为什么
采用 TI UCD3138数字控制器
设计电源

程文涛
高性能隔离电源产品线
德州仪器半导体技术

Agenda

Why Digital ?

- Where are Digital Power Supplies Used **?**
- Digital vs. Analog
  - Boot-Loading
  - Auto-Tuning
  - Adaptive Voltage Scaling(AVS)
  - Communication

Why UCD3138 ?

- UCD3138 Innovations
- Flexible Configurability
  - Interleaved PFC, Bridge-less PFC, LLC, PSFB, HSBF, ZVS/ZCS, …
- Ideal Startup / Power-Down / DIP / Fault protection
- High Efficiency Over Load / Input Condition
  - Sync_FET On/Off Control, Ideal Diode Emulation, Mode Switching, Burst Mode, …
- Constant Power – Constant Current
- Copper Trace Current Sensing with Thermal Calibration

When to Choose ?

Where are Digital Power Supplies Used

Datacom/Telecom

Server/Storage

Test and Instrumentation Medical

Communications

- Base stations
- Routers

- Looking for Looking for boot-loading , power rail's monitoring and adjustment

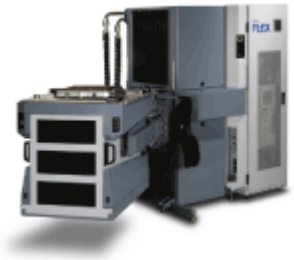
Enterprise Computing

- Servers
- Storage
- Memory power
- I/O power

- Looking for boot-loading , voltage margining, sequencing management and Vcore adjustment

Industrial, Test and Measurement

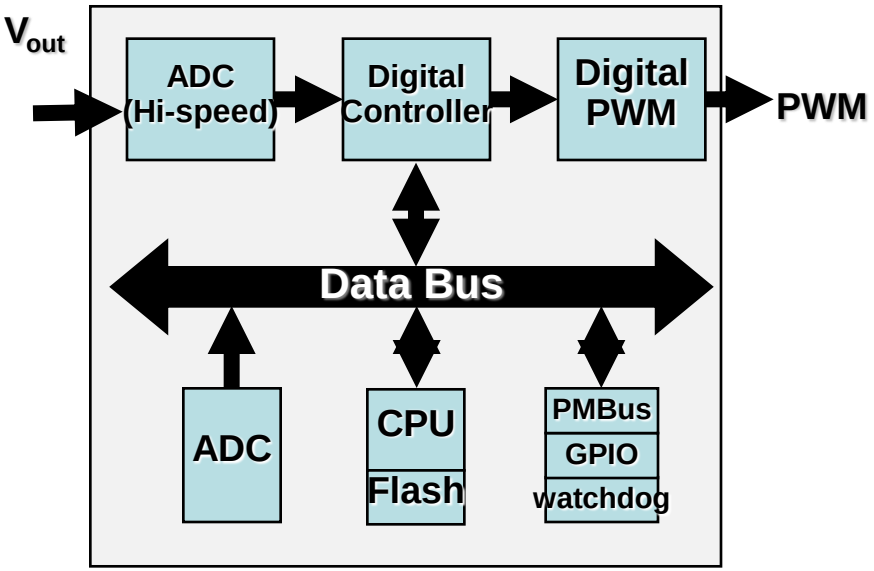
- Semiconductor Test Equipment
- Smart Lighting
- Medical equipment



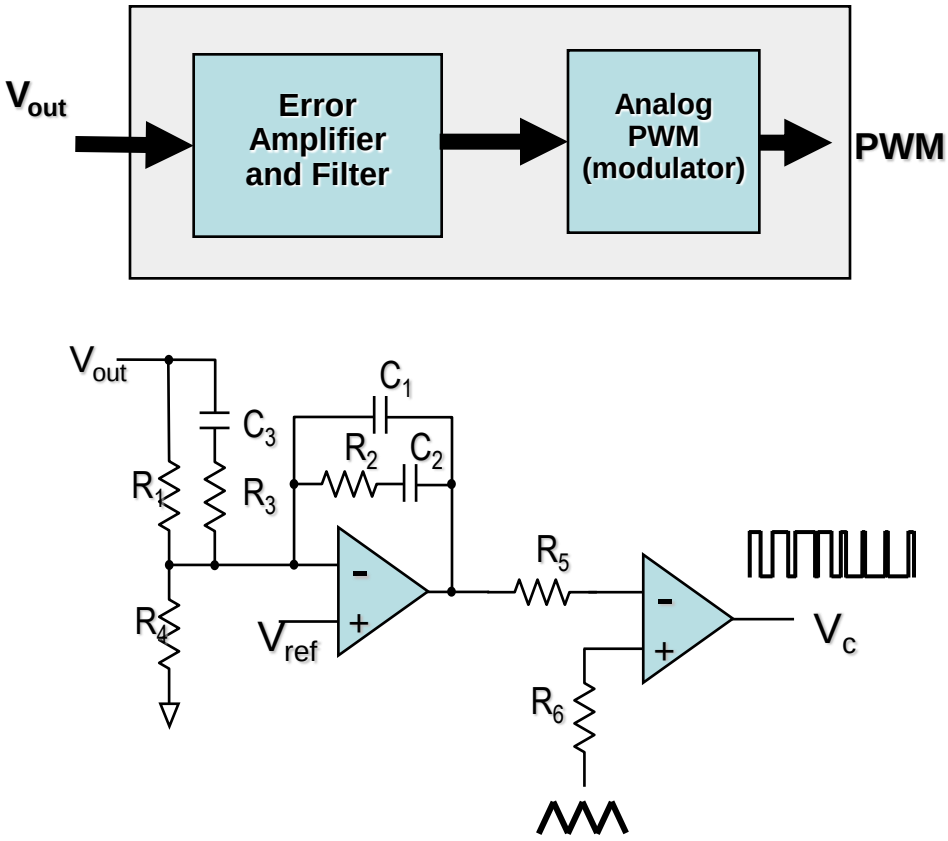
- Looking for flexibility of power management

Digital Power vs. Analog Power

Digital Controller



Analog Controller



Analog vs. Digital Solution Tradeoffs

	Strengths	Weaknesses
ANALOG	• Infinite sample rate • Low power consumption • Single chip solutions available (integrated high voltage / high current devices)	• Hardwired design • No Integral Monitoring • Sophisticated sequencing difficult • Need separate system manager to do monitoring / sequencing / communication
DIGITAL	• Easy to change configuration • Easy board development – Programmable parameters: Clock Sync, Vout, Dead-Time, Fault limits, Sequencing, Frequency, Soft start, Operation Mode, Fault response behavior, etc.. • On-line configurable and Dynamic compensation • Robust and Intelligent fault protection • Reliability – Real time monitoring – Fault logging • GUI	• Higher quiescent current • Dual chip solution (controller + driver) • Need to manage digital quantization noise

Boot-loading Trends Power Supplies

Key Drivers for Boot-loading:

- Field Upgrade of Firmware
- Production Line Upgrade of Firmware

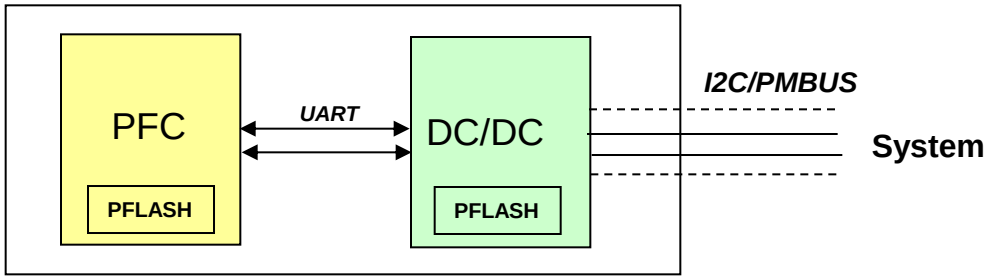
Impact to Controller:

- Need for digital programmable controller
- Need for a back-up program flash image (failsafe)
- Need for higher memory
- More communication options

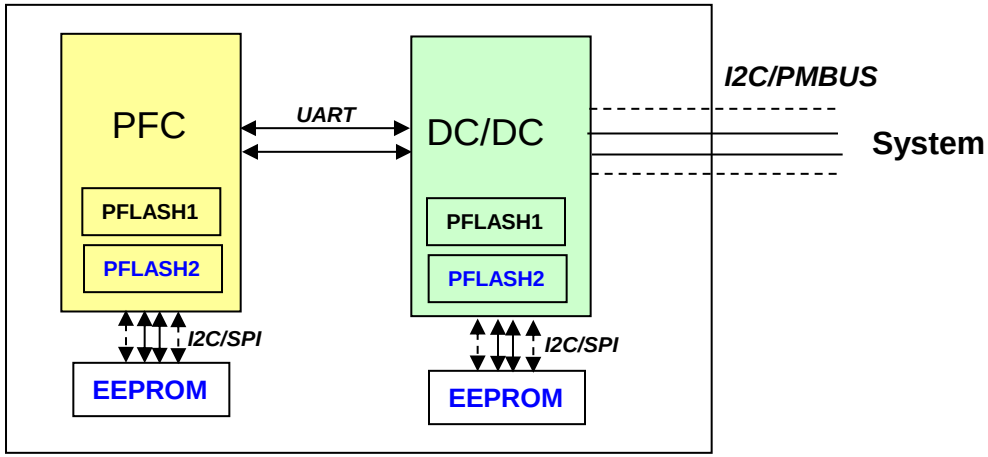
Boot-loading Protocol:

- Say, program executing out of PFLASH1
- New f/w programmed into PFLASH2 (while power supply is running – HOT boot-loading)
- If PFLASH2 is programmed properly, transfer execution to PFLASH2
- If PFLASH2 is NOT programmed properly, continue out of PFLASH1
- EEPROM may be an intermediary in Boot-loading
- EEPROM for additional memory storage (critical data)

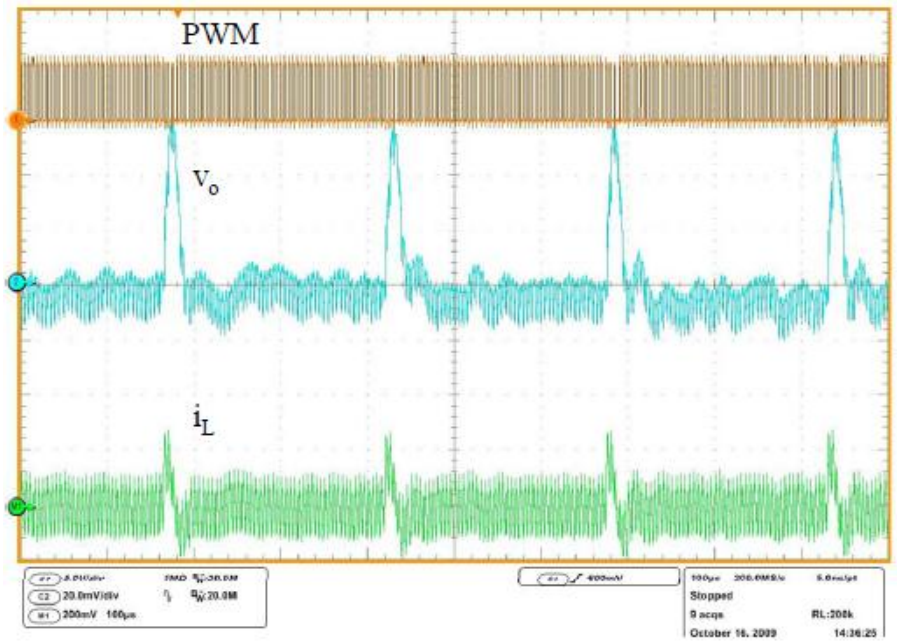
Isolated Power Supply

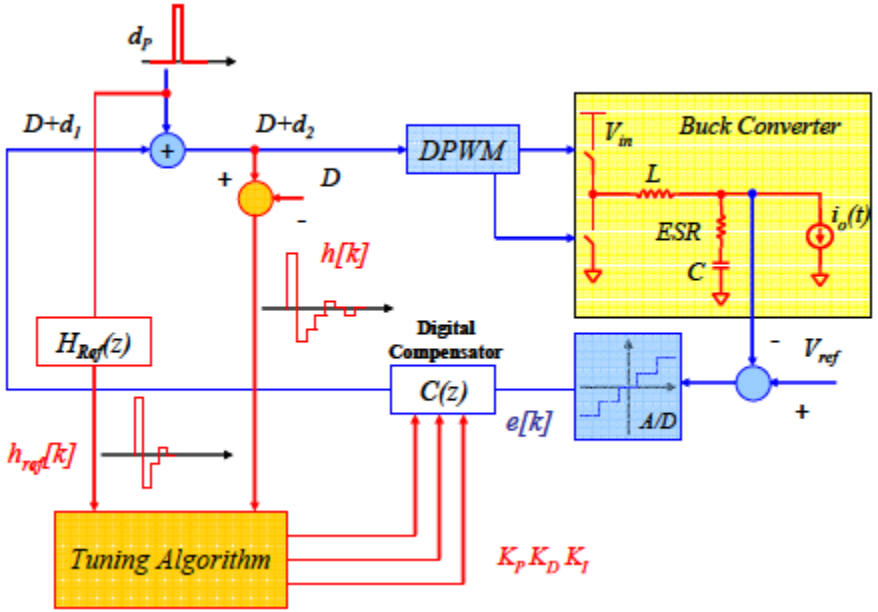


Isolated Power Supply



Preliminary Auto-tuning Architecture

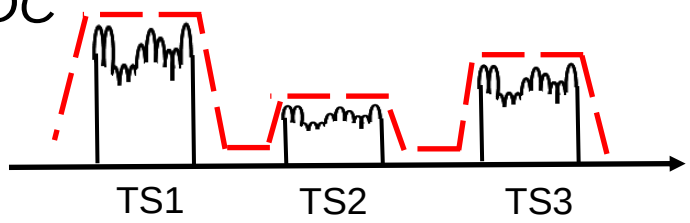




- Use effect of load/reference transients as the “excitation” source
- No additional excitation required
  - Could consider further improvements based on one-time startup tuning with perturbation + continuous tuning based on transients
- Continuously adjust compensator to achieve acceptable settling time/overshoot based on sensed output voltage

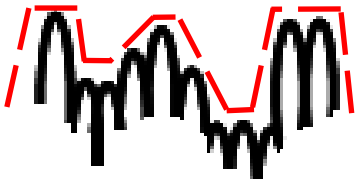
Enables Voltage Tracking

Adjustable DC



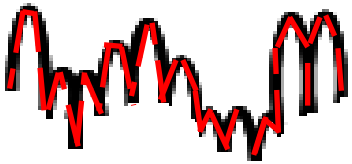
- Power supply voltage set by the burst's peak power
- Voltage tunable on a per time slot basis

Slow ET



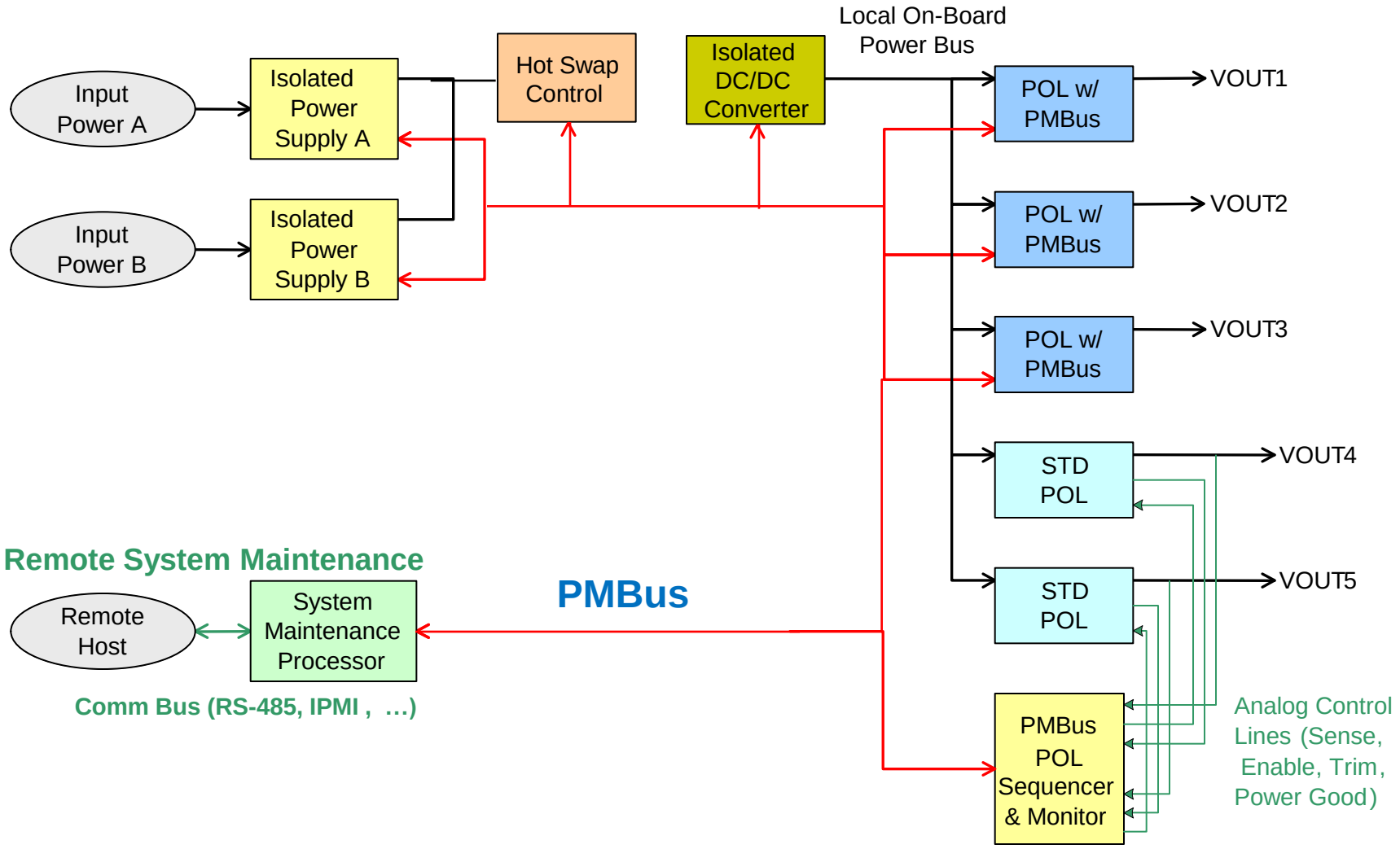
- Amplitude envelope peaks are tracked (slower tracking)
- Closed loop bandwidth is less compared to a FAST AET

Fast ET



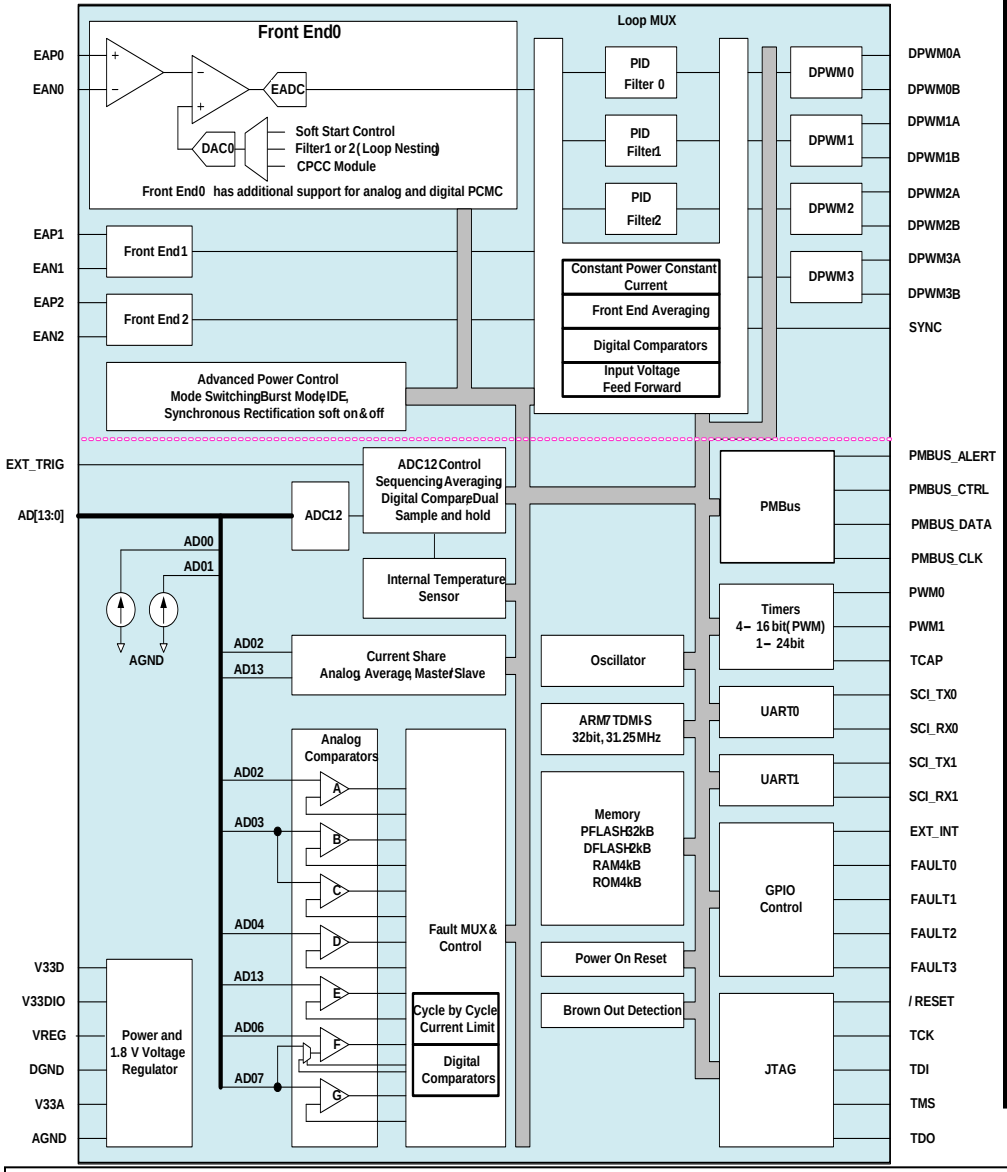
- Amplitude envelope is tracked exactly
- Requires high bandwidth power supply

Inter-System Communication



UCD3138

UCD3138 Block Diagram



Key Features

- 3 Independent, Multi-Nestable Feedback Loops
- 16MHz Error Analog to Digital Converter (EADC)
- 14-bit (effective) DAC for control loop reference
- Dedicated PID hardware, 2p/2z configurable
- 8 High Resolution DPWM Outputs with Leading, Trailing or Dual Edge (Triangular) Modulation
- 4ns Freq resolution, 250ps Pulse Width resolution
- 2MHz Max Switching Frequency

- High-Performance 31.25MHz, 32-bit ARM7 Processor
- On-Chip Program & Data Flash, RAM and ROM
- 14 Channel, 12-bit, 265ksps general purpose ADC
- 2 UART's + PMBus Interface + JTAG Debug port
- 7 50ns Analog Comparators, Cycle-by-cycle I_{LIMIT}
- On-chip (BOD / POR), Single Supply Operation (3.3V)
- External Interrupt + Fault Input & Output
- Bootload using ROM (PMBUS) and Program Flash (UART)

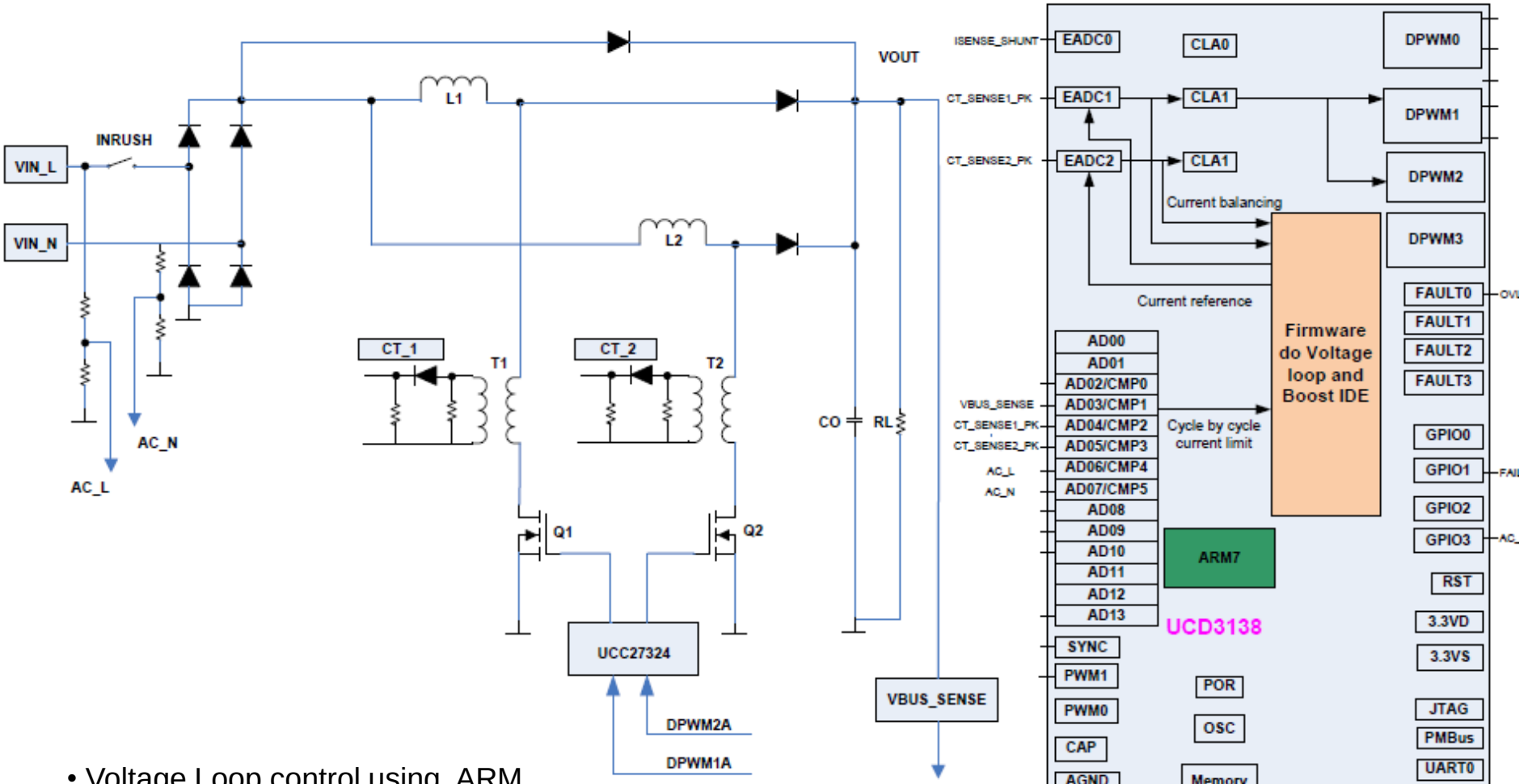
- Configurable Feedback Control
  - Voltage Mode
  - Average Current Mode
  - Peak Current Mode with slope compensation and programmable blanking time
  - Constant Current, Constant Power
- Configurable Modulation Methods
  - Frequency Modulation/Resonant Mode
  - Phase Shift Modulation
  - Pulse Width Modulation
- Input Voltage Feed-forward
- Multiple Light Load Efficiency Modes
- Integrated Copper Trace Current Sensing
- AND MORE!!!

- -40° C to +125° C Extended Temp Range
- 64pin and 40pin QFN packages
- Low Standby Power Modes

UCD3138 Innovations

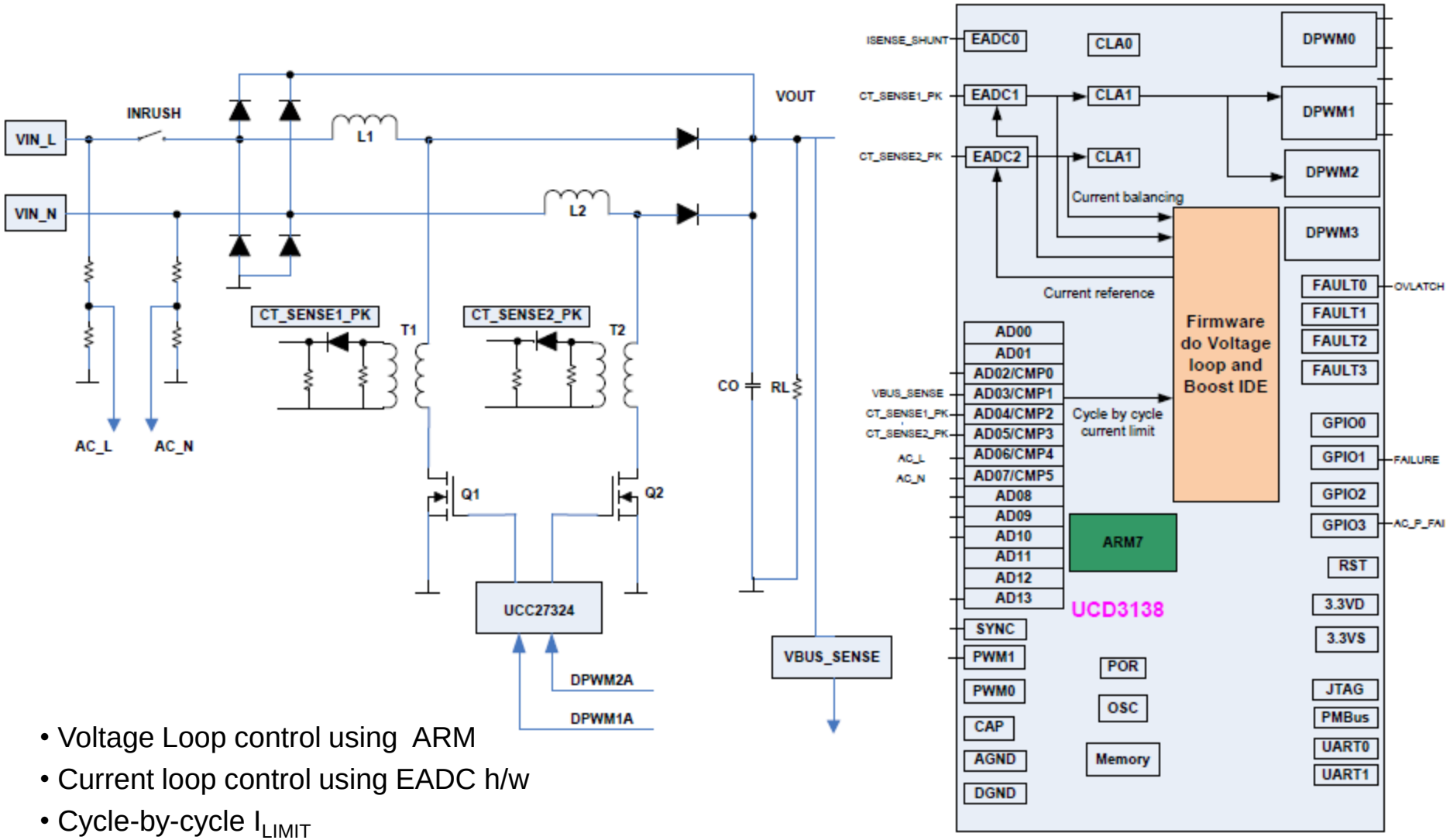
- Hardware based loop control
- Optimized power controller and high integration and high power density
- MCU based house-keeping, and on-the-fly configuration
- Fast dynamic response and flexible programming;
- Fast Fault Protection
- Support extensive topologies:
  - Voltage Mode Control and Peak Current Mode;
  - HSFB, Phase-Shift Full Bridge, LLC, ACF, Boost, Buck, Push-Pull, Flyback, and more….
- Flexible control and advanced features implementation;
  - Burst mode, Dynamic PID, Dead-time tuning, Frequency modulation, Mode-switching….

UCD3138 – Interleaved PFC Configuration



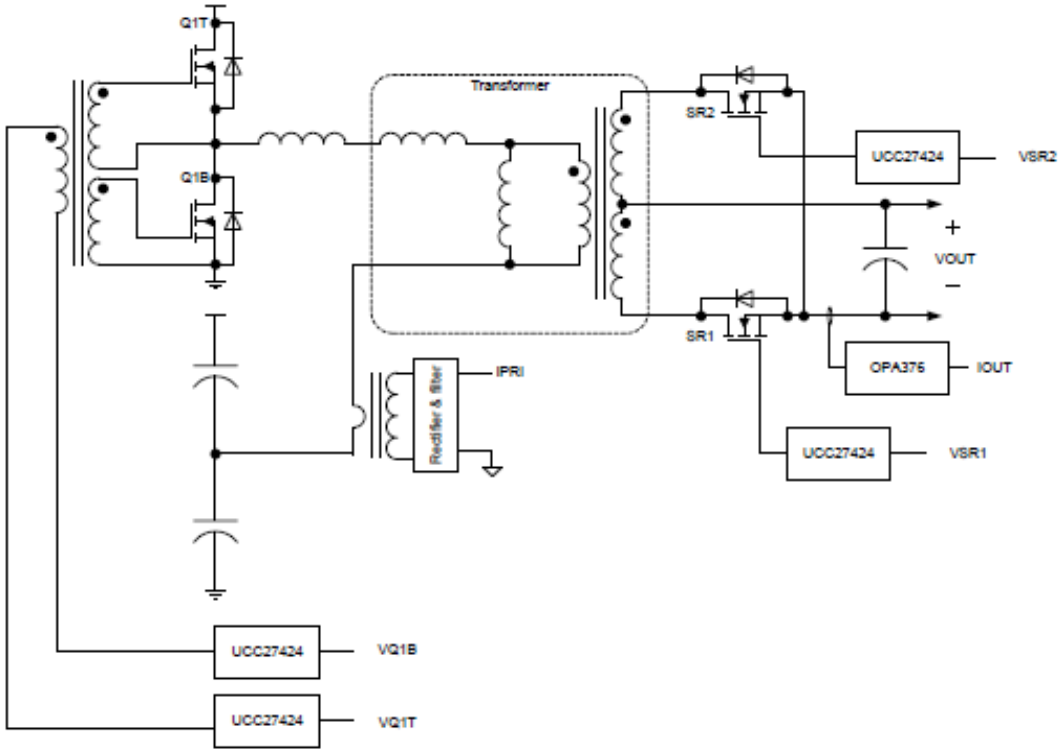
- Voltage Loop control using ARM
- Current loop control using EADC h/w (RSNS & CT sensing options)
- CT sensing for current balancing, Cycle-by-cycle I_{LIMIT}
- 8X Oversampling for very low THD at light load
- ZVS/ZCS Control at Low Line (TI Proprietary)

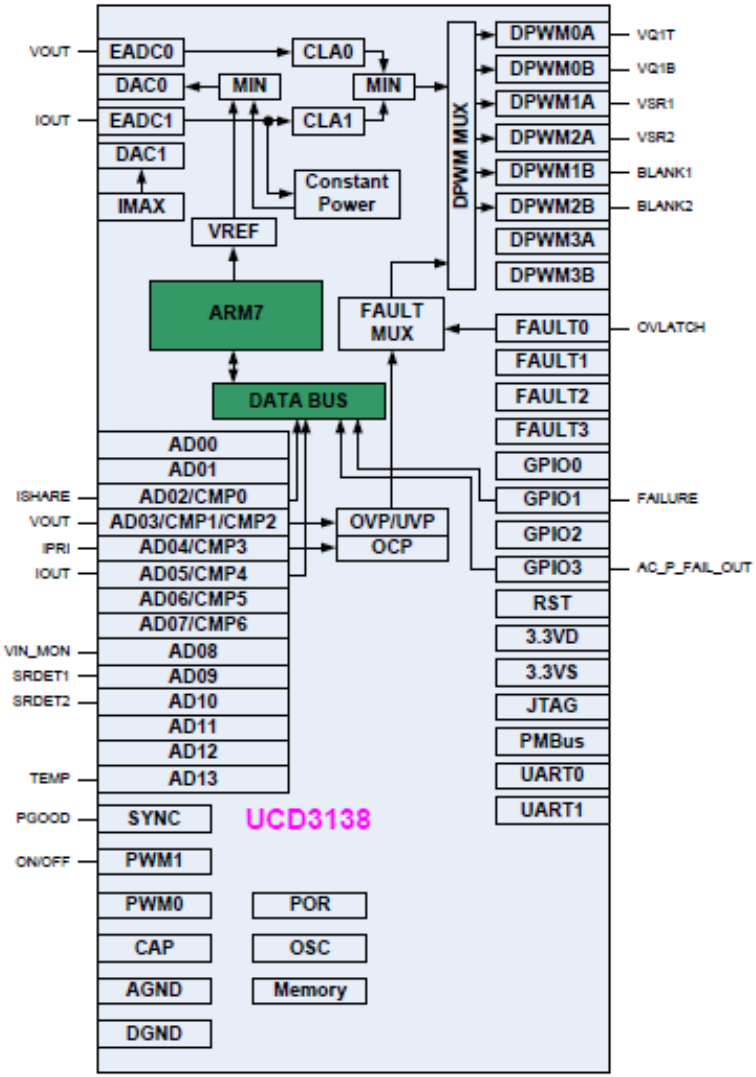
UCD3138 – Bridgeless PFC Configuration



- Voltage Loop control using ARM
- Current loop control using EADC h/w
- Cycle-by-cycle I_{LIMIT}

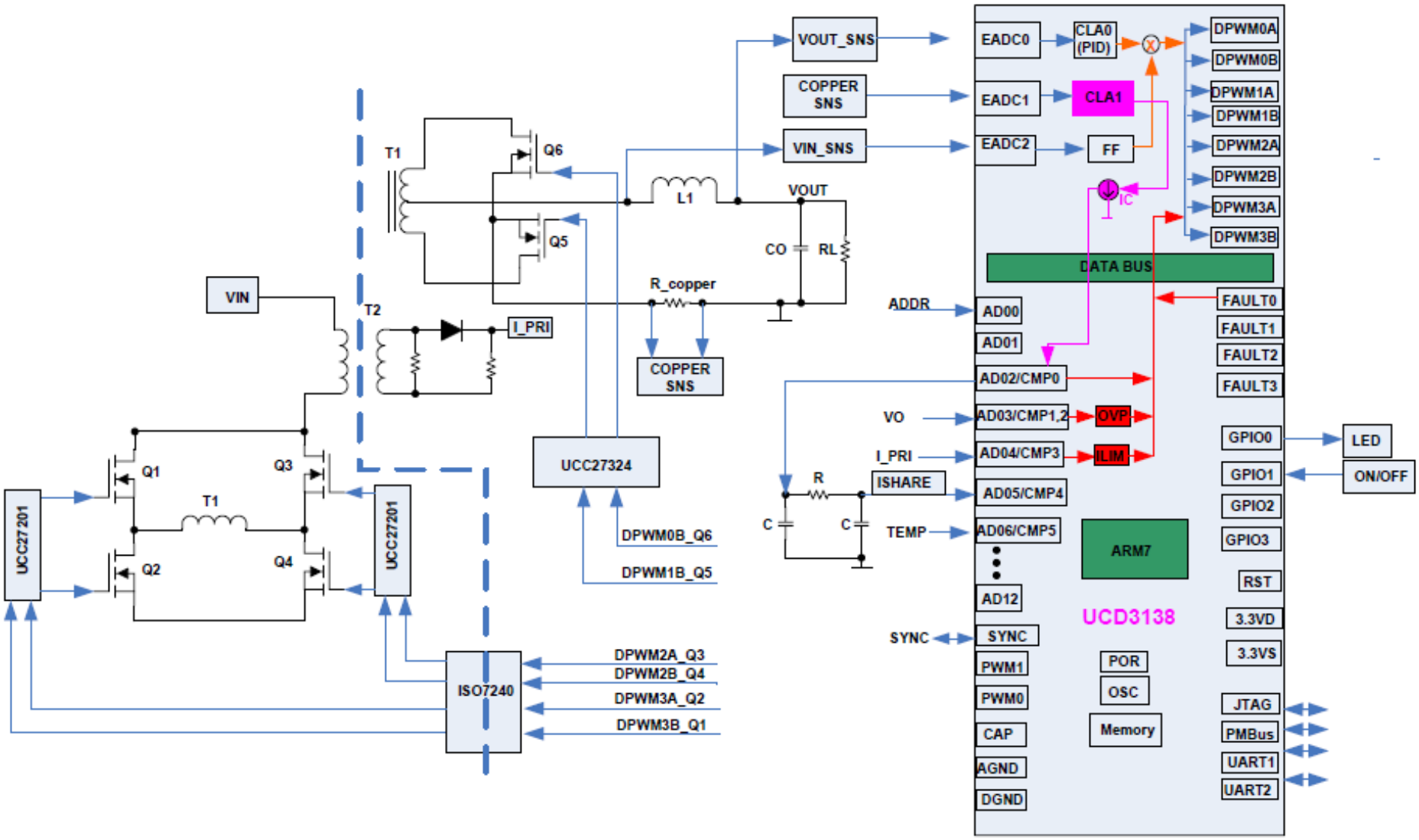
UCD3138 – LLC + Sync-Rec Configuration



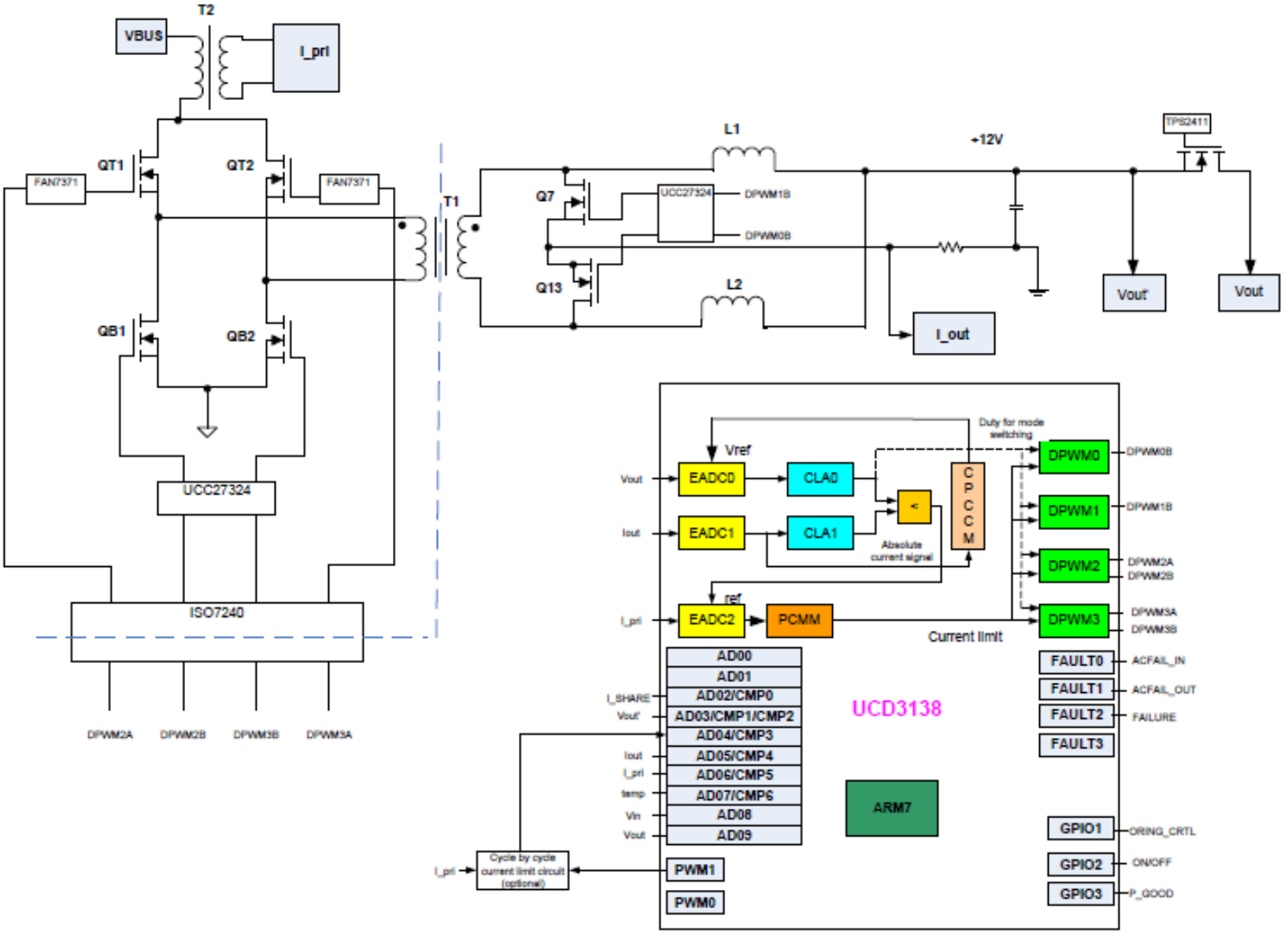


- 2ndary side Control
- VOUT control (voltage regulation) & IOUT (constant current control) control using EADC digital hardware
- Primary MOSFET outputs + integrated SR outputs

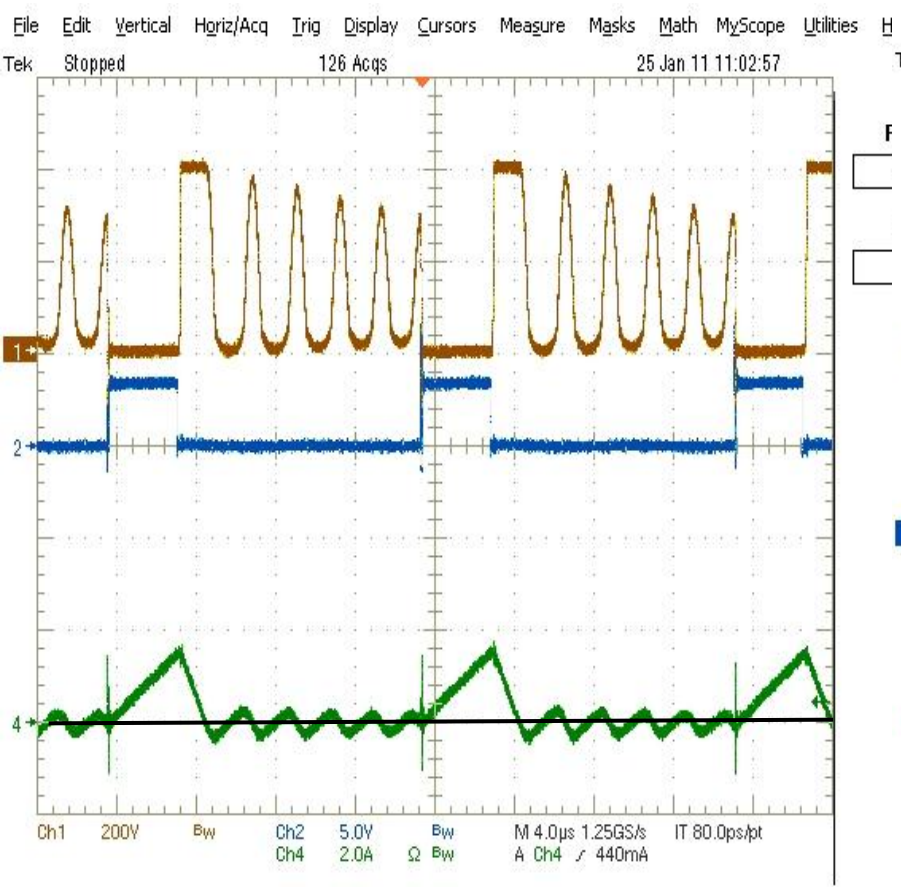
UCD3138 – HS Full-Bridge + SR Configuration

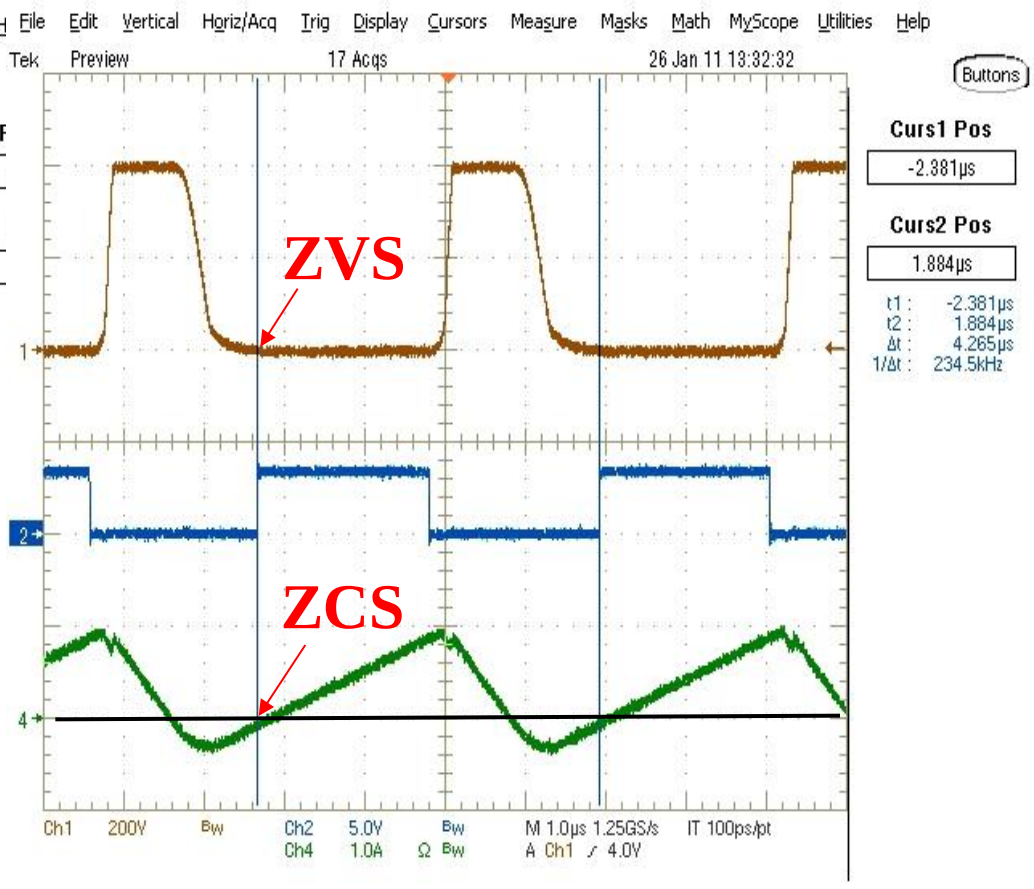


UCD3138 – PSFB + Sync-Rec Configuration



PFC ZVS Operation





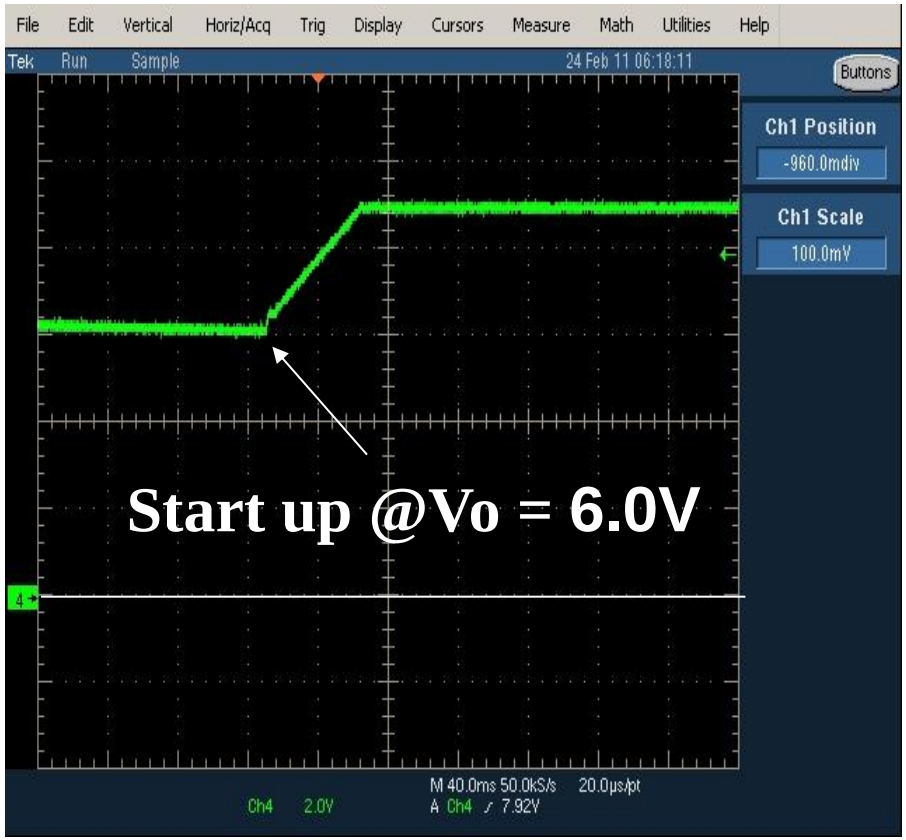
Conventional Control
Switch randomly turns on

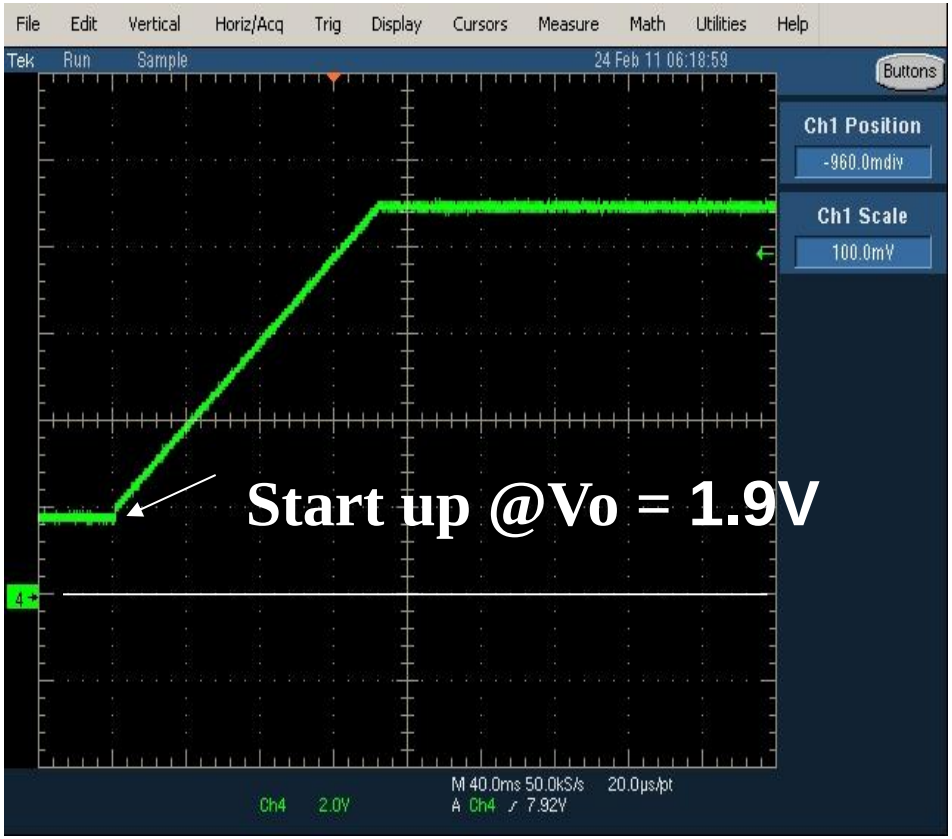
Adaptive ZVS Control
Switch turns on with ZVS and ZCS

Vin = 120V, Vout = 390V, Load = 39W (Ch1: Vds, Ch2: PWM Ch4: I_inductor)

Pre-Bias Start Up

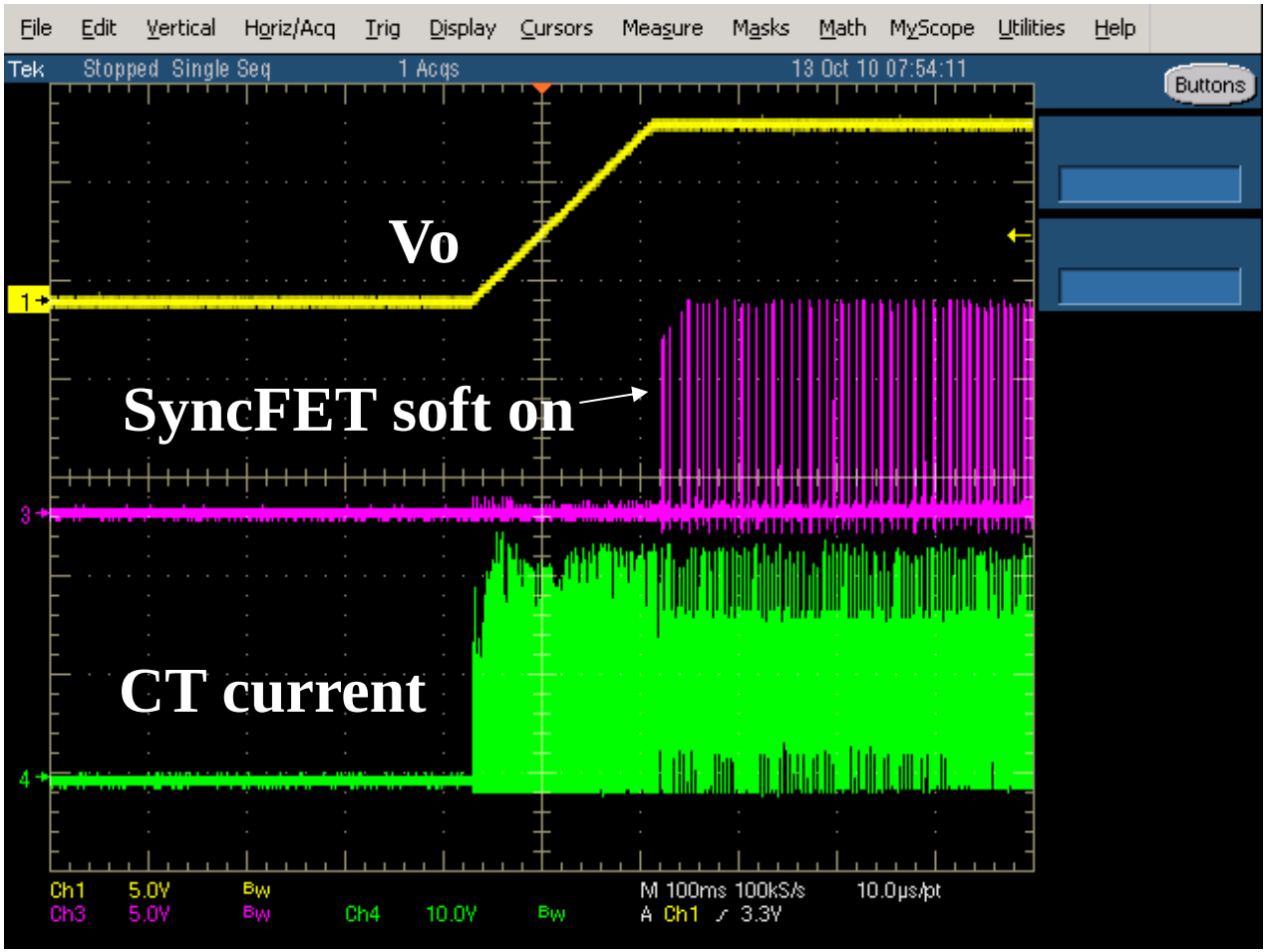
-- 1/8 brick Reference Design





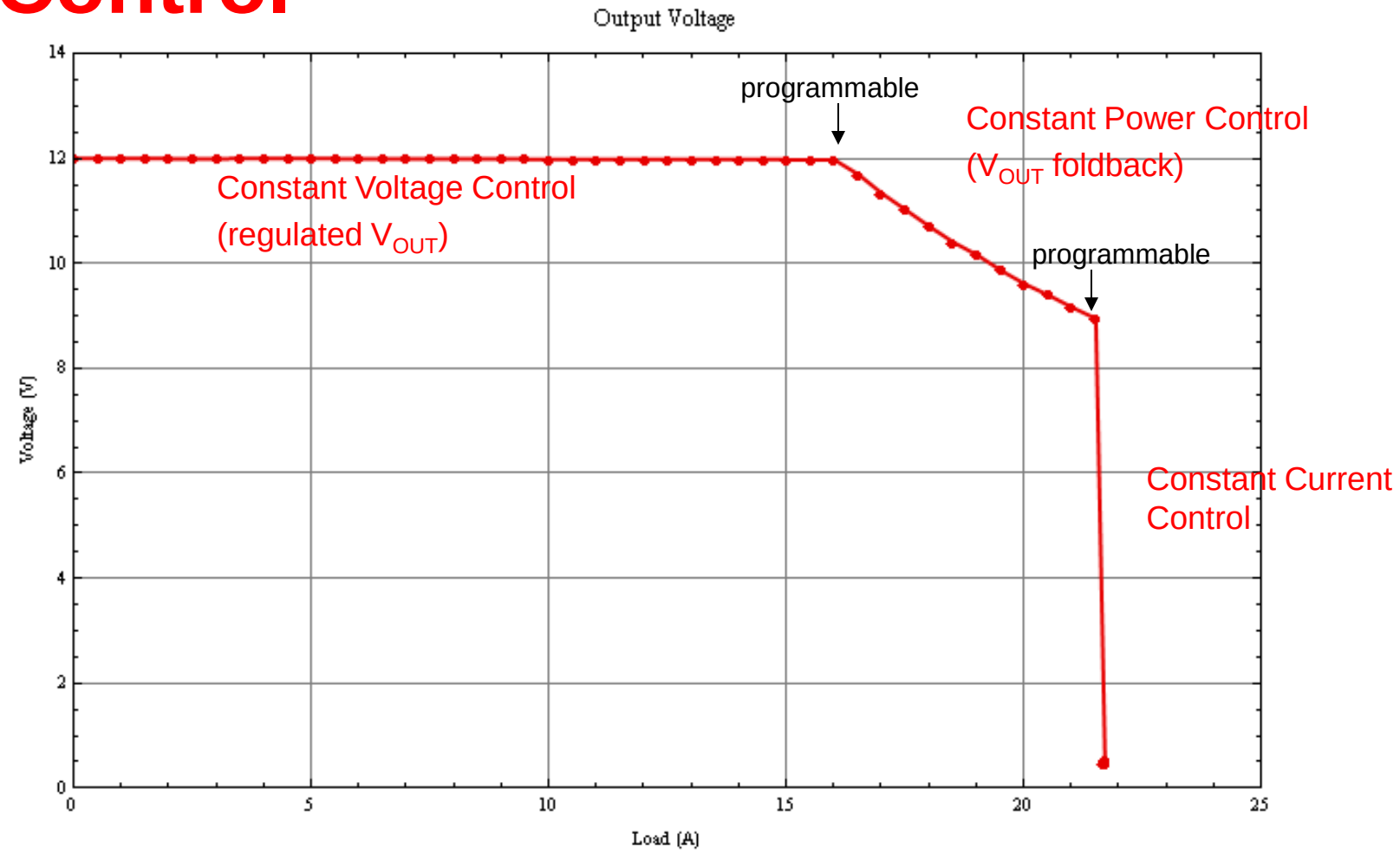
Synchronous FET Soft On

-- 1/8 brick Reference Design



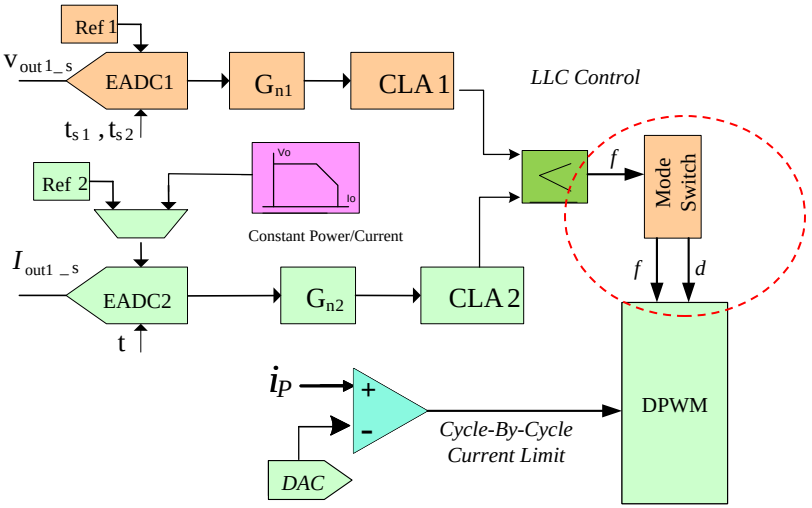
V_{OUT}(Ch 1), DPWM1B(Ch 3), V_{ct} (Ch4), I_{out} = 1A

Constant Power Constant Current Control

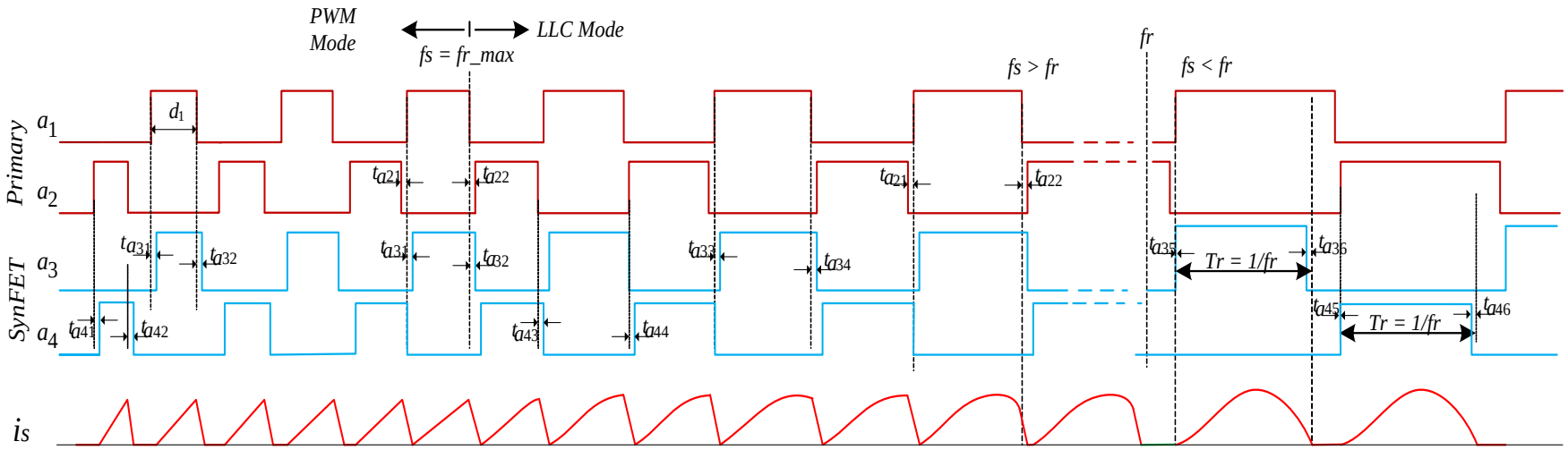


CC/CP control beneficial for Short-circuit protection

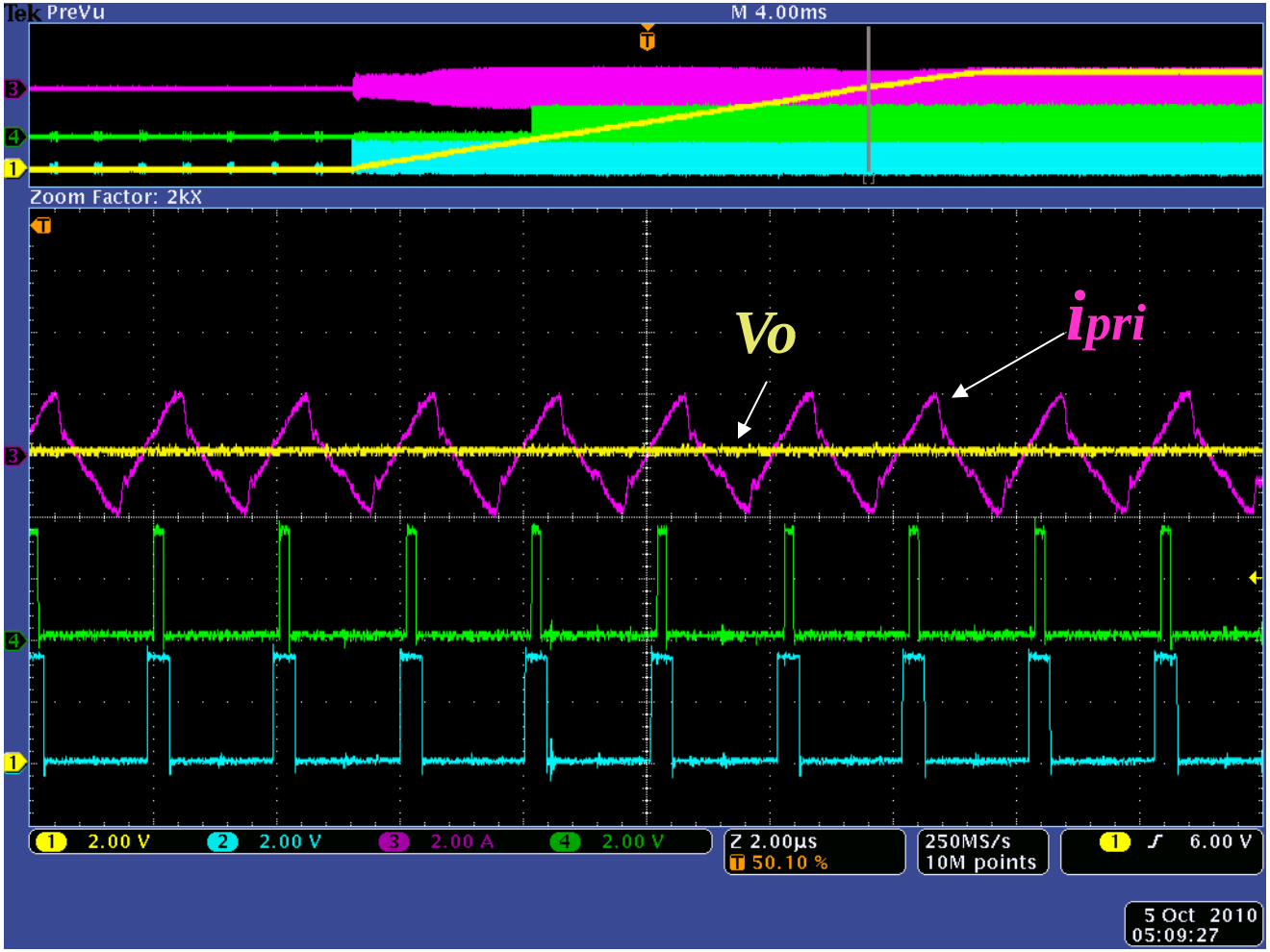
Auto Mode Switching: PWM and Frequency Modulation



- Auto Mode Switching, with programmable Frequency threshold
- Programmable Dead times
- Hardware logic and programmable syncFET gate signal outputs



LLC Ramp up at PWM Mode

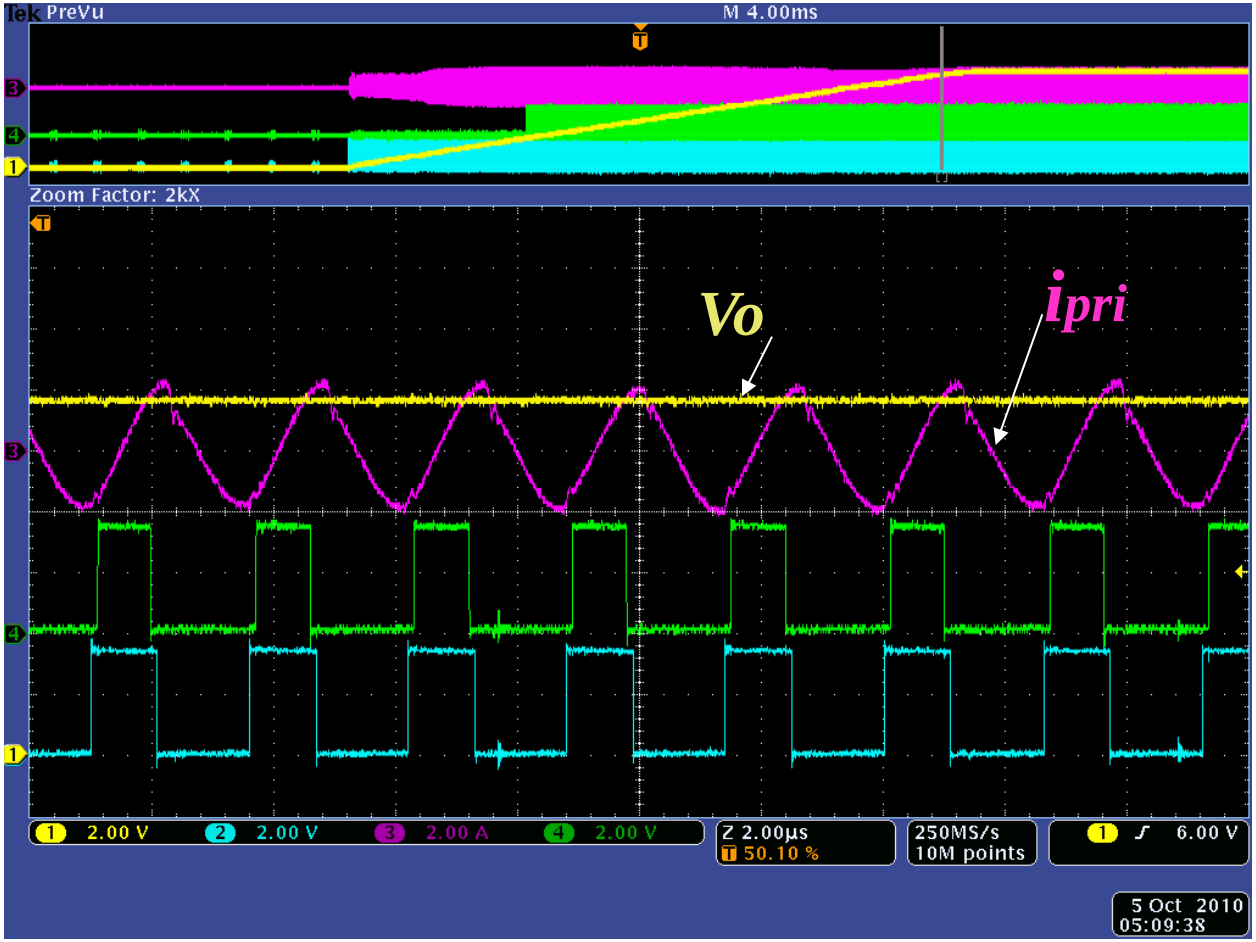


Channel 1: V_{OUT} (P6139A) (V_{IN}=300V)
Channel 2: DPWM0A ,Primary FET
Channel 3: L1 current (TCP0030)
Channel 4: DPWM1A , SyncFET

Qsyn1

Qpri1

LLC Entering FM Mode



Channel 1: V_{OUT} (P6139A) (V_{IN}=300V)
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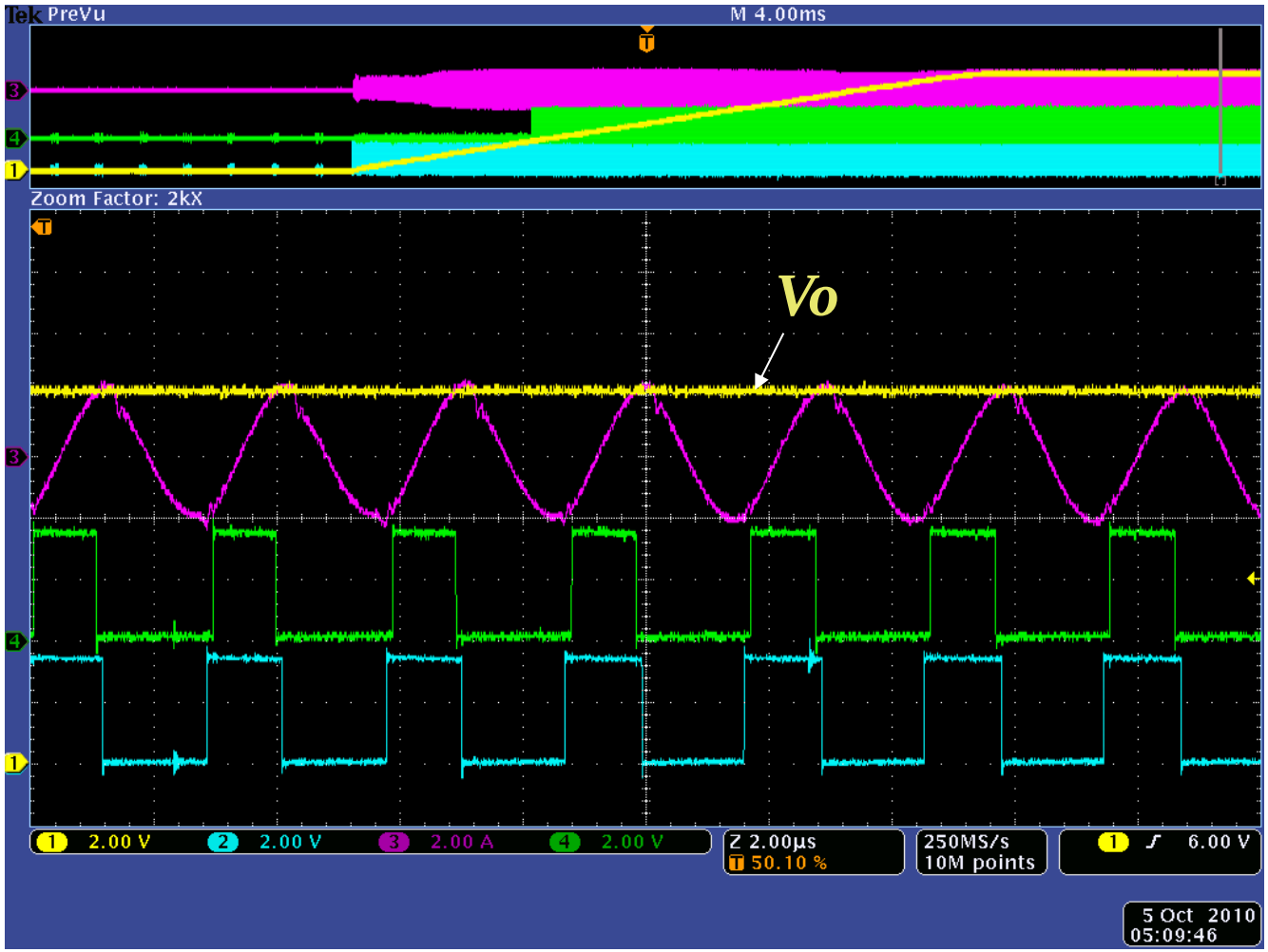
Qsyn1

Qpri1

LLC Operating at FM Mode with fs > fr



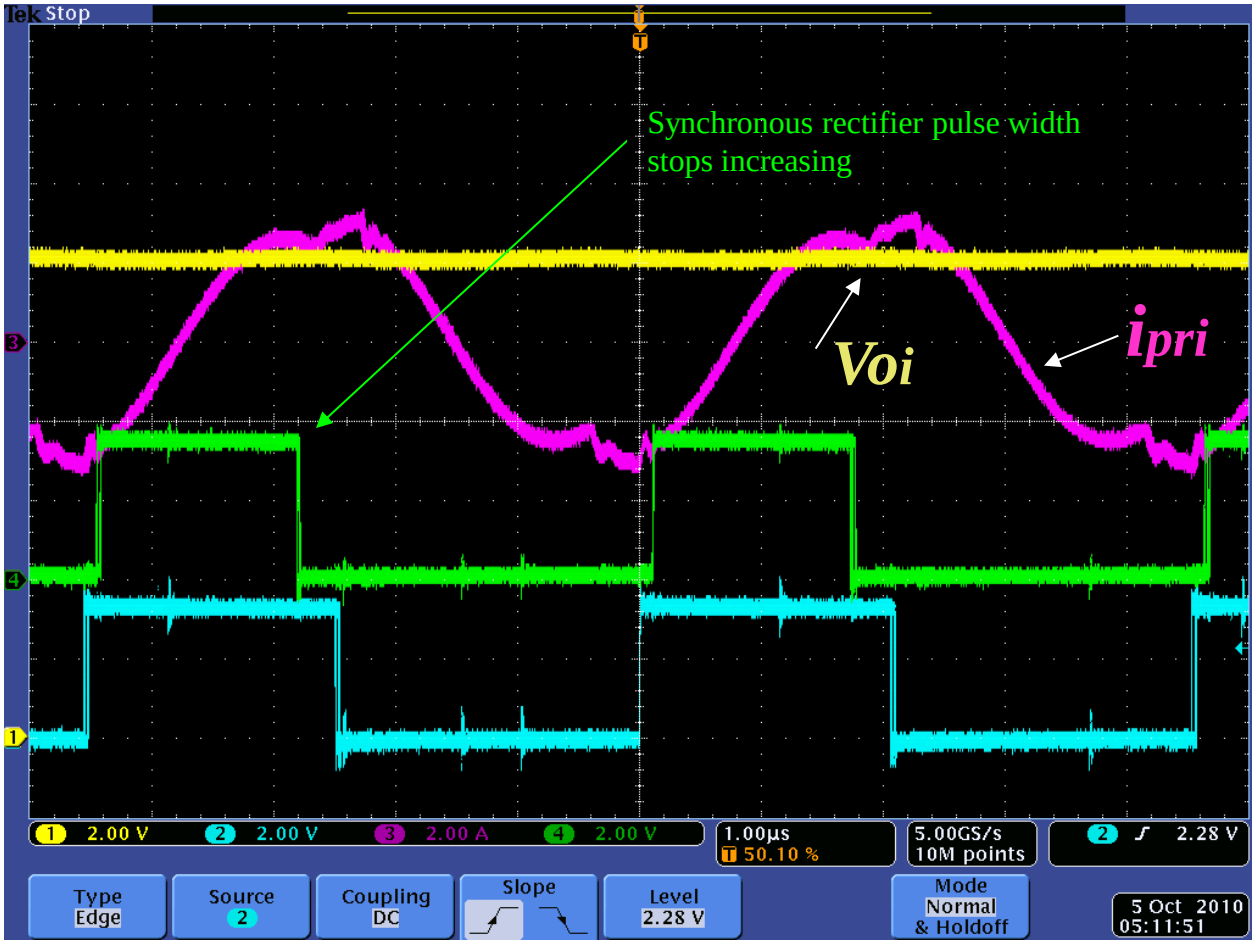
Channel 1: V_{OUT} (P6139A) (V_{IN}=300V)
Channel 2: DPWM0A ,Primary FET
Channel 3: L1 current (TCP0030)
Channel 4: DPWM1A , SyncFET

ipri

Qsyn1

Qpri1

LLC Operating at FM Mode with fs < fr



Channel 1: V_{OUT} (P6139A) (V_{IN}=300V)
Channel 2: DPWM0A ,Primary FET
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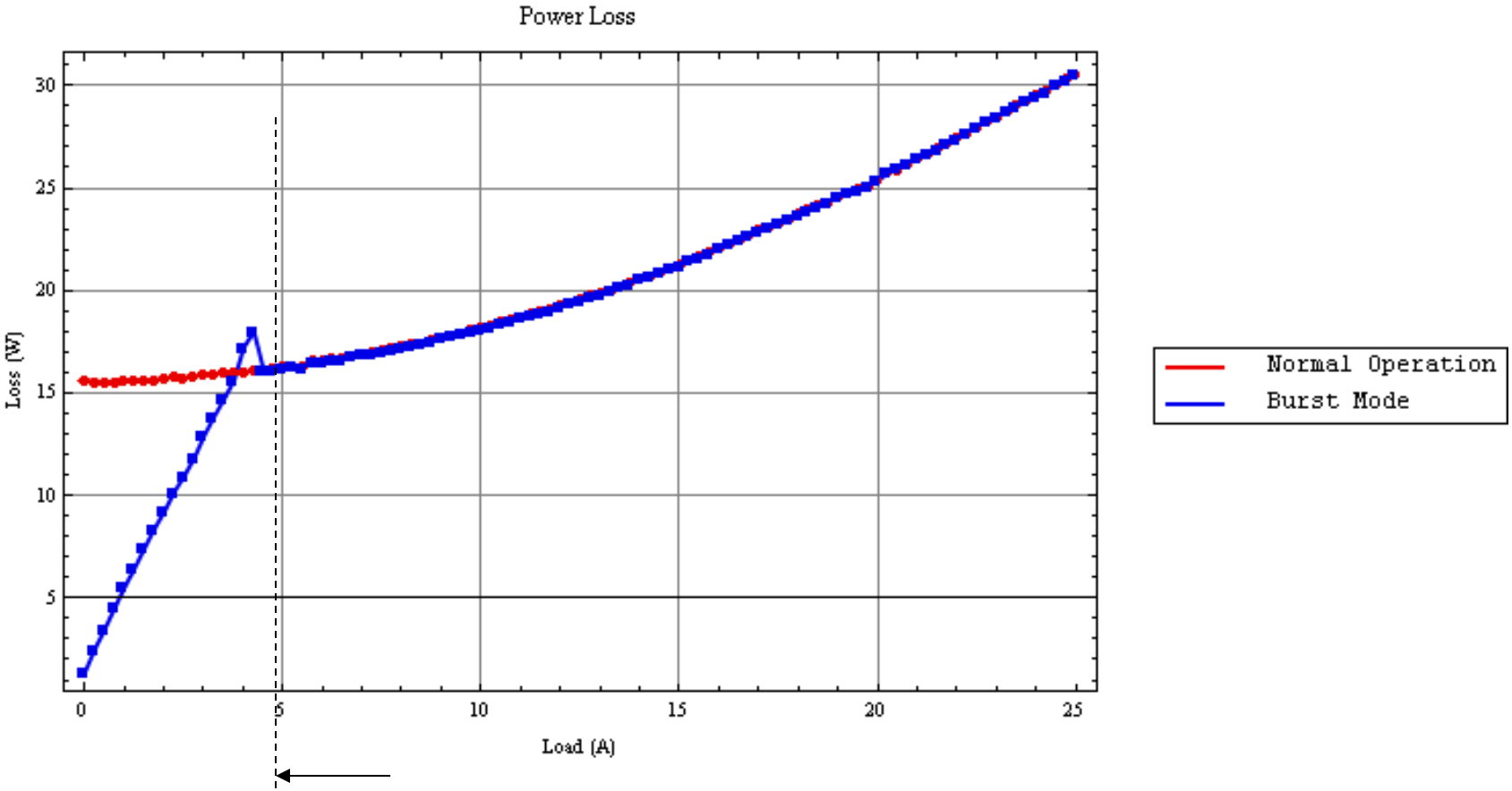
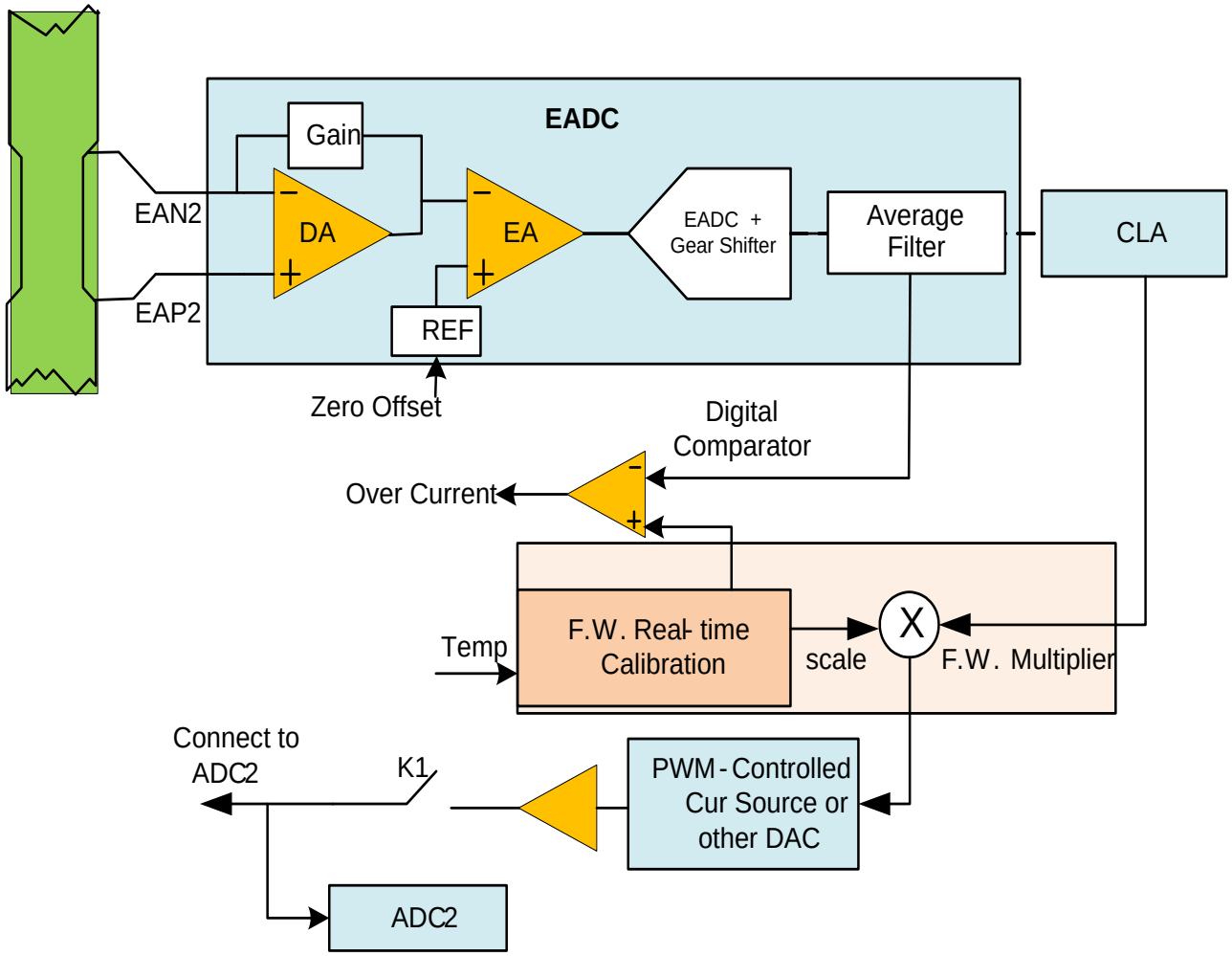
Burst Mode Power Savings



Burst Mode

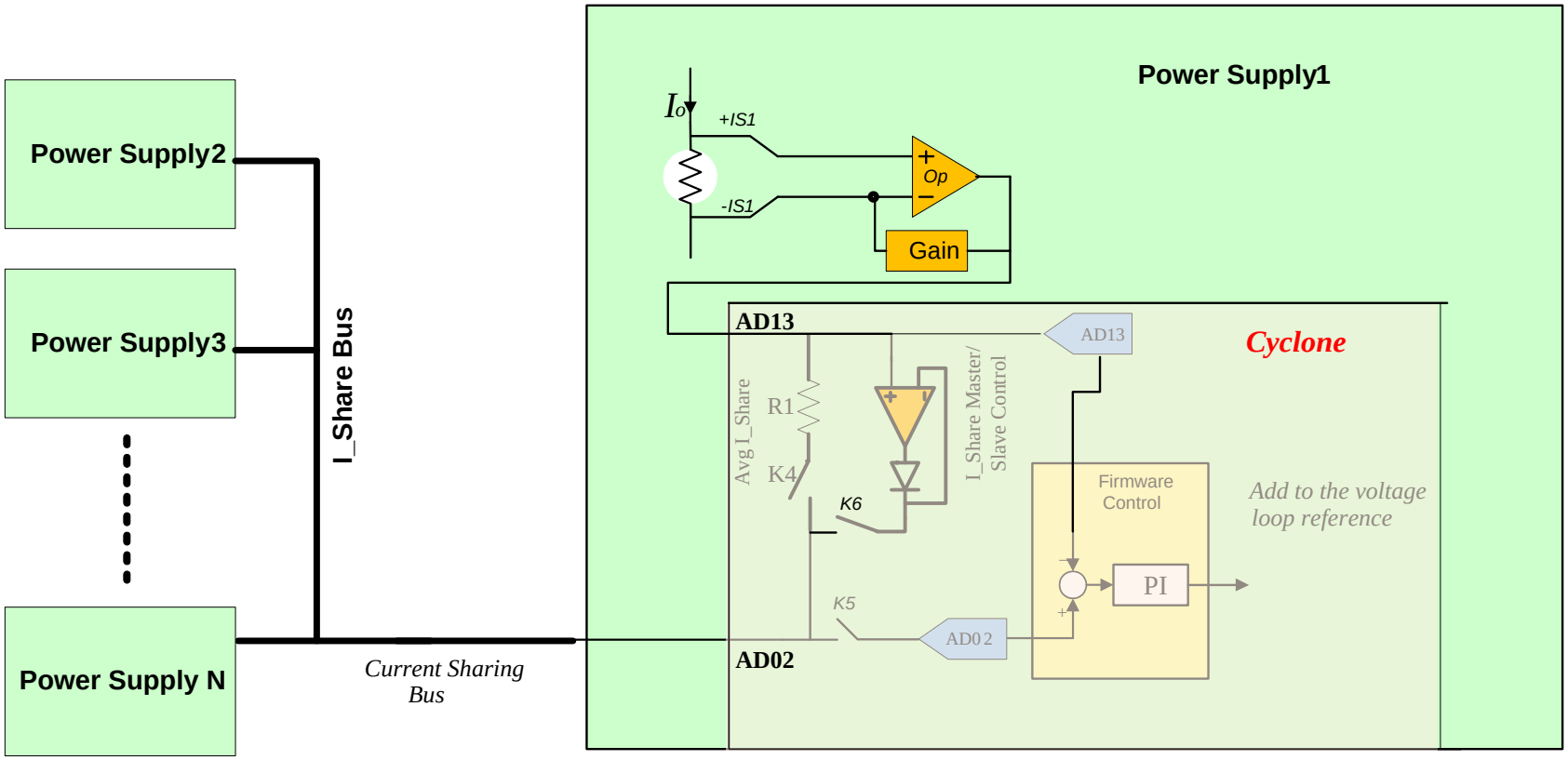
(transition point can be optimized)

Copper Trace Current Sensing



- 8x oversampling or averaging
- Digital Comparator for OC
- Firmware copper resistance and temperature calibration
- Current signal DAC output
- Digital current signal for constant current control and current sharing control

Current Sharing



Options:

- **Average Mode Current Sharing**
- **Slave/Master Mode Current Sharing**

When to Choose

When to choose Analog		When to choose digital	
System requires…	**Part**	**System requires…**	**Part**
Ultra low standby power Example: tablet / cell phone chargers, AC adapters for laptop, cameras, gaming, etc.	UCC28710 UCC28740 LM5023	Sophisticated control scheme Example: HV Air Conditioner, UPS, Electro Vehicle, etc.	C2000 family
Ultra low solution cost Example: AC adapters for set-top-box, networking, etc.	UCC28700 UCC28720	Robust performance under varied input/load/fault conditions Example: Startup into Pre-Biased load, input DIP transient, etc.	UCD3138
Ultra small form factor Example: Telecom 1/32 brick power modules	LM5025A LM5020	Communication, diagnostic, hot-booting, self-calibration / auto-tuning Example: power supply for RRU of Base Station, Solar Energy system, etc.	UCD3138 UCD3138064 C2000 family
Ultra simple Example: Power supplies for home appliance with PWM logic and high voltage driver/FET integrated, non-isolated AC/DC buck for powering microcontrollers & LED displays, LED lamp, etc.)	UCC25230LM5017 LM5018 LM5019	System level efficiency optimization Example: Power supply for server, high end networking, etc.	UCD3138 UCD3138064

Thanks