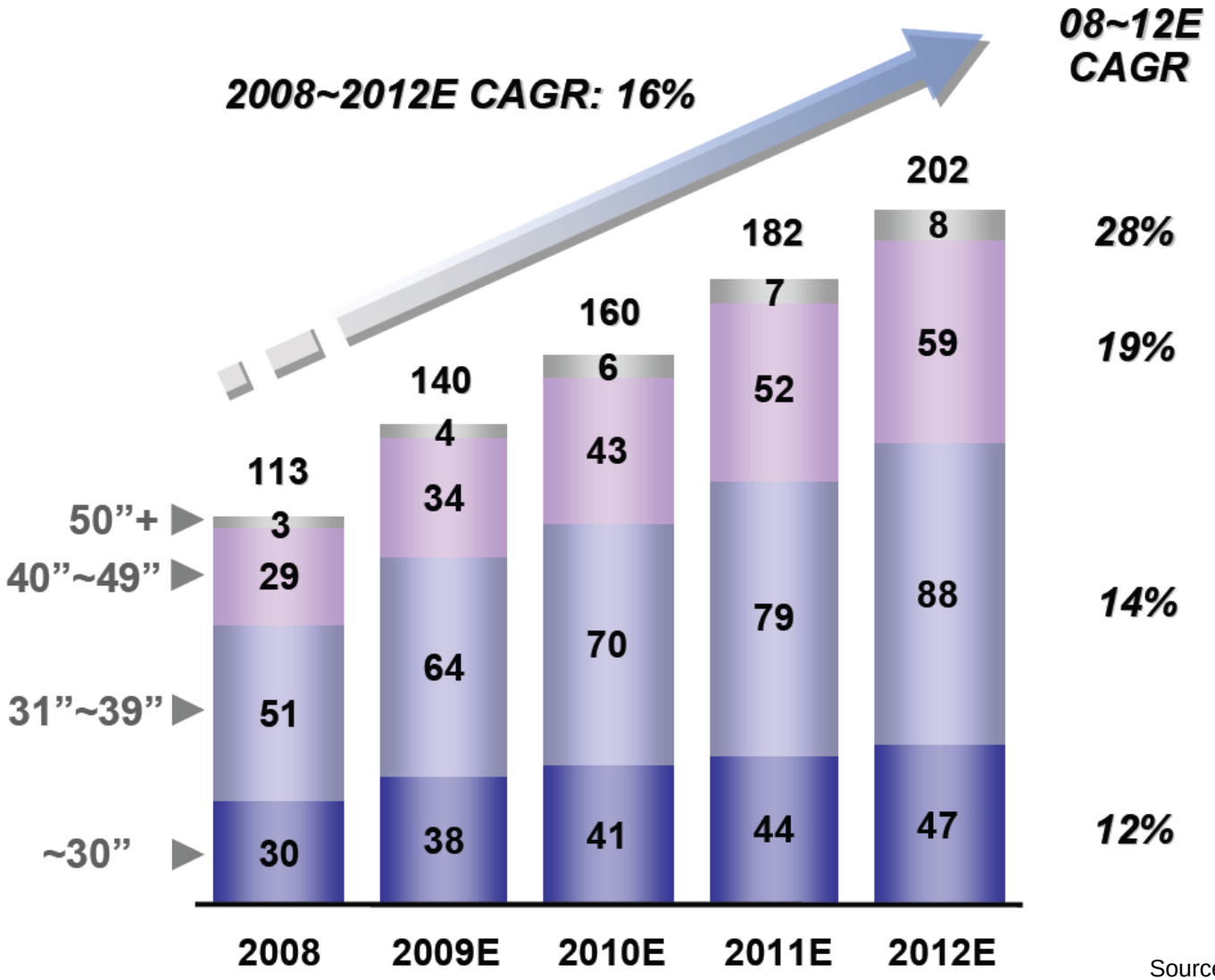
ON Semiconductor®

AC-DC LCD TV Power Architecture and LED Backlight

LCD TV Power Architecture and LED Backlight

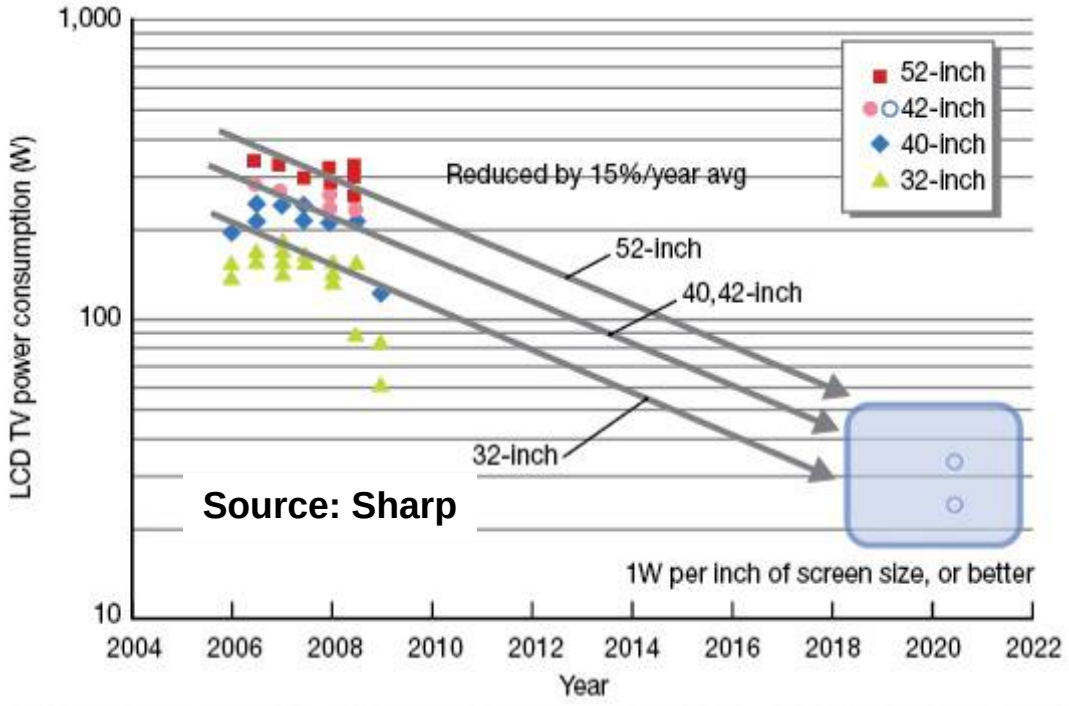
- **LCD-TV Market**
  - Power Reduction Trend
  - Edge LED LCD TV Backlight
- **26” to 42” H-V LIPS Reference Design**
- **46/47” Power Reference (PSU) for any Backlight solution**
  - Interleaved Frequency Clamp CrM PFC with NCP1631
  - Quasi Resonance Valley lock out Flyback Converter with NCP1379
  - ECO Standby SMPS Solution with NCP1053A
- **46/47” Backlight solution**
  - LIPS Inverter
  - Edge LED Driver
- **Conclusion**

LCD-TV Shipments by Size

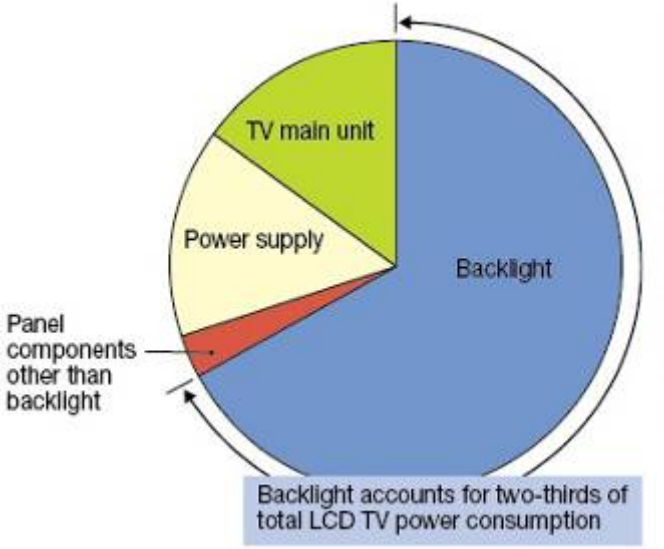


Source: Displaysearch 2Q 09

Power Reduction Trend



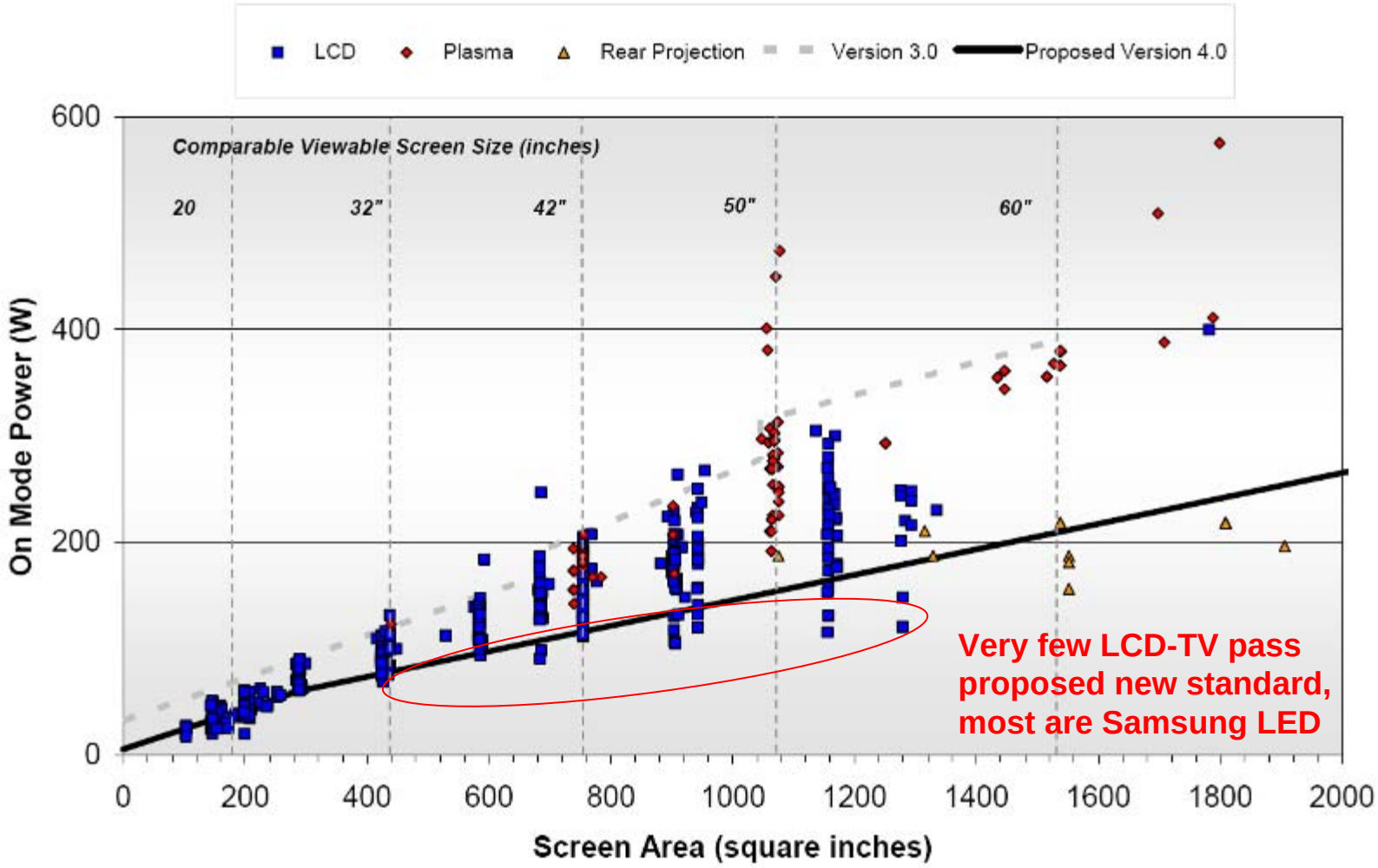
- Regulatory reduce power consumption in active and standby mode
- New technologies focused on improving efficiency



- Proposed ENERGYSTAR TV regulations (V4.0) will lower <u>average</u> power targets

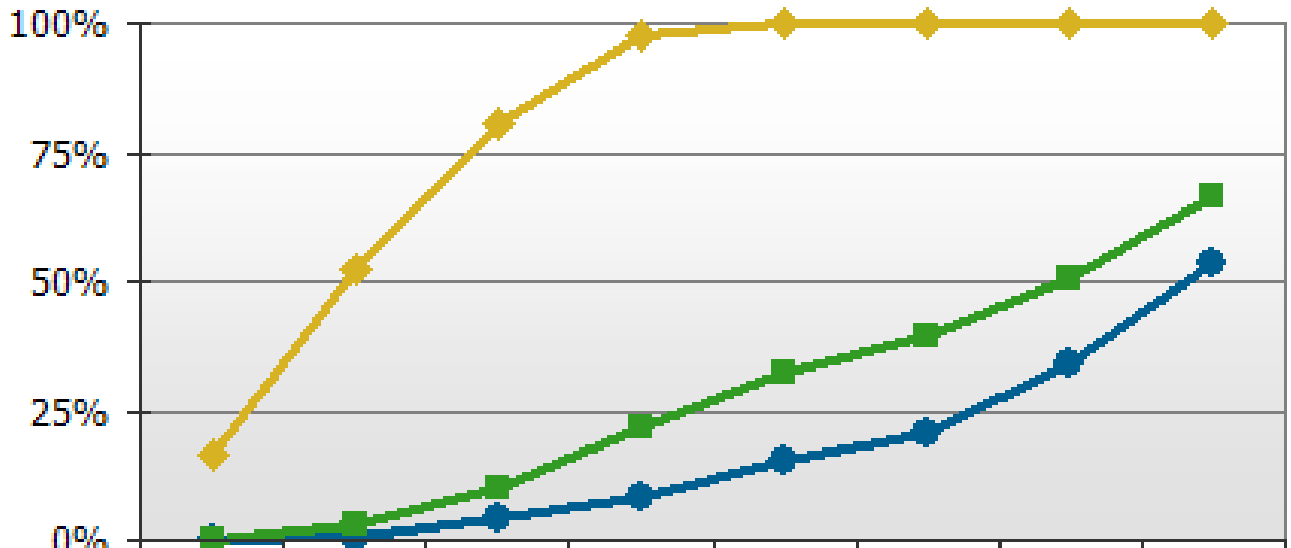
Power consumption reduction ~ - 50% over 2 years

Proposed ENERGY STAR rev4.0 Standards



Target Effective Date: May 2010

LCD-TV LED Backlighting



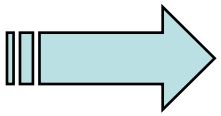
	2008	2009	2010	2011	2012	2013	2014	2015
LED Backlight in Notebook	16%	52%	81%	97%	100%	100%	100%	100%
LED Backlight in Monitor	0%	1%	4%	8%	15%	21%	34%	54%
LED Backlight in LCD TV	0%	3%	10%	22%	32%	40%	50%	66%

Source: DisplaySearch July 2009

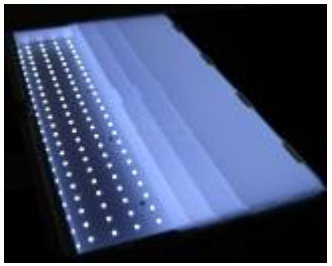
LED TVs is forecast to grow to 20-32% (~64 M#) by 2012

Comparison of LED LCD TV Backlight Options

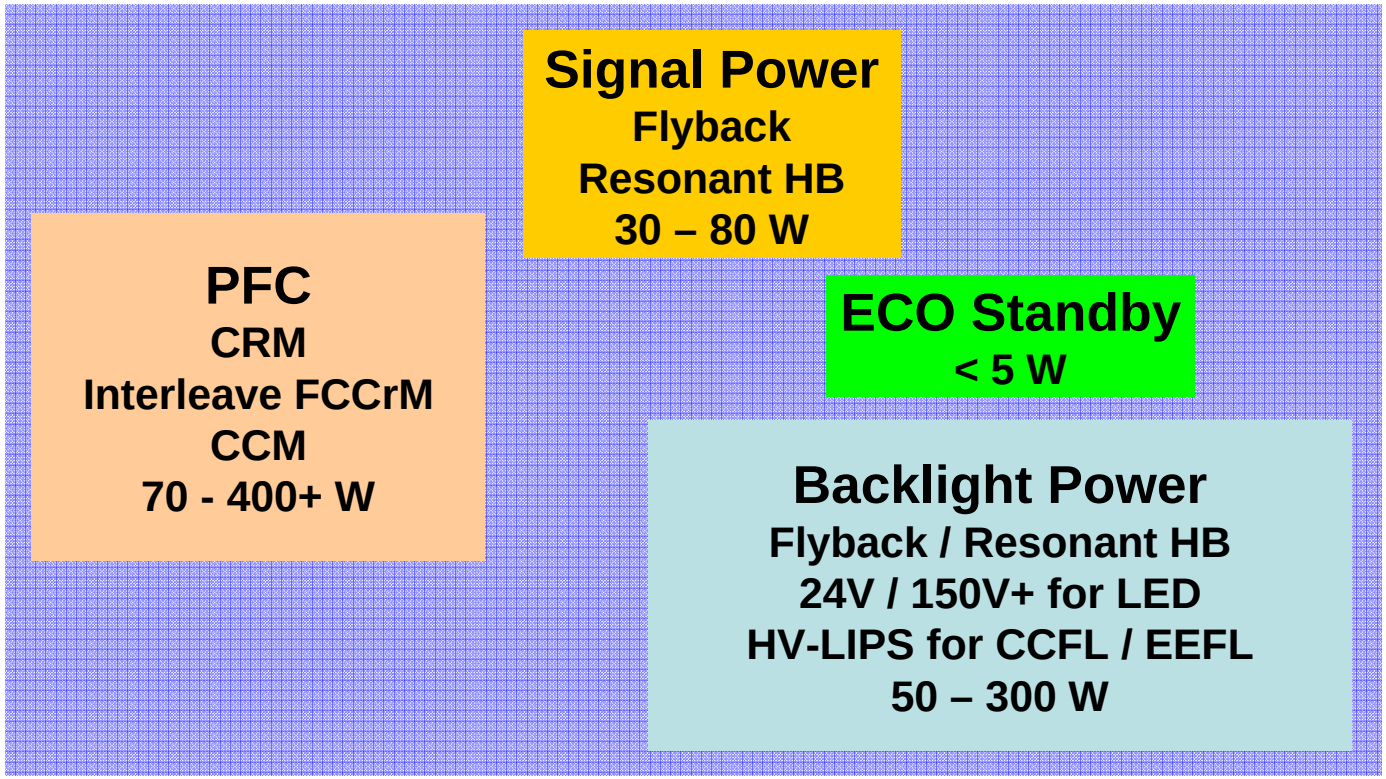
	Edge-lit LED BLU	Direct-type LED BLU
LED driver	High voltage Boost, buck, linear with Vf adjustment	Boost or Buck plus Multi-channel linear
Merit	• High Power Efficiency • Good system reliability independent LEDs performance. • **Cost down of system** • **Slim LCD TV**	• Deep blacks, better contrast • Local dimming • Scanning for higher frame rate • Low power consumption • **Complex signal processing**
Concerns	• System Noise & EMI • Using lots of external components (Inductor, capacitor, diode)	• Thermal limitations • High system cost due to number of LEDs and # of Drivers • Picture artifacts



Edge LED > 90% ?



Power Architectures Remain Varied



Traditional 24 V Backlight and HV-LIPS approach
Thin TV design impacts solutions choices as well

32” HV-LIPS Reference Design

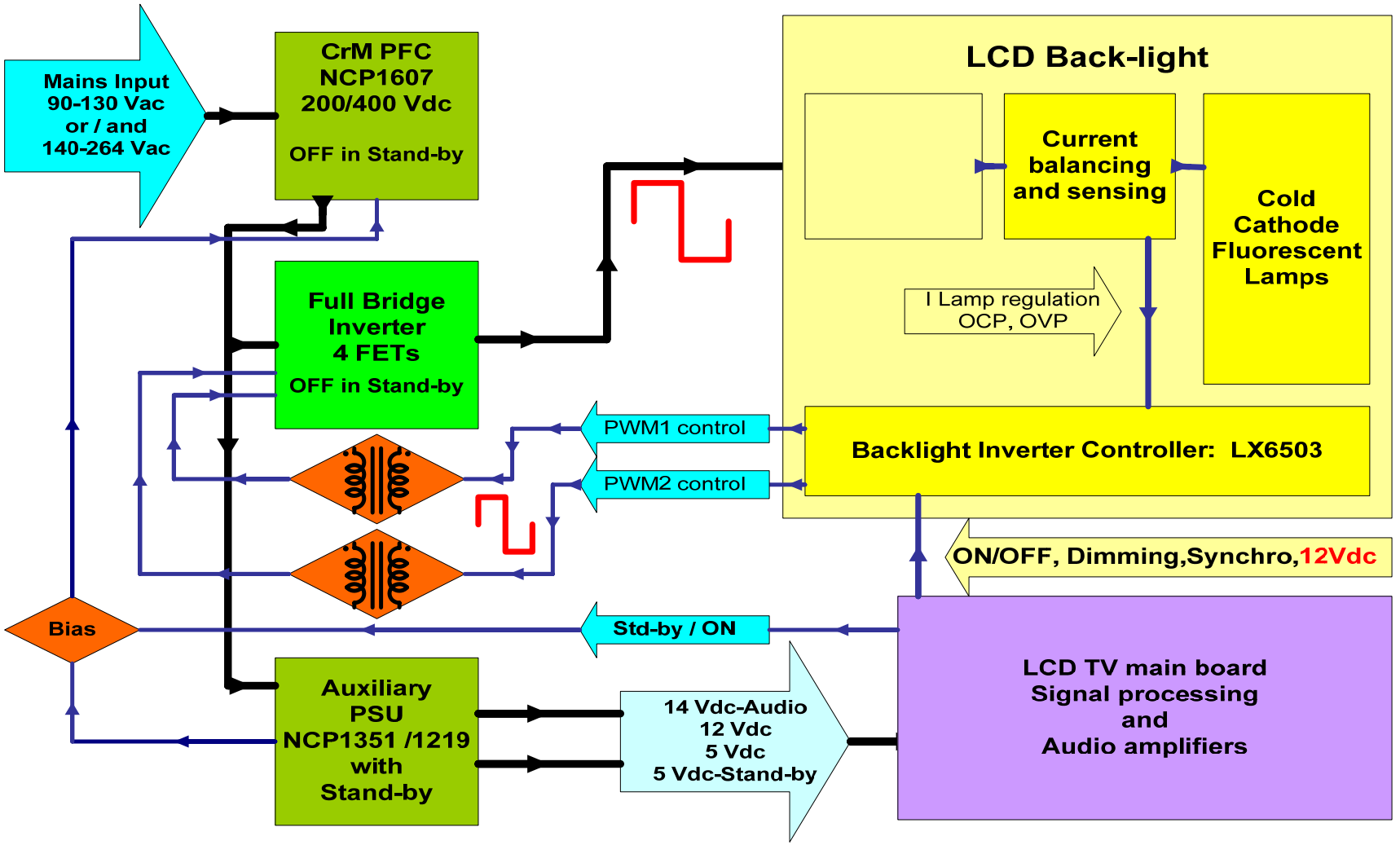
- **For 32” (highest volume size) with possible extension to 26/42”**
  - Available since March 2009
  - For CCFL (>> 95% of backlight) with possible extension to EEFL
  - Single PCB with **L**CD and **I**nverter **P**ower **S**upply

- **Very Cost effective solution**
  - No extra Standby SMPS
  - Straightforward CrM PFC

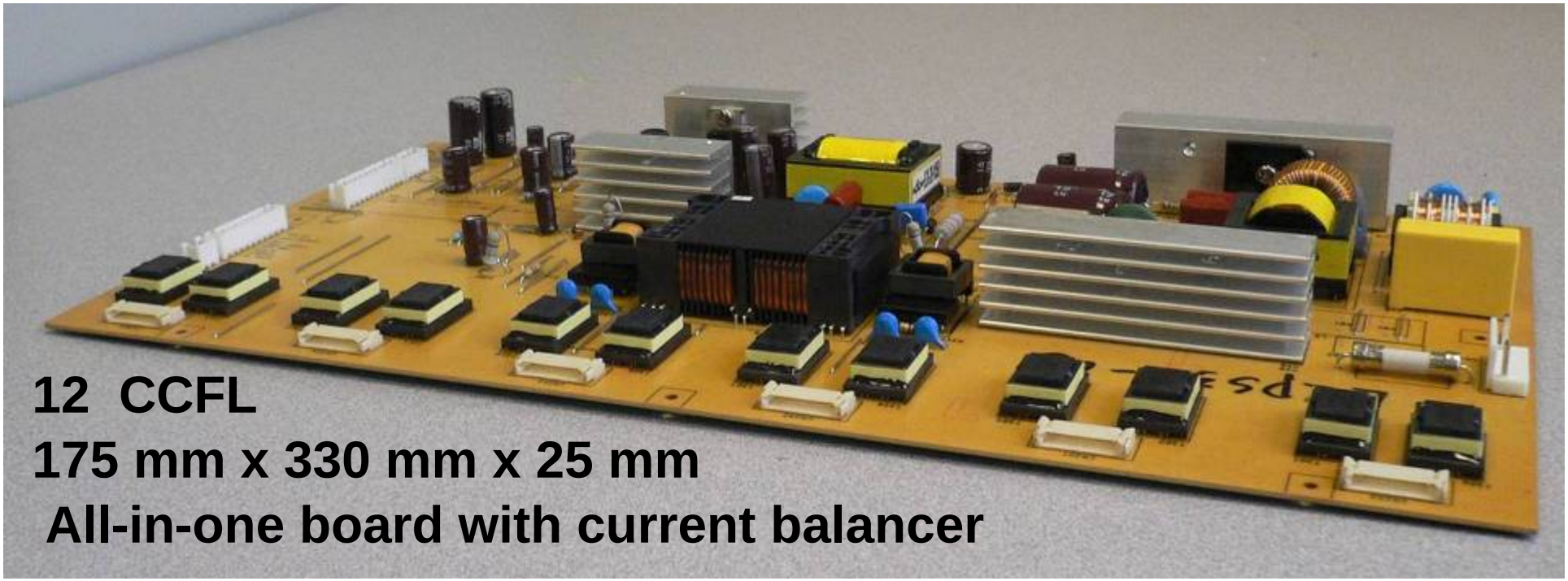
- **Key ON Semiconductor ICs**
  - **NCP1607** as CrM PFC controller
  - **NCP1351** or **NCP1219** as Flyback with low power standby mode

- **LX6503 Microsemi Backlight controller**
  - Full Bridge High Voltage Inverter without High Side Driver (discrete circuit)
  - Jin balance solution

32” HV-LIPS LCD TV Block Diagram



HV-LIPS LCD TV Complete Solution

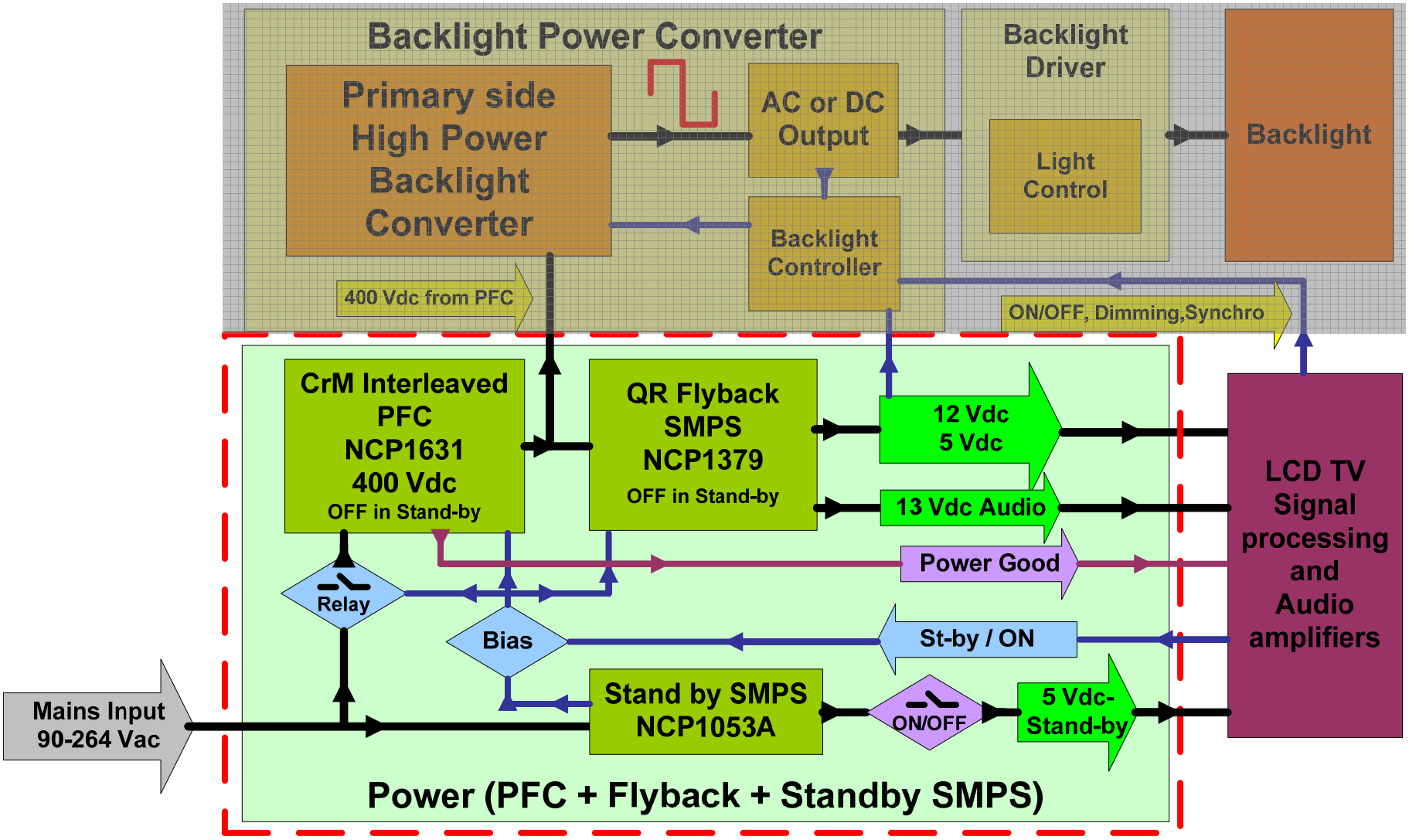


Green Point Reference design documentation:
http://www.ONSemiconductor.com/pub_link/Collateral/TND360-D.PDF

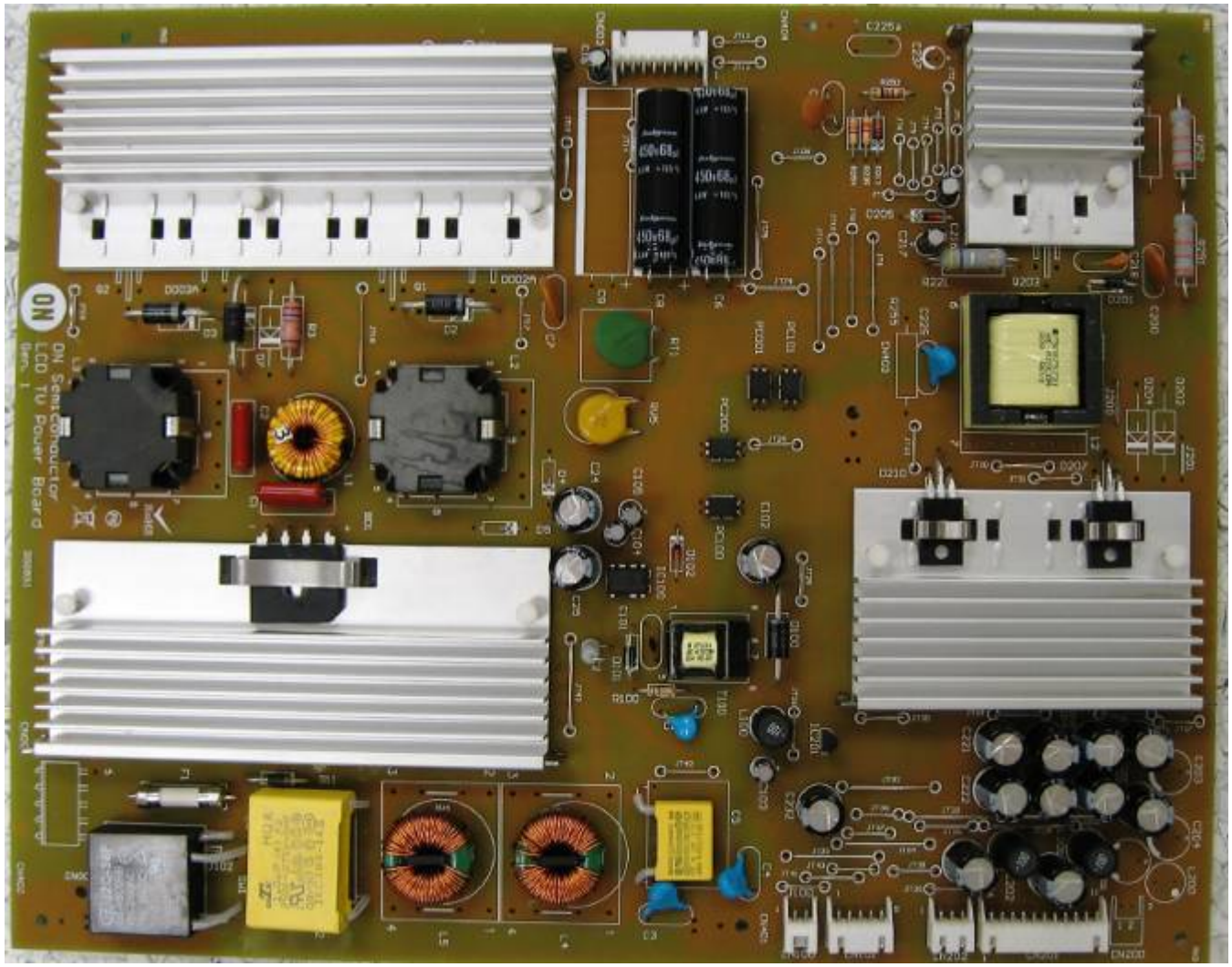
46/47” Power Reference (PSU)

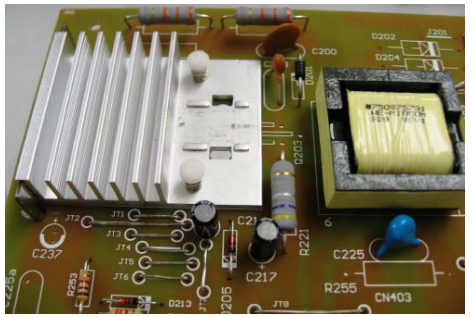
- **Higher power LCD-TVs from 40/42” to 52”/55”**
- **Project focusing on power stage only**
  - **ECO standby “OFF mode”**
  - **Interleaved frequency clamp CrM PFC**
  - **Up to 70 W Flyback**
  - **Up to 200 W for backlight**
- **Low profile design**
  - **1st phase: < 13 mm**
  - **2nd phase: < 8 mm**

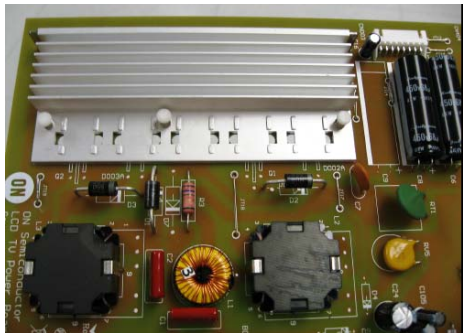
46” LCD TV Power Block Diagram

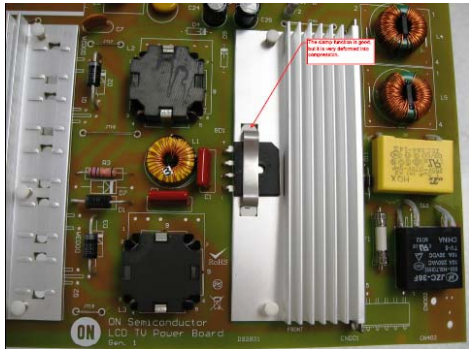


46” LCD TV Power Solution Unit (PSU)





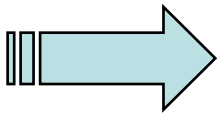




Low Profile design < 13 mm / 17.5 mm total

46” LCD TV PFC Solution

- **Up to 300 W Interleaved Frequency Clamp CrM PFC**
  - **Better EMI and EMC**
  - **Lower I_{rms} for output C**
  - **Better for SLIM design**
  - **Standard parts (= 32”CrM)**
- **New controller NCP1631**
- **Easy SLIM narrow range version**



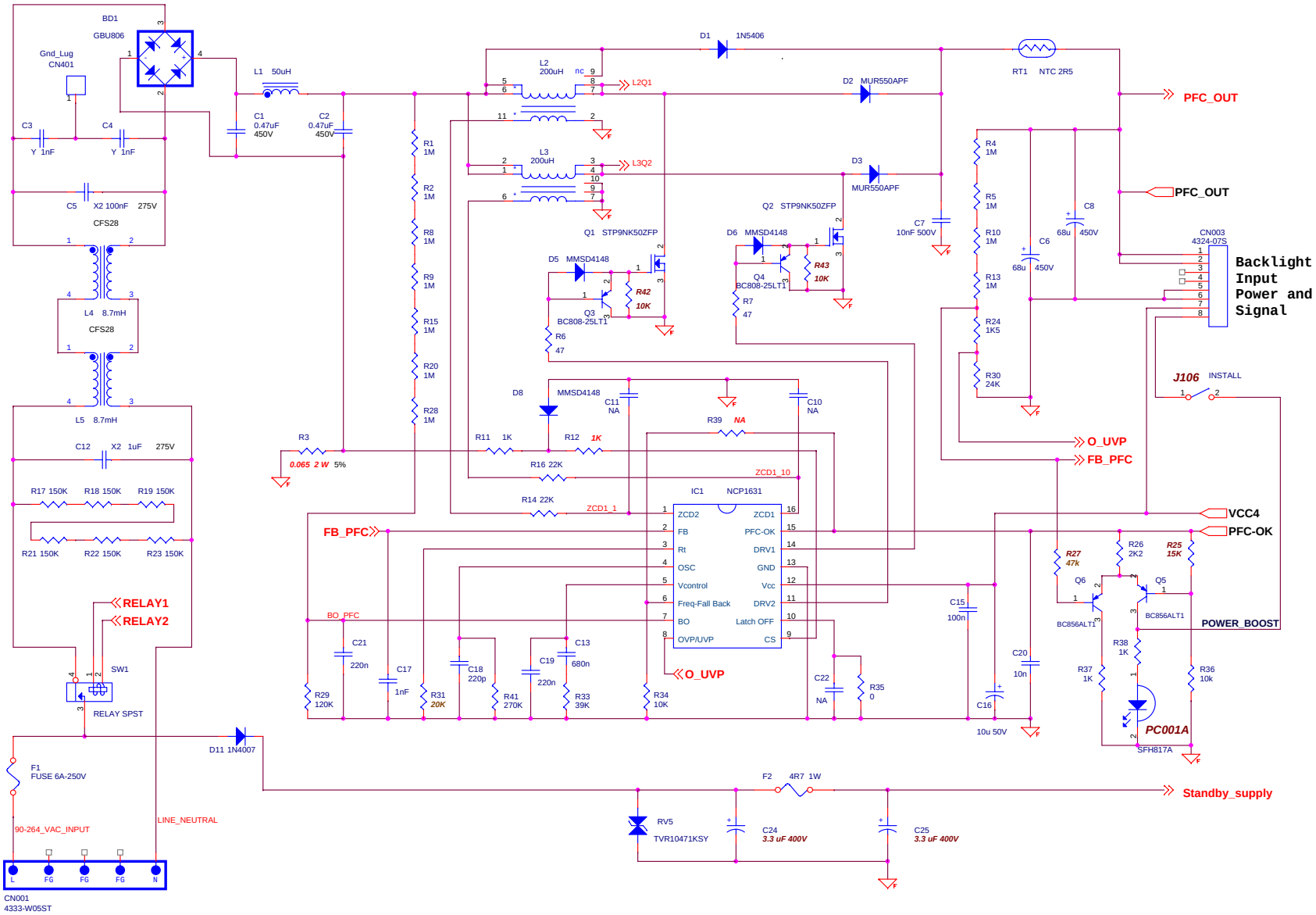
Interleaved FCCrM PFC for > 200 W & SLIM design

PFC Summary

	Single FCCrM stage		Interleaved FCCrM stage		Single CCM stage	
	General	300-W, wide mains	General	300-W, wide mains	General	300-W, wide mains
$\Delta I_{in\,(max)}$ (A)	Independent on L	10.0 A	Independent on L	2.6 A	Depends on L	2.6 A (at 90 V_{ms}, full load if L = 250 µH)
Inductor	1 coil 	75 µH $I_{L,pk(max)}$ = 10 A $I_{L,rms(max)}$ = 4.1 A $L*I_{pk}^2$ = 7.5 mJ	2 coils 	150 µH $I_{L,pk(max)}$ = 5.0 A $I_{L,rms(max)}$ = 2.0 A $L*I_{pk}^2$ = 3.7 mJ	1 coil 	250 µH $I_{L,pk(max)}$ = 6.3 A $I_{L,rms(max)}$ = 3.5 A $L*I_{pk}^2$ = 9.9 mJ
Total MOSFET conduction losses (with below MOSFETs)	$\frac{4 \cdot R_{DS(on)}}{3}\left(\frac{P_{in(avg)}}{V_{in(ms)}}\right)^2\left(1-\left(\frac{8\sqrt{2}\cdot V_{in(ms)}}{3\pi V_{out}}\right)\right)$	4.6 W	$\frac{2 \cdot R_{DS(on)}}{3}\left(\frac{P_{in(avg)}}{V_{in(ms)}}\right)^2\left(1-\left(\frac{8\sqrt{2}\cdot V_{in(ms)}}{3\pi V_{out}}\right)\right)$	4.6 W	$R_{DS(on)}\left(\frac{P_{in(avg)}}{V_{in(ms)}}\right)^2\left(1-\left(\frac{8\sqrt{2}\cdot V_{in(ms)}}{3\pi V_{out}}\right)\right)$	3.5 W
MOSFETs		1 * SPP20N60 or 2* SPP11N60		2 * SPP11N60		1 * SPP20N60 or 2* SPP11N60
Diode	Ultrafast	MUR550 (TO220) 	2 * Ultrafast	2 * MUR550 (axial) 	Low t_{rr} diode	High speed diode (SiC..) 
$I_{C(rms)(max)}$ (A)	$\sqrt{\frac{32\sqrt{2}\cdot\left(\frac{P_{out}}{\eta}\right)^2}{9\pi\cdot V_{in(rms)}\cdot V_{out}}-\left(\frac{P_{out}}{V_{out}}\right)^2}$	2.0	$\sqrt{\frac{16\sqrt{2}\cdot\left(\frac{P_{out}}{\eta}\right)^2}{9\pi\cdot V_{in(rms)}\cdot V_{out}}-\left(\frac{P_{out}}{V_{out}}\right)^2}$	1.3	$\sqrt{\frac{8\sqrt{2}\cdot\left(\frac{P_{out}}{\eta}\right)^2}{3\pi\cdot V_{in(rms)}\cdot V_{out}}-\left(\frac{P_{out}}{V_{out}}\right)^2}$	1.7
EMI complexity	DM: high CM: moderate		DM: moderate CM: moderate		DM: moderate CM: high	
Characteristics	Compact design		Low profile designs		Compact design	

Compared to CrM, FCCrM allows the use of smaller inductances (due to frequency clamp)
The inductance for the single and interleaved FCCrM stages is based on a 130 kHz frequency clamp (high frequency design).
The switching frequency is also supposed to be 130 kHz for the CCM stage.

46” LCD TV PFC Schematic

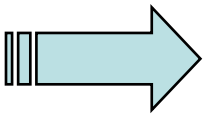


46” LCD TV QR Flyback Solution

- **Flyback converter**
  - Up to 70 W max
  - Up to 3 output with 4 A Max
- **Quasi Resonance Flyback Converter**
  - Reduced EMI
  - Best safety behaviors
- **New NCP1379 controller**
  - Valley-lockout system
  - Variable frequency mode for ultra low power mode
  - Over current protection with auto recovery internal timer

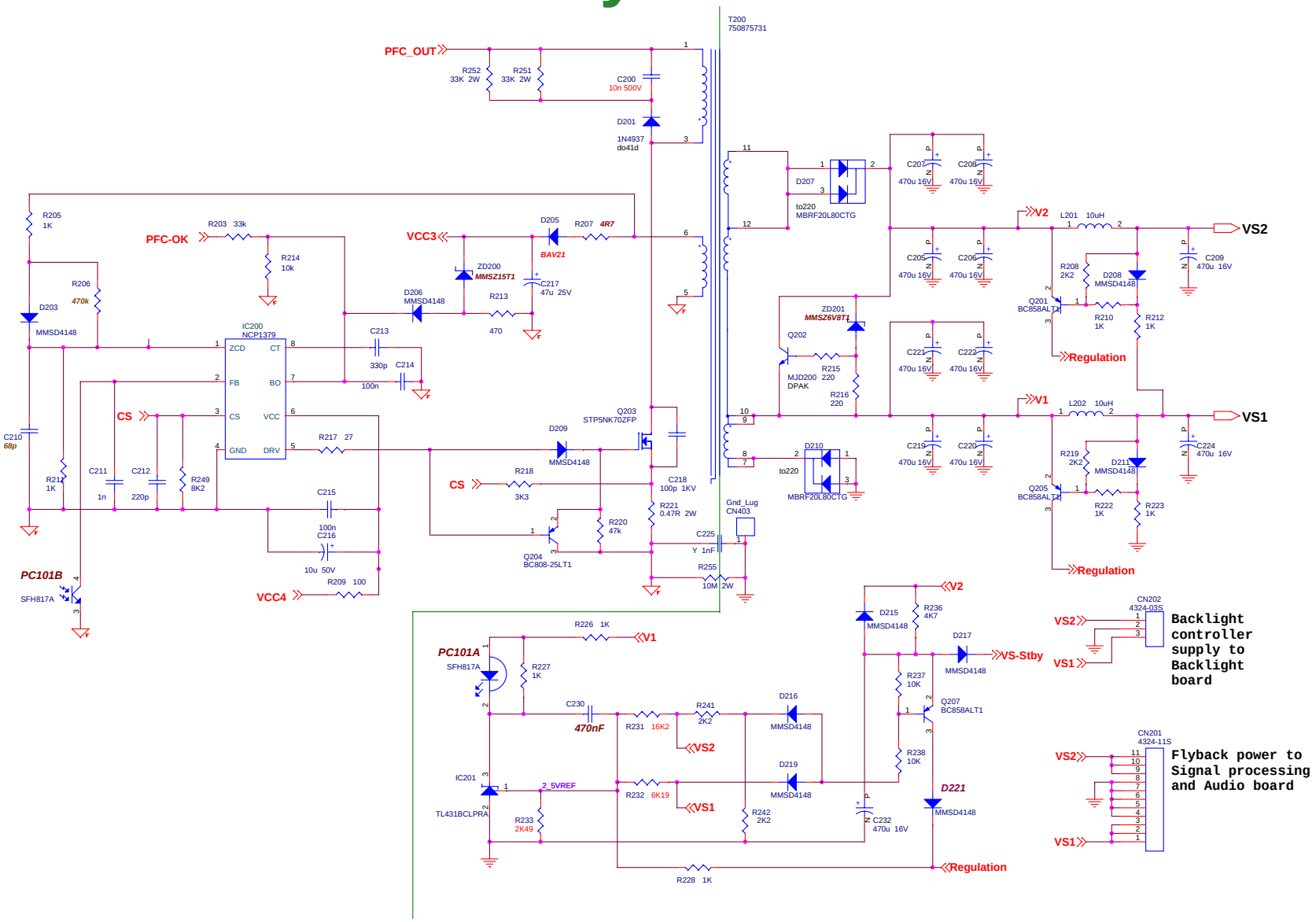
46” LCD TV PWM Fixed F Flyback Solution

- **PWM Fixed Frequency Flyback converter**
  - 50 kHz Fixed frequency
  - Allow natural CCM
- **New NCP1252 controller**
  - Adjustable switching frequency with skip mode
  - Adjustable soft start
  - Over current protection with internal timer
- **Alternative solution to previous QR mode**
  - Both designs
    - on the same PCB
    - with the same switching frequency
    - with the same key parts

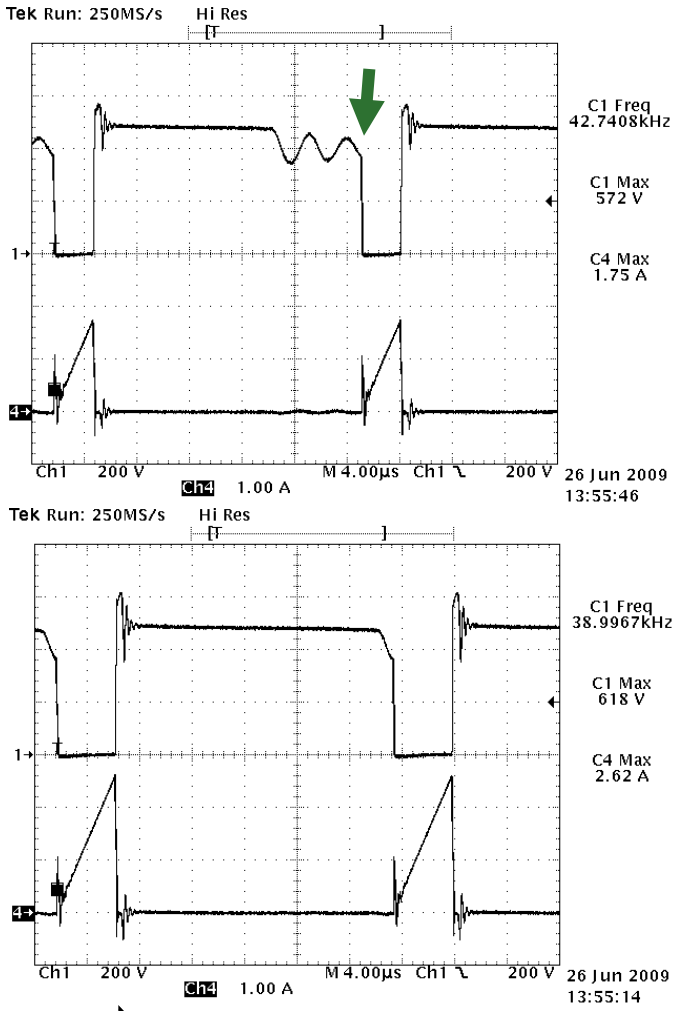


QR Valley lock-out or PWM Flyback SMPS up to 70 W

46” LCD TV Flyback Schematic



46” LCD TV QR Flyback Waveforms



- **QR mode with valley lock-out**
  - With valley lock-out for low P
  - With lower frequency by P Max
- Top Trace
  - Vin = 400 Vdc **Pout = 34 W**
  - 1.75 A at 42.7 kHz
  - V max = 572 V
- Bottom Trace
  - Vin = 400 Vdc **Pout = 70 W**
  - 2.62 A at 39 kHz
  - V max = 618 V

Valley lock-out is a Key improvement of QR mode

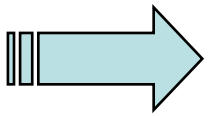
ECO Standby SMPS Solution (1)

- **Dedicated 5W ECO Power Standby SMPS**
  - **P_{in} < 90 mW for P_{out} = 40 mW @ 230 Vac**
  - **Integrated High Voltage switcher NCP1053A (400 mA / 40 kHz Max)**
    - **Hysteretic mode improves**
    - **Low frequency mode allows DCM**
    - **Limited current reduces possible noise issues**

Hysteretic, Low Freq & DCM for ECO Standby SMPS

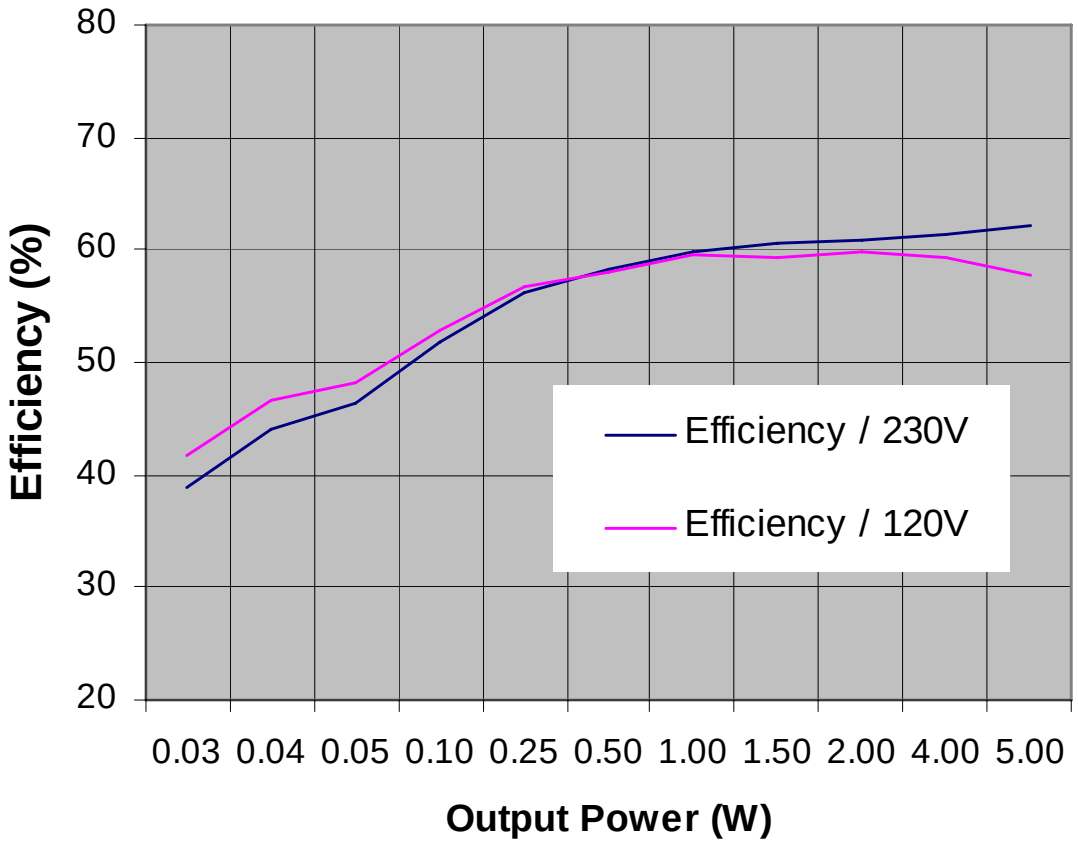
ECO Standby SMPS Solution (2)

- **Standby relay**
  - **Disconnect all "parasitic" standby load (~100-150 mW @ 230 Vac)**
  - **Directly controlled by TV µP**
- **Optional ECO "ON / OFF switch"**
  - **Low cost 2A / 10V non-isolated switch**
  - **OFF mode: P_{in} < 20 mW by no load @ 230 Vac**



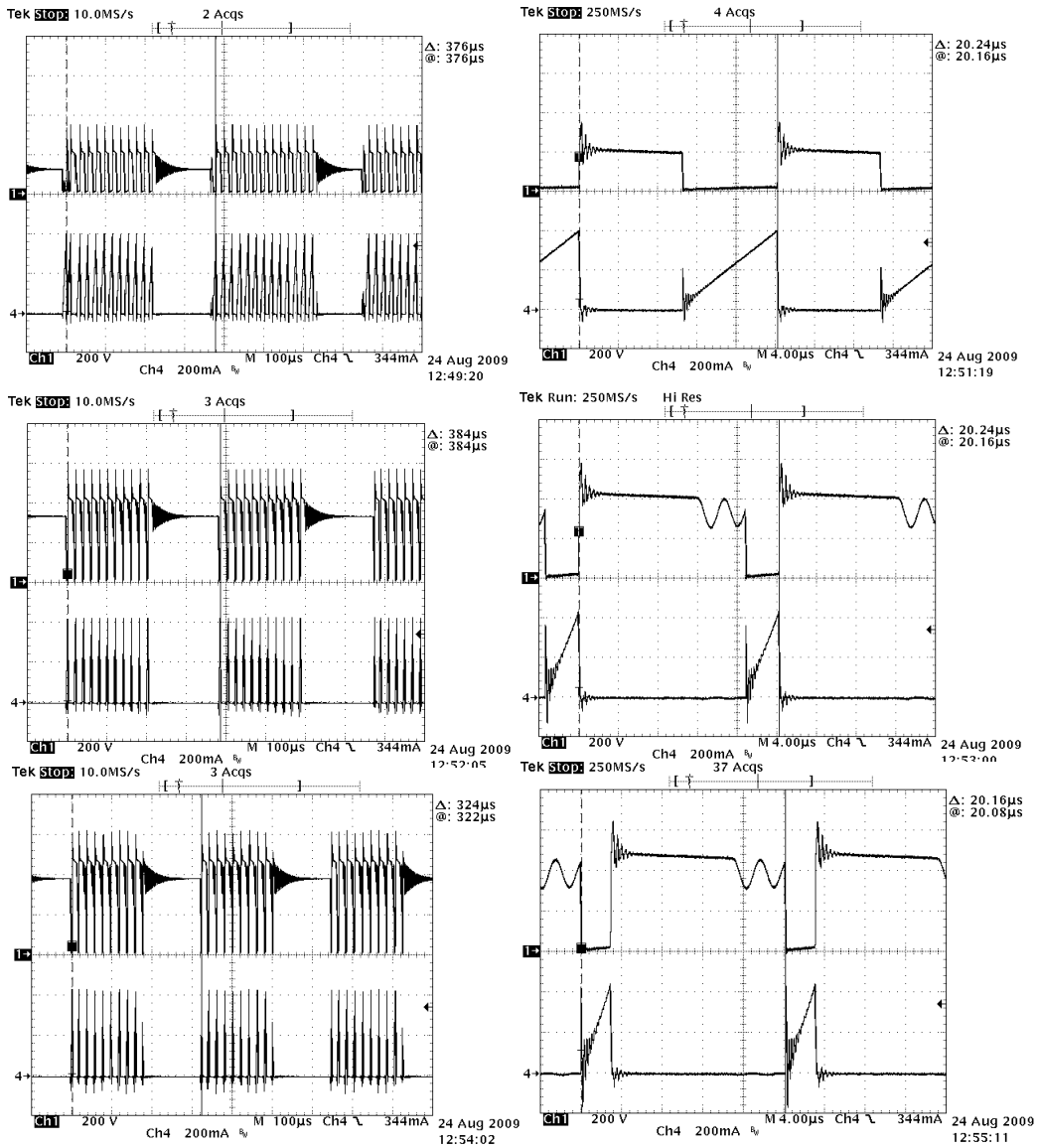
ECO switch provides "ON/OFF" without Mains switch

ECO Standby SMPS efficiency



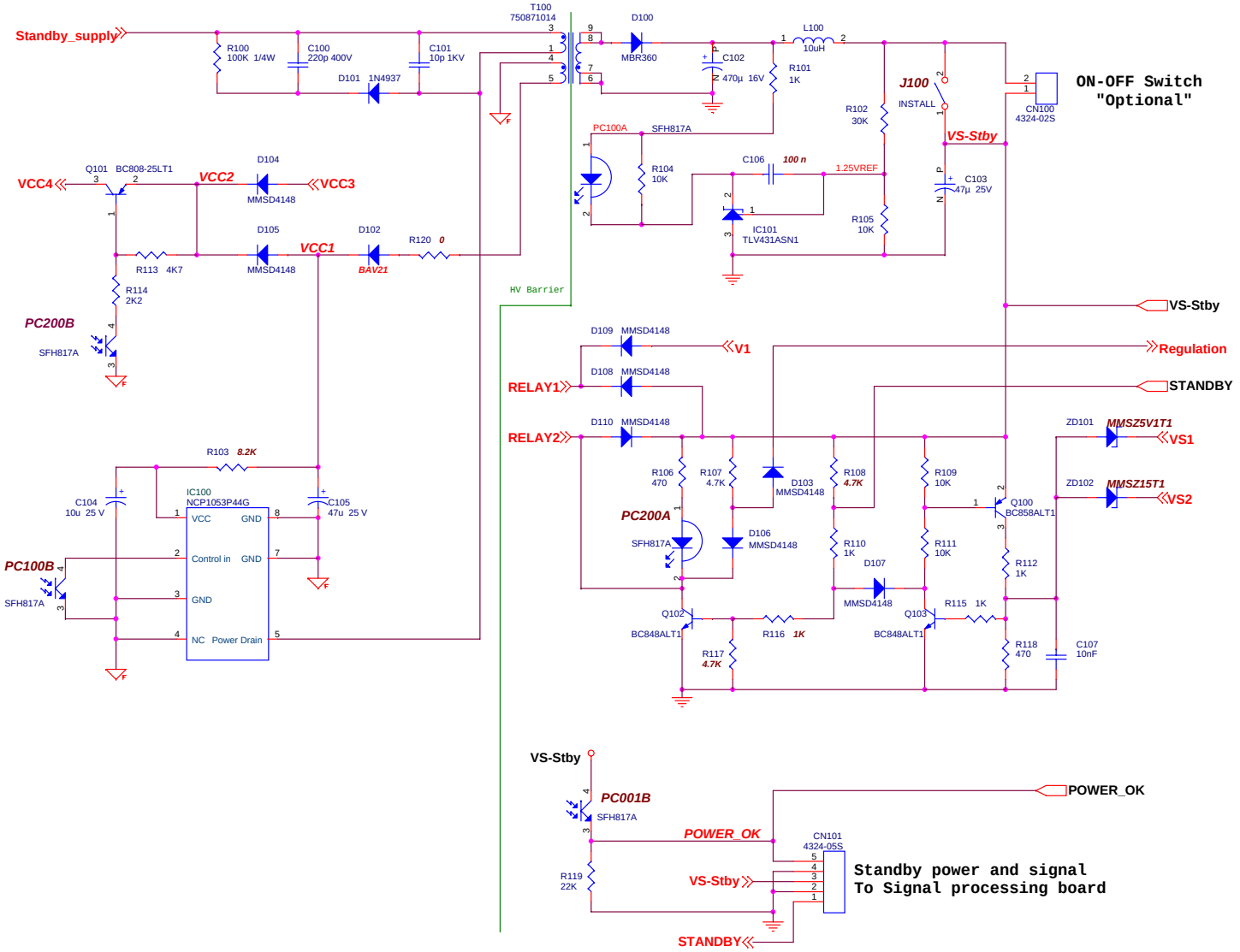
OFF mode / no load: P_{in} < 20 mW @ 230 Vac (15 @ 120 Vac)
Standby / 40 mW Out: P_{in} < 90 mW @ 230 Vac (86 @ 120 Vac)

ECO Standby SMPS Waveforms



- Drain Voltage and Current of NCP1053A Switcher
  - 200 V/div & 200 mA/div
- For 5 V & 1 A = 5 W Output
- Left: Hysteretic Burst mode
  - (100 µs/div)
- Right: Detailed cycle
  - (4 µs/div)
- Top Trace: 90 Vac
- Middle Trace: 230 Vac
- Bottom Trace: 264 Vac

ECO Standby SMPS Schematic



46” Flat TV PSU - Backlight Interface

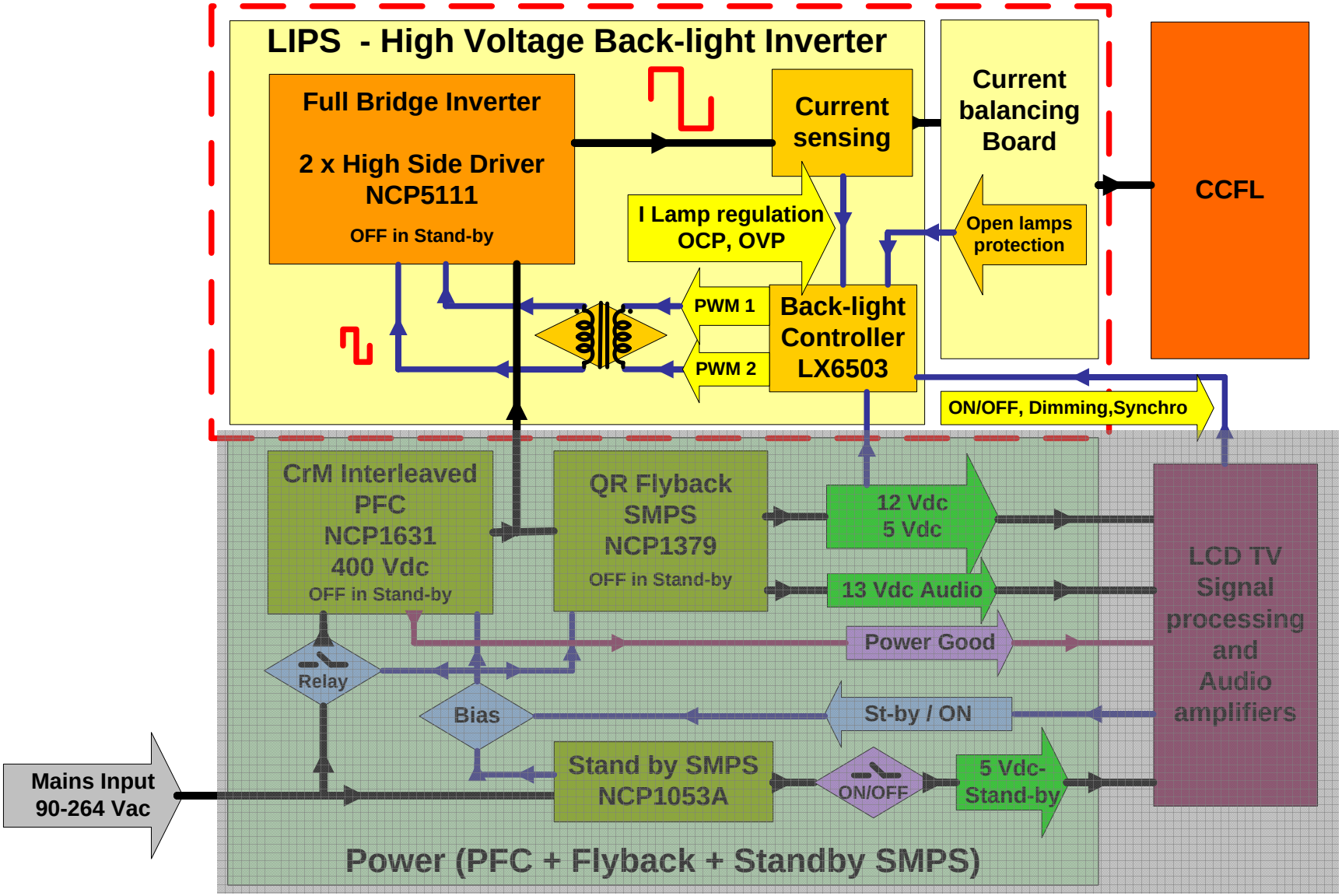
- **Interconnection on Power to any Backlight solutions**
  - **400 Vdc / 200 W**
  - **PFC OK**
  - **5 V and 12 V**
  - **Power Good**

- **Separated & Dedicated Backlight solutions**
  - **High Voltage LIPS for CCFL / EEFL**
  - **High DC Output Voltage HB LLC** for LED Driver
  - **Classical 24 Vdc HB LLC**
  - **PDP dedicated Power converter**

46”LIPS Inverter

- **Higher power LCD-TVs**
  - **With extension to 40/42” or 52”/55” for both CCFL or EEFL**
  - **Follow on of *32” LIPS Reference Design***
  - **Full Bridge fixed frequency ZVS with possible synchronization**
  - **High efficiency, low EMI and sinusoidal lamp current**
- **Dedicated LIPS module**
  - **To be interconnected with *46” Power Ref Design Step 1 < 13 mm***
  - **Microsemi Backlight controller LX6503**
- **ON Semiconductor IC’s**
  - **2 High Side Drivers NCP5111**
  - **1 single signal driver transformer**
- **Low profile design**
  - **< 13 mm on top of PCB**

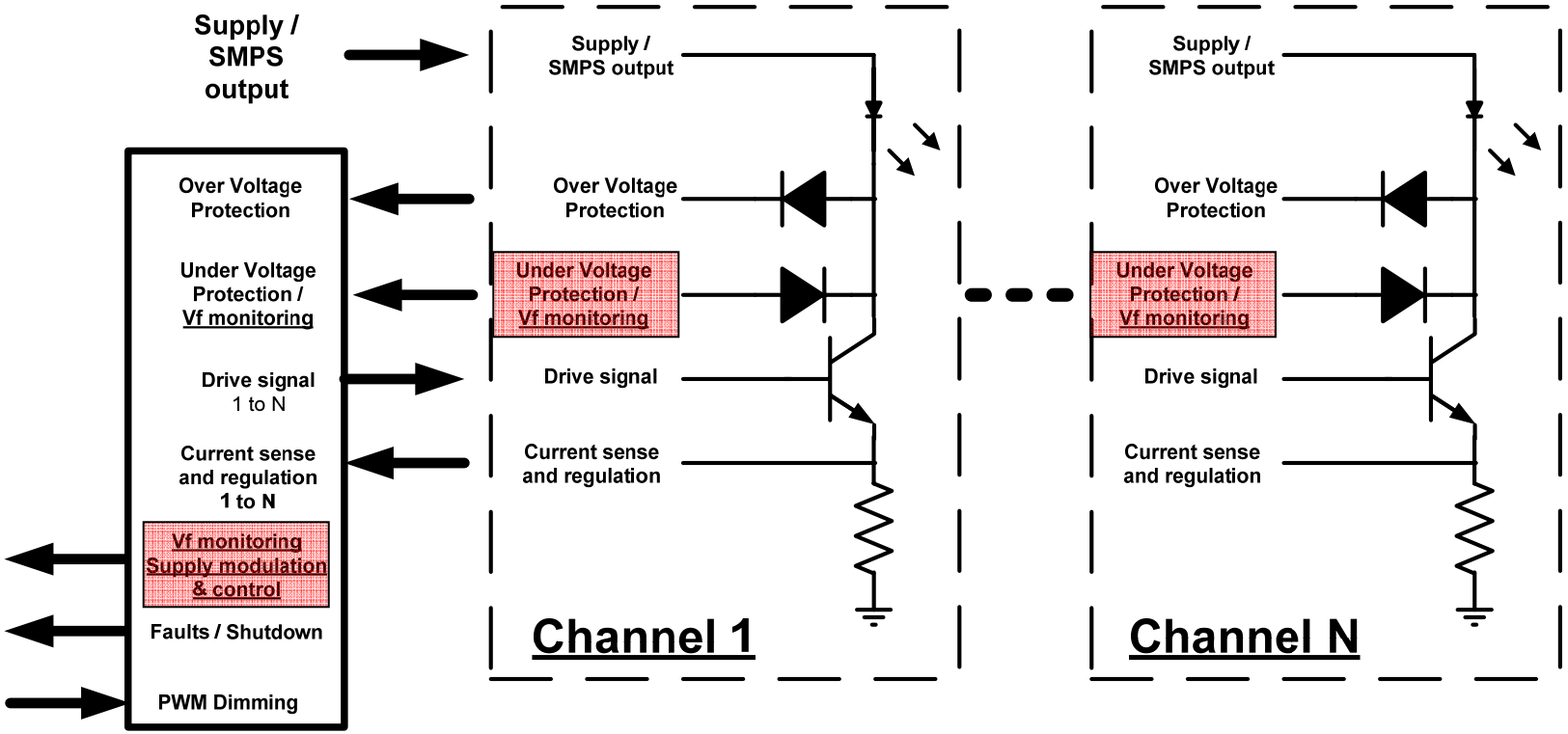
46” LIPS Inverter Block Diagram



46” LED Backlight Power

- **Higher power LCD-TVs**
  - **With extension to 40/42” or 52”/55”**
  - **HB LLC dedicated to Backlight power**
  - **High DC output voltage to power directly LED drivers**
- **Separate / Dedicated LED Power module**
  - **To be connected with *46” Power Ref Design step 2 < 8 mm***
- **ON Semiconductor IC’s**
  - **New NCP1397**
  - **New**
  - **New LED driver controller CAT4206**
- **Low profile design**
  - **< 8 mm on top of PCB (< 12.5 mm total)**

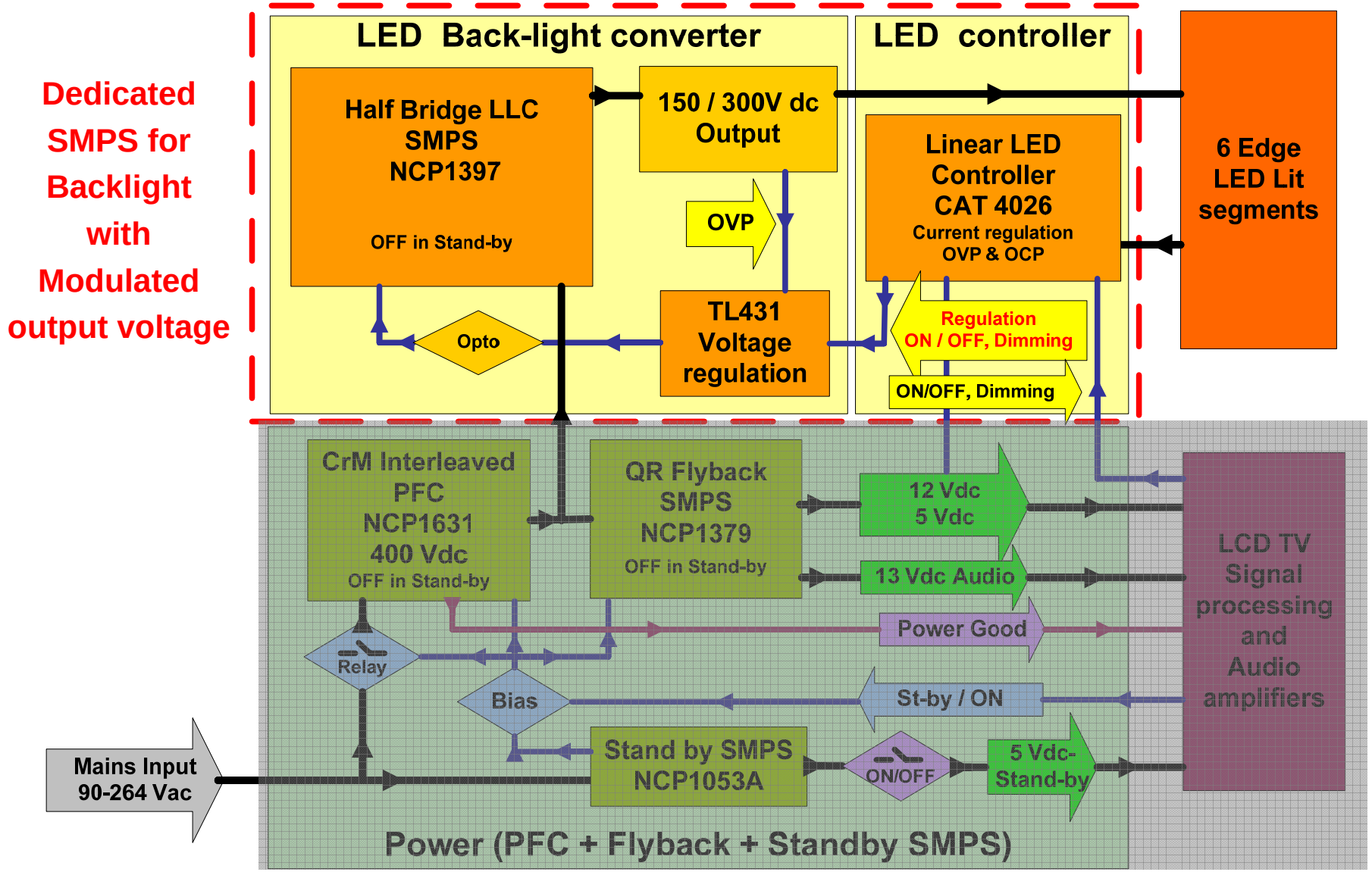
Multiple LED Linear Drivers with CAT4026



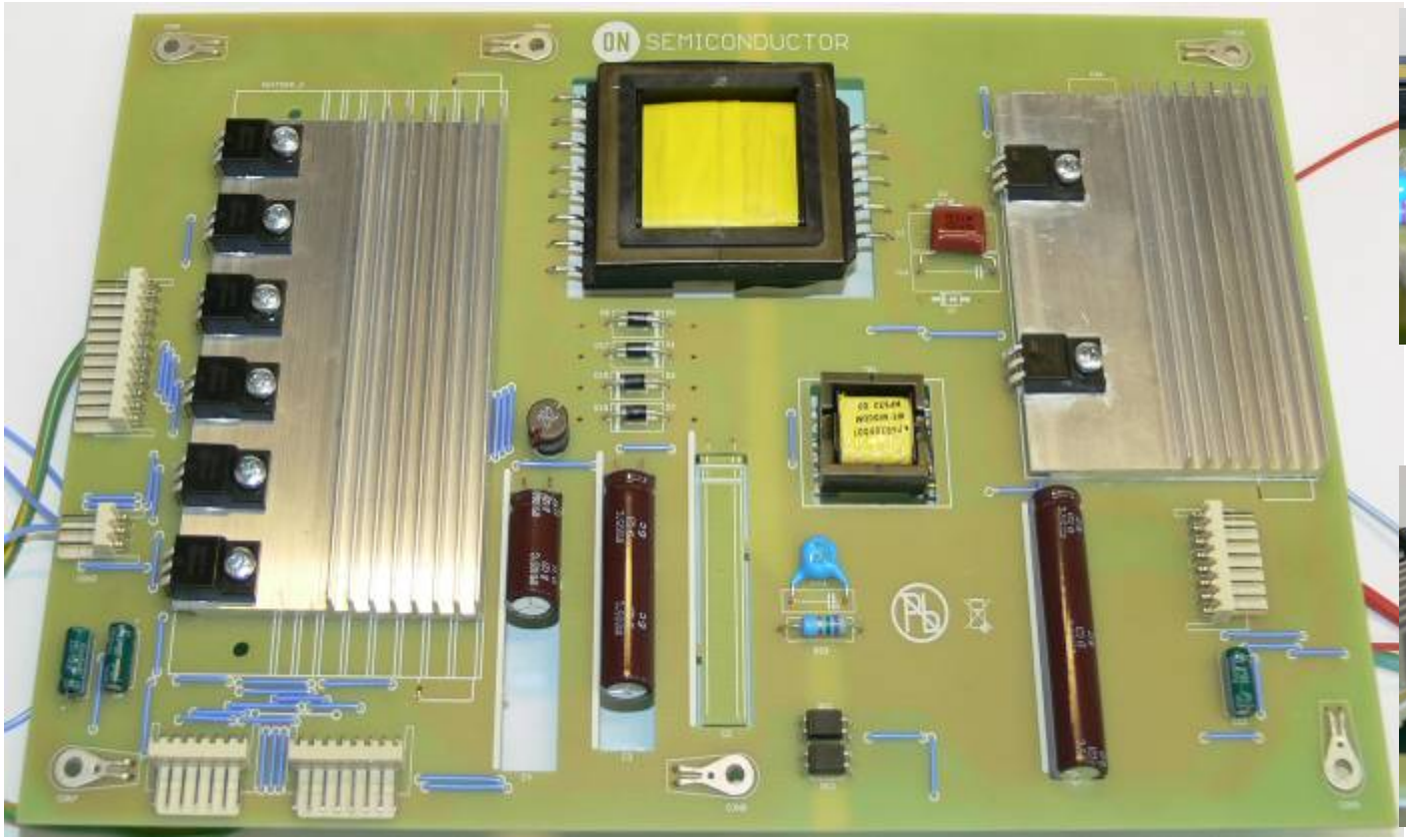
- Up to 6 channels with linear bipolar transistors Linear:
- "V_f monitoring and supply modulation & control"

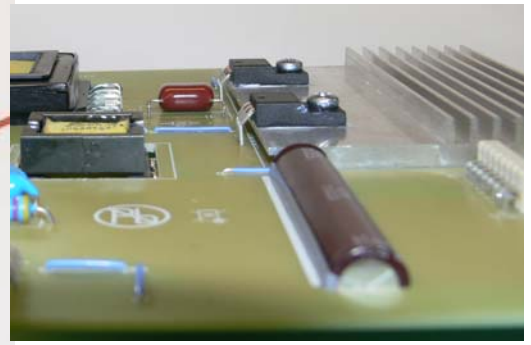
Dedicated SMPS to support output voltage modulation

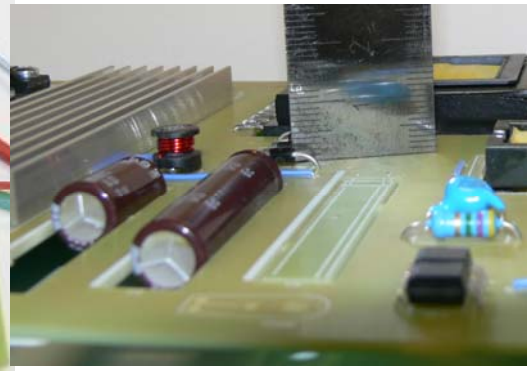
46” Linear Edge LED Driver TV Block Diagram



46” Linear LED Driver Backlight Solution





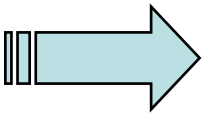


- **Special technologies**
- **PCB size: 250 mm x 165 mm**

Ultra SLIM design < 8 mm / 12.5 mm total

HB LLC for Ultra Slim SMPS

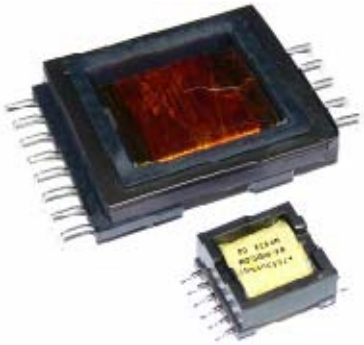
- **Limited number of components**
- **Zero Voltage Switching (ZVS)**
- **Zero Current Switching (ZCS)**
- **Higher power density**



High efficiency and EMI friendly for low profile SMPS

Resonant Inductance Location?

External inductance



Benefits:

- **flexibility**
- **EMI**
- **use resonant coil for OCP**

Drawbacks:

- **cooling**
- **insulation**

Internal leakage inductance

Benefits:

- **insulation**
- **cooling**
- **One component**

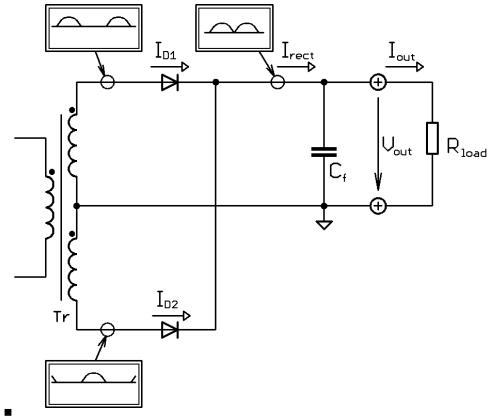
Drawbacks:

- **flexibility**
- **EMI + stray flux**
- **window utilization**

External resonant coil is better for ultra slim design

Secondary Rectification

Push-pull configuration



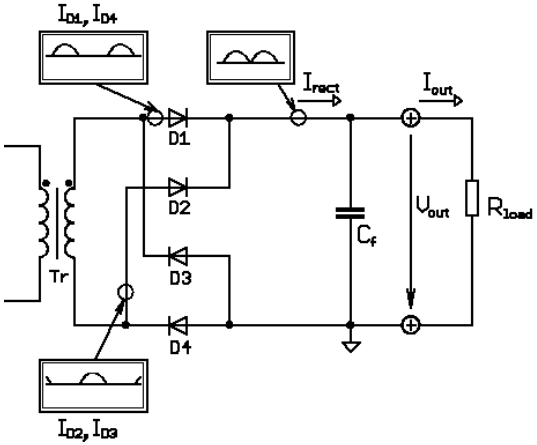
Benefits:

- **voltage drop**
- **Single diodes**

Drawbacks:

- **secondary winding**
- **matching**
- **window utilization**
- **Higher voltage rectifiers**

Bridge rectifier



Benefits:

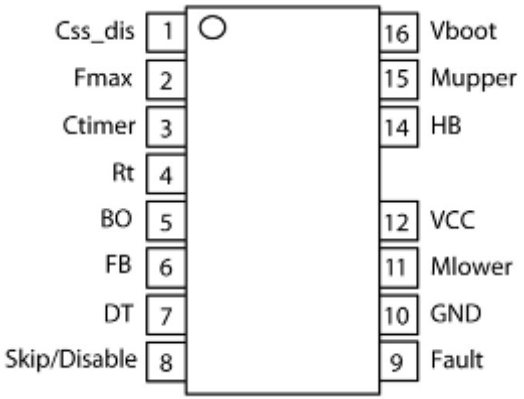
- **one winding**
- **Lower voltage diodes**
- **Matching**

Drawbacks:

- **Higher losses**

Bridge rectifier is better for HV output applications

NCP1397 - LLC Stage Controller



Features:

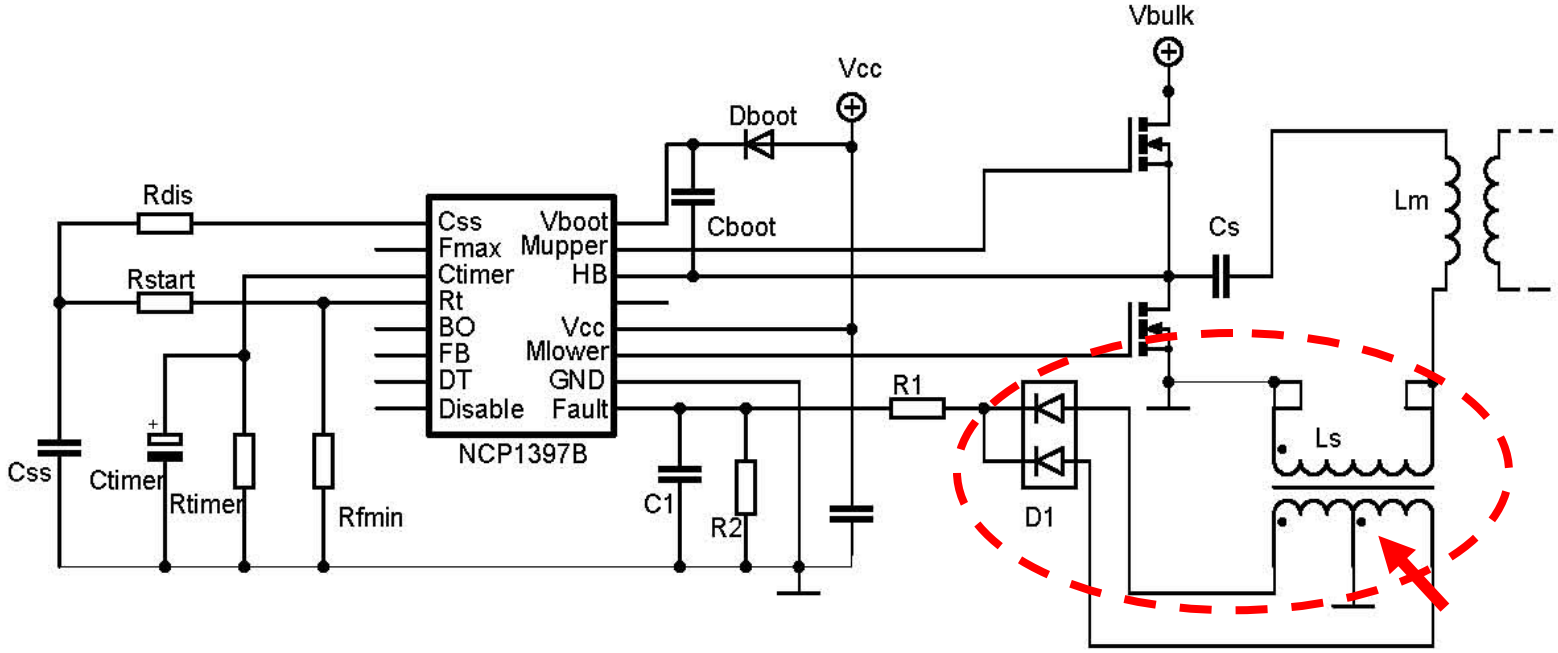
- operation from 50 kHz up to 500 kHz
- 600 V driver
- Startup sequence via an externally adjustable soft-start
- Brown-out protection combined with latch input
- Disable input for ON/OFF control (skip mode)

Benefits for backlight application:

- No driver transformer
- Simple skip mode
- Simple OCP

NCP1397 is cost effective and highly safe solution

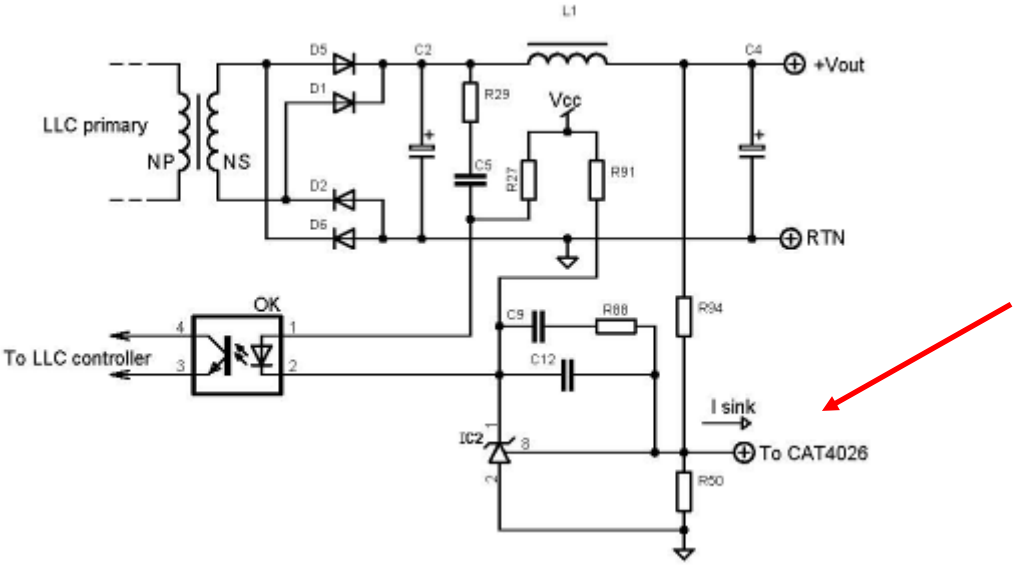
New OCP Implementation



- **Adjustable delayed fault**
- **Short circuit protection with frequency shift**
- **<u>New Double phase current information from auxiliary winding of resonance coil</u>**

Res. Coil aux. winding provides accurate and fast OCP

Output Voltage Modulation

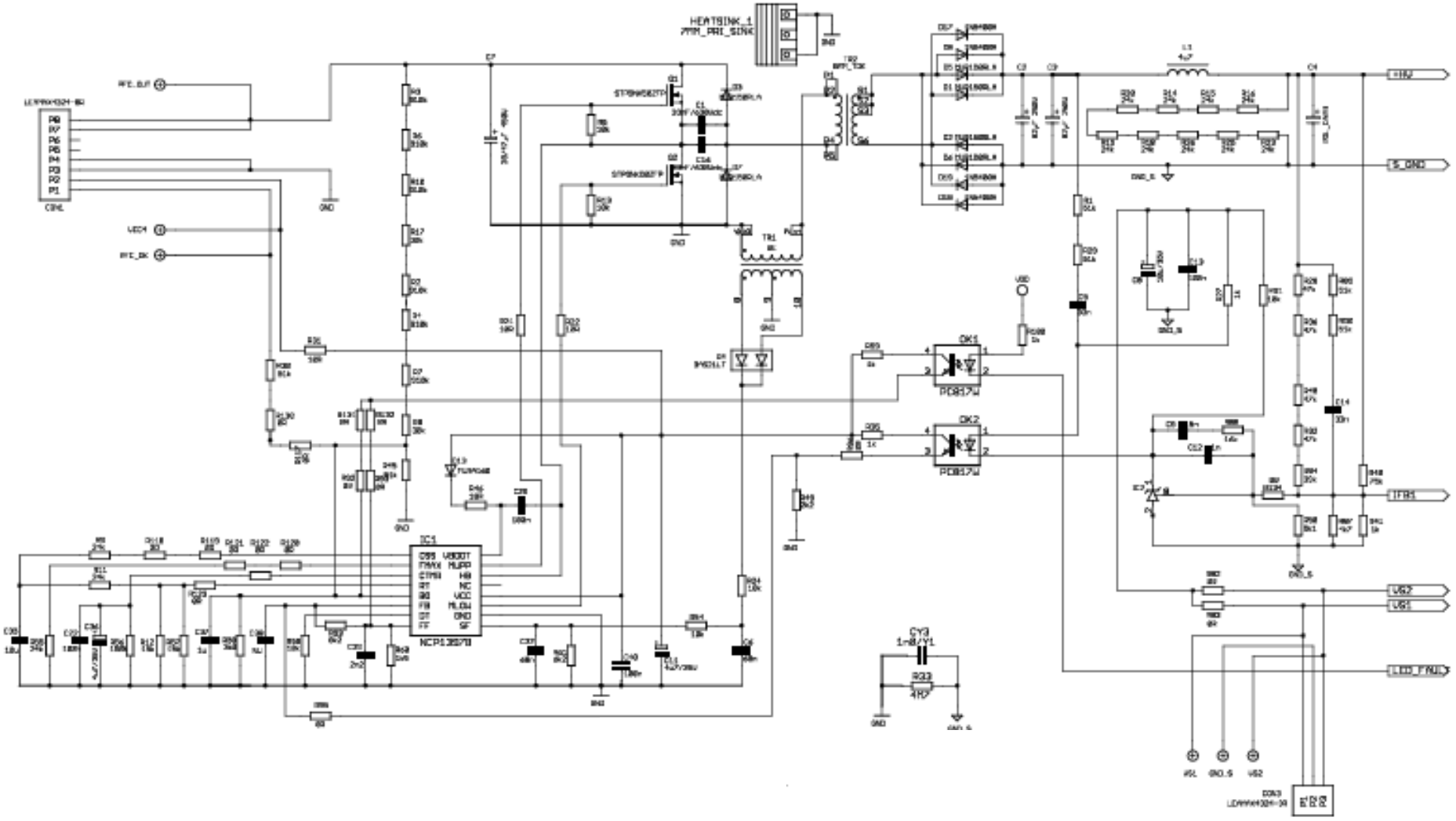


CAT4026 sinks current from FB divider to increase output voltage

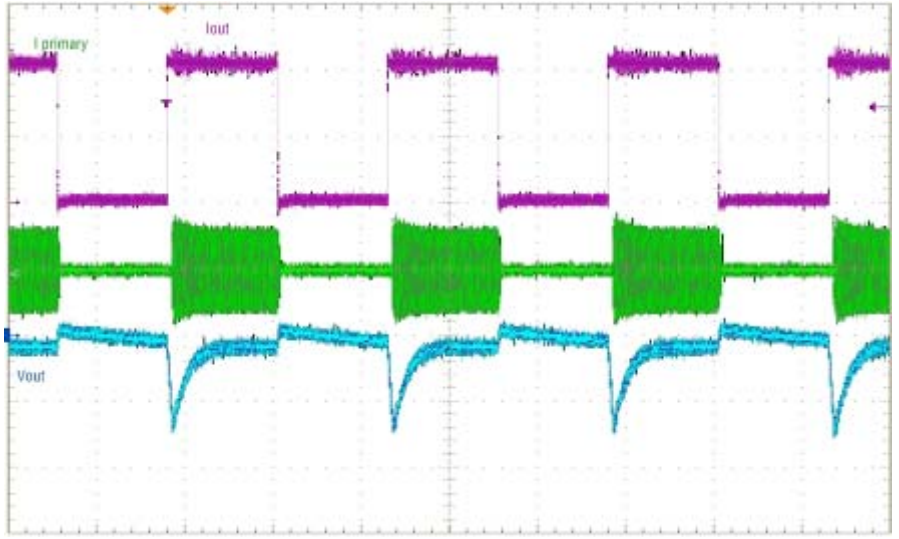
- **Linear LED Drivers impact**
  - **Dedicated SMPS to support output voltage modulation**
  - **<u>Does not allow to get added auxiliary voltages</u> for Audio & Signal processing**

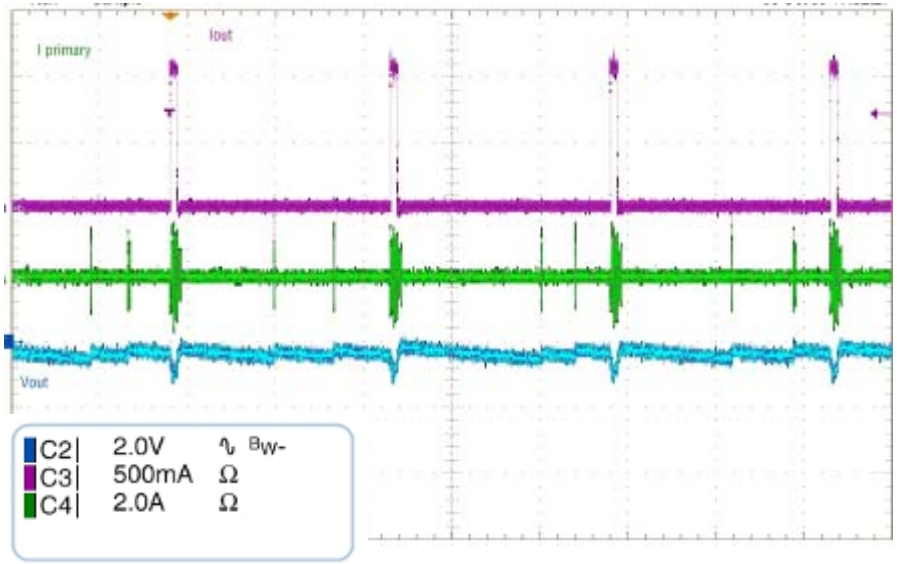
Single Output Voltage modulated for Linear Driver

HB LLC Schematic for Linear LED Driver



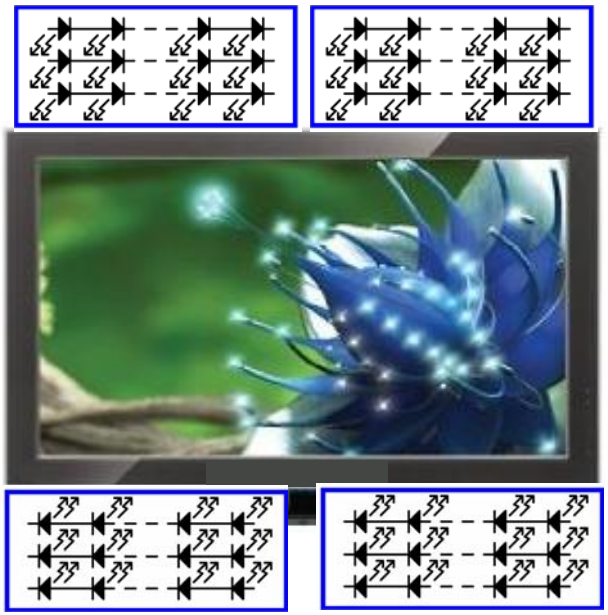
HB LLC Waveforms

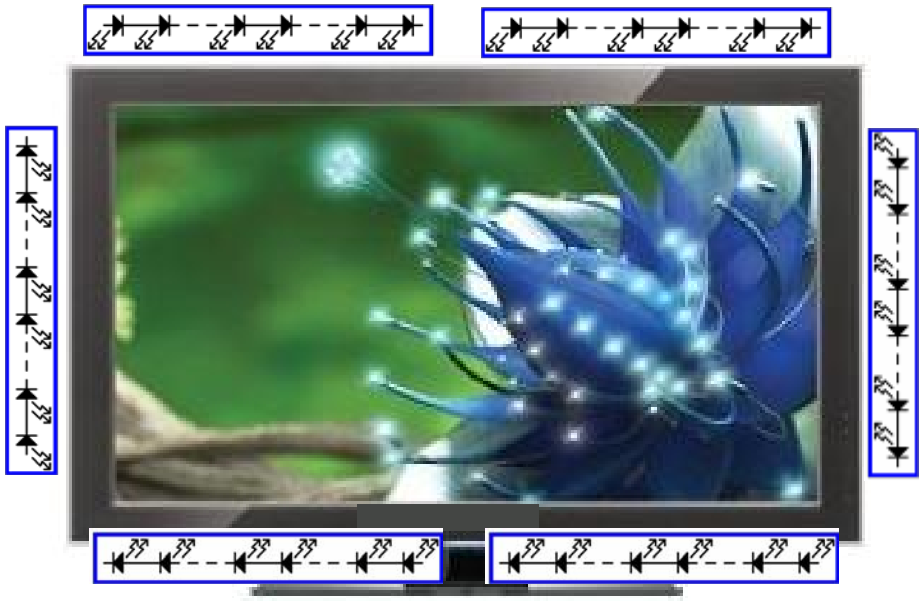




- Strong load variation (0 to 100%) on HB LLC with 100 Hz dimming
- Traces:
  - Top: Output current from 0 to 1 A (0.5 A/div)
  - Middle: Primary current 2 A/div
  - Bottom: Output voltage ripple 2 V/div (120 Vdc)
- Top picture: 50% dimming
  - HB LLC works in Burst
  - Up to 3 V_{peak} ripple on V_{out}
- Bottom picture: 5% dimming
  - HB LLC works in Burst
  - < 0.5 V_{peak} ripple on V_{out}

Edge-LIT LED Backlighting Trends

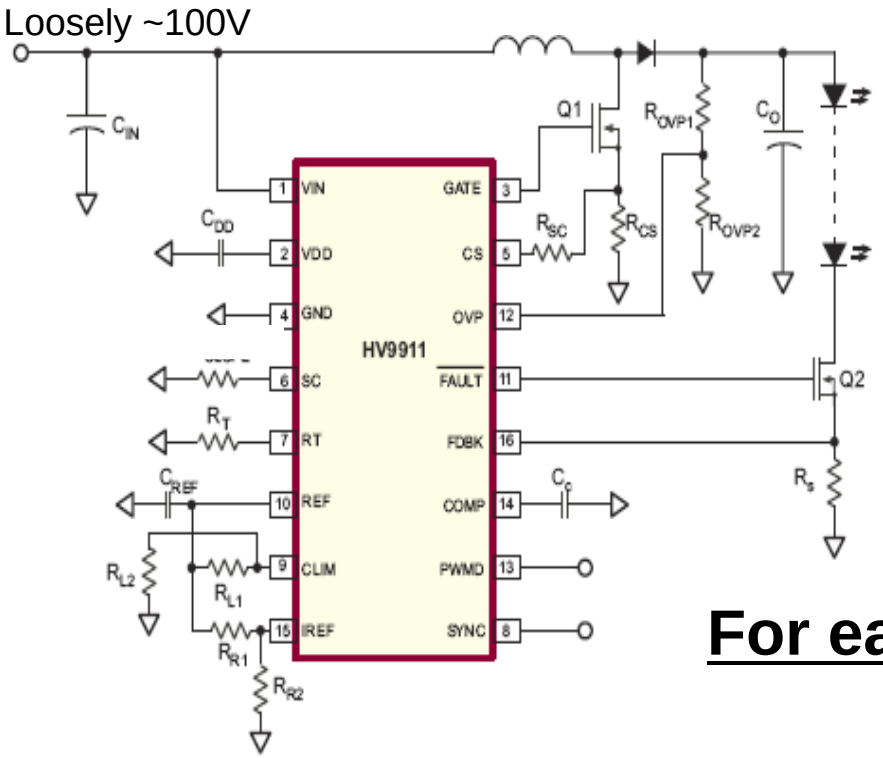




- ‘LED Light bars’ vary in configuration
  - Single LED Strings of High Power (~ 200 V+ , 100 mA+)
  - Multiple LED Strings (up to 4) of Lower Power (~ 100 V+ , 50 mA+)

LED Driver solutions must handle from 4 to 16 channels

Existing Large Panel Backlight Solution



For each LED channels!

Advantage: Independent Channel

Efficiency and LED-Fault handling

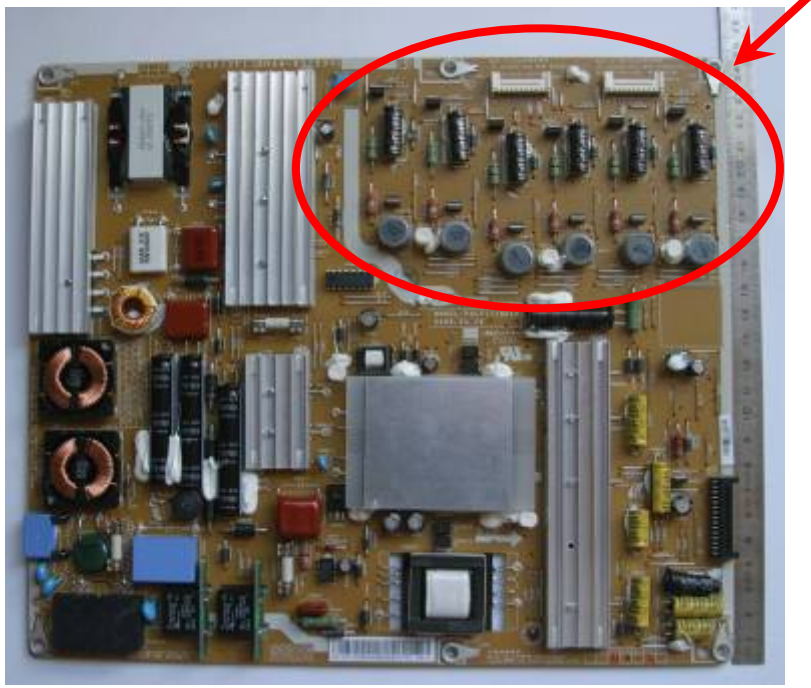
Loosely regulated input supply

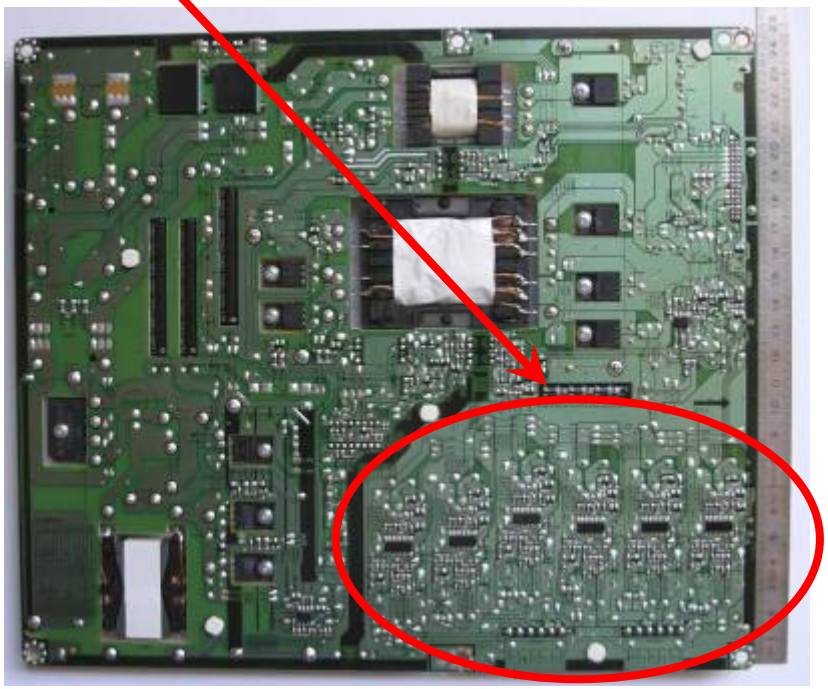
Drawback: Cost and Complexity

Existing LED Driver Backlight Solution

- Large-size panel power Module used for 6 Channel Edge-LIT LED TV
- Each channel has a **Dedicated Driver IC + inductive DC/DC boost + switch**

6 Ch = 6 x (DC-DC Boost + additional switch)

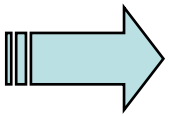




6 Ch = 6 x Driver IC

Multi-channel “Linear” Edge-Lit Solution

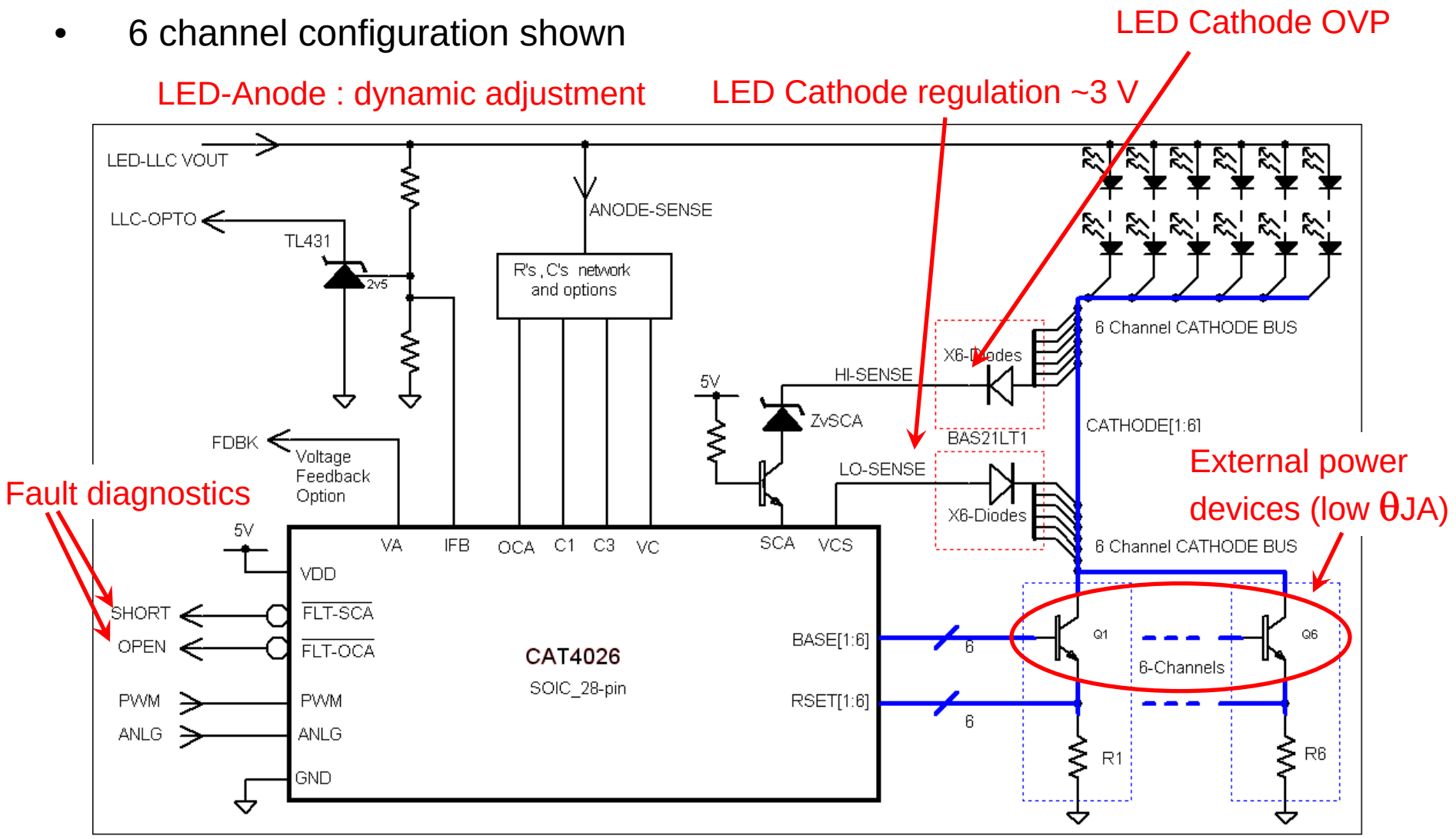
- **Cost effective solution to address a wide number of channels**
- **VF Monitoring to dynamically adjusts Anode voltage**
- **Efficiency target range >90%, 94% typ. (varies with LED mismatch)**
- **Thermal dissipation addressed by external Power BJT’s**
- **Address various LED string faults**



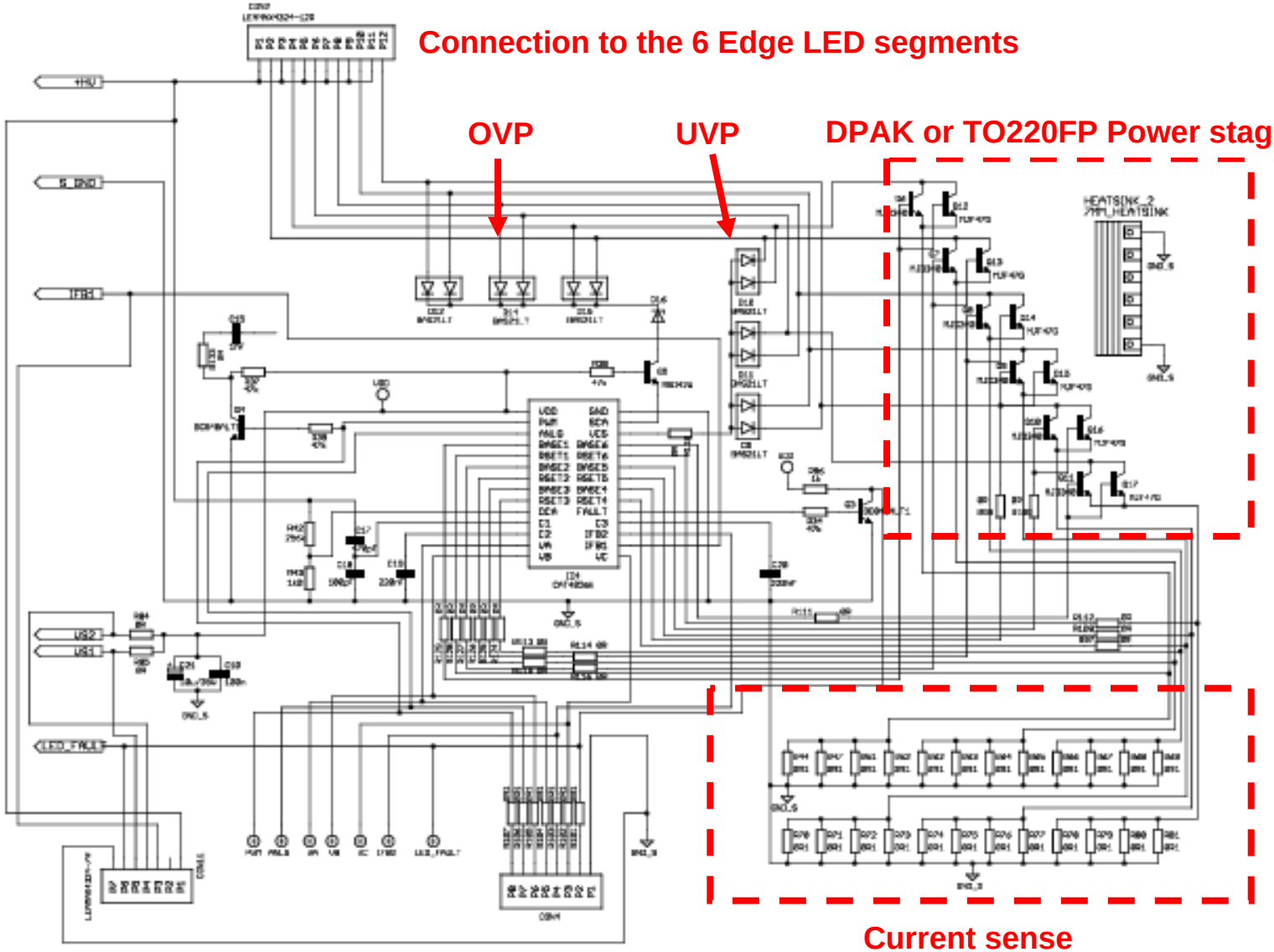
“Linear LED Driver”: A cost effective solution for multiple channels

Multi-channel “Linear” Edge-Lit Solution

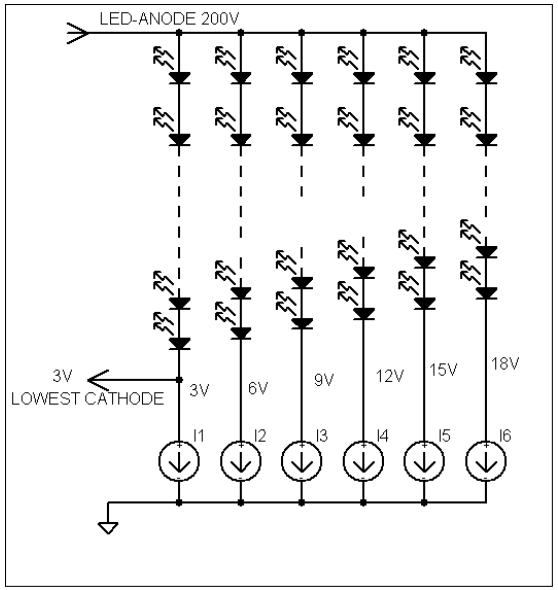
- 6 channel configuration shown

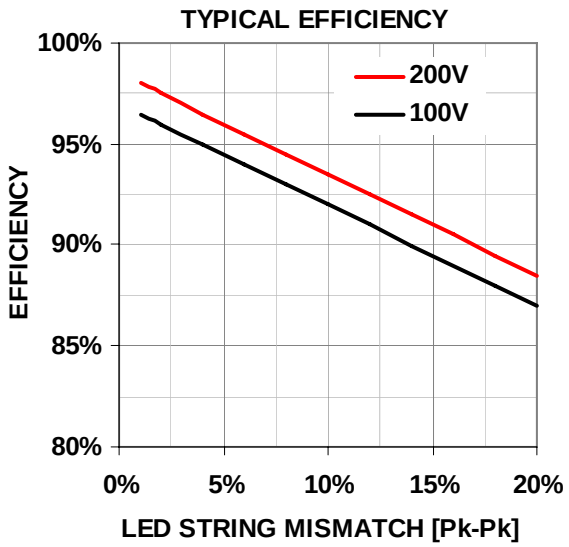


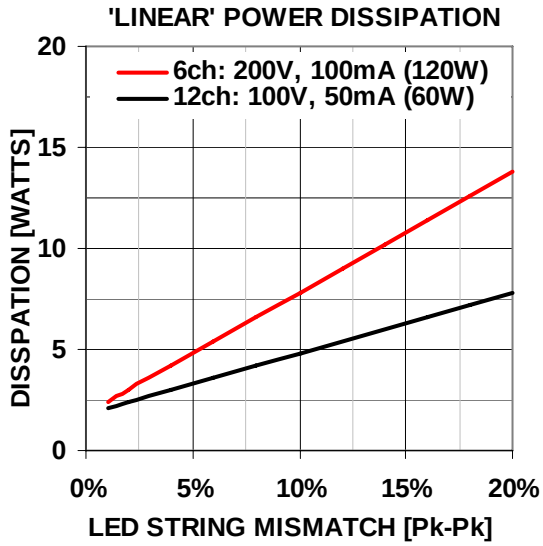
Multi-channel “Linear” Edge Driver Schematic



Optimized Dynamic LED-Anode Control



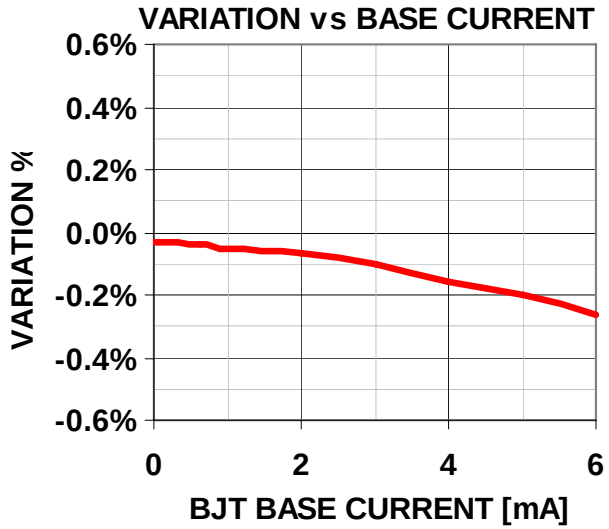


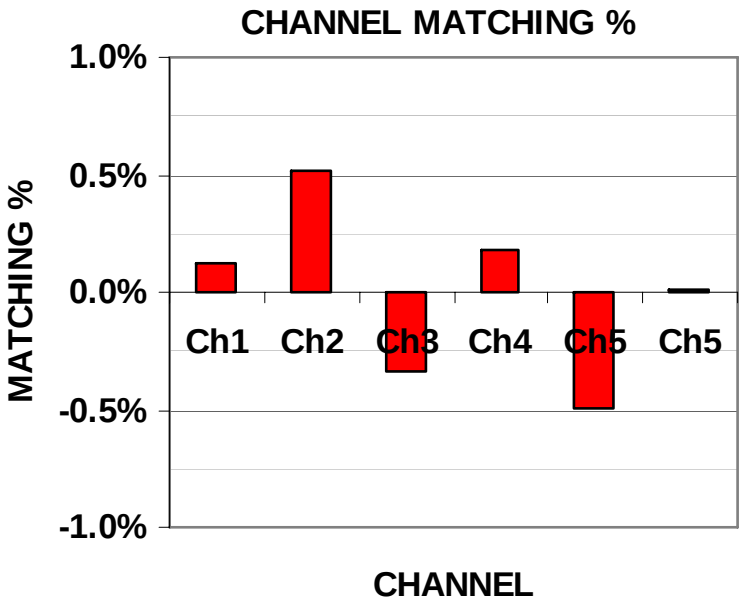


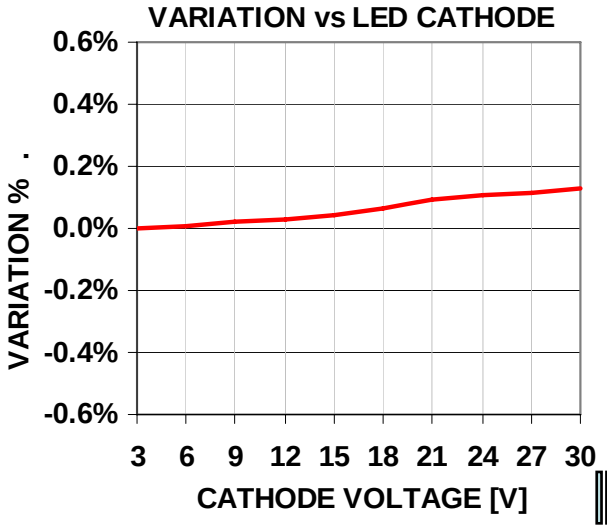
- **Efficiency depends on LED string matching**
- **200V LED strings (with 10% mismatch) delivers ~ 94% efficiency**
- **Thermal power dissipation levels : ~ 5 to 10 watt range**

V modulation & control to limit overall Power dissipation

LED Channel Current Matching



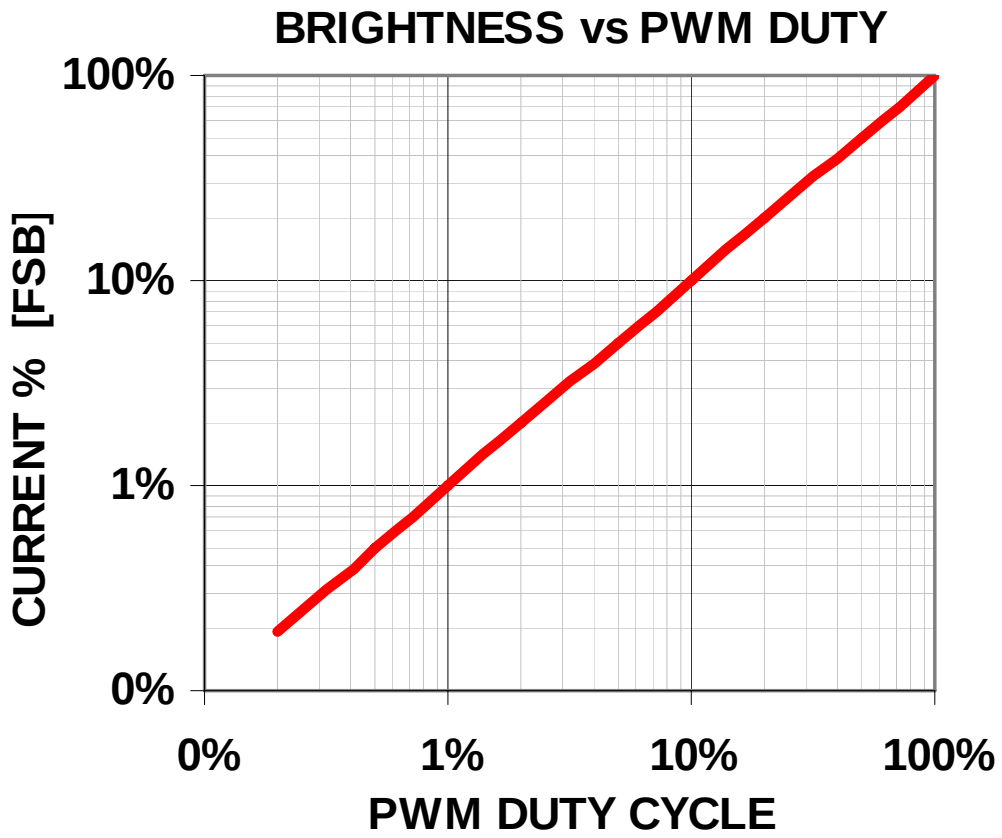




- **Initial channel matching tolerance ~ ± 0.5%**
- **Variation with BJT Base current : < 0.25%**
- **Variation with Cathode to 30V : < 0.15%**
- **Overall Channel matching less than ± 2%**

Very good current matching < +-2%

Optimized Wide PWM Dimming Range

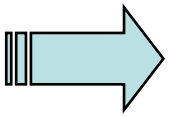


- No concept limitation for very short “ON” time
- CAT4026 Linear Driver is optimized for PWM dimming
- Strong power variation managed directly by SMPS

Down < 1% for 400Hz PWM dimming

Edge LED Linear Backlighting Summary

- **Provides reduced total solution cost**
- **VF monitoring minimizes & optimizes power dissipation**
- **Minimizes EMI**
- **Offers competitive Channel to Channel LED matching**
- **Offers competitive wide range PWM dimming with good linearity**
- **Supports Fault diagnostics against Open-LED and Short-LED modes**



The Linear is a easy to design and cost effective solution

Conclusion

- **Complete roadmap of LCD TV solutions**
  - **32” LIPS**
    - **A cost optimized solution for CCFL from 26” up to 42”**
  - **46” Power**
    - **Power for any type of Backlight from 40” up to 55”< 13 or 8 mm**
  - **46” LIPS**
    - **< 13 mm with separate LIPS**
  - **46” Edge LED**
    - **SLIM < 8 mm with separate LED Drivers with very efficient Linear Edge LED driver solution**

- **Approach**
  - **Synergy by re-use solutions, speeding up the design process**

For More Information

- View the extensive portfolio of power management products from ON Semiconductor at www.onsemi.com
- View reference designs, design notes, and other material supporting the design of highly efficient power supplies at www.onsemi.com/powersupplies