LIPS Solution for LED TV Backlighting

Aug. 23th, 2010

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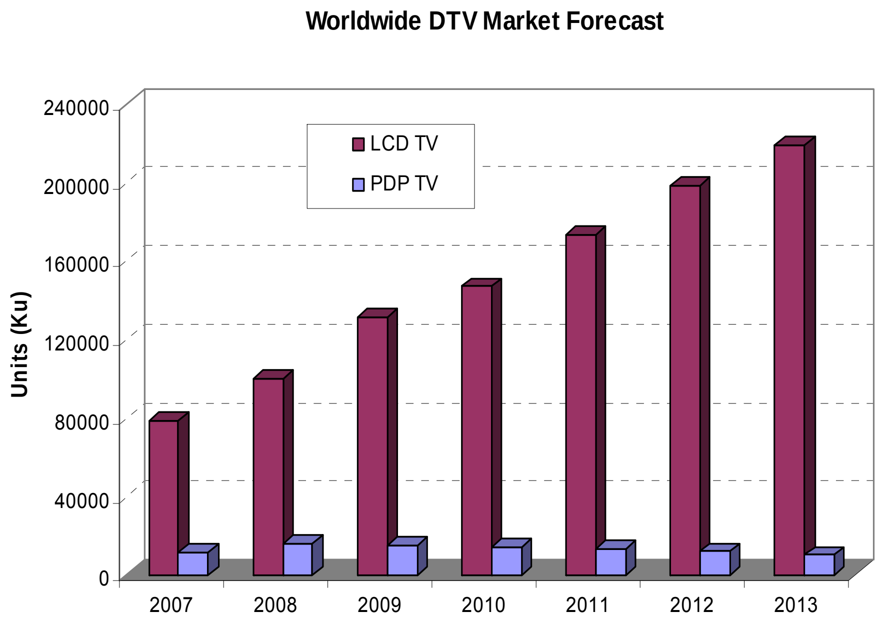
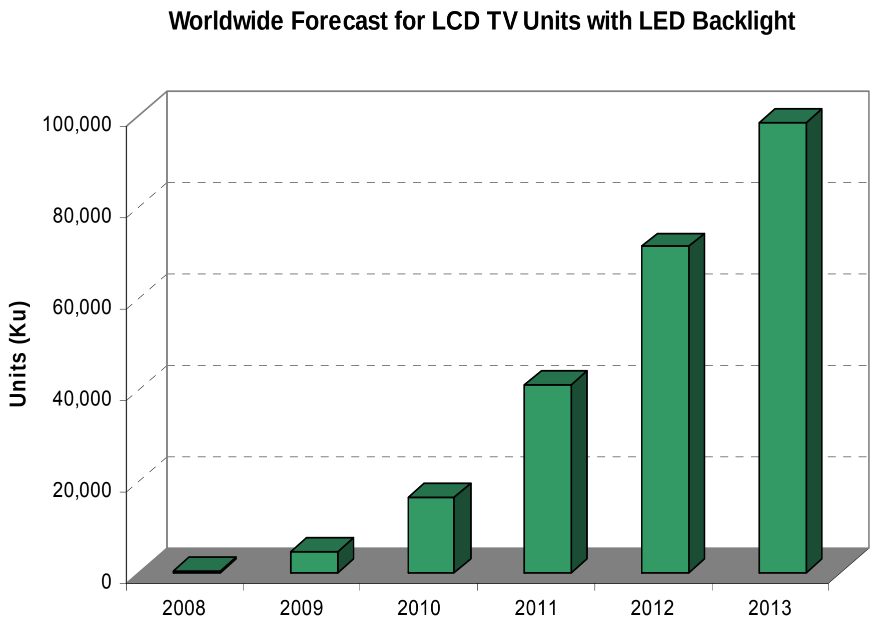
Outline

- DTV Market Trend
- Multi-Transformer Current Balancing
- Advantage Compare to Traditional Driver
- Transformer Design & Component Selection
- Feedback, Dimming and Protection
- Test Result
- Conclusion
- Introducing

DTV Market Trend





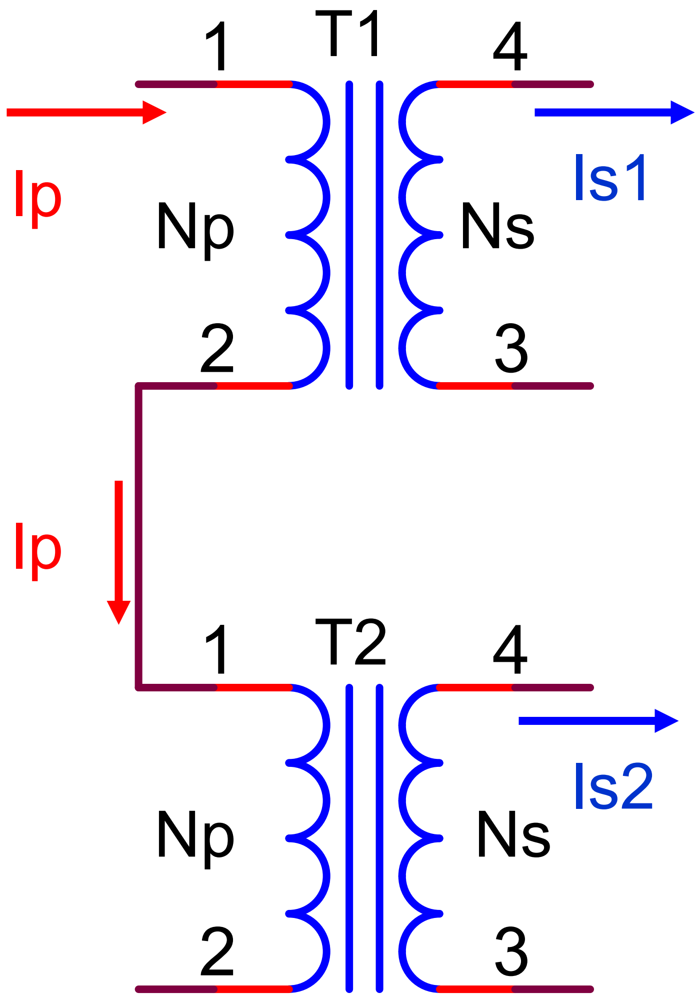
Source: iSuppli *"Worldwide TV Market Tracker Q3 2009"*

- DTV market forecasted to grow at 15% CAGR with LCD-TV expected to account for ~90% of total TV market by 2013
- LED backlighting application is hot; 5 year CAGR of 141%
- Edge lit LED TV dominates (90%) market – simpler, enable slim designs & cost effective
- CIP team strategy to support WLED TV backlighting applications; RGB will be supported by C2000 & DCP groups

Multi-Transformer Current Balancing

- **Why transformer can Balancing Current**
- **Multi-Transformer Architecture**
- **Why Current is not serious Influenced by Inductance**

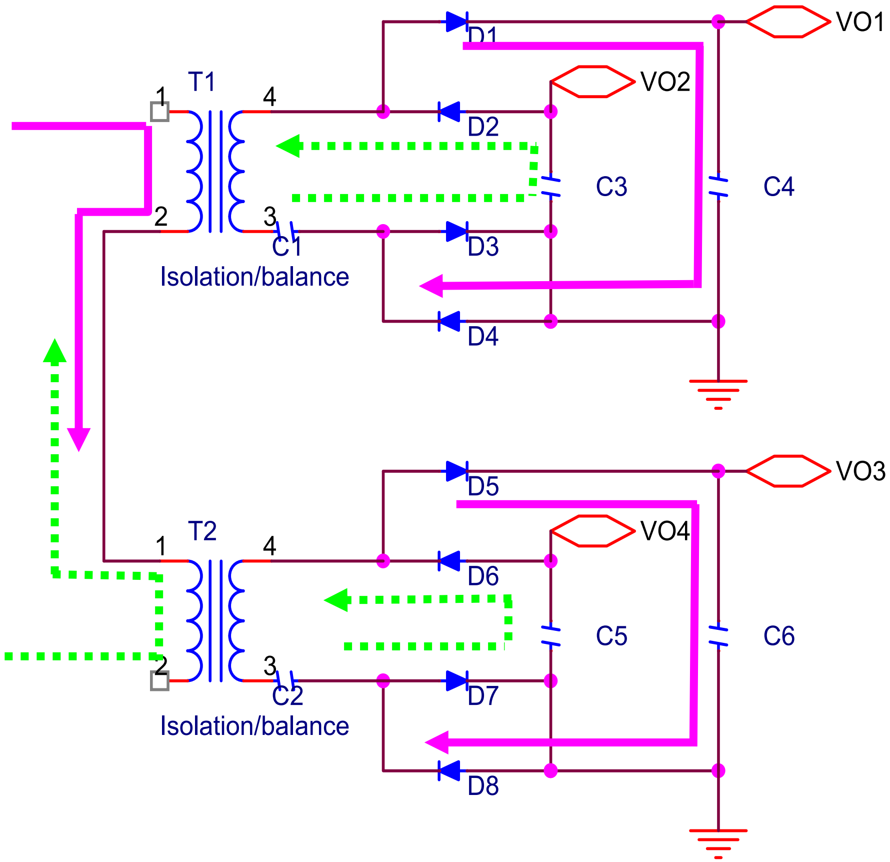
Why Transformer Can Balance Current

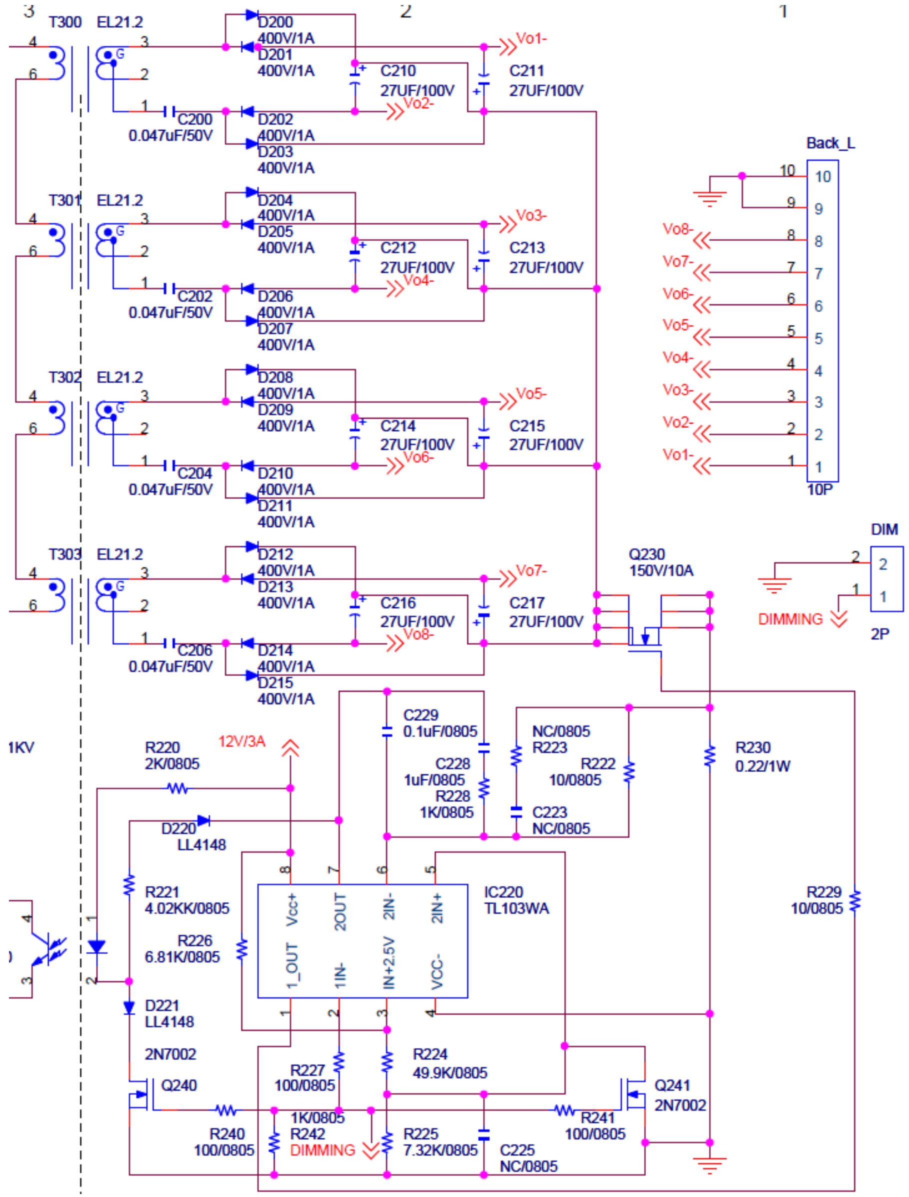


- Transformer current is in reverse proportion to turn ratio
- Ip/Np = Is/Ns; Is=Ns*Ip/Np
- When transformer primary is connected together, their primary current must be the same
- When T1 is the same as T2 because of transformer operation principle their secondary current is the same
- Is1=Ns*Ip/Np=Is2

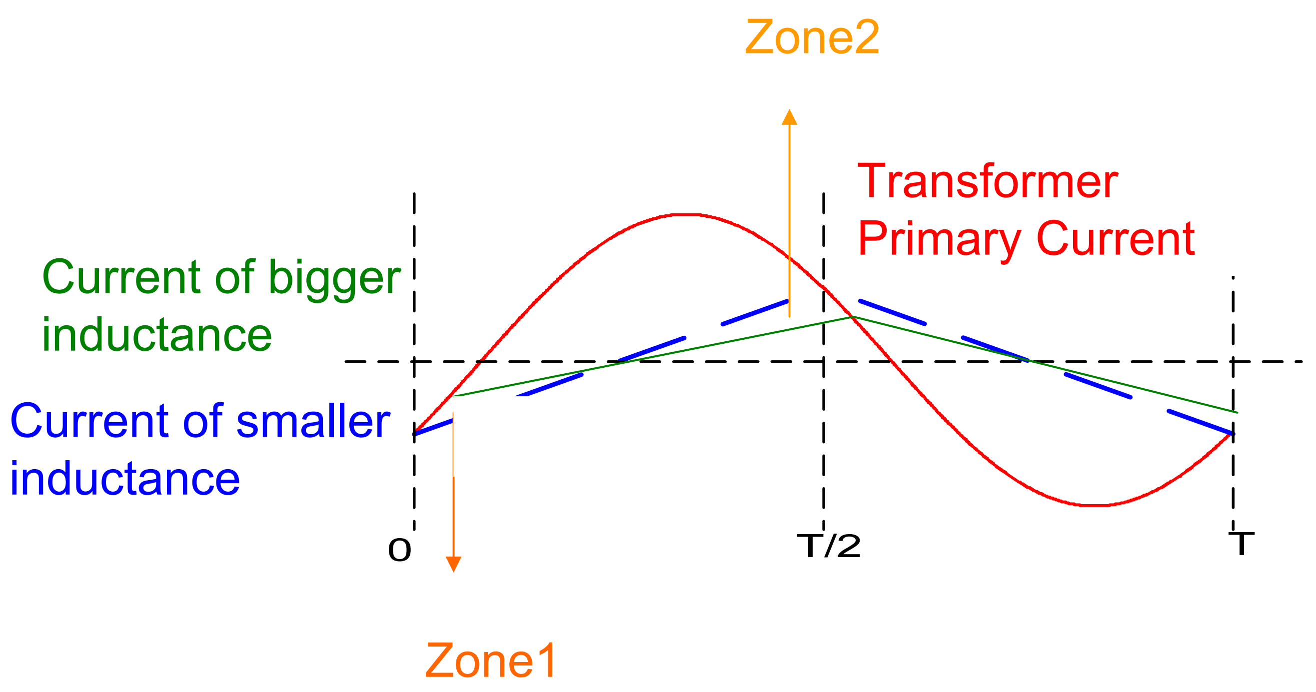
Multi-Transformer **Architecture**

(*TI Patented*)





Why Current is not serious Influenced by Inductance



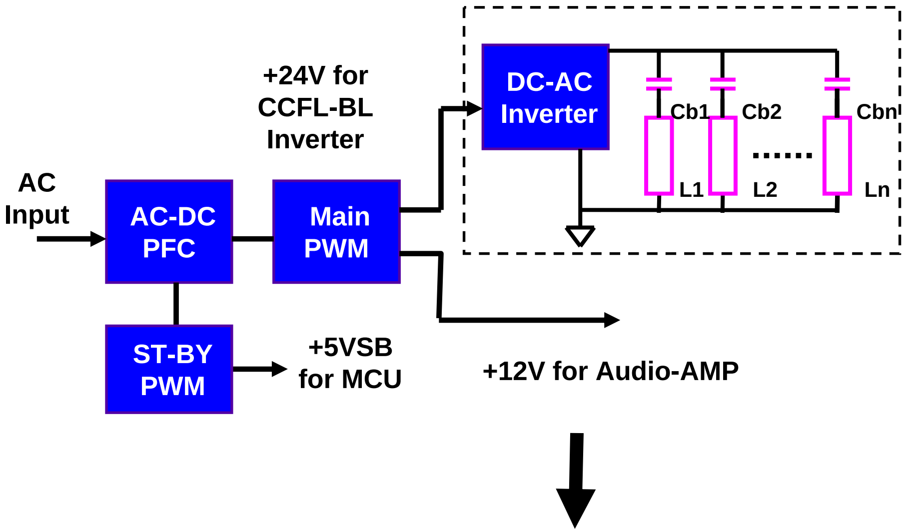
Because Zone1 is almost same as Zone2, inductance not series influence output current

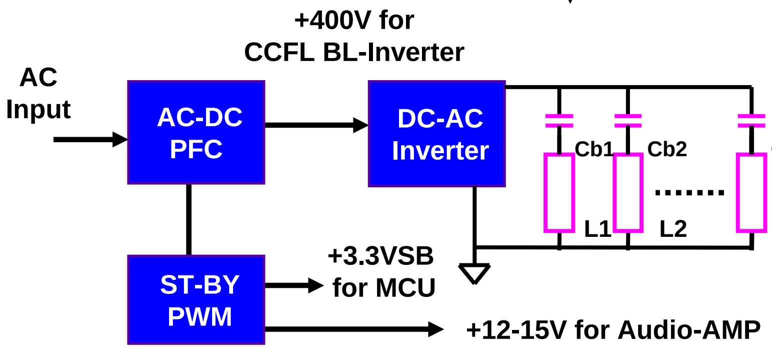
Advantage **Compare to Traditional Driver**

- **Solutions for Back Light Driver**
- **LED Back Light Comparison**

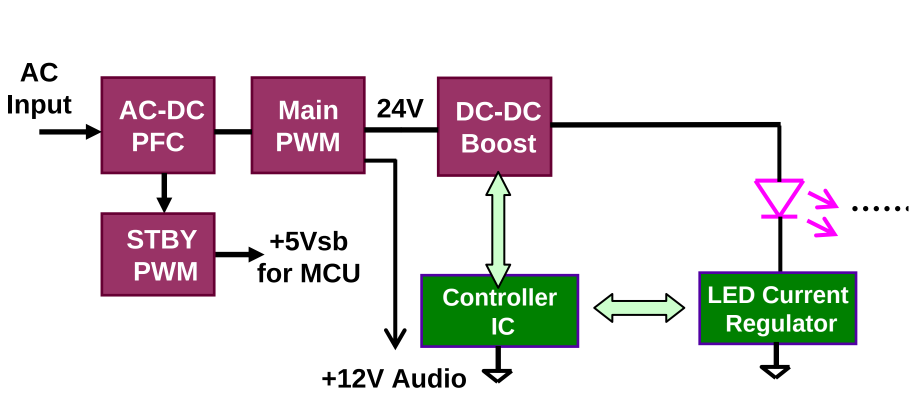
Solutions for Back Light Driver

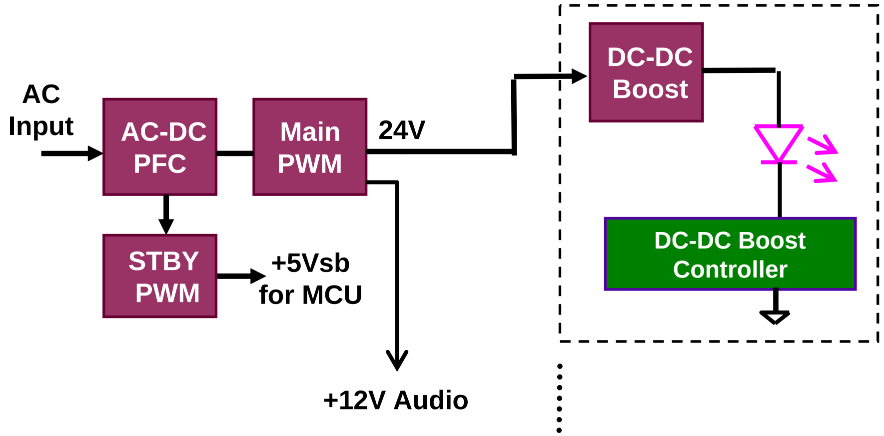
Power Supply Unit/ LIPS Architecture for LCD-TV





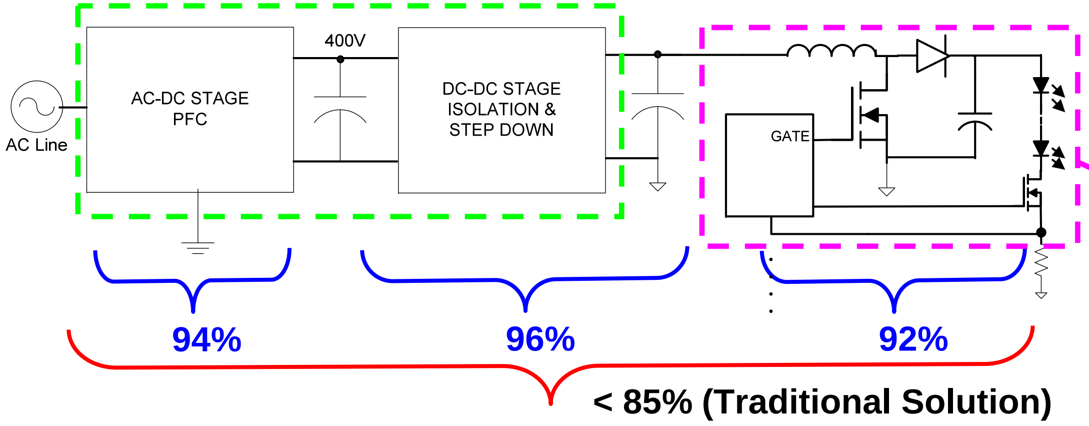
Power Supply Architecture for LED Backlighting TV Today



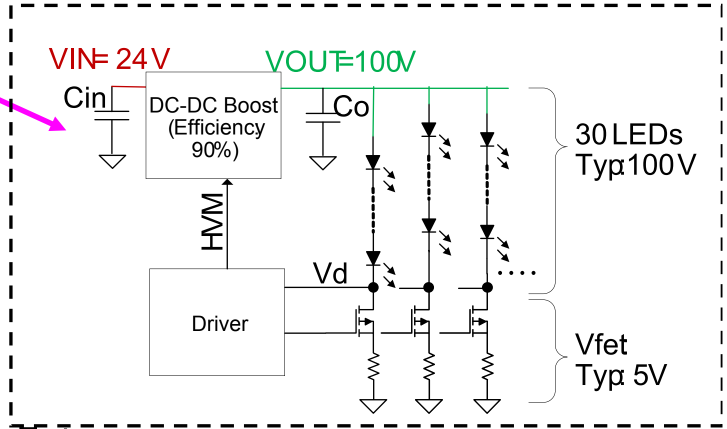


LED **Back Lingt Comparison**

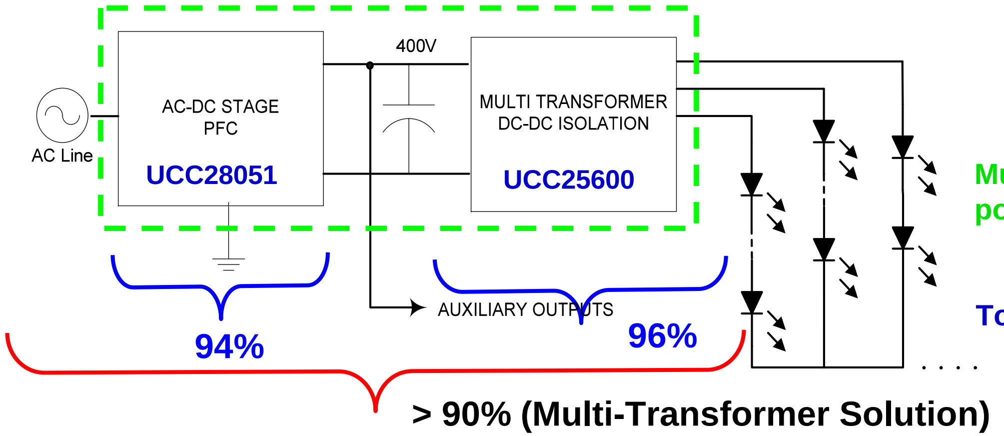
Power Supply Architecture for LED Backlighting TV Today



1* DC Boost + 8-16 LED Current Regulators



Power Supply Architecture for LED Backlighting TV in the Future



Multi-transformer outputs designed on AC/DC LIPS power module (higher efficiency & low cost) inside DTV.

Today- UCC25600

Advantage Compare to Traditional Driver

- Transformer Design
- Key Component selection
- Feedback and Dimming
- Protection

Transformer Design

For LLC transformer design, firstly we should transfer all parameter into the same unit. In this case we transfer all parameter into primary resistance. Considering 88V, 120mA load and two outputs for each transformer means each transformer output power is $P_{out} = 2 * V_{out} * I_{out} = 22.2316W$

Because there are four transformers in series and half-bridge topology, we got following equation.

$R_L = P_{out} / (V_{in})^2$ $\quad V_{in} = 400V / 4(inseries) / 2(halfbridge) = 50V$ $\quad R_L = 112.453\Omega$

To analyze LLC behavior easily we set $Q = \frac{\omega L_k}{R_L}$ $\quad K = \frac{L_m}{L_k}$

L_k means leakage inductance, L_m means magnetizing inductance.

In normal design we set frequency to 110K Hz to avoid 150K EMI conduction issue and also minimize transformer size.

Also set Q to 0.2 and K to 5 for better efficiency and enough hold up time.

From the equation of Q we got

$$L_m = K \times L_K = 163.225\mu H \qquad L_k = \frac{Q \times R_L}{\omega} = \frac{0.2 \times 112.453}{2 \times \pi \times 110000} = 32.645\mu H$$

Transformer Design

DC gain of LLC converter $M = \frac{V_0}{V_i}$ and $\omega_n = \frac{f}{f_o}$

f_o is the resonant frequency and it is equal to 110K Hz

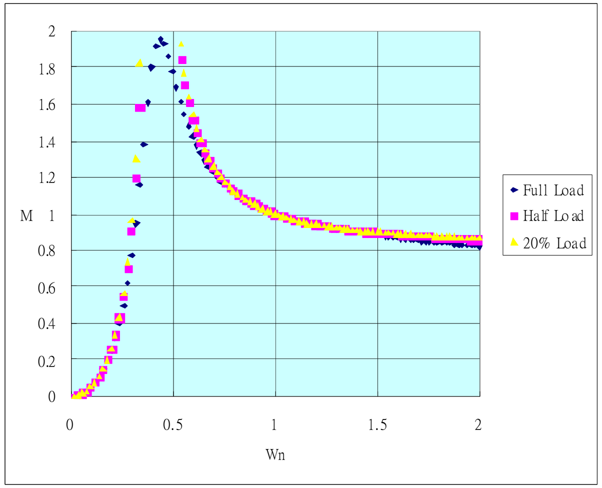
ω_n means normalized frequency

According the graph, maximum DC gain happens when $\omega_n = 0.44$

Minimum switching frequency is set as $\omega_n = 0.51$

to keep enough margin.

So the Minimum switching frequency is $f_{\min} = 110K \times 0.51 = 56.1KHz$



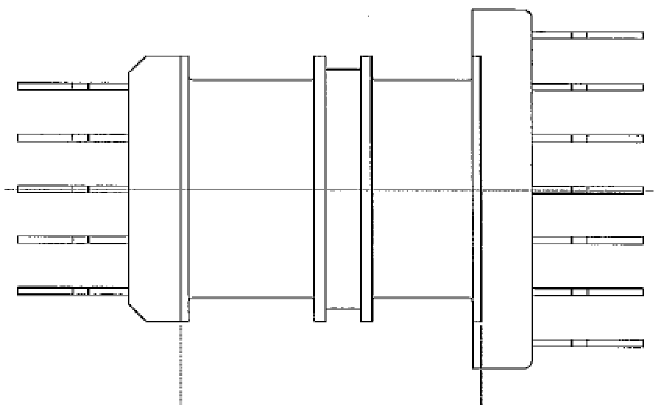
$V_{in} = 50V$ same as calculated above, maximum switching cycle can be calculated as $t = \frac{1}{2 \times f_{\min}} = 8.913\mu s$

Flux density B set as 0.5T because the flux can be both negative and positive. Cross-section area A is 30.1mm^2 according to the transformer we choose

According to transformer basic operation rule $V_{in} \times t \leq N \times B \times A$

$N \geq \frac{V_{in} \times t}{B \times A} = 30turns$ to avoid saturated.

Transformer Design



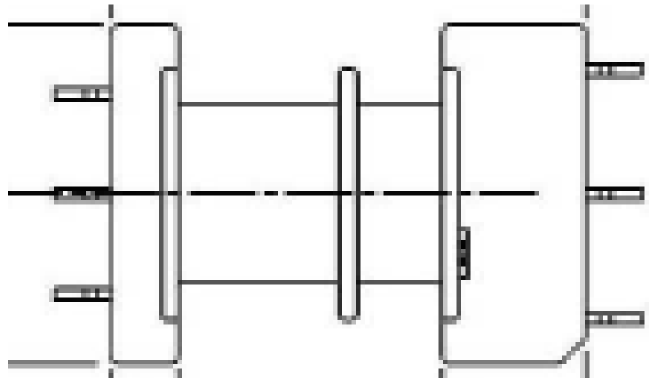
Leakage Inductance is high

Use additional cap to isolate

Can not assemble automatically

Litz wire to avoid eddy current

Fit for higher output power



Leakage Inductance is low

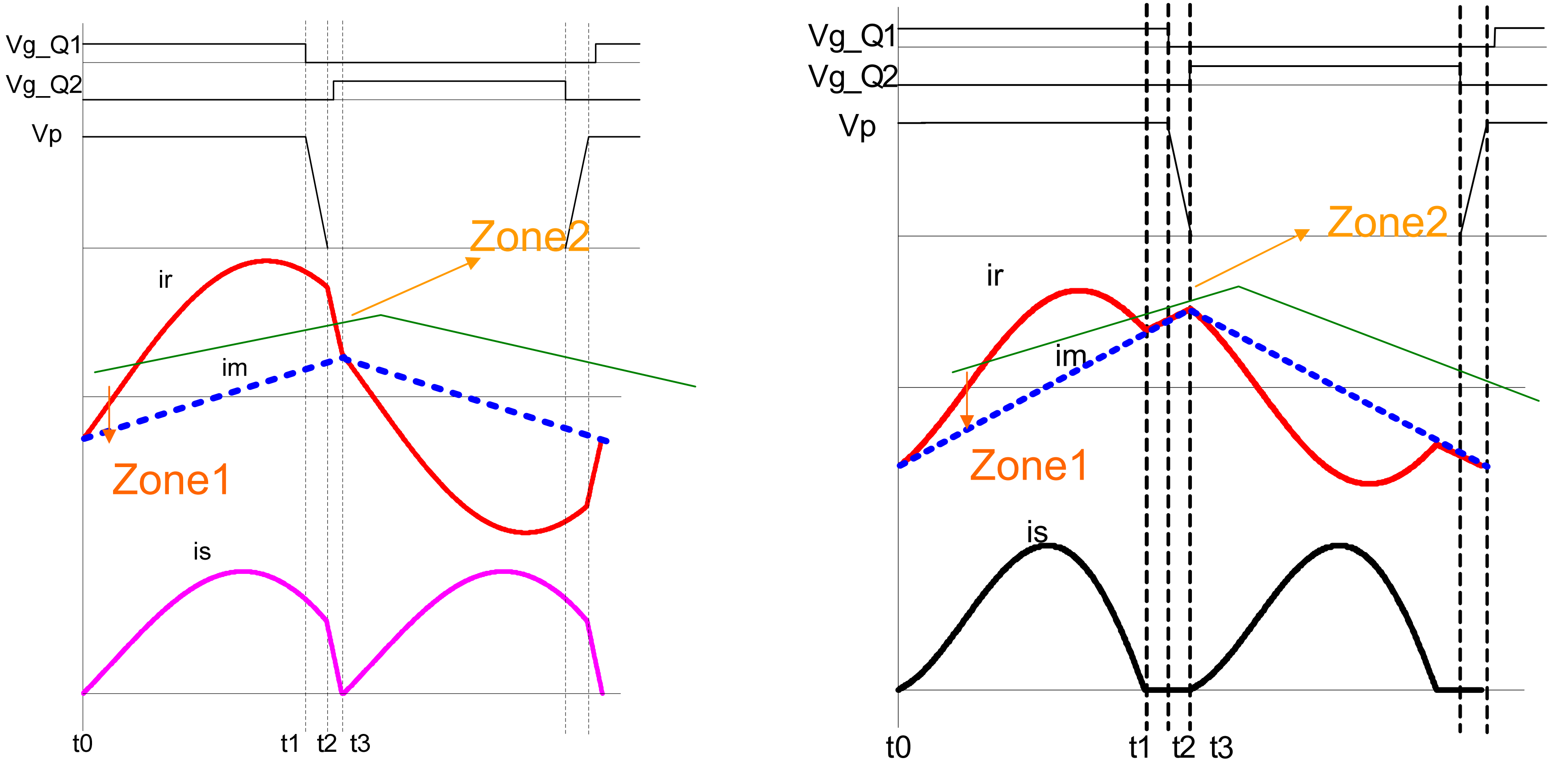
Use isolated wire to isolate

Assemble automatically

Thin line to avoid eddy current

Fit for smaller output power

Transformer Design



While CCM Zone1 and Zone2 is still almost the same but while DCM Zone1 and Zone2 with obvious different that is why current is more unbalance when DCM.

Transformer Design

1. B1 PFC Vout maximum

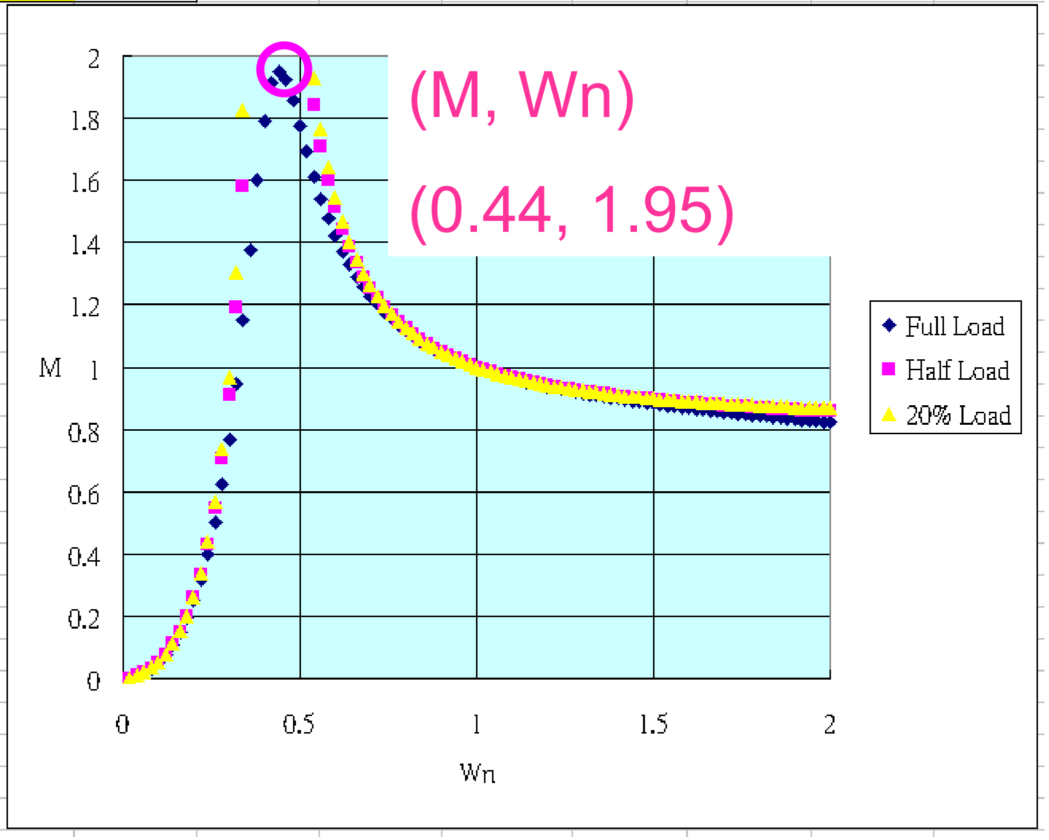
2. C1 How many transformer in series

3. A3 output voltage

4. B3 output current per transformer for dual output design it should be doubled

5. A5 output diode Vf for there are 2 diodes in series it should be doubled

	A	B	C	D	E	F	G	H
1	Vin_max	400	4	Transformers		Each	100	V
2	Vo1	Io1	Vo2	Io2	Vo3	I		
3	88	0.24	0	0				
4	Vf1		Vf2		Vf3			
5	2							
6	Pout	21.						
7	Pin	22.2316						
8	RL	112.453	Ω					
9	F	110	KHz					
10	Q	0.2145	(wL/RL)		Lk	35.01128	uH	
11	K	5	Lm/Lk		Lm	175.0564	uH	
12							nF	
13	Wn_							
14	M_m						V	
15	B=							
16	Ae=	30.1	mm*mm					
17	V=	50	V					
18	t=	8.91266	uS	fmin=	56.1	k		
19	N>	29.6102						
20	Primary turns		30	turns				
21	Winding turns			Winding RMS current				
22	Output1	54	turns	Output1	0.2664	A		
23	Output2	0	turns	Output2	0	A		
24	Output3	0	turns	Output3	0	A		
25	Output4	0	turns	Output4	0	A		
26								
27	Bulk Cap	78	uF					
28	Bulk Cap minima voltage			385	V			
29	other output		60	W				
30	Hold up time		24.8548	mS				
31								



TEXAS INSTRUMENTS

Transformer Design

	A	B	C	D	E	F	G	H
1	Vin_max	400	4	Transformers		Each	100	V
2	Vo1	Io1	Vo2	Io2	Vo3	Io3	Vo4	Io4
3	88	0.24	0	0				
4	Vf1		Vf2		Vf3			
5	2		0					
6	Pout	21.12		Eff	0.95			
7	Pin	22.2316						
8	RL	112.453	Ω					
9	F	110	KHz					
10	Q	0.2145	(WL/RL)		Lk			
11	K	5	Lm/Lk		Lm			
12					C			
13	Wn_min	0.51						
14	M_max	1.73237		Min working voltage				
15	B=	0.5	T					
16	Ae=	30.1	mm*mm					
17	V=	50	V					
18	t=	8.91266	uS	fmin=				
19	N>	29.6102						
20	Primary turns		30	turns				
21	Winding turns			Winding RMS				
22	Output1	54	turns	Output1				
23	Output2	0	turns	Output2	0	A		
24	Output3	0	turns	Output3				
25	Output4	0	turns	Output4				
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27	Bulk Cap	78	uF					
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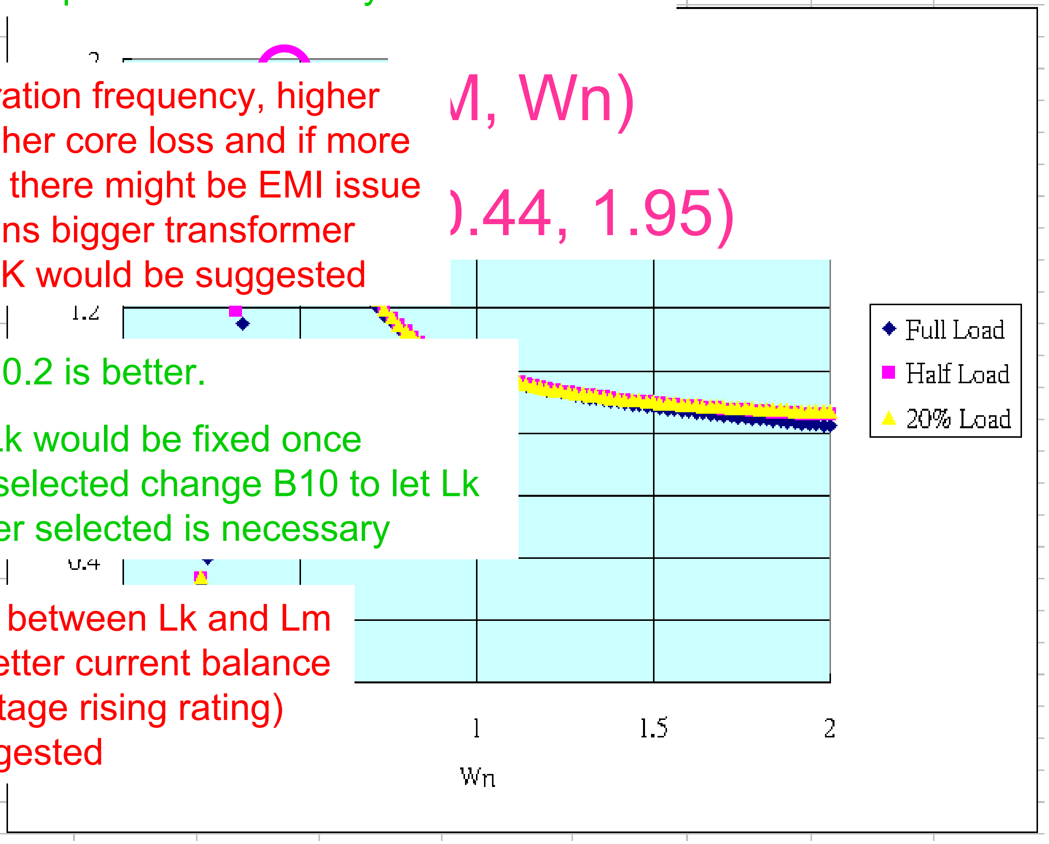


6. E6 is predicted efficiency

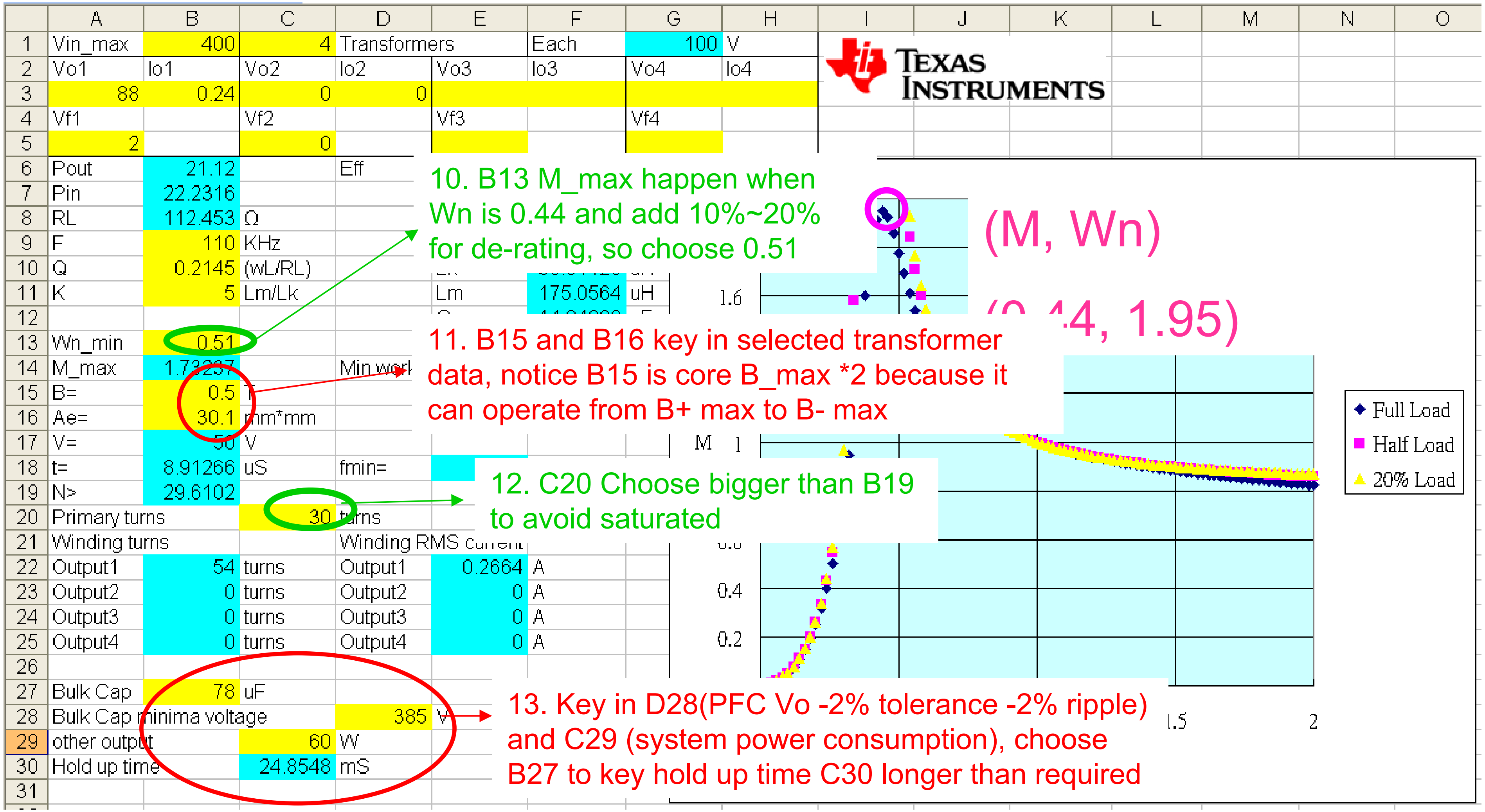
7. B9 operation frequency, higher means higher core loss and if more than 150K there might be EMI issue lower means bigger transformer 100K~120K would be suggested

8. B10 choose 0.2 is better.

Because F10 Lk would be fixed once transformer is selected change B10 to let Lk fit to transformer selected is necessary

9. B11 K is ratio between Lk and Lm bigger means better current balance but lower M (voltage rising rating) choose 5 is suggested

Transformer Design



Resonant Capacitor Selection

- Capacitance calculated by transformer design tool
- Voltage rating should be 1.2* maxima voltage on resonant capacitor.
- Ripple current rating should over (output watts/200) * 1.5
- Arco R75, R76 or Panasonic ECWH or other capacitor with high ripple current rating is suggested.

DC Blocking Capacitors

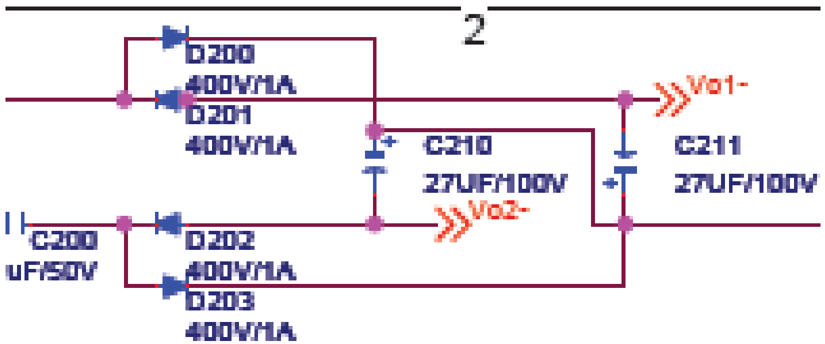
- Capacitance value ~ 1 to 3% of C_{OUT} of each channel
  - Large enough for 10% maximum ripple voltage
  - Small enough to settle quickly
- Voltage stress: Equal to VOUT to keep margin during single output short.
- Ripple current stress: 2.5* output current

Output Capacitor selection

- Voltage rating should be 1.25 * output voltage to keep margin
- Ripple current on capacitor is 1.2* output current
- Use ripple current rating as 1.5* output current for margin

Output Rectifier Selection

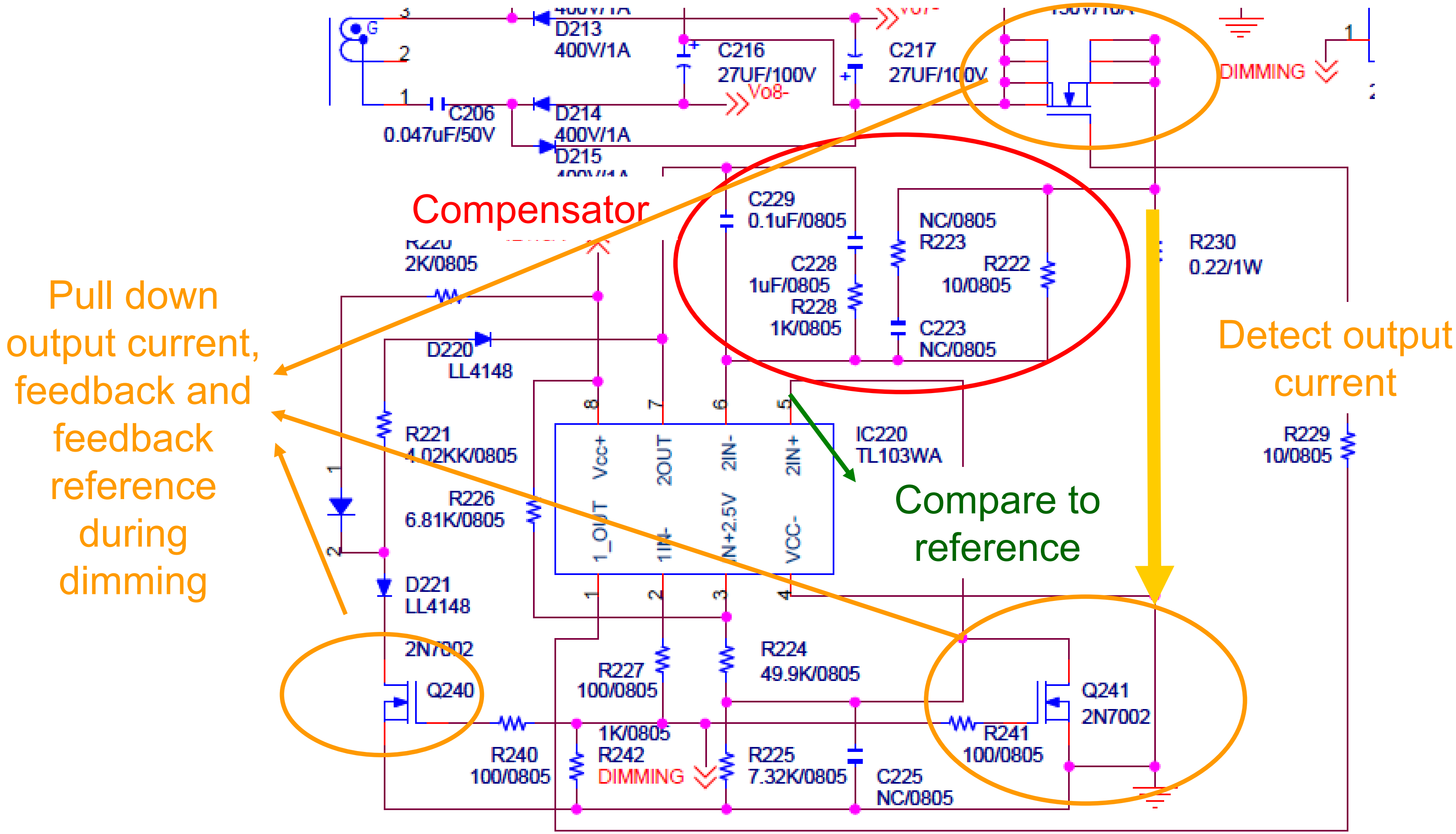
- Reference design D200~D215
- Super-fast recovery
- 2.5* output voltage
- 1A rating above
- Trr 35ns
- Why?
  - Higher efficiency
  - Better current matching at low duty cycle dimming



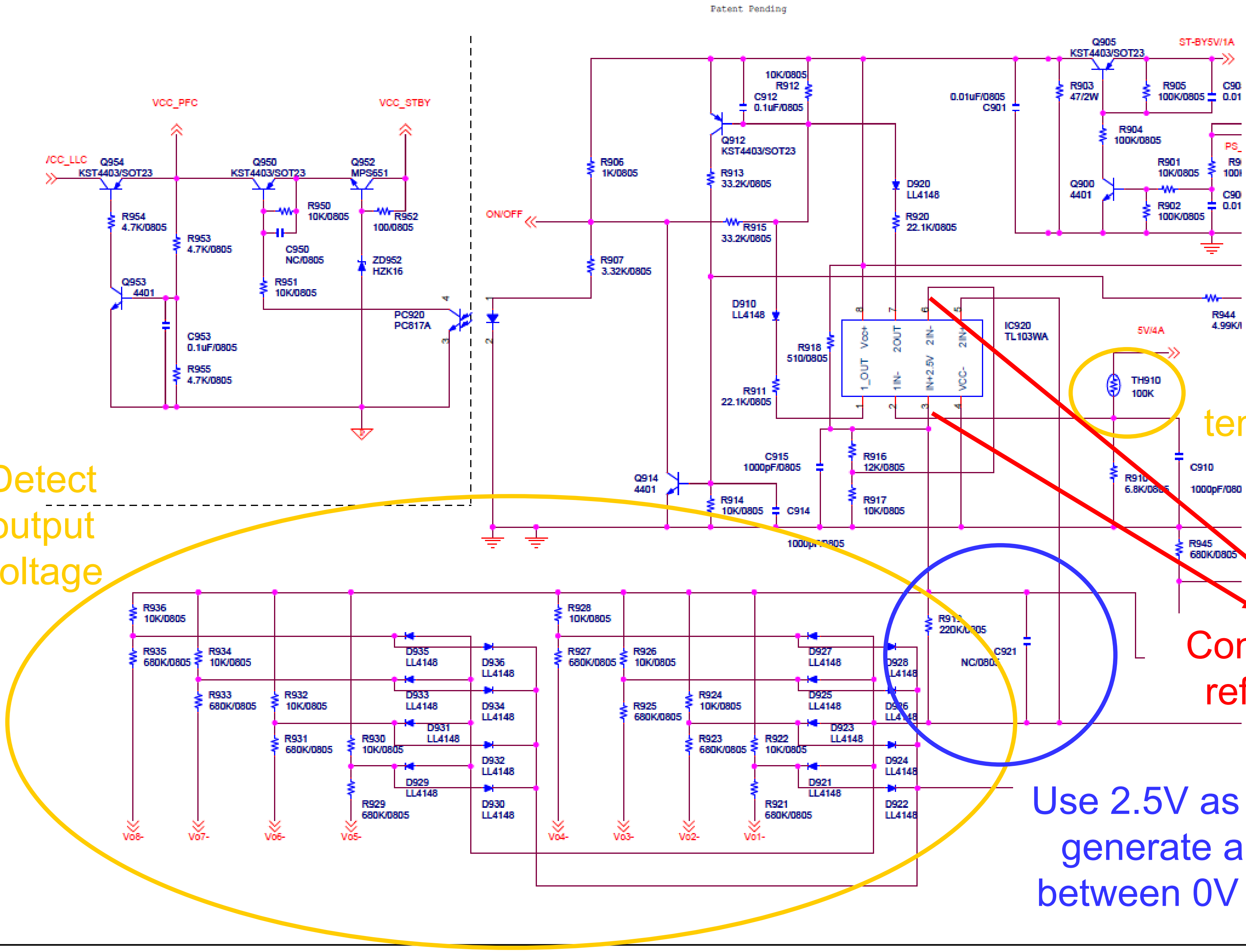
Feedback, Dimming and Protection

- **Feedback And Dimming**
- **OVP and OTP**
- **UVP**

Feedback and Dimming



OVP and OTP



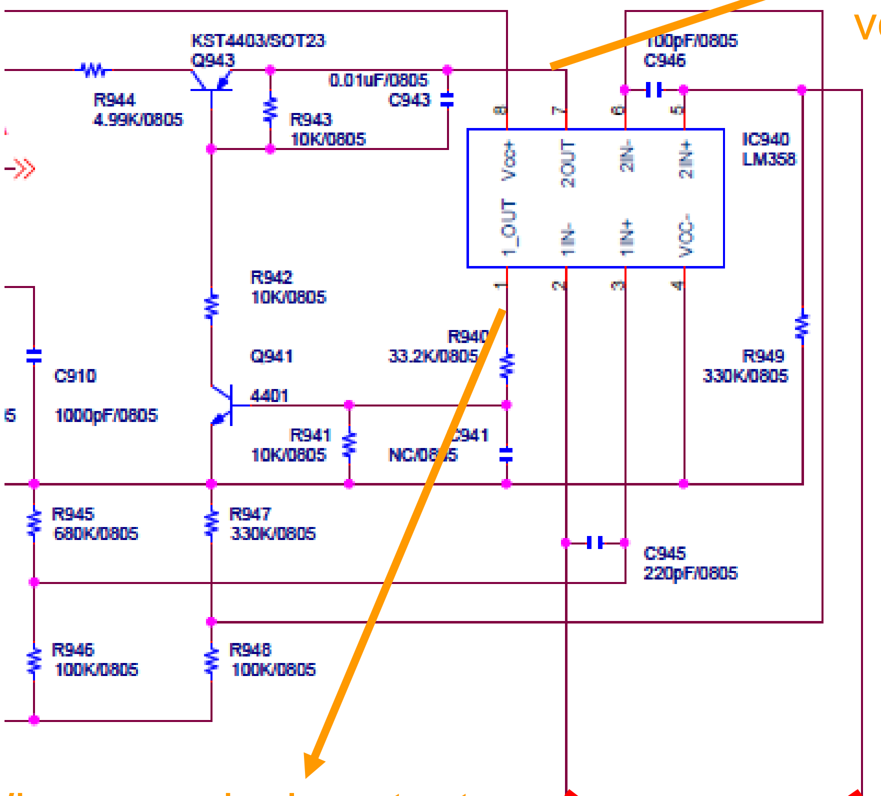
Detect output voltage

Detect temperature

Compare to reference

Use 2.5V as a base to generate a voltage between 0V and 2.5V

UVP



When any single output voltage is lower than 20V UVP triggered

When any single output voltage is higher than 80V UVP function enabled

Detect output voltage

To avoid UVP triggered during dimming, one more circuit to detect if the dimming situation is necessary.

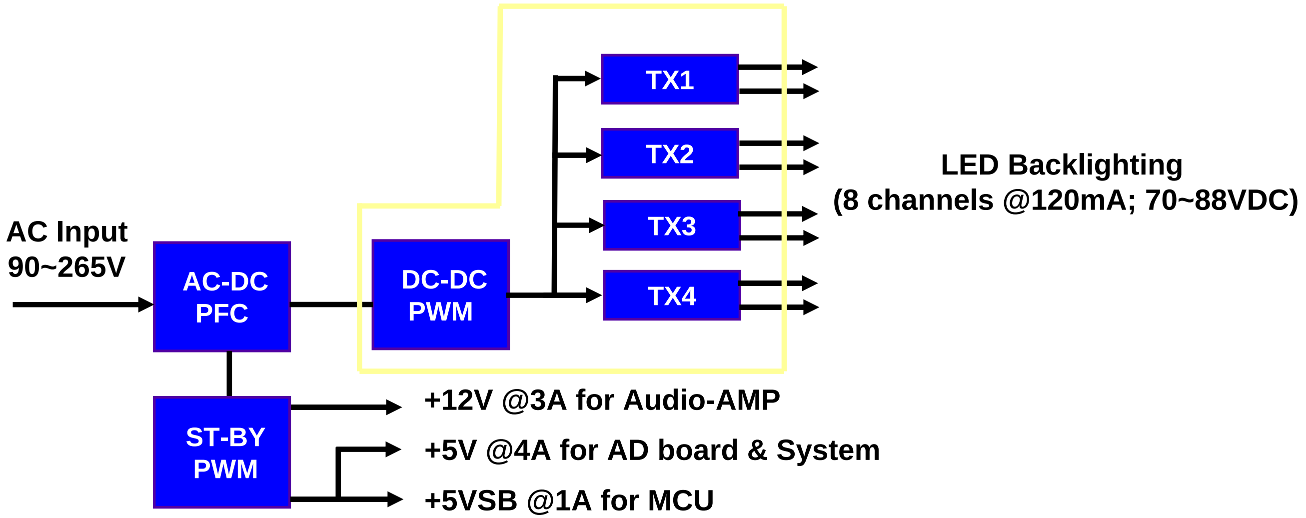
In this case, detect output voltage to enable the UVP function is used.

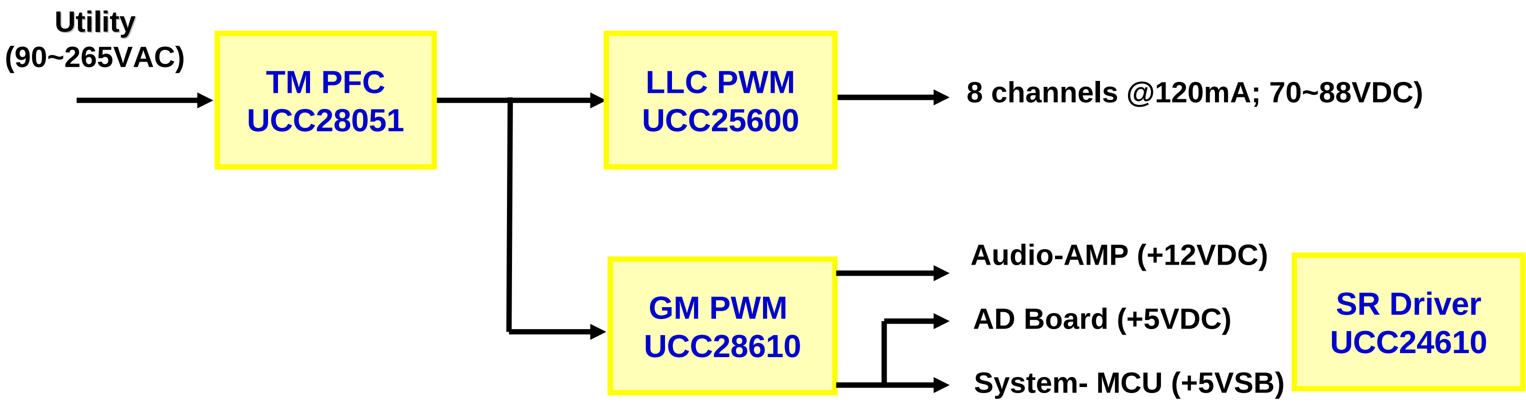
While any output voltage is over minus 80V the UVP function is enabled and if there is any output voltage still lowers than 20V the UVP is triggered.

Test Result

- Block Diagram
- Performance
- Cross Regulation
- LED Current Tolerance
- Efficiency
- Dimming Waveform
- Summary

Block Diagram





Performance

Specification:

→ Support to universal 90~264Vac range

→ LED 8 outputs @120mA, 70V~88V, 5Vsb@1A, 5V@4A, 12V@3A

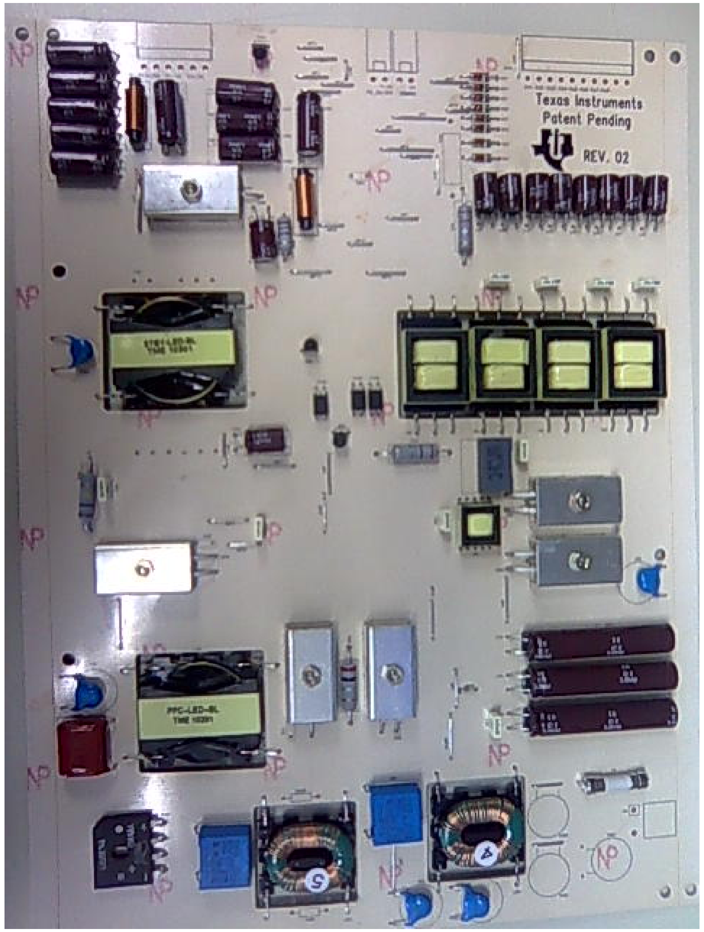
→ Eff 86.1%@90Vac, 89.6%@264Vac

→ Secondary side 160Hz blanking control for dimming

→ 8mm height and 6mmheight for LED magnetic components

→ Board dimension 300mm(L) * 210mm(W) * 8mm(H)

→ LED output common + and LED OVP and UVP



Cross Regulation

Cross Regulation					
Load Condition			Output Voltage		
5Vsb	5V	12V	5Vsb	5V	12V
20mA	0.5A	0.1A	4.88V	4.88V	13.74V
20mA	0.5A	3A	4.88V	4.88V	11.46V
20mA	4A	0.1A	4.86V	4.84V	13.75V
20mA	4A	3A	4.85V	4.83V	12.5V
1A	0.5A	0.1A	4.87V	4.87V	13.75V
1A	0.5A	3A	4.87V	4.87V	12.05V
1A	4A	0.1A	4.84V	4.83V	13.75V
1A	4A	3A	4.84V	4.83V	12.64V

LED Current

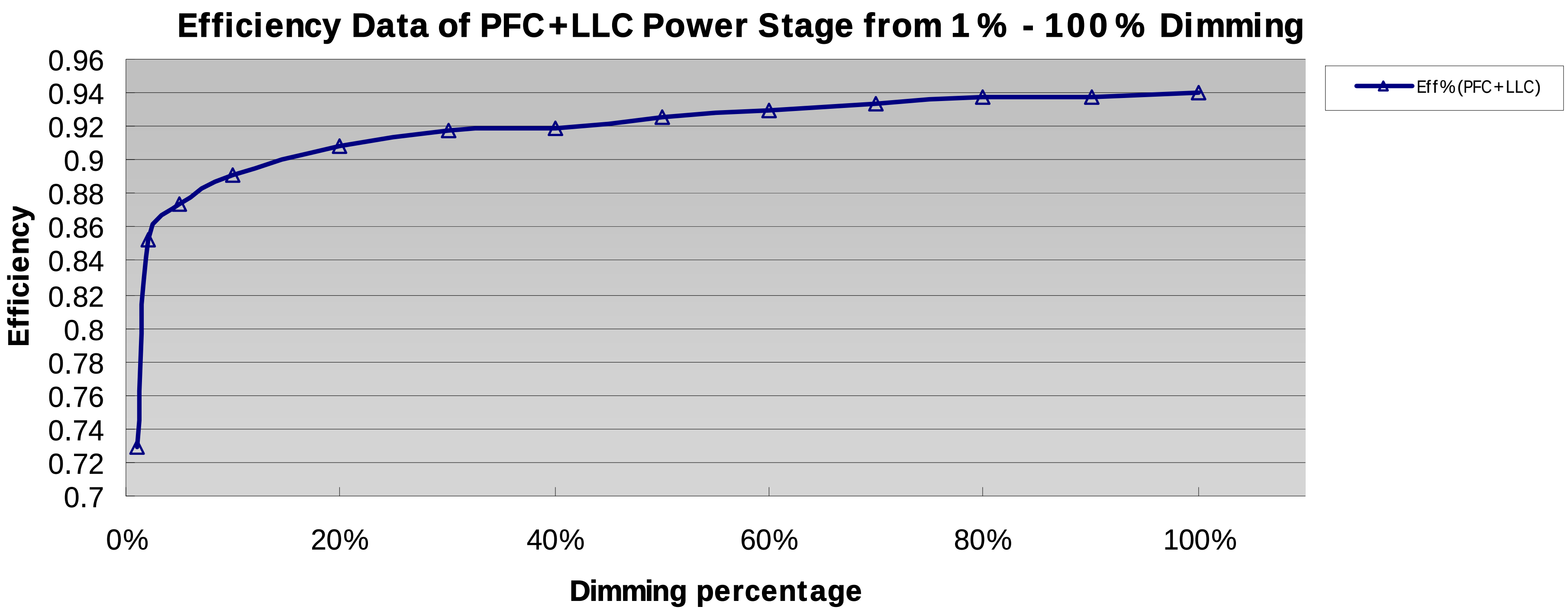
	LED1	LED2	LED3	LED4	LED5	LED6	LED7	LED8	AVG
Voltage	83.6	84.4	85.8	84.2	84.2	80.3	80.6	84.7	
100%	122.11	122.04	121.92	122.02	125.55	125.52	123.12	123.09	123.171
90%	109.52	109.44	109.88	109.63	112.86	112.96	110.14	110.12	110.569
80%	97.01	96.93	97.54	97.37	100.18	100.36	97.37	97.41	98.0213
70%	84.63	84.47	85.05	85.19	87.45	87.66	84.6	84.52	85.4463
60%	72.17	72.11	72.66	73.03	74.98	75.08	71.78	71.62	72.9288
50%	59.81	59.68	60.47	61.18	62.37	62.38	59.81	59.81	60.6888
40%	47.48	47.44	48.18	48.86	49.56	49.55	47.24	47.26	48.1963
30%	36.19	36.02	35.92	36.45	37.17	37.21	36.82	36.82	36.575
20%	23.92	23.75	23.58	23.86	24.3	24.4	23.85	23.84	23.9375
10%	10.77	10.82	10.77	11.18	11.3	11.38	11.21	11.24	11.0838
5%	4.92	4.94	5.04	5.03	5.11	5.08	4.84	4.84	4.975
2%	1.78	1.77	1.77	1.77	1.82	1.82	1.78	1.78	1.78625
1%	0.66	0.66	0.65	0.65	0.67	0.67	0.64	0.64	0.655

LED Current Tolerance

	Tolerance1		Tolerance2		Tolerance3		Tolerance4		Tolerance5		Tolerance6		Tolerance7		Tolerance8	
100%	-0.8616	%	-0.9184	%	-1.0159	%	-0.9347	%	1.93125	%	1.9069	%	-0.0416	%	-0.06597	%
90%	-0.9485	%	-1.0209	%	-0.6229	%	-0.849	%	2.07224	%	2.16268	%	-0.3878	%	-0.40586	%
80%	-1.0317	%	-1.1133	%	-0.491	%	-0.6644	%	2.20233	%	2.38596	%	-0.6644	%	-0.62359	%
70%	-0.9553	%	-1.1425	%	-0.4637	%	-0.2999	%	2.34504	%	2.59081	%	-0.9904	%	-1.08401	%
60%	-1.0404	%	-1.1227	%	-0.3685	%	0.13883	%	2.81268	%	2.9498	%	-1.5752	%	-1.79456	%
50%	-1.448	%	-1.6622	%	-0.3604	%	0.80946	%	2.77028	%	2.78676	%	-1.448	%	-1.44796	%
40%	-1.4861	%	-1.5691	%	-0.0337	%	1.37718	%	2.82958	%	2.80883	%	-1.9841	%	-1.94258	%
30%	-1.0526	%	-1.5174	%	-1.7908	%	-0.3418	%	1.62679	%	1.73616	%	0.66986	%	0.669856	%
20%	-0.0731	%	-0.7833	%	-1.4935	%	-0.3238	%	1.51436	%	1.93211	%	-0.3655	%	-0.40731	%
10%	-2.8307	%	-2.3796	%	-2.8307	%	0.86839	%	1.95105	%	2.67283	%	1.13905	%	1.409721	%
5%	-1.1055	%	-0.7035	%	1.30653	%	1.10553	%	2.71357	%	2.11055	%	-2.7136	%	-2.71357	%
2%	-0.3499	%	-0.9097	%	-0.9097	%	-0.9097	%	1.88943	%	1.88943	%	-0.3499	%	-0.3499	%
1%	0.76336	%	0.76336	%	-0.7634	%	-0.7634	%	2.29008	%	2.29008	%	-2.2901	%	-2.29008	%

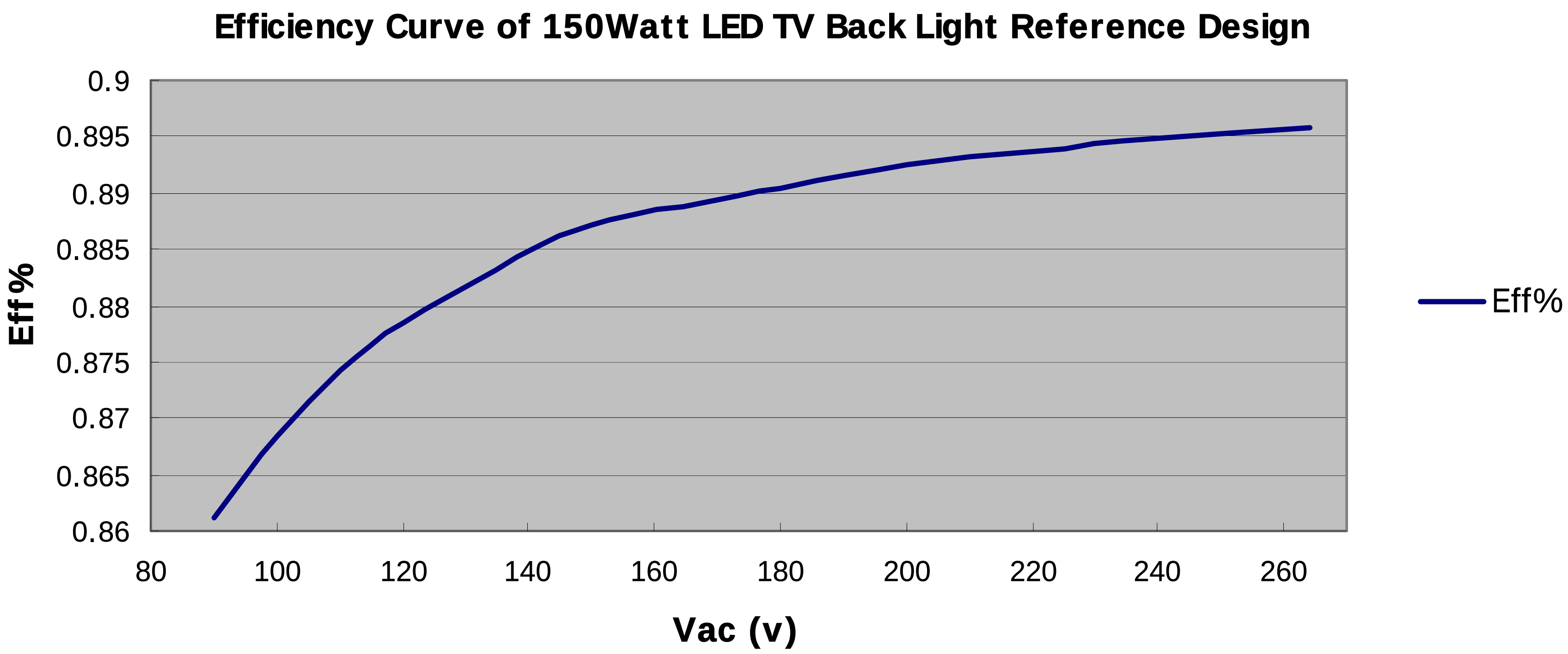
Inductance tolerance 3% might cause current tolerance 1%

LLC Efficiency



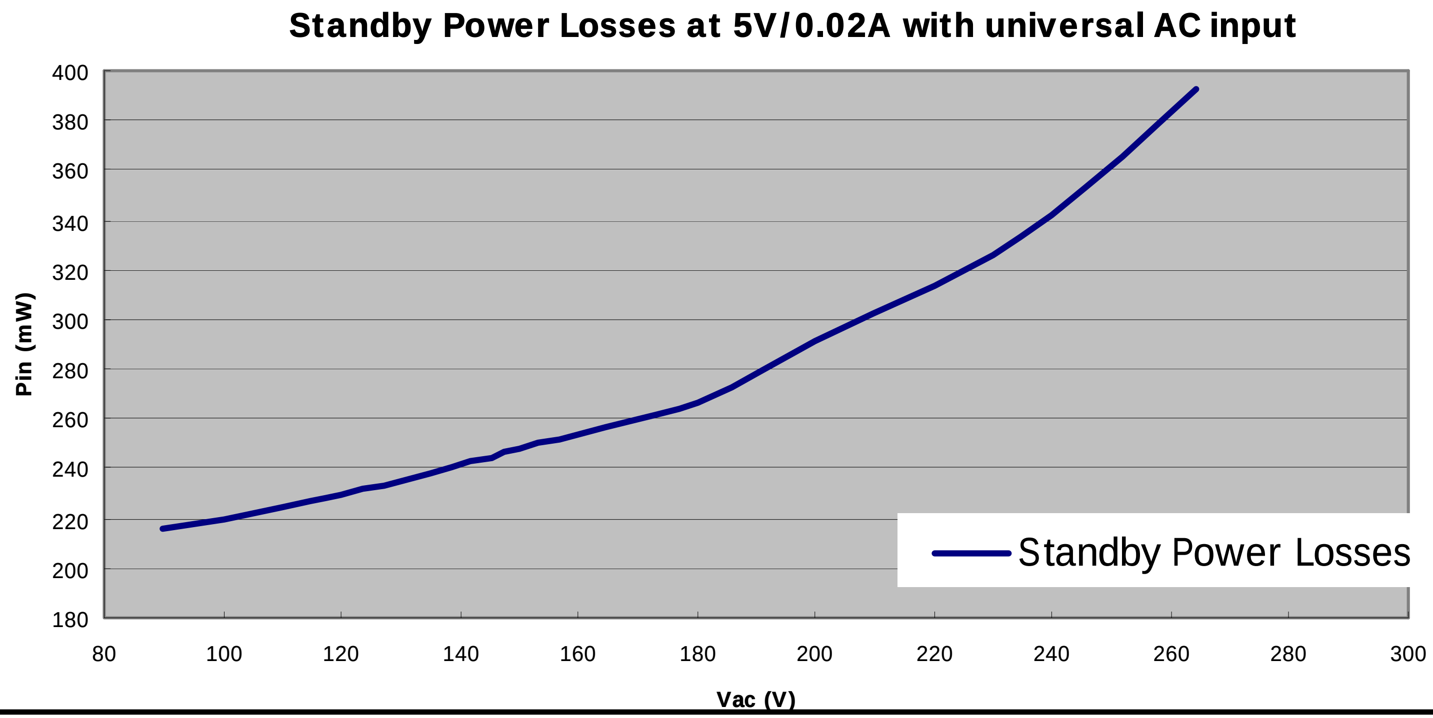
Efficiency exclude Stby Power Converter at full load condition ~ 94%

Efficiency



Vin	90	100	110	120	135	150	180	200	220	240	264
Pin	167.6	166.2	165.1	164.3	163.4	162.7	162.1	161.7	161.5	161.3	161.1
Eff	0.86112	0.86837	0.87416	0.87841	0.88325	0.88705	0.89033	0.89254	0.89364	0.89475	0.89586

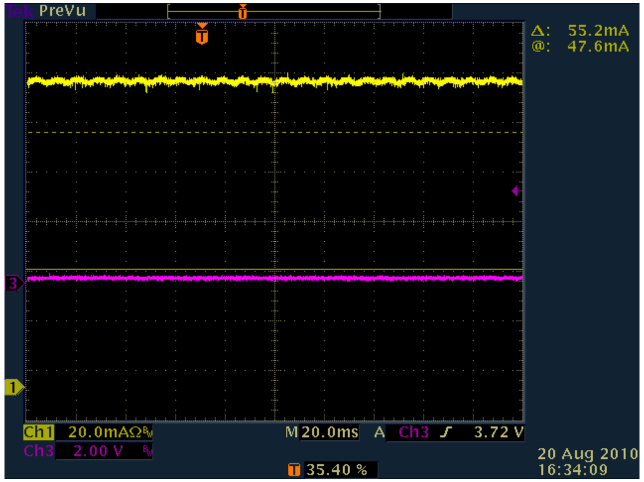
Standby Mode Power Consumption Performance – @5V/ 0.02A



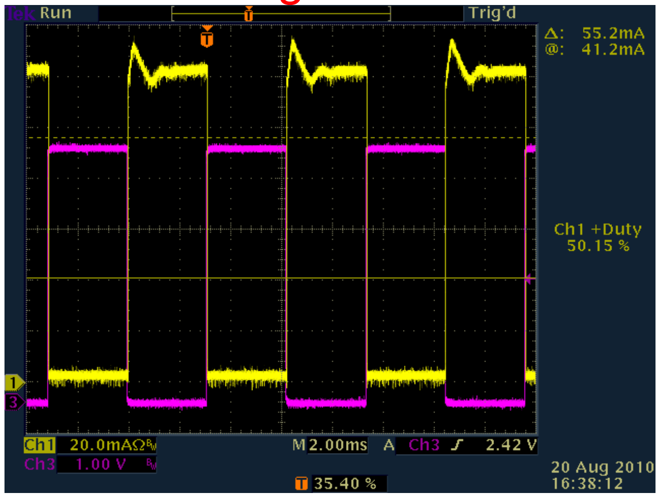
STBY power 5Vsb 0.02A											
Vin	90V	100V	110V	120V	135V	150V	180V	200V	220V	240V	264V
Pin	216mW	219mW	224mW	229mW	238mW	248mW	267mW	291mW	313mW	342mW	393mW

Dimming Waveforms

100% Dimming



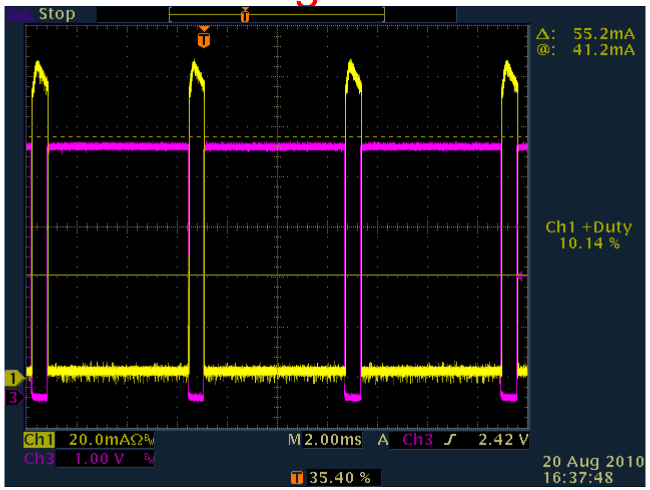
50% Dimming



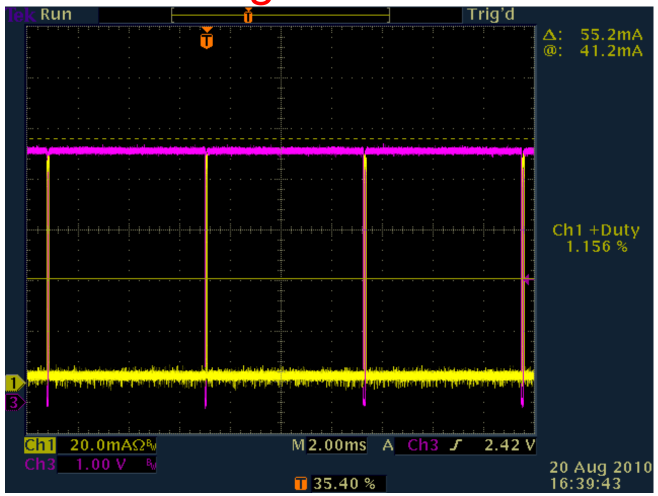
Current

Voltage

10% Dimming



1% Dimming



Summary

- Two stage will be a market trend for LED-TV back light power architecture base on cost & performance point of view.
- Simple design concept- cascading the Ls of transformer at primary side (Multi-Transformers Architecture) to implement the current balancing at secondary side for each channel ideally– Achieving <1% tolerance dimming range in reality.
- Fully utilize the transformer – Two-channels common anode LED driven by single transformer.
- Higher efficiency ~89.6%@ 220Vac/ ~86%@90Vac compare to the traditional 3-stages scheme. (<85%)
- Exclude the standby converter, the efficiency of PFC +LLC power stage ~94%.
- Dimming voltage range can work from 1% - 100% and the tolerance of current between each strings less than 1%.
- Saving the heat sinks for MOSFETs of linear regulators at secondary side. – more thinness, cost-saving.

Conclusion

- Digital TV (DTV) vendors are always challenged on providing consumer reliable product with aggressive cost.
- Multi-transformer design helps to decrease parts count so that reliability is increased and cost is decreased.
- Higher efficiency also increases life time and decreases cost on dealing with thermal issues.
- Also because there is no MOSFET consume power more wide output tolerance and more failure LED is acceptable.
- With these three advantages, we can have a conclusion about multi-transformer design help customer much.
- The difficulty of Multi-transformer balancing is still on transformer design, with more and more people understand how to design the transformer, this balancing way will certainly become most popular way.

Conclusion

Flyback		Flyback + LLC	
Efficiency	about 88%	Efficiency	about 92%(LLC95% Flyback 86%)
Loss on LDO circuit	some load condition	Loss on LDO circuit	No
Regulation	about +20% / -10%	Regulation	within +/-5%
Minima load for cross regulation	200mA	Minima load for cross regulation	30mA
12V/24V load effect when standby	yes	12V/24V load effect when standby	No

65W Flyback cost is higher than 25W Flyback + 40W LLC because of following point

1. 65W Flyback slim transformer cost is high.
2. 65W Flyback require additional linear regulator to keep regulation.
3. Flyback required double time of output cap than LLC
4. Flyback required additional output filter choke
5. Flyback Required Snubber and 800V MOSFET, LLC only need 600V MOSFET

According to performance and cost compare shown above use 5V only standby power and 12V/24V LLC is strongly suggested

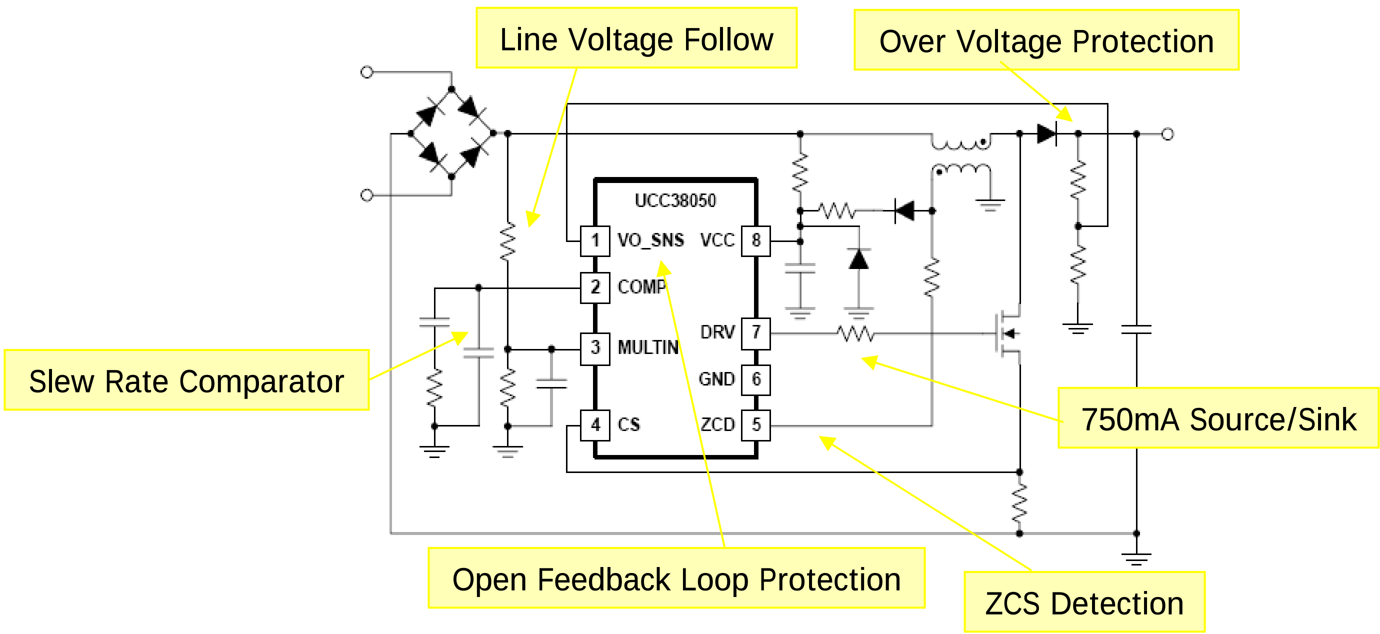
UCC28051 Transition Mode PFC Controller

Features

- Slew Rate Comparator for Improved Transient Response
- Zero Power Detect to Prevent Over Voltage Conditions under Light Load
- Over Voltage Protection
- Open Feedback Protection and Enable Circuits
- Low Startup & Operating Current
- 750mA Source/ Sink Peak Gate Drive to Reduce Switching Losses

Applications

- LCD-TV Power Board
- AC-DC Open Frame Power
- Mid to High Power AC Adapters



Introducing

- UCC28051
- UCC28610
- UCC25600
- UCC24610

UCC28051 Transition Mode PFC Controller

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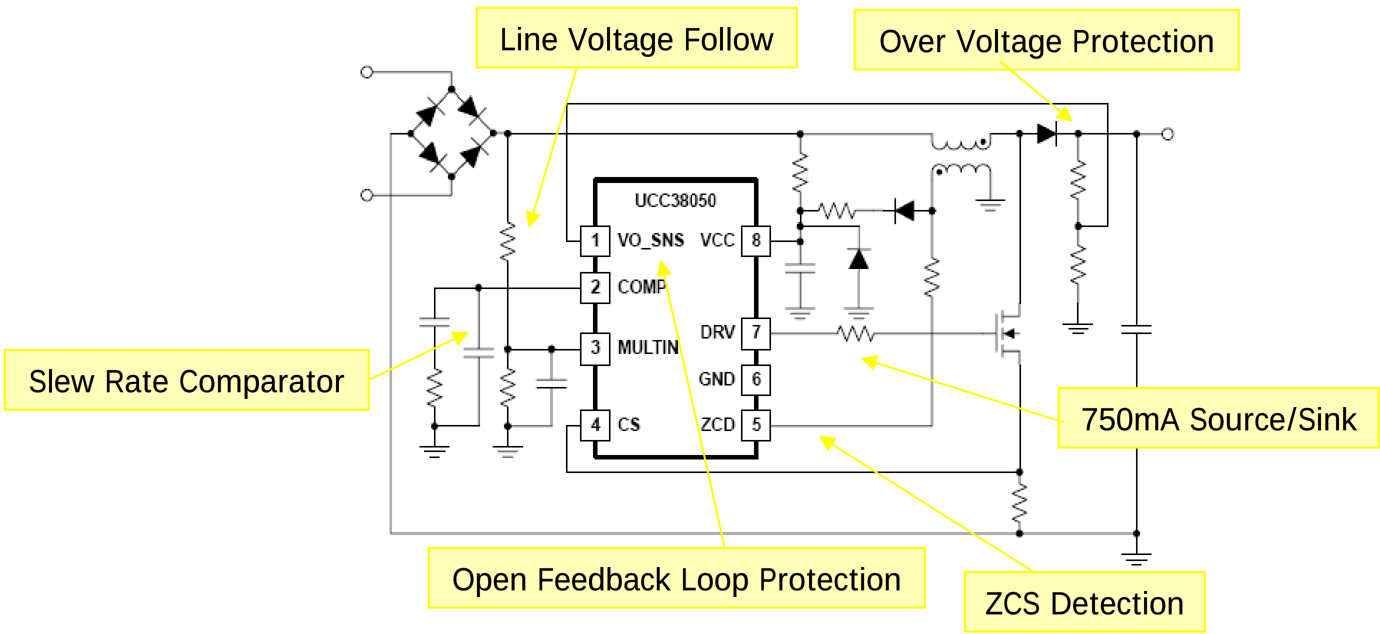
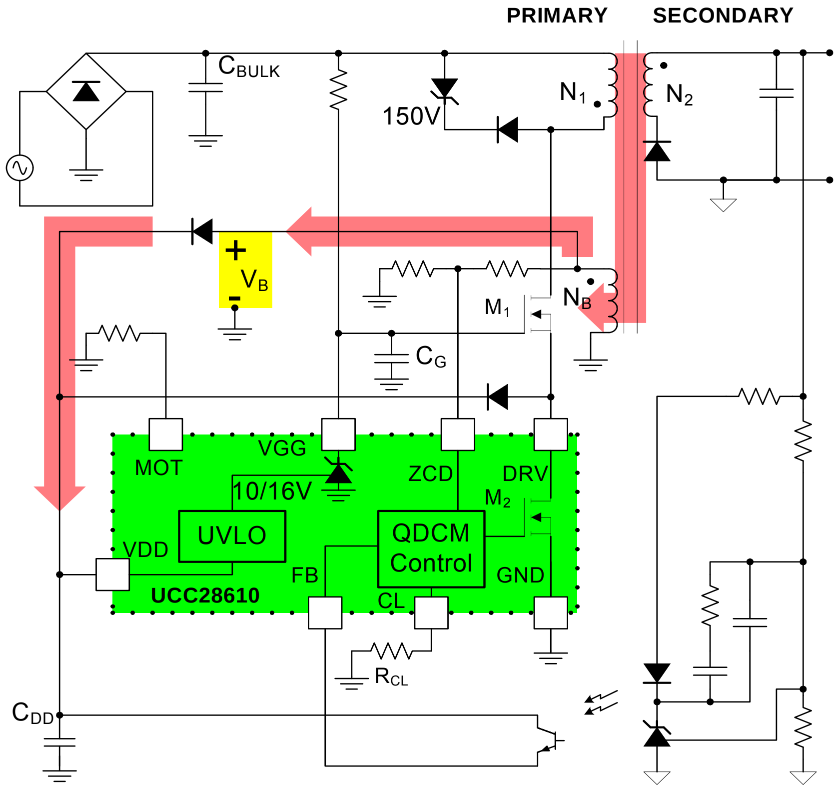


UCC28610 QR-GM Cascoded Flyback PWM

Features

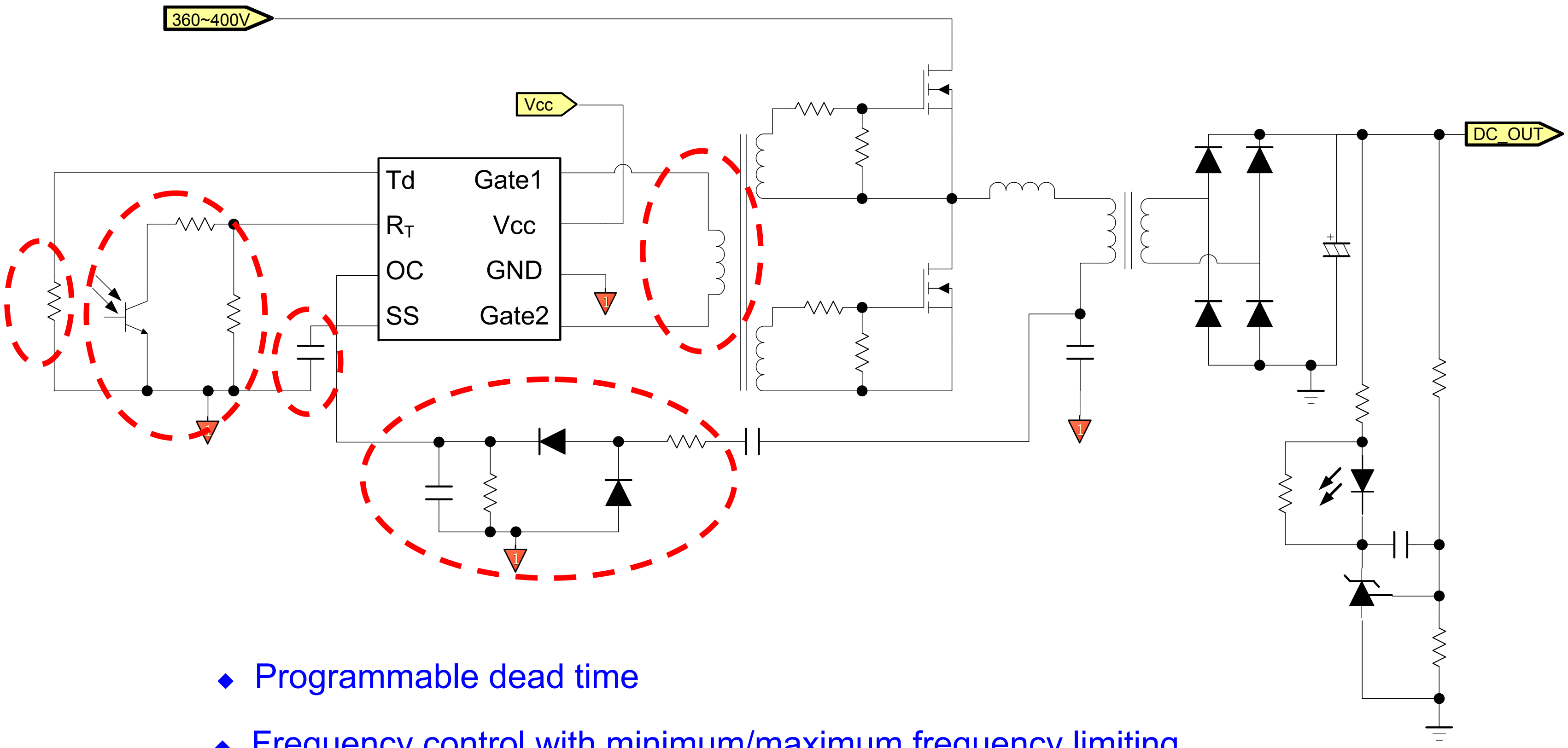
- Quasi-Resonant Green Mode PWM Operation
- Multiple Modes: Pulse Position Modulation (PPM); Discontinuous Conduction Mode (DCM); Burst Operation
- Surge Protection is Externally Set
- Valley Switching is always Engaged – Limits Primary and Secondary RMS Currents
- Fast Latched Fault Recovery for Output OVP, Timed OCP, Over Temperature Protection
- External Shutdown & Latched Shutdown at MOT Pin
- Current Sensing for Current Limit uses Rds(on) of Internal FET



Applications




UCC25600 Resonant (LLC) 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 Gate output with 50ns tolerance

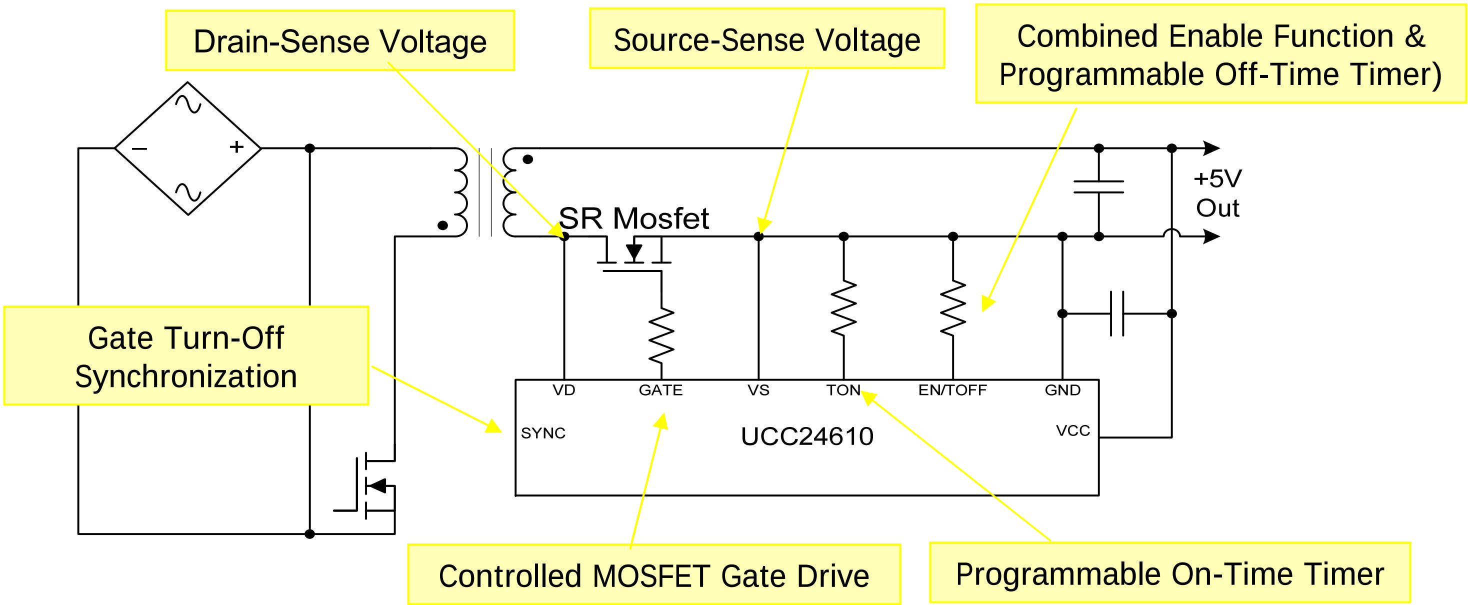
UCC24610 SR Controller for 5V Systems

Features

- Up to 800kHz operating frequency
- VDS MOSFET-sensing
- 1.4 ohm sink, 2.0 ohm source gate-drive impedances
- Micro-power Sleep current for 90+ designs
- False-triggering filter; SYNC input for CCM operation
- 20ns typical turn-off propagation delay
- Available in 8-pin SOIC and QFN packages

Applications

- AC/DC 5V Adapters
- 5V Bias Supplies
- Low Voltage Rectification Circuits



Question?

Thanks for Your Time !

Back up