NXP Next Generation of HV Half-bridge Resonant Inverter

Zhang Zheng Quan

Senior Application Engineer, NXP Semiconductors

China Power Technology Forum 2008

November 2008 in Shenzhen

Agenda

- Inverter Mains Isolation Strategy: Fluorescent Lamp Backlighting
- “HV_Half_bridge_Resonant” incentive: Fluorescent Lamp Backlighting
- HV half-bridge-resonant Inverter: UBA2071(A)
  - UBA2071(A), Directly drive power devices
  - UBA2071(A): Ignition Principle
  - UBA2071(A): Hard-switch detection
  - UBA2071(A): PWM dimming operation
- LCD-TV LIPS in the market using the UBA2071 backlight inverter controller

Inverter Mains Isolation Strategy

Fluorescent Lamp Backlighting

Inverter Mains Isolation Strategy (LV/MV)

Architecture applicable for Low Voltage (24V) and Medium Voltage (60V) solutions

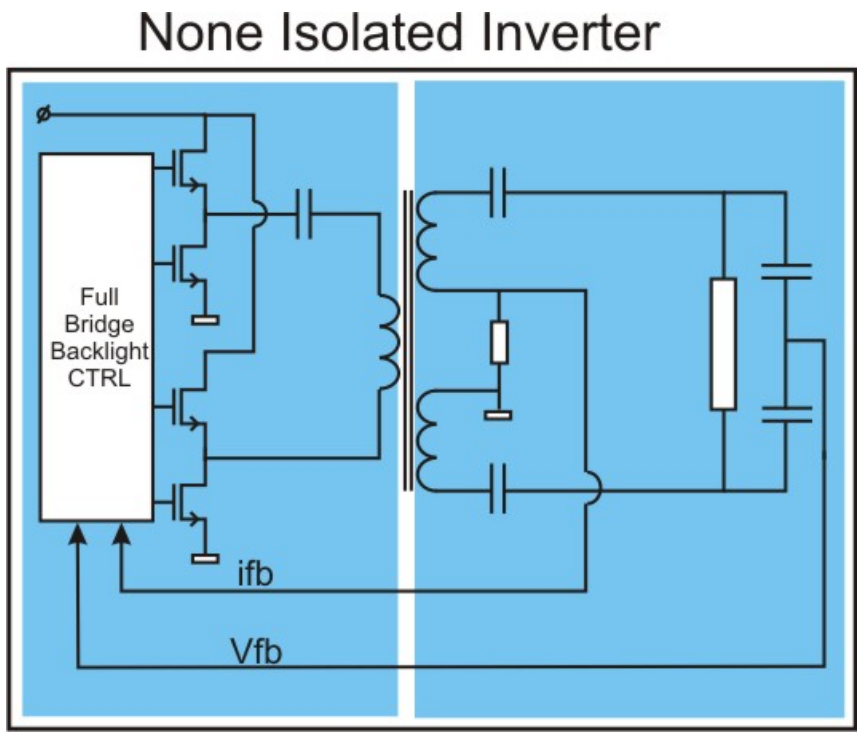
Isolation taken care of in previous power stage

Advantages:

- Simple design implementation

Disadvantage:

- Total System Cost: Requires supply from isolated power stage, most often a resonant type power supply



NXP Product offering:

UBA2072	9~30 Volt
UBA2074(A)	>30 Volt

Inverter Mains Isolation Strategy (HV)

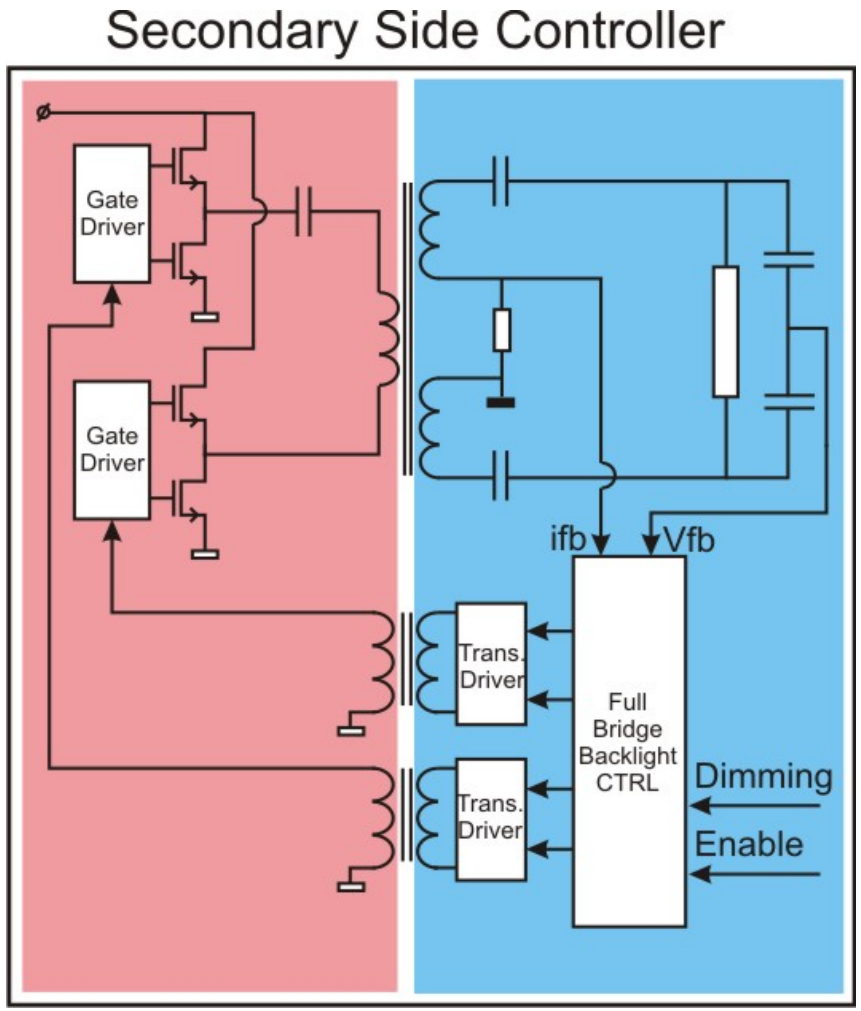
Architecture applicable for High Voltage (400V) solutions, supplied from PFC stage

Advantages:

- Low number of isolation crossings
- Low voltage controller possible

Disadvantage:

- Higher cost per isolation crossing
- Less control & protection for power stages



NXP Product offering:

UBA2072 Full-Bridge

Inverter Mains Isolation Strategy (HV)

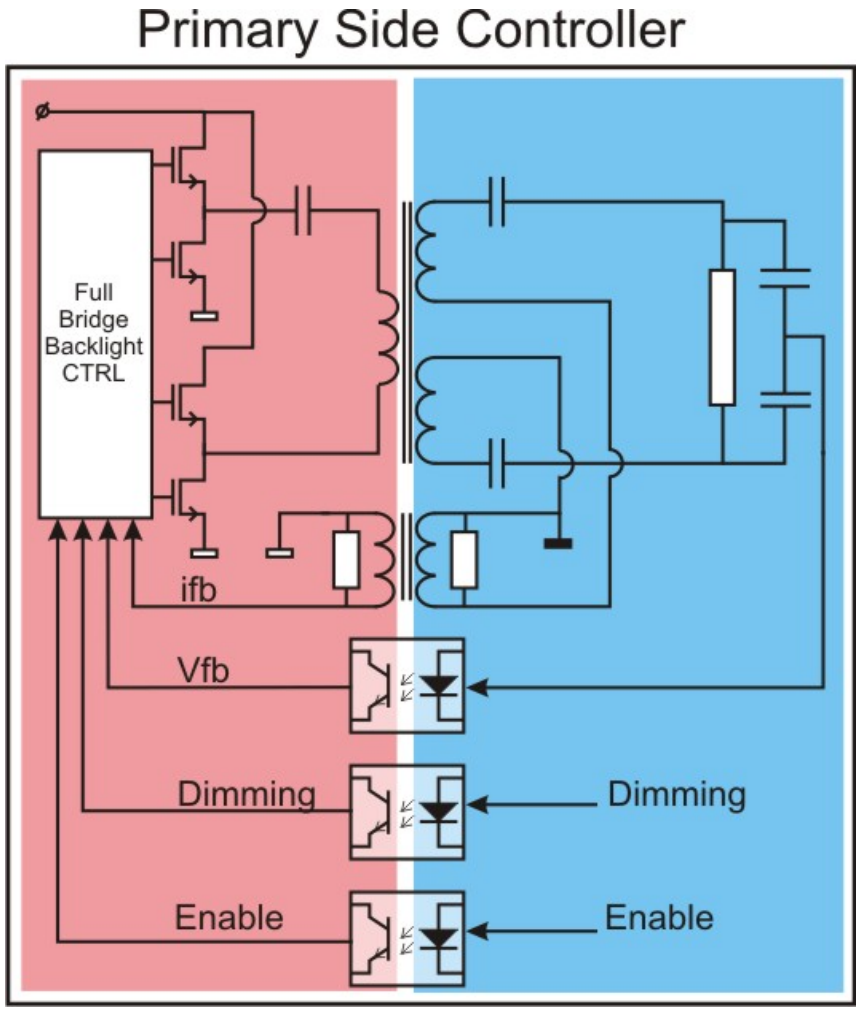
Architecture applicable for High Voltage (400V) solutions, supplied from PFC stage

Advantages:

- Low cost integrated bridge drive structure
- **Reliable bridge control & protection**

Disadvantage:

- Higher number of mains isolation crossings



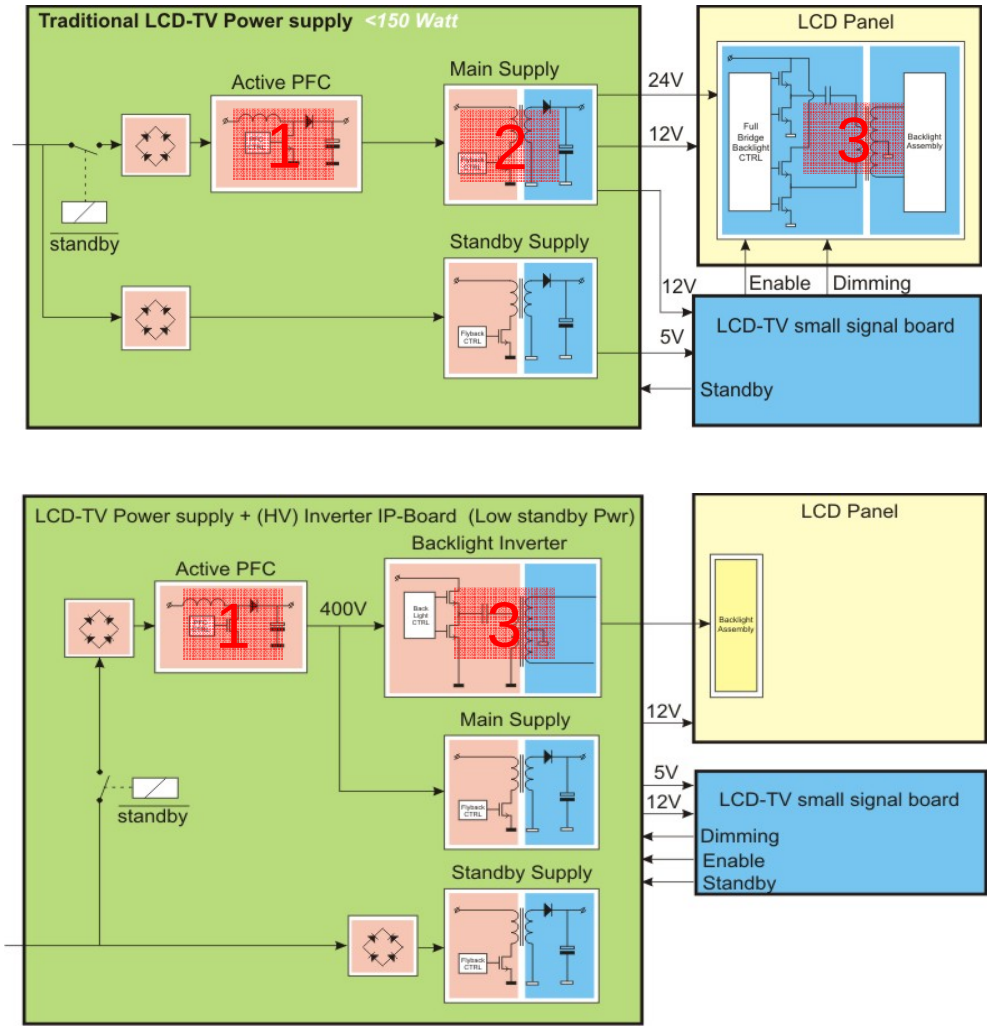
NXP Product offering:

UBA2071	Half-Bridge (Master)
UBA2073	Half-Bridge (Slave)
UBA2074(A)	Full-Bridge

“HV_Half_bridge_Resonant” incentive

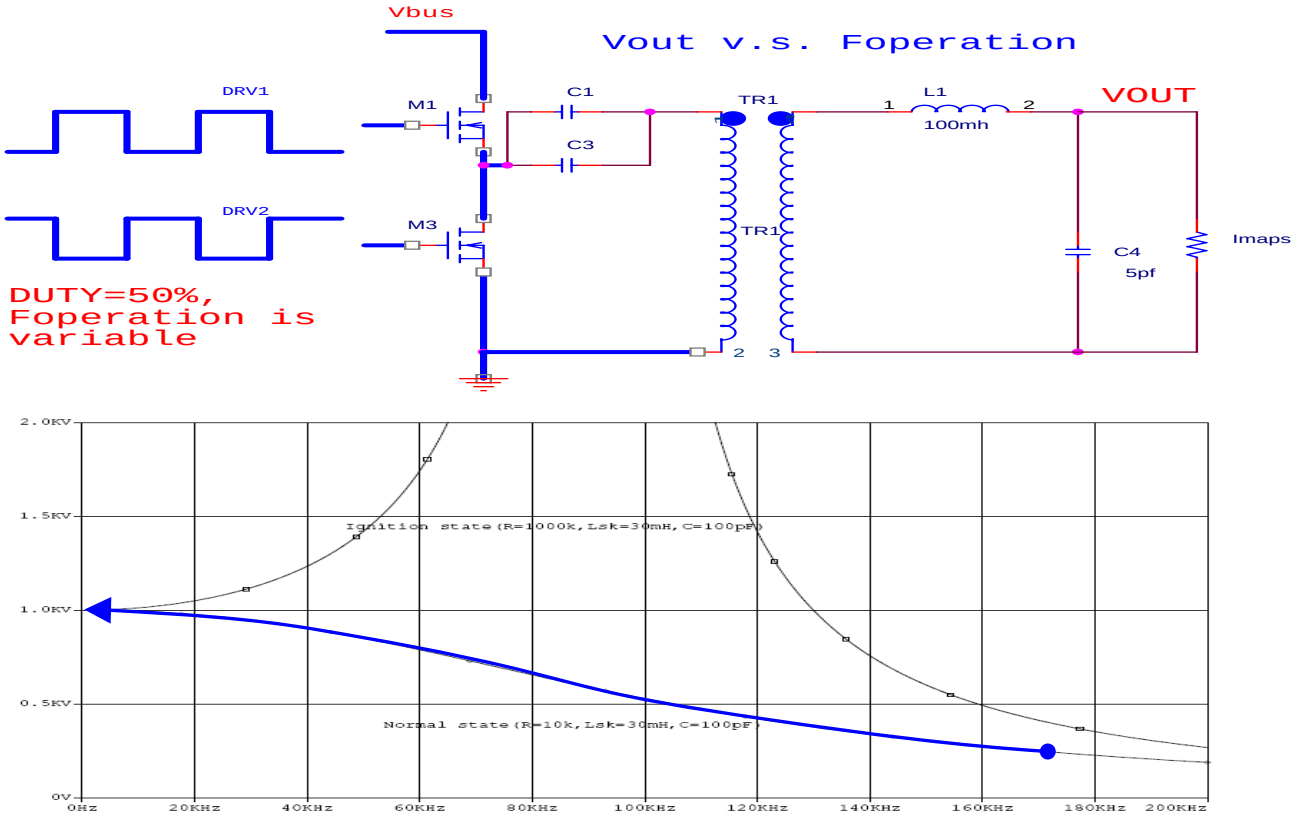
Fluorescent Lamp Backlighting

(HV incentive) three-stages → two-stages



- **HV-inverter is not more expensive than LV-inverter**
  - Mains isolation → little cost-up
  - Less cost in power structures (lower currents) → cost down
  - Effect on total cost = small
- **PFC power requirements are lower, as system efficiency is higher**
  - Therefore, the cost of PFC can be a little lower.
  - Effect on total cost = relatively small
- **Main power supply does not need to supply backlight power**
  - 40~70 Watt fly-back PSU versus >200 Watt Resonant power supply
  - For <1 Watt standby PWR requirements Fly-back PSU can double for standby supply, eliminating the full cost of the standby supply on the BOM
  - **Effect on total cost = high**

Resonant incentive__ theory

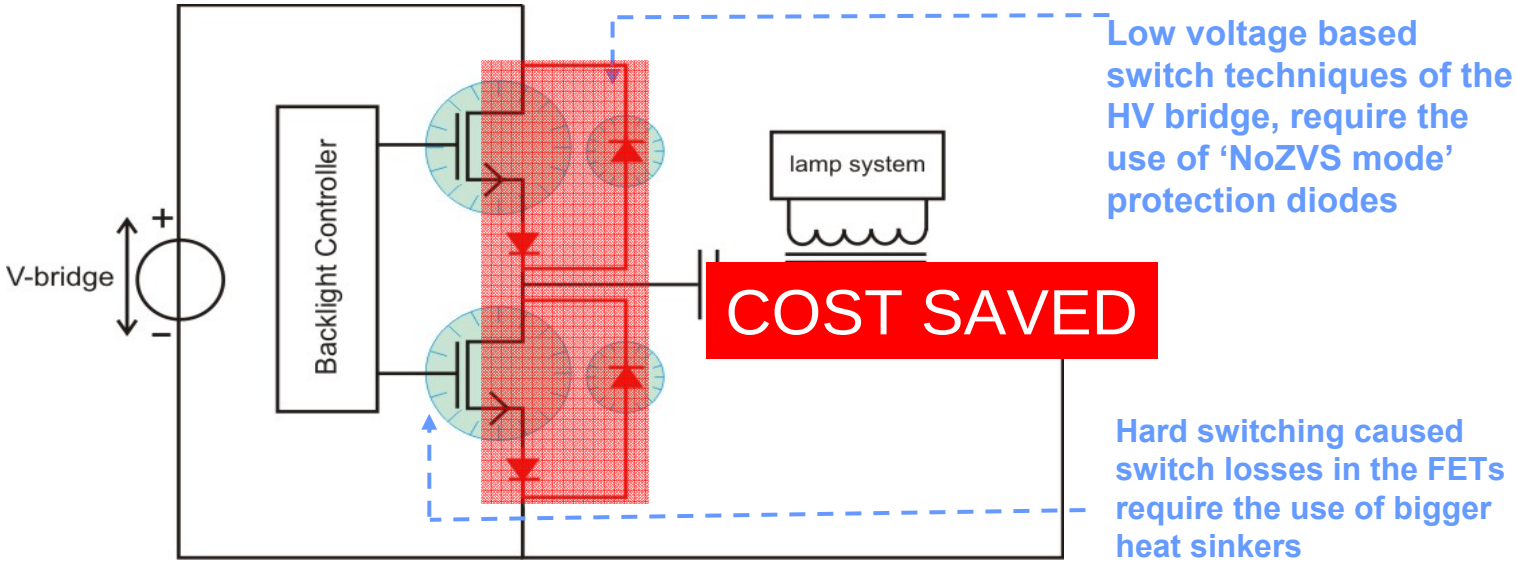


Vout is affected by the Operation Frequency. Frequency decreases, Vout is increase when state is in inductive area.

Resonant incentive ___ merits

- **Half_bridge_Resonant can easily obtain Zero Voltage switch(ZVS)**
  - Almost fixed maximum duty cycle easily assures the realization of ZVS;
  - Variable operation frequency With fixed maximum duty cycle Avoids No-ZVS during PWM dimming mode;
  - Maximum duty cycle supports good sinusoidal output current waveform;
  - EMI can be improved with ZVS;
- **Half_bridge_Resonant effectively reduces amount of components**
  - Auxiliary diodes and schootky are eliminated;
  - Easily choose power devices (MOSFETs);
  - Heat sinker's size is smaller;

Resonant incentive ___ Fixed frequency IC



1. In fixed frequency status, output power is controlled through changing duty cycle of drive signals. To assure MP reliability, the normal duty cycle is usually small, such as 35%--38%, this low duty cycle easily induces NoZVS status.

2. During PWM dimming mode, fixed frequency IC usually gradually increases duty cycle from very small, such as 10%, to normal duty cycle. Therefore, NoZVS status must occurs.

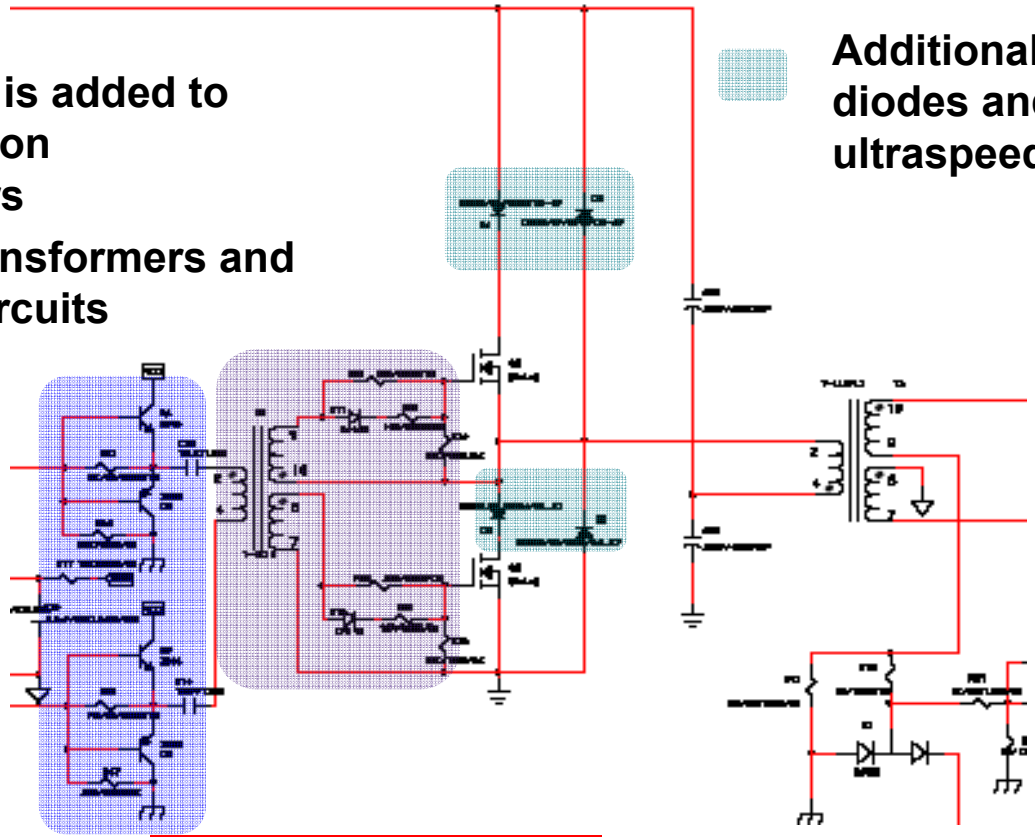
auxiliary diodes and schottkies , bigger heat sinkers

Resonant incentive __ Fixed frequency IC

Totem-pole is added to drive isolation transformers

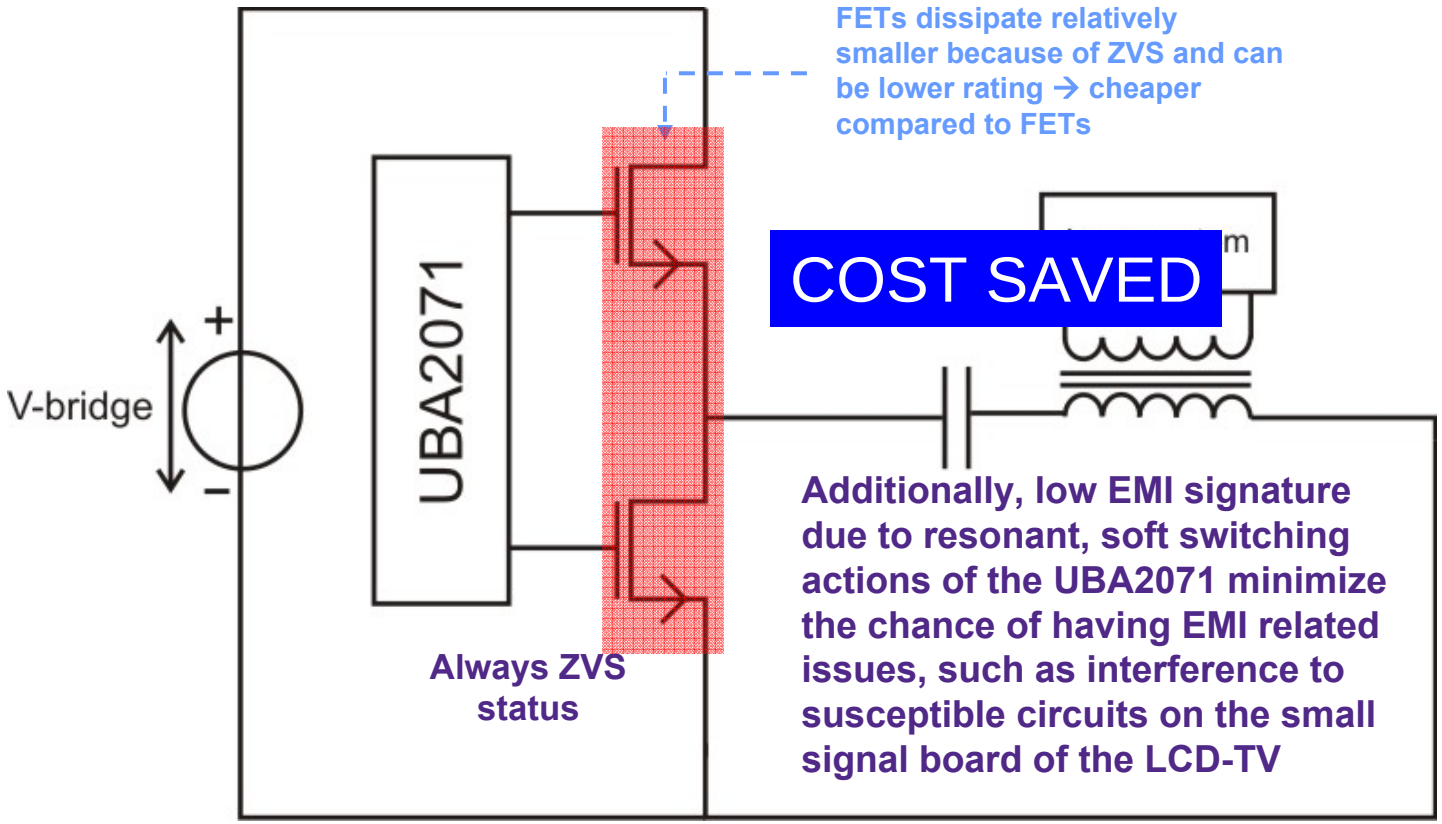
Isolation transformers and speed-up circuits

Additional High-voltage diodes and high-voltage ultraspeed schootky



COST SAVED

Resonant incentive ___ half_bridge Resonant IC

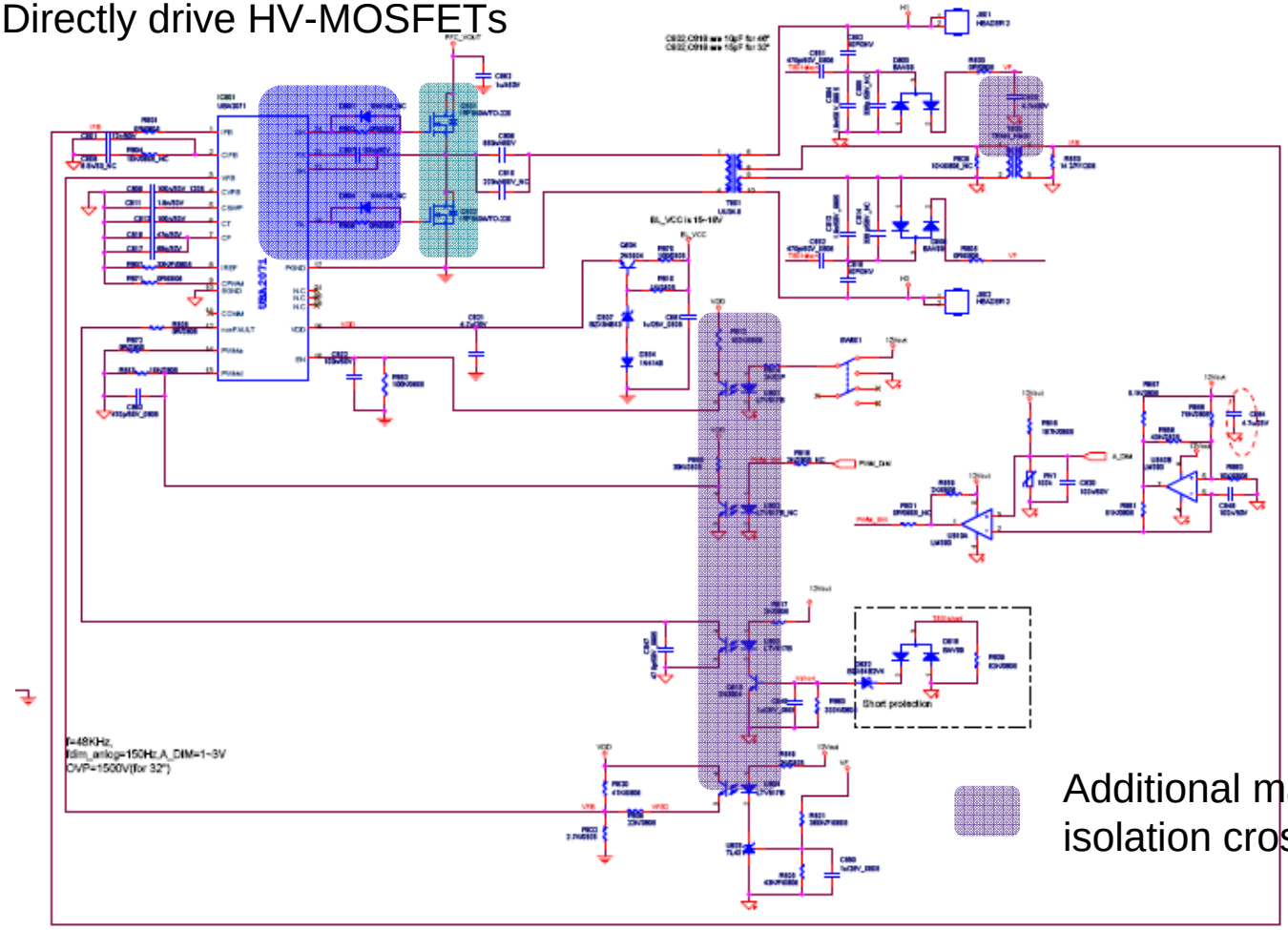


No auxiliary diodes and schottkies , smaller heat sinkers

Resonant incentive ___ half_bridge Resonant IC

No auxiliary component

Directly drive HV-MOSFETs



Additional main isolation crossings

HV half-bridge-resonant Inverter

UBA2071(A)

UBA2071(A)

HV,half_bridge_Resonant Inverter IC

Special Features

High-voltage(550v), half-bridge resonant

Directly drive Power devices, Hard-switching control

Integrated level shifters & bootstrap diodes

Supports master/slave operation with UBA2073(SO8)

Over-voltage control

Output short and open protection

lamp short & open protection

Protection against sparking

Analog and external PWM dimming

UBA2071(A)

HV,half_bridge_Resonant Inverter IC

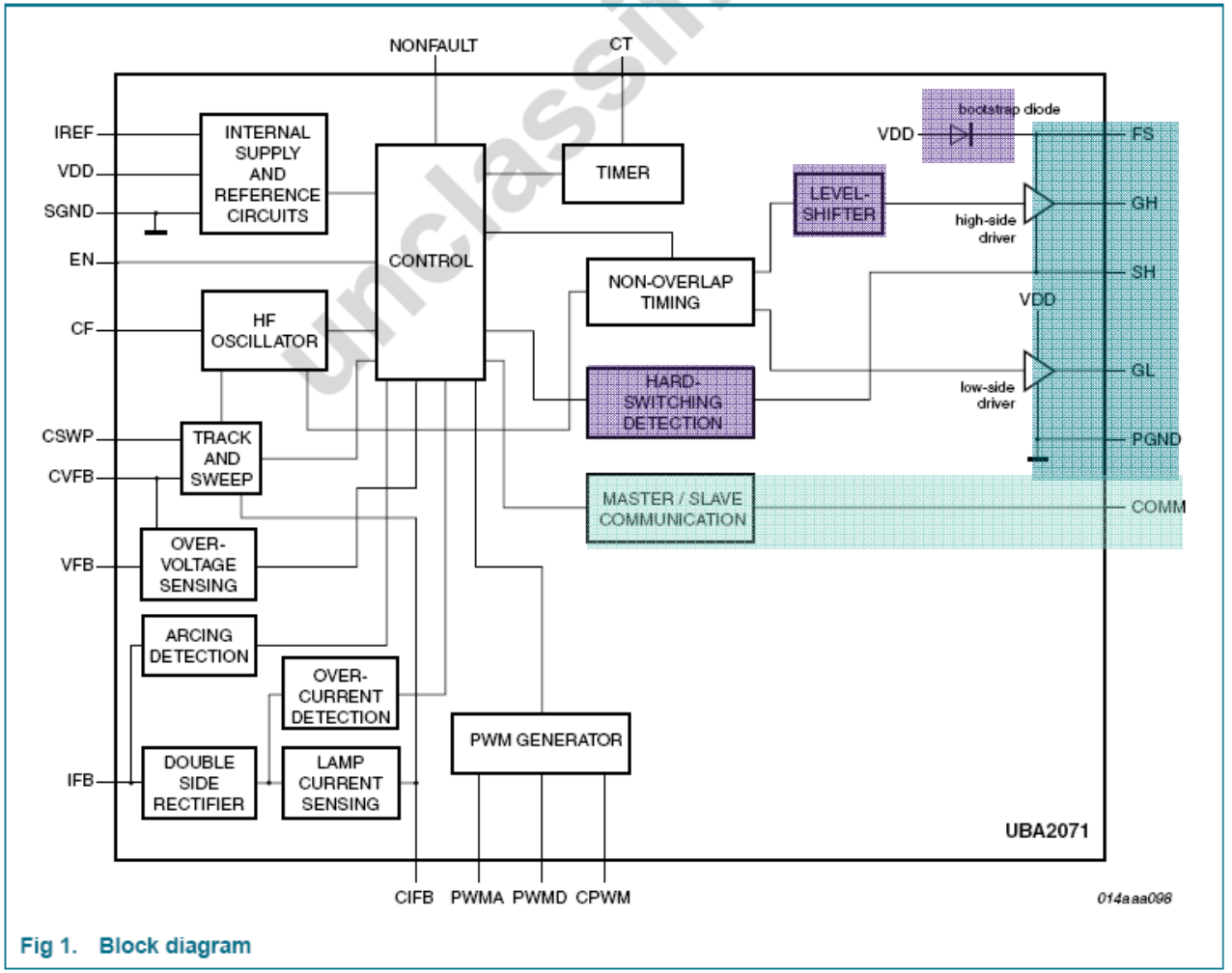
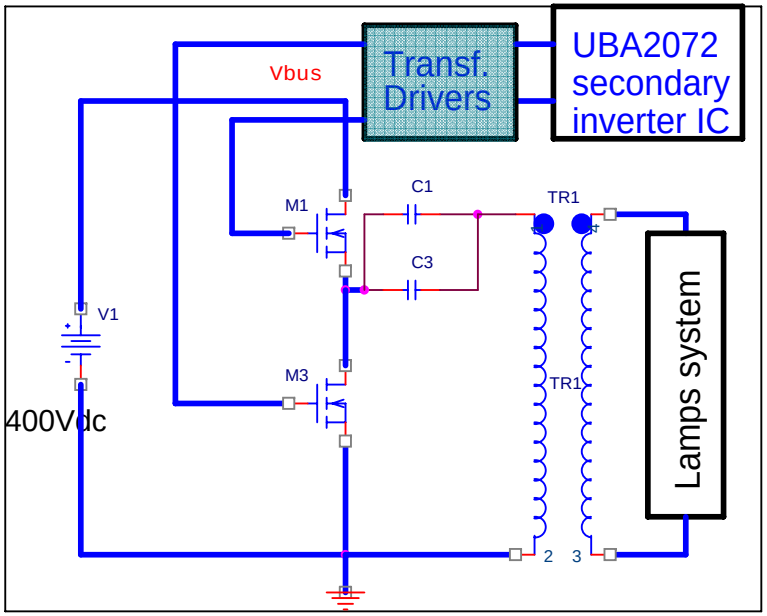


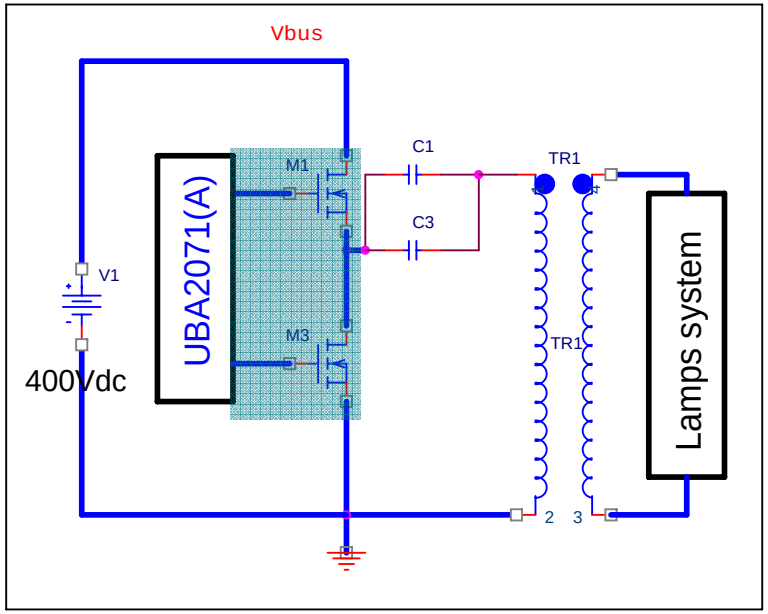
Fig 1. Block diagram

HV half-bridge-resonant Inverter

UBA2071(A): Directly drive power devices

Directly Drive power devices





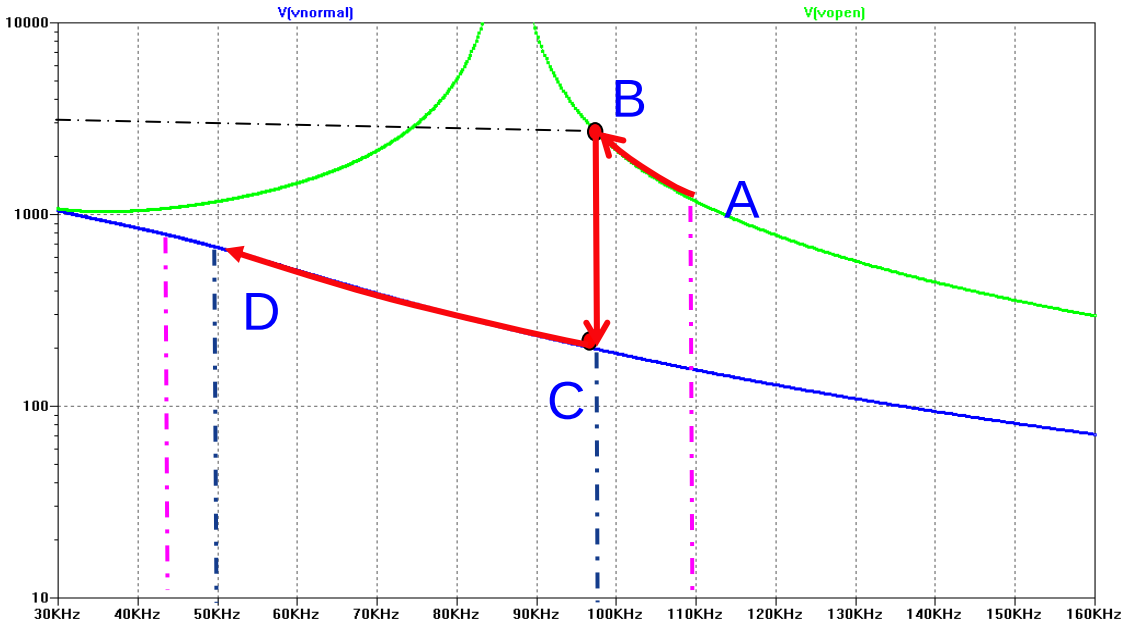
UBA2071 can directly driver primary high voltage power MOSFET. Comparison with secondary inverter IC, driver_transformers are no needed, about 0.3USD is saved.

COST SAVED

HV half-bridge-resonant Inverter

UBA2071(A): Ignition Principle

Ignition principle



Unloaded resonant cure

Loaded resonant cure

Start at Fmax=2.4*Fmin with duty=50%---- A

Decrease frequency,hitting iginition voltage----B and C;

Frequency decreased untill Ilamp=regulated----D

Advantages of the sweep rather then a fixed ignition frequency :

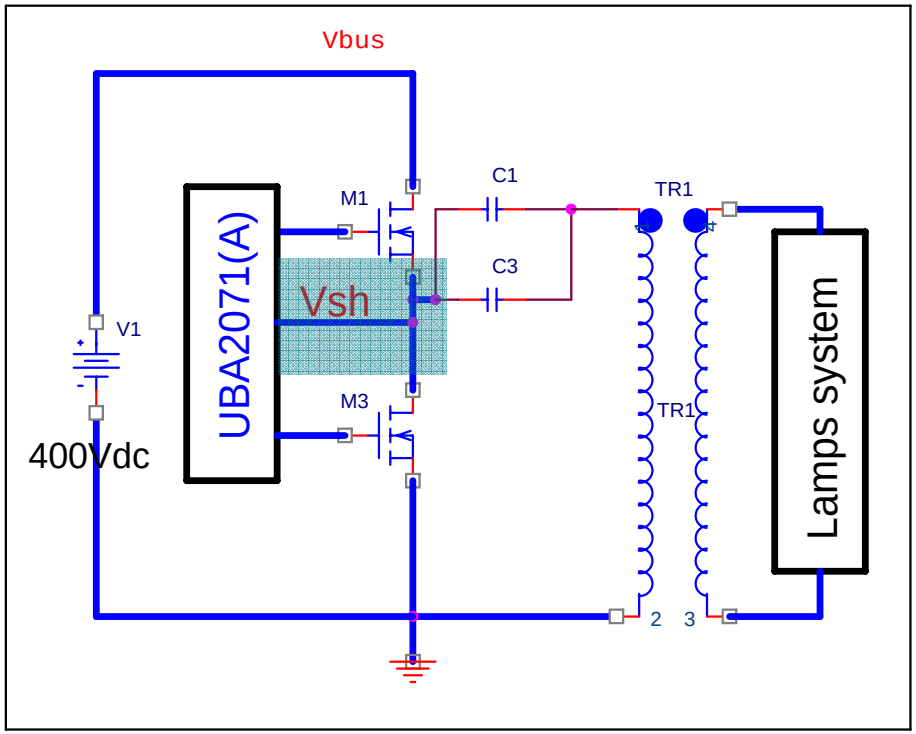
1.Sensitivity for spread in resonance frequency is much lower.

2.Non-sensitive of ambient temperature and ignition voltage(aged panel).

HV half-bridge-resonant Inverter

UBA2071(A): Hard-switch detection

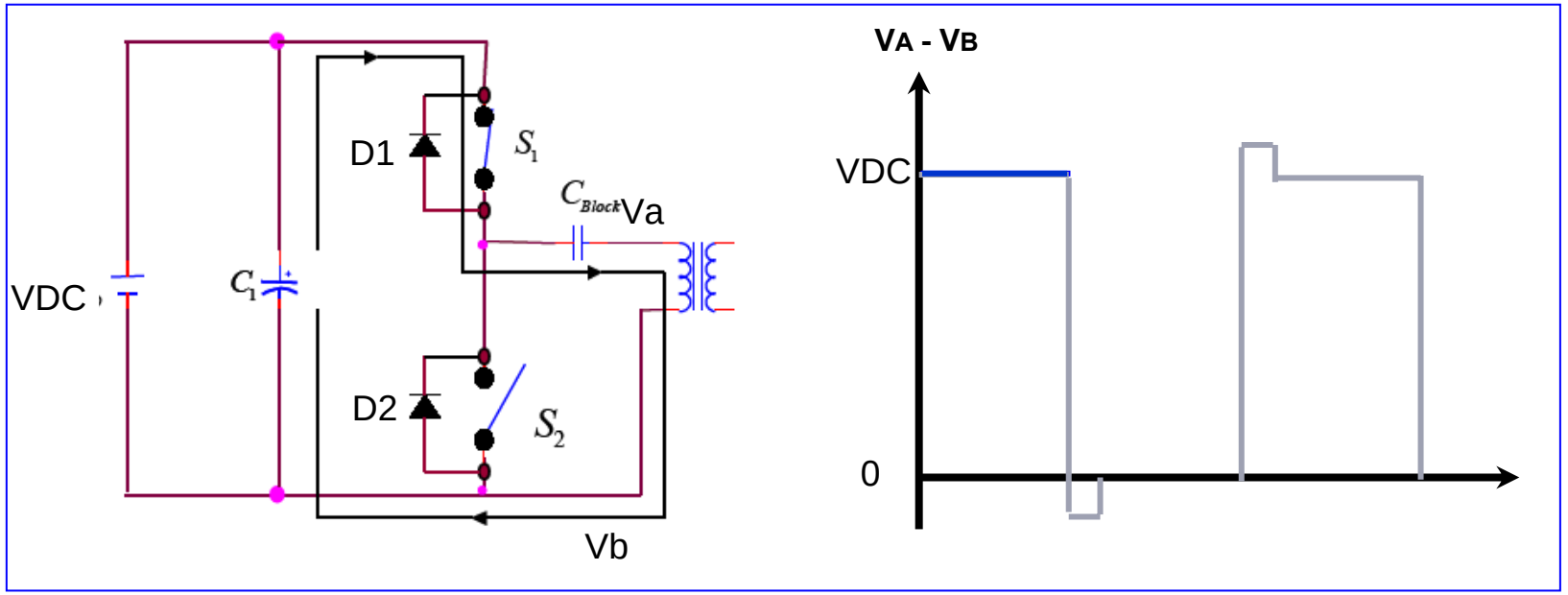
Hard-switch detection



UBA2071 is directly connected with primary high voltage MOSFETs, so hard-switch status can be detected through voltage level on Vsh pin. Hard-switch detection function assures system reliability in HV inverter.

Hard-switch detection

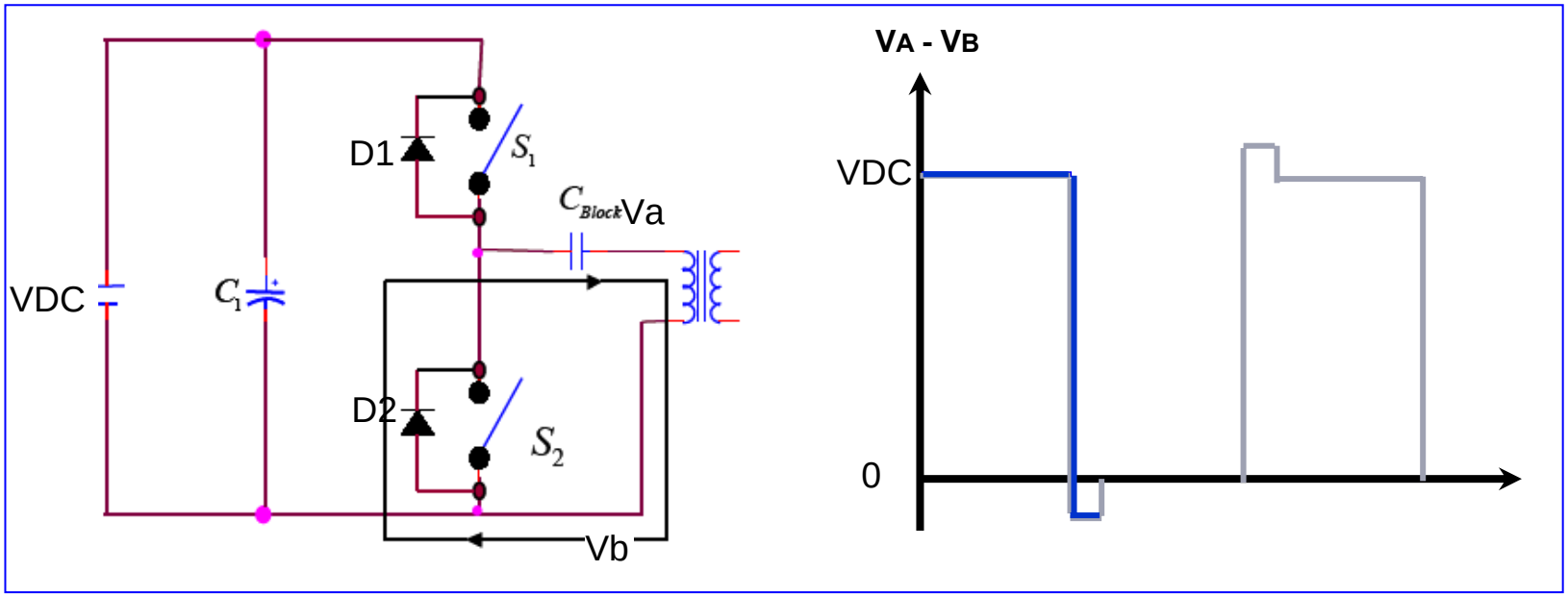
step1



S1 is on,D1,D2 and S2 are off. Current flows with direction shown as above figure. Va-Vb=VDC/2=200v.

Hard-switch detection

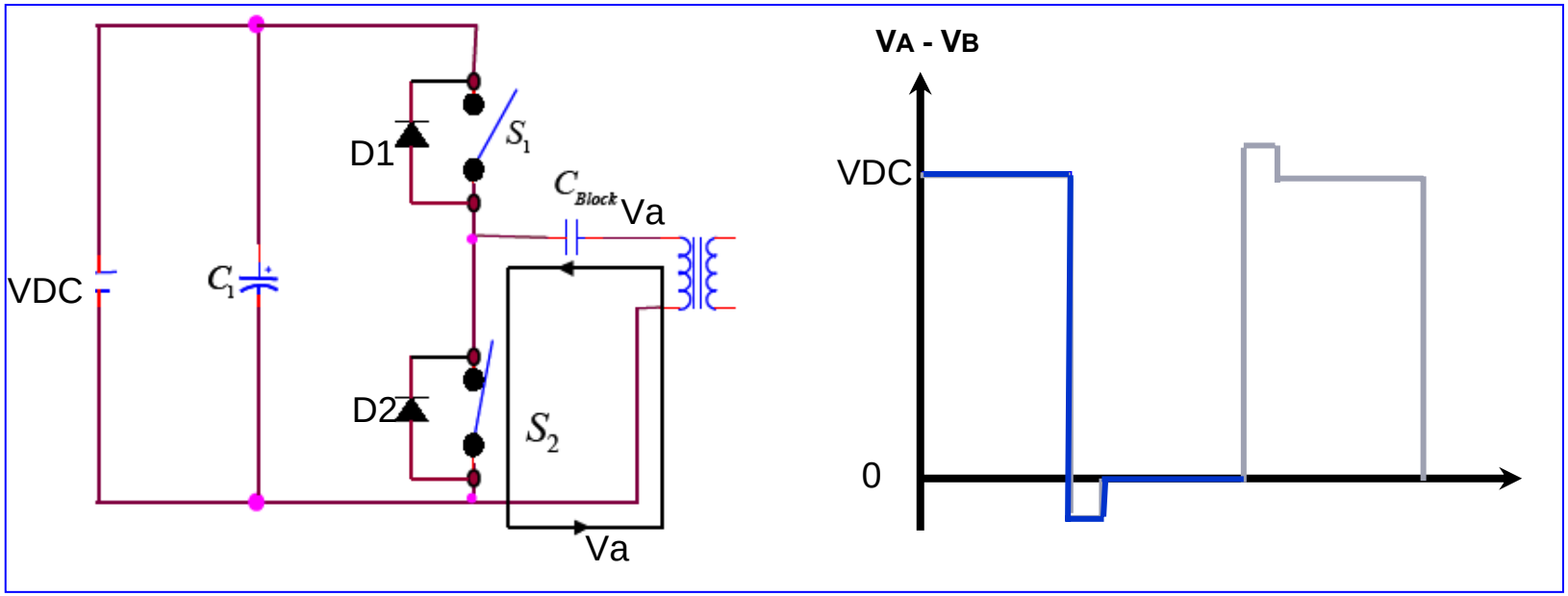
step2



S1 ,D1,and S2 are off. D2 is on because of magnetizing current.Current still flows with direction shown as above figure. But Va-Vb=-Vdiode-forward.

Hard-switch detection

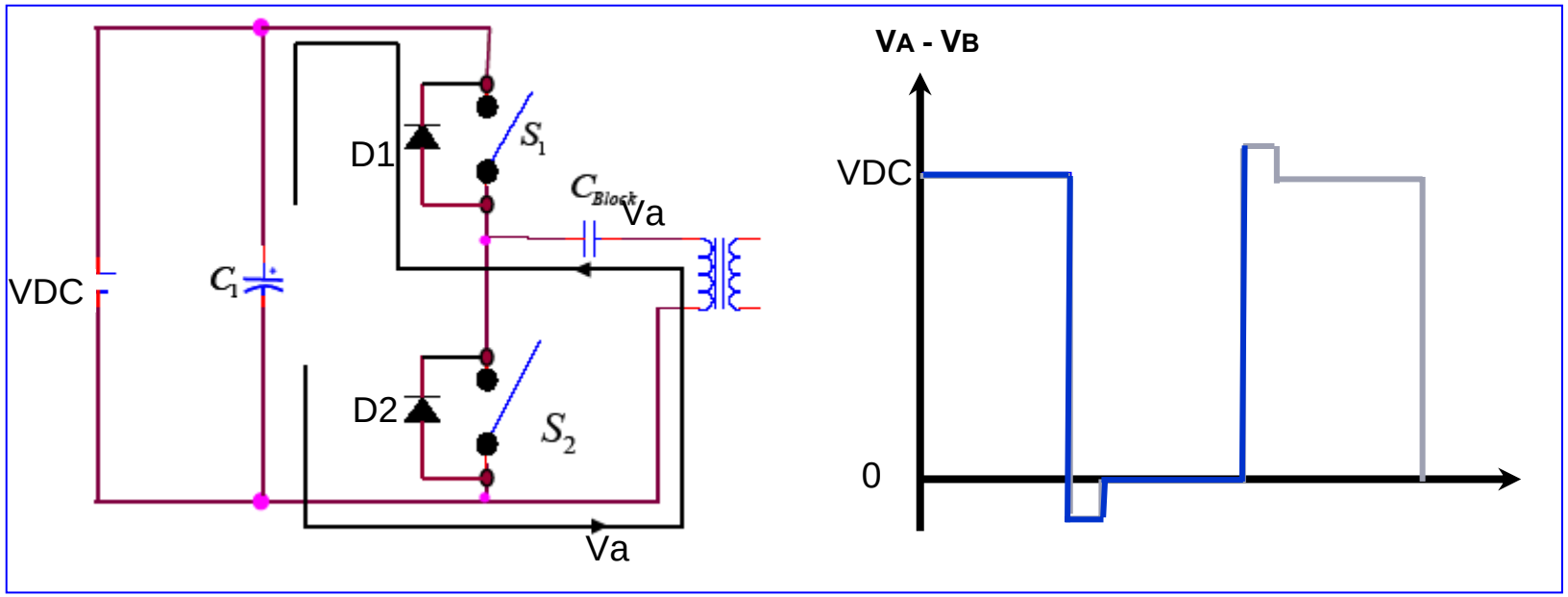
step3



D2 ,D1,and S1 are off. S2 is on (ZVS-on). Current will reverse direction and Va-Vb=0.

Hard-switch detection

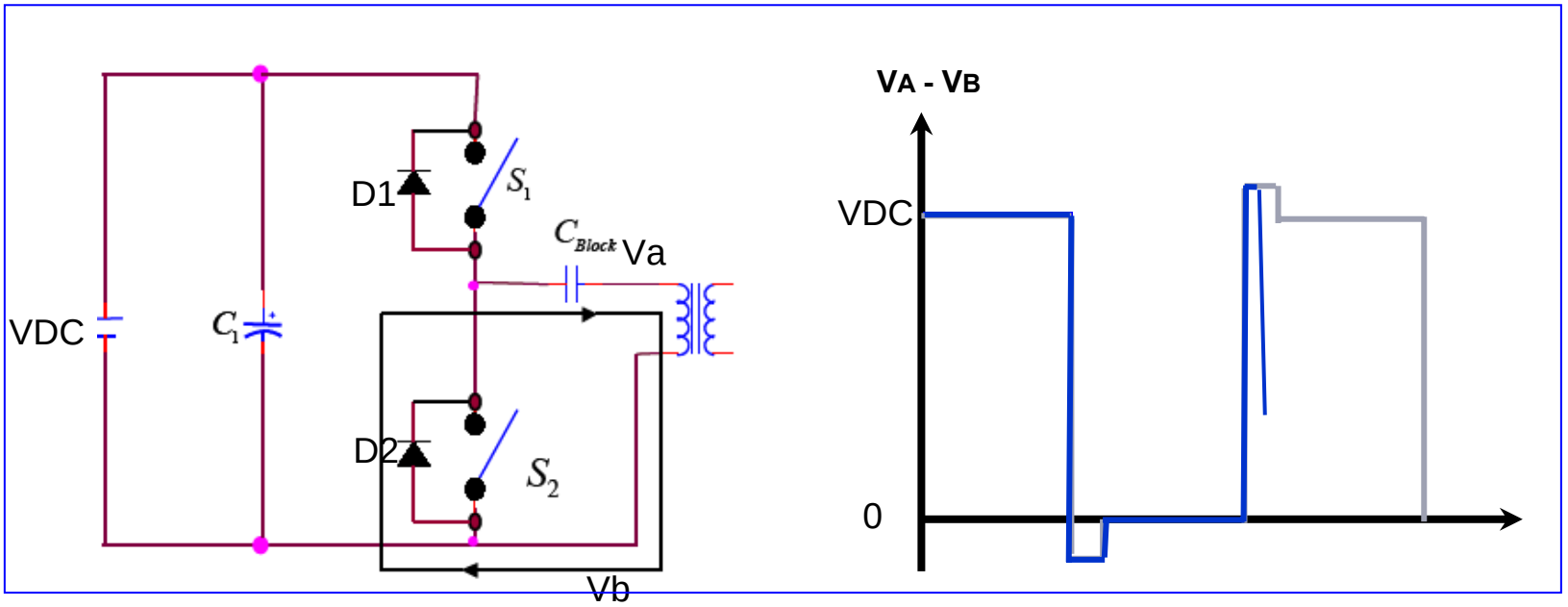
step4



S2 ,D2,and S1 are off. D1 is on because of magnetizing current.Current still flows with direction shown as above figure. Therefore, Va-Vb=Vdiode-forward.

Hard-switch detection

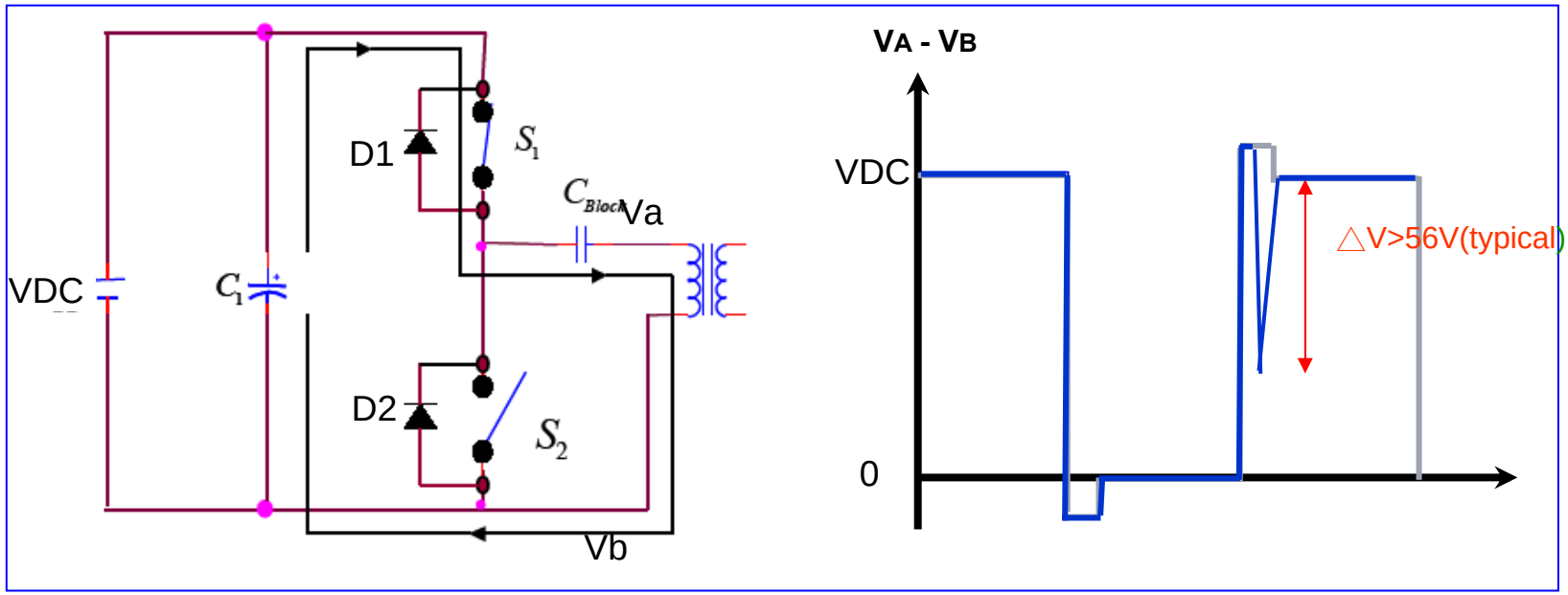
step5



If magnetizing current is not enough big, before switching on S1,current direction will reverse shown as above fig. during dead-time interval. Voltage across drain and source of S1 will be not very high above zero, hard switching occurs.

Hard-switch detection

step6

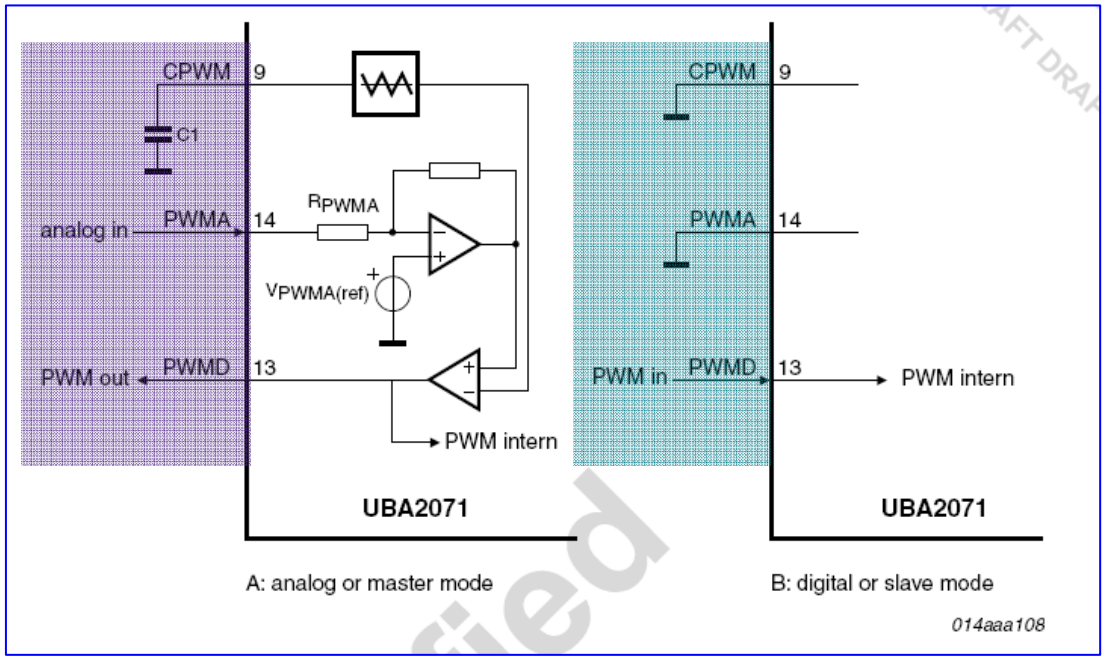


UBA2071 will detect the voltage (Vsh_pin) at source terminal of S1at the moment of turning on S1,if finding a glitch of above 56V,hard-switch protection will be triggered.

HV half-bridge-resonant Inverter

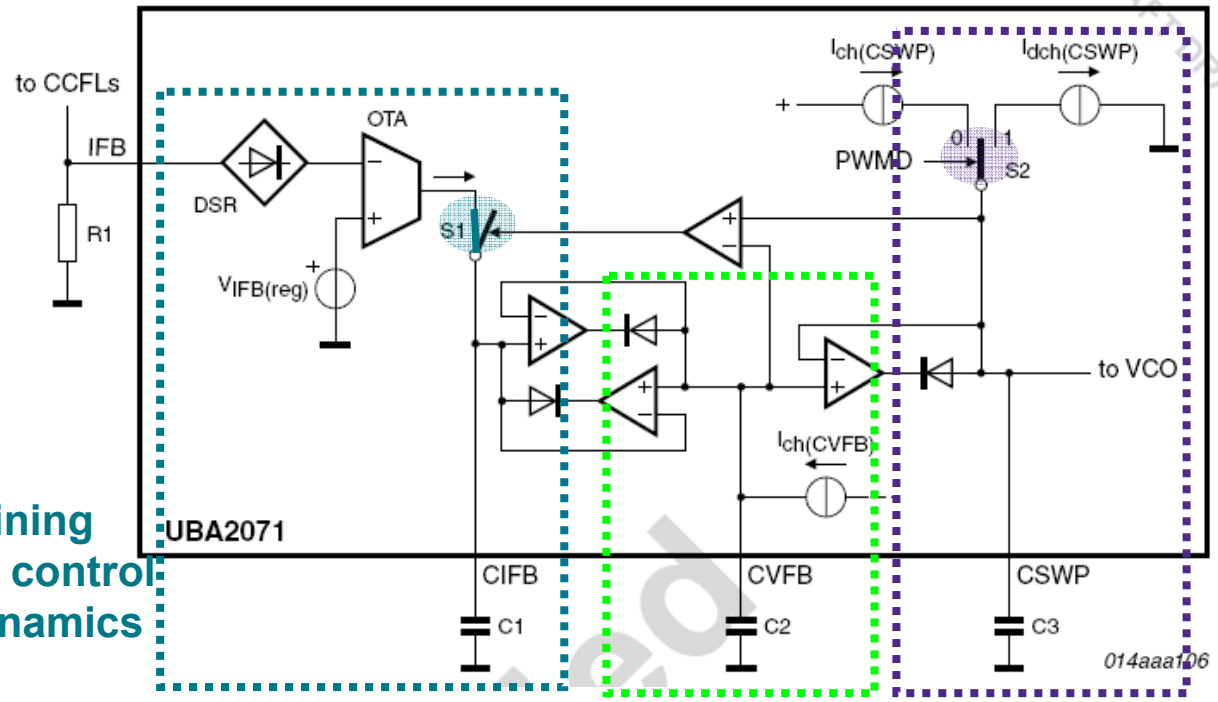
UBA2071(A): PWM dimming operation

PWM dimming operation



Configuration as A circuit----analog Dimming with analog voltage input (1.2v—3v);
Configuration as B circuit----digital Dimming with external PWM voltage input (Dmin=12%);

PWM dimming operation



Determining PWM dimming, frequency 'attack' and 'decay' behavior

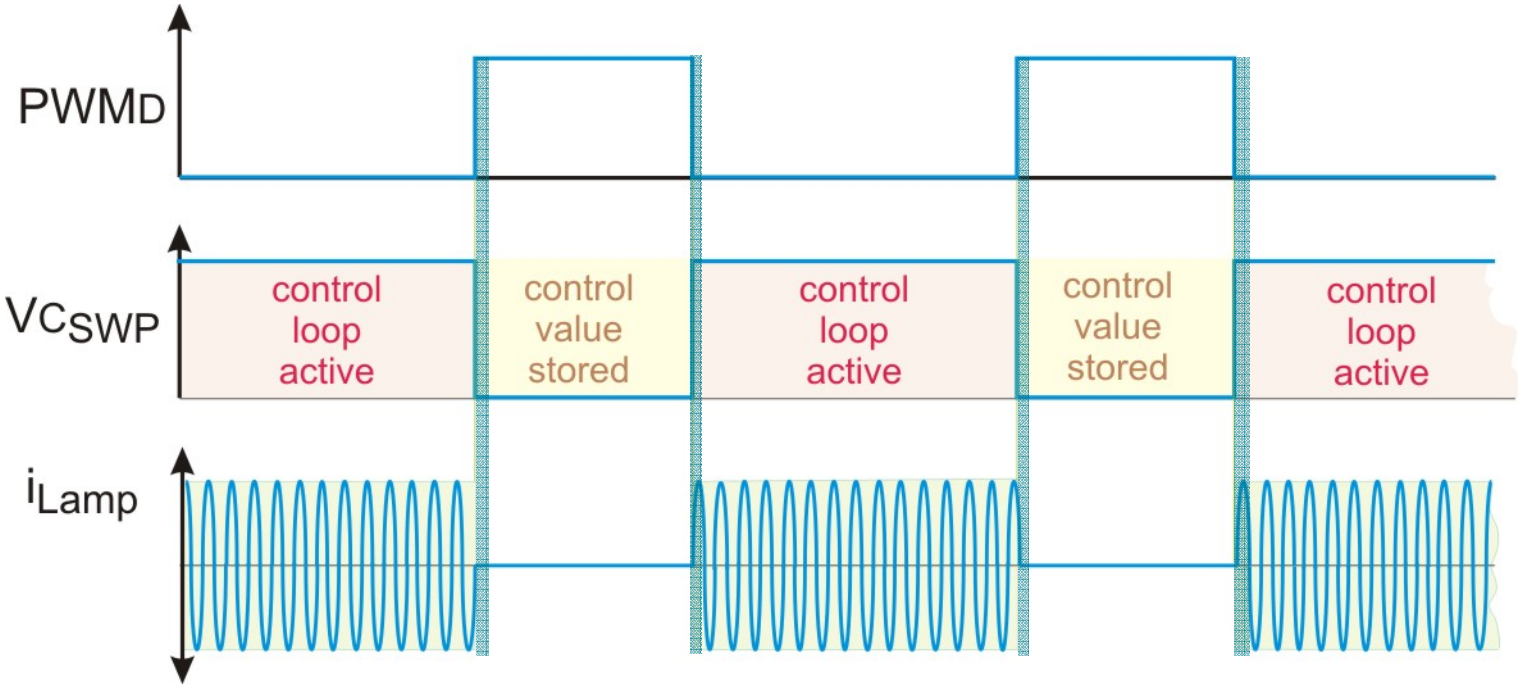
Determining Current control loop dynamics

Determining Voltage Control loop

- UBA2071 utilizes three separately definable time constants for current control loop dynamics, voltage control loop and PWM dimming control.

PWM dimming operation

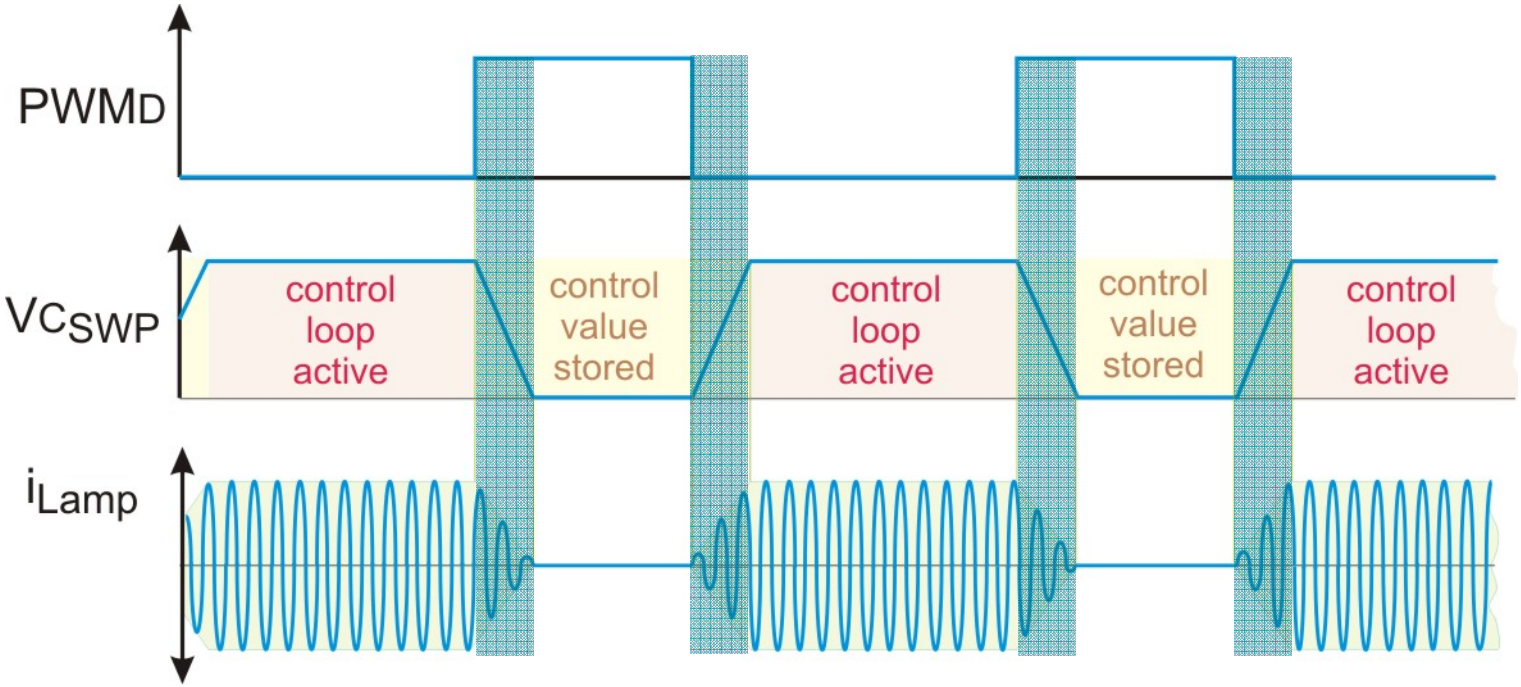
Enables an ultra-steep PWM envelope (min. Brightness=12%) without any lamp current overshoot.



Increasing CSWP value will result in a less steep PWM 'attack' and 'decay' of the PWM lamp current envelope.

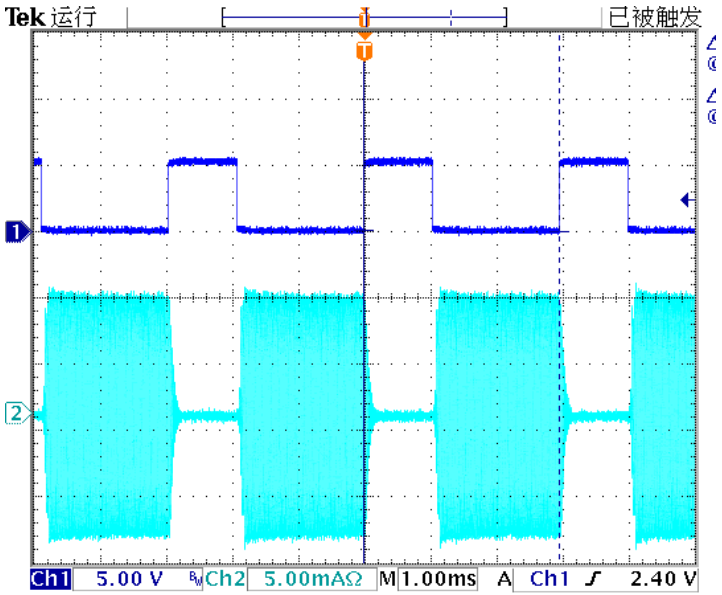
PWM dimming operation

Programmable PWM envelope ‘softness’ helps reducing potential inverter transformer audible noise.



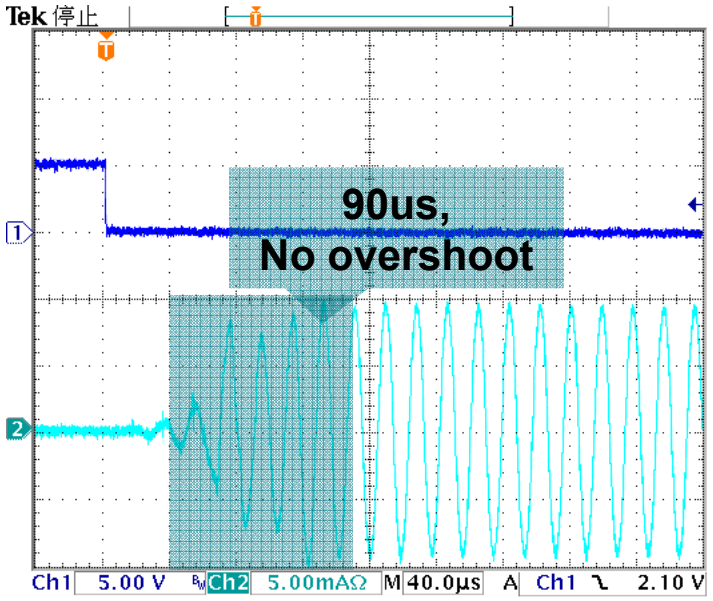
Just changing CSWP capacitance, PWM rising and falling time can be controlled without affecting soft ignition process of lamps

PWM dimming operation waveforms during PWM dimming



Ch1:pwm; ch2:lamp current

ultra-steep PWM envelope



Ch1:pwm; ch2:lamp current

Rising time is only about 90us, almost without lamp current overshoot.

LCD-TV LIPS in the market using the UBA2071 backlight inverter controller

Case Study

- Philips Cineos™ :
  42PFL74XX, 42PFL96XX and 42PFL97XX

  and Philips' latest Aurea™ top-of-the-line:
  37PFL99XX and 42PFL99XX

  All Apply UBA2071ATS backlight inverter controller

UBA2071ATS in Philips High-end Cineos™ 42PFL740X

- The Philips 42PFL740X was the first of a range of Philips LCD-TV's that apply the UBA2071ATS backlight controller in a Philips proprietary power topology
- Two-stage LIPS topology with buck-mode PFC, running the backlight inverter from 160 Volt none-isolated supply rail, using the UBA2071ATS.

•100 Hz LCD

•HD Natural Motion

•Pixel Plus 3 HD

•3D-combfilter

•Active Control with lightsensor

•Dynamic contrast enhancement

•Contrast 30.000:1

•Progressive Scan

UBA2071ATS in Philips High-end Cineos™ 42PFL9603 & 42PFL9703

- The Philips 42PFL960X and 42PFL970X were the second and third Philips LCD-TV that apply the UBA2071ATS backlight controller in a Philips proprietary power topology (including Ambilight supply)
- Two-stage LIPS topology with buck-mode PFC, running the backlight inverter from 160 Volt none-isolated supply rail, using the UBA2071ATS.

- 100 Hz, 1080p Clear LCD
- Perfect Pixel HD Engine
- Perfect Natural Motion
- Progressive Scan, 1080p
- Perfect contrast 30.000:1
- Wide Color Gamut
- 3:2/2:2 motion pull-down
- 3D-comb filter
- Active Control with light sensor

UBA2071ATS in Philips new range of Aurea™ top models: 37PFL990X and 42PFL990X

- The latest addition to the line of Philips LCD-TV's applying NXP's UBA2071ATS backlight controller IC's will be in range of the "top-of-the-line" Aurea™ LCD-TV's

Thank You!