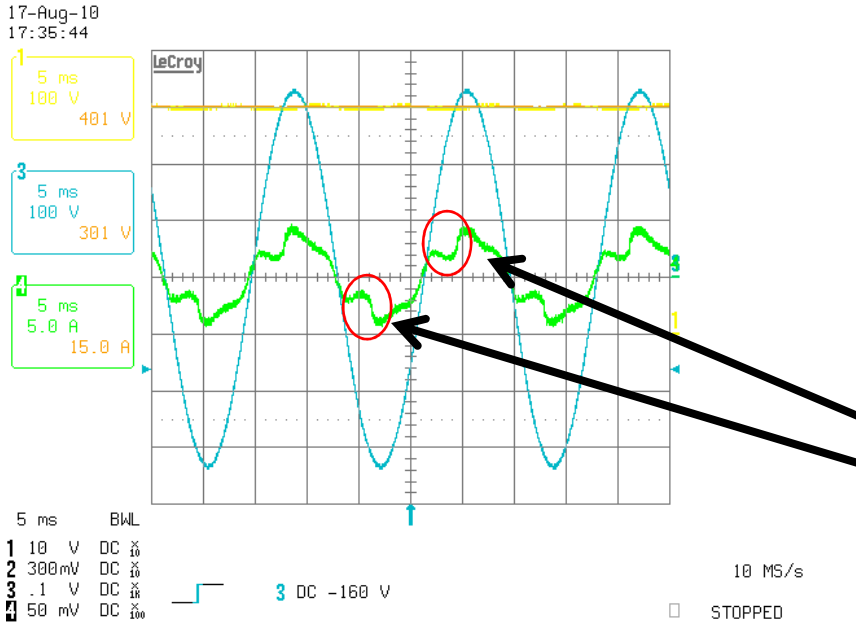


PRIMARY SIDE	X
SECONDARY SIDE	X

PFC Discontinuous Conduction Mode (DCM)

- Transfer function becomes non-linear in DCM mode
- Control system can compensate for different operating modes

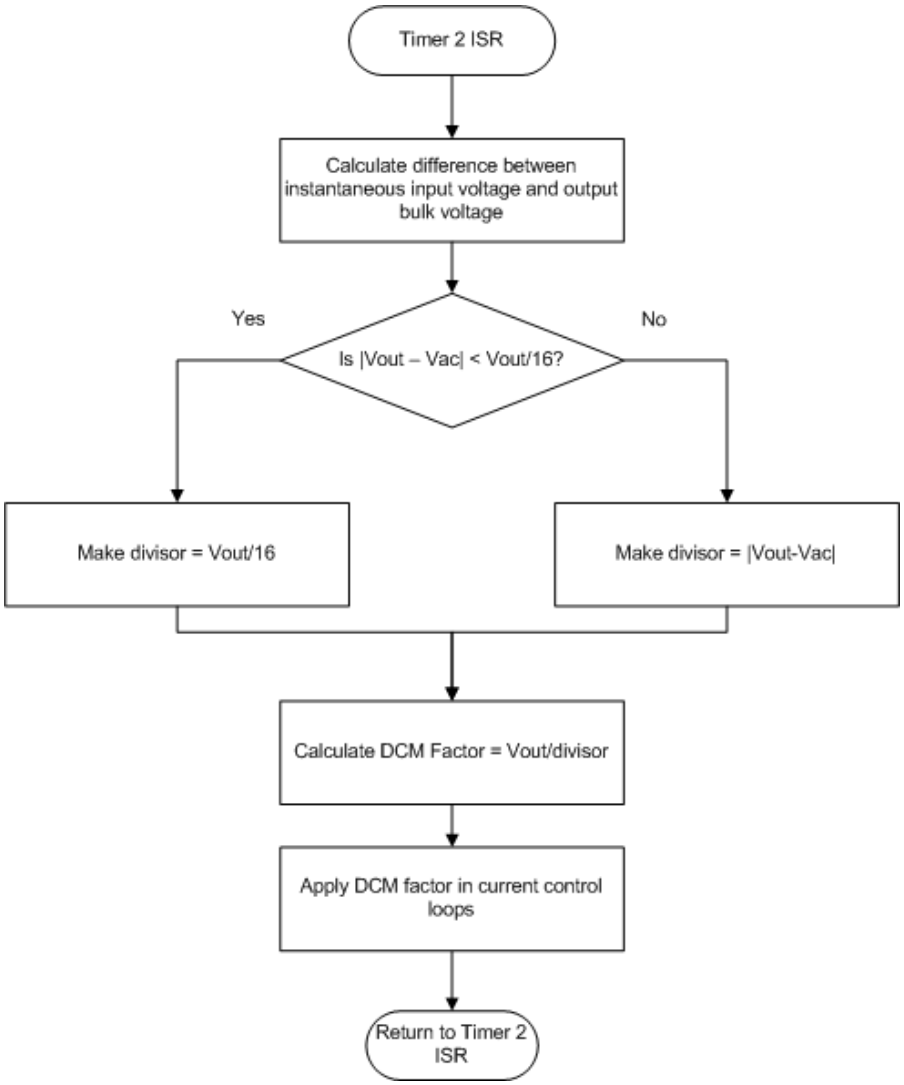




Worst Case:
50-50% CCM and DCM operation

DCM Correction

- **Transition between CCM mode and DCM mode for PFC causes waveform distortion**
- **A correction factor is added to current control algorithm to improve PF and THD at light loads due to DCM-CCM transitions**

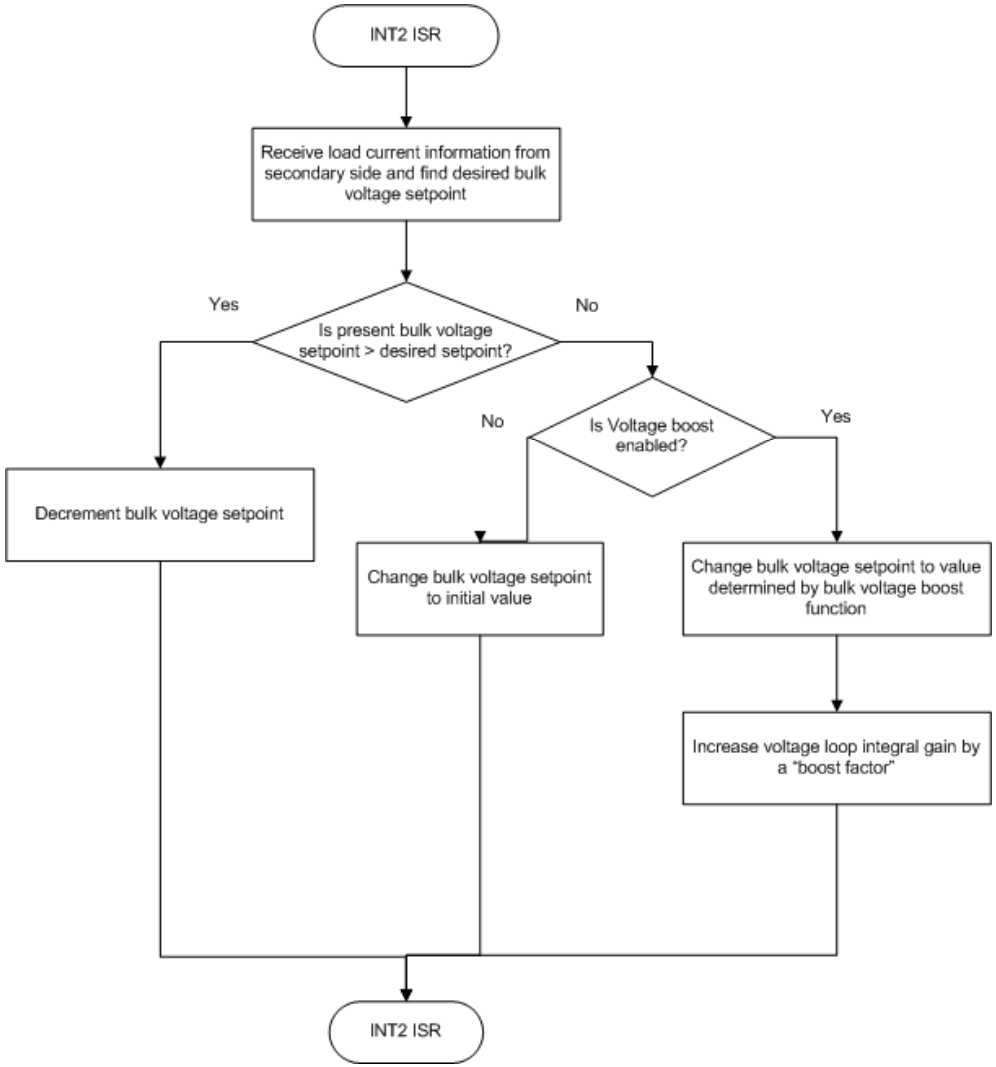


PRIMARY SIDE	X
SECONDARY SIDE	

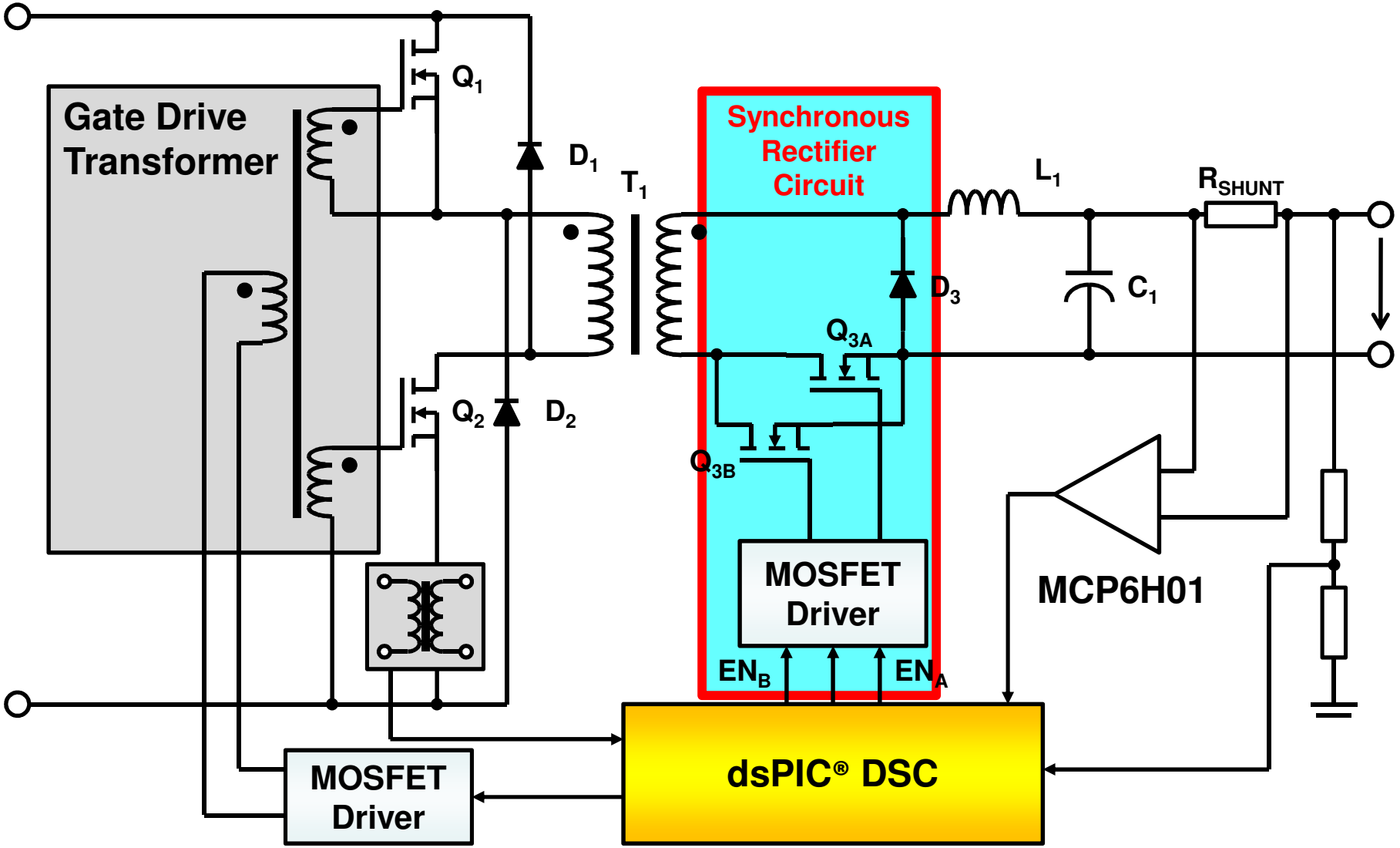
Bulk Voltage Reduction/Boost

- **PFC Output Bulk voltage is reduced to improve efficiency**
- **At light loads, a reduced bulk voltage can still allow the DC-DC**
- **Output Bulk Voltage is increased instantaneously in the event of a load transient to maintain good response**

PRIMARY SIDE	X
SECONDARY SIDE	

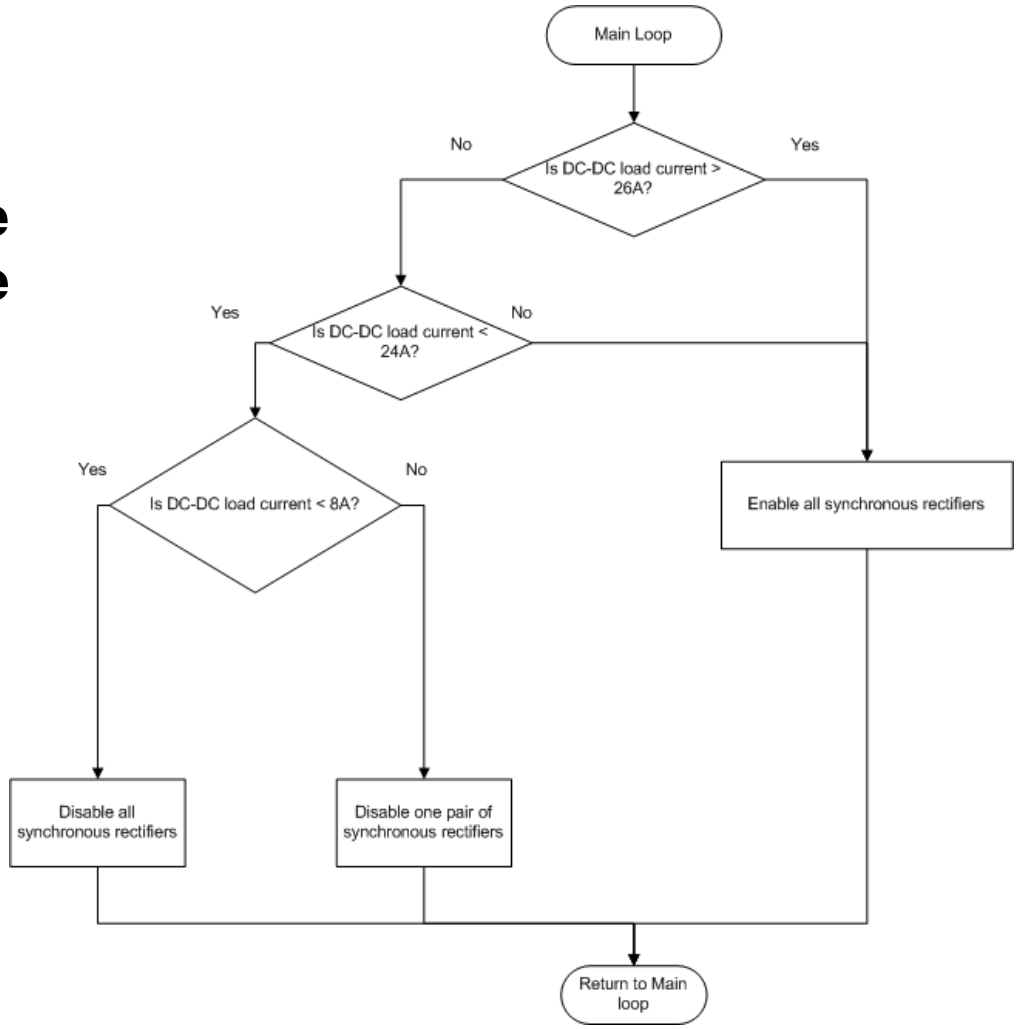


Synchronous Rectifier Control



Synchronous Rectifier Control

- The system implements two pairs of sync. rectifiers
- One or both pairs can be disabled at light loads to save switching losses and improve efficiency
  - Iout > 26A, all ON
  - 8A < Iout < 24A, 1 pair ON
  - Iout < 8A, both pairs OFF

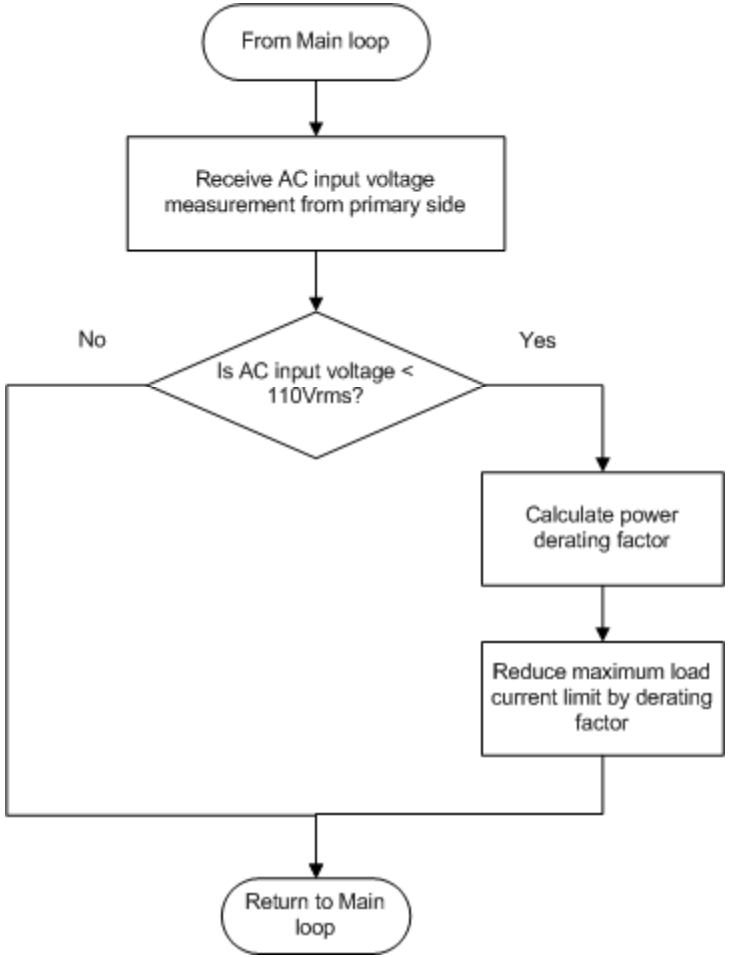


PRIMARY SIDE	
SECONDARY SIDE	X

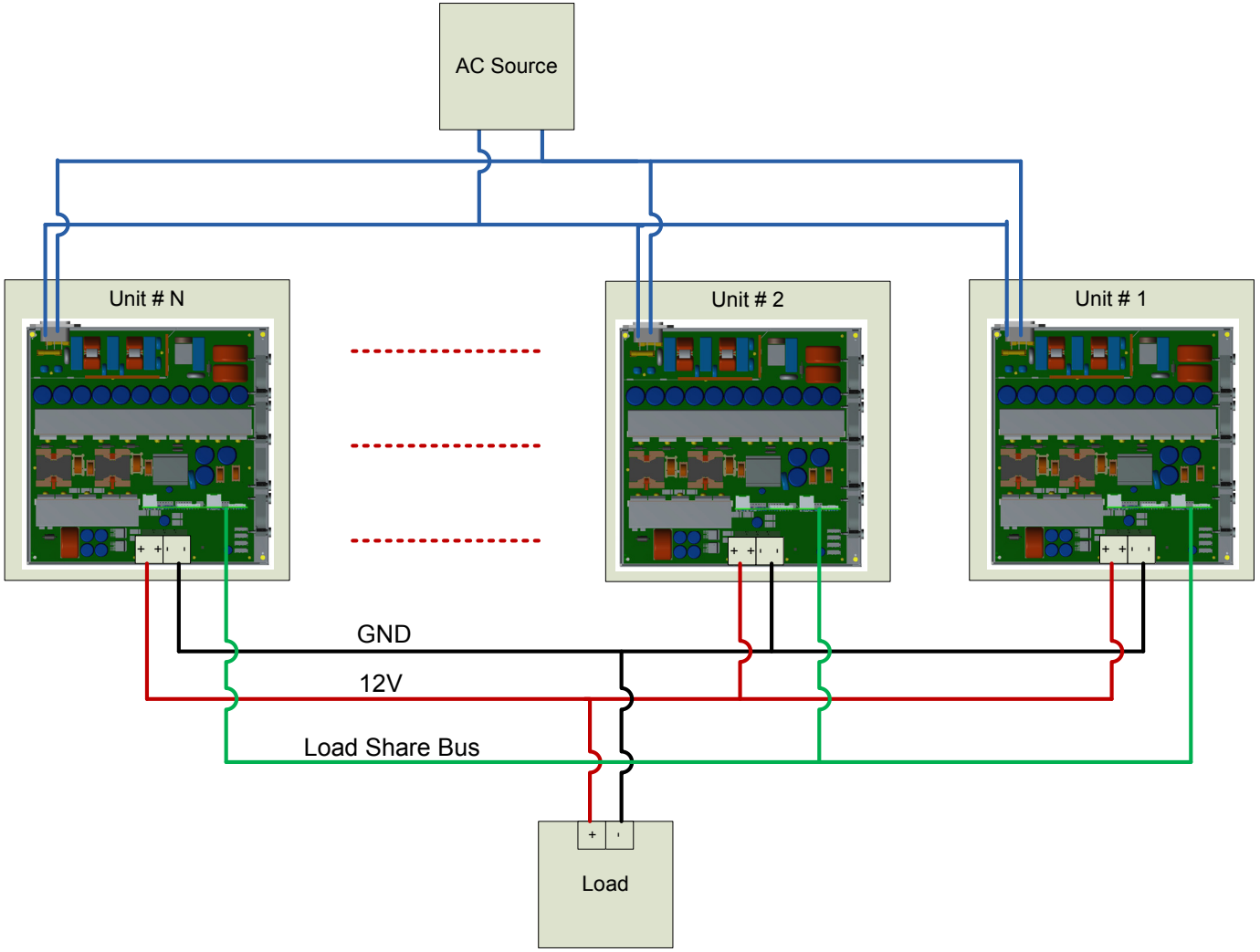
Power De-rating

- AC Input voltage information is transmitted to secondary side
- If AC Input Voltage drops below $110V_{rms}$, maximum output power of the system is de-rated
- De-rating is achieved by modifying the output current limit by a de-rating factor
- De-rating factor is proportional to ($110V_{rms} – V_{in\_rms}$)

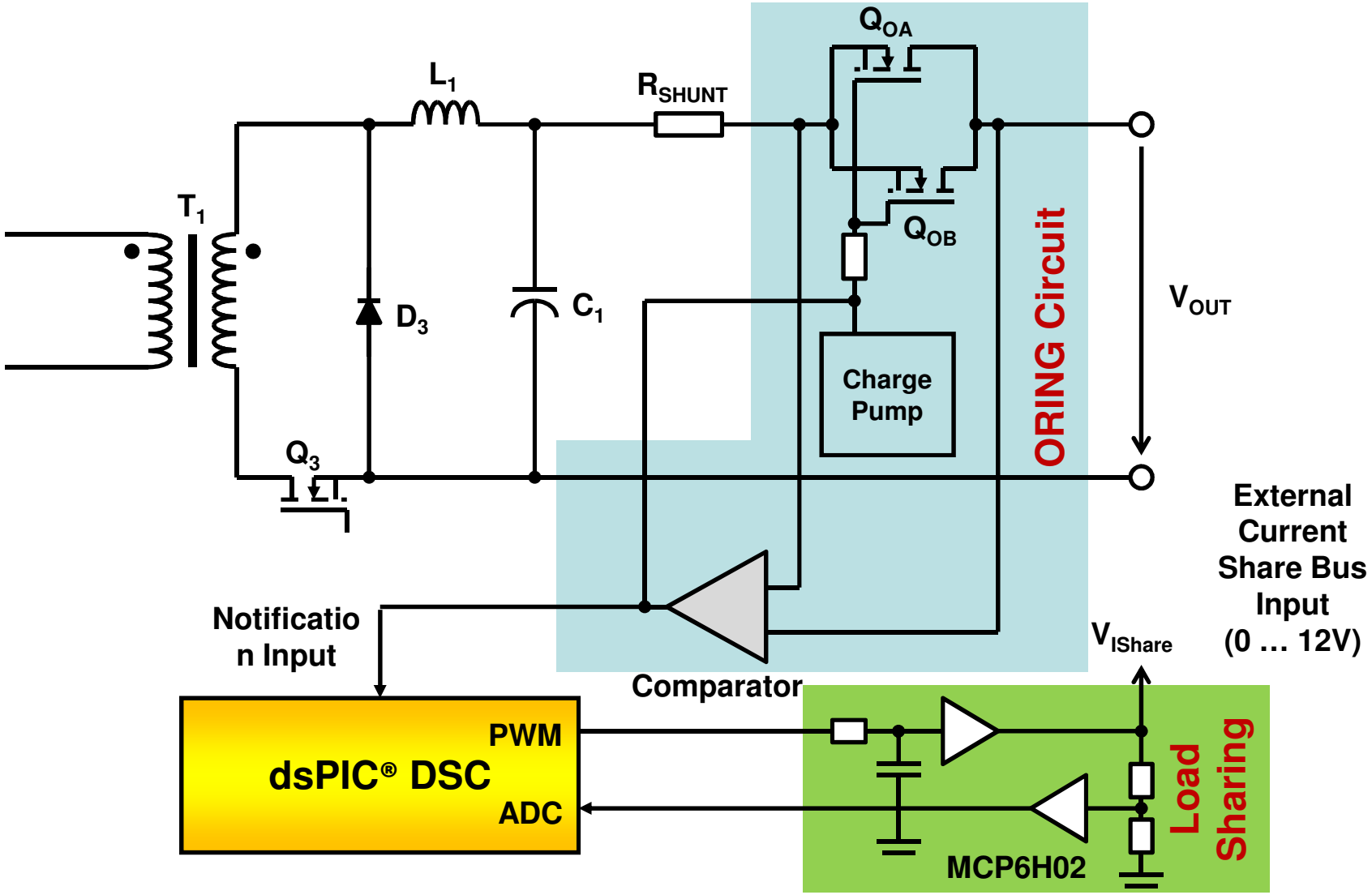
PRIMARY SIDE	
SECONDARY SIDE	X



Parallel Operation (N+1 Redundancy)



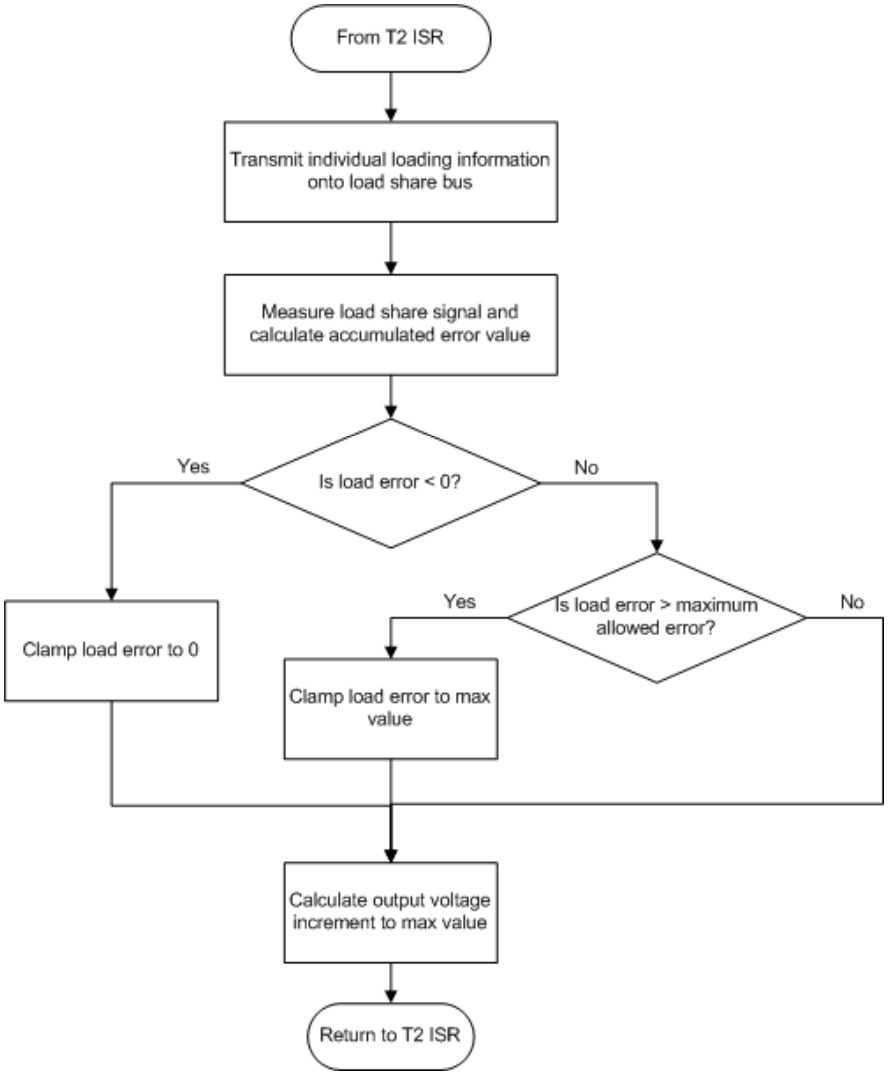
ORing and Load Sharing



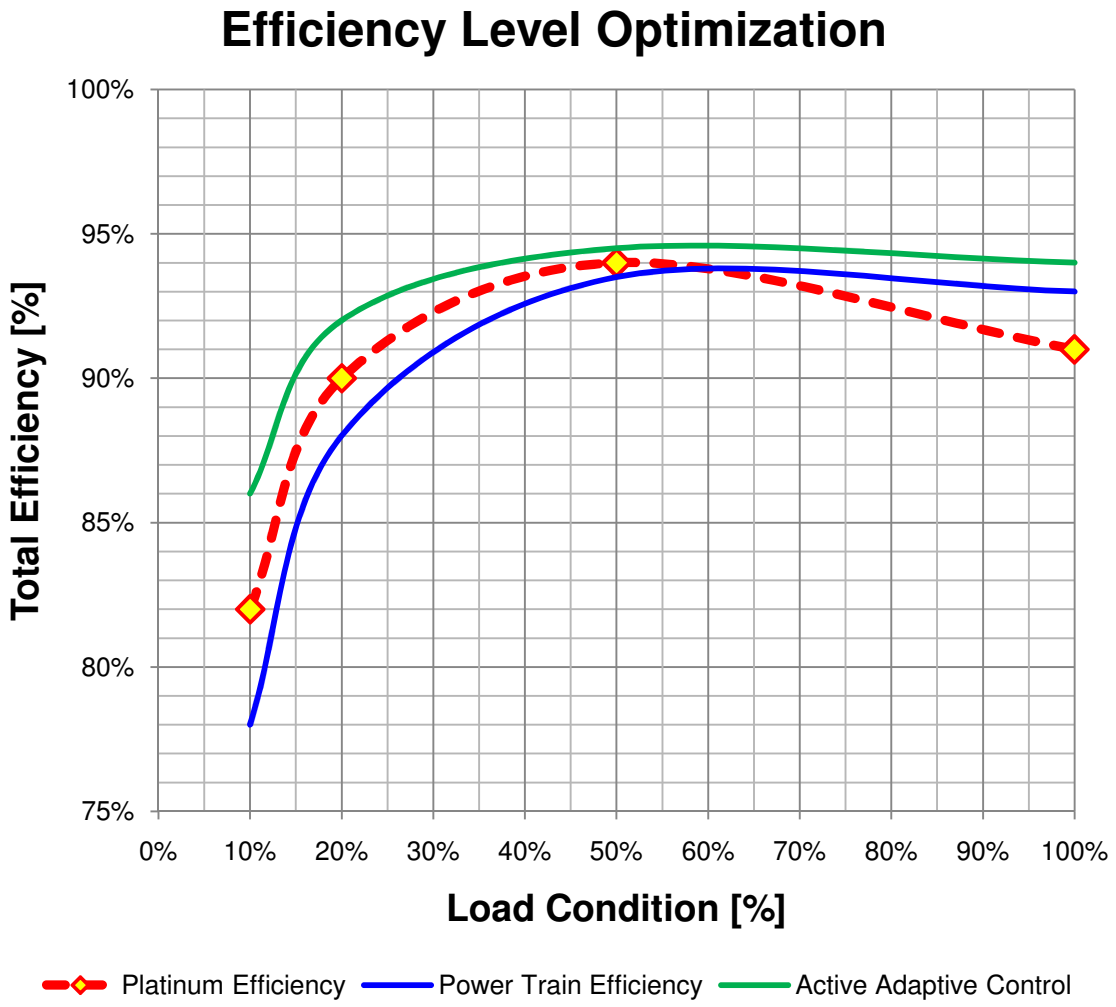
ORing and Load Sharing

- System supports N+1 redundancy through OR-ing circuitry
- In addition to OR-ing circuit, the software implements load sharing through an analog load share bus
- Software adjusts the power level delivered by the system to balance the loading between different systems

PRIMARY SIDE	
SECONDARY SIDE	X



Efficiency Analysis



Test Conditions:

- **230Vac / 50Hz Input**
- **Red:**
  CSCI Platinum Efficiency with given Reference Points
- **Blue:**
  Efficiency with no enhanced features enabled
- **Green:**
  Efficiency with enhanced features enabled

Additional Resources

- Platinum-rated AC/DC Reference Design Application Note (DS-01421)
- Efficiency Measurement Guidelines document
- Demo Instructions Document
- Schematics, PCB and BOM
- Primary and Secondary Firmware

Thank You