The Power to Amaze.

SIMPLIFIES DESIGN & DELIVERS CONSTANT BRIGHTNESS

Single-Stage PSR Flyback for LED Lighting Designs

Juhyuk Choi, Fairchild Field Application Engineer

2015/01/29

Agenda

- Design Challenges and Key Elements of LED Lighting Design
- Critical Conduction Mode (CRM) Single-Stage Flyback Basics
- Discontinuous Conduction Mode (DCM) Single-Stage Power Factor Correction (PFC) Primary Side Regulation (PSR) Flyback
- New Generation Single-Stage PSR Flyback Controller FL7733A
- Analog Dimming with FL7733A
- New Generation Single-Stage PSR Dimming Controller FL7734
- Summary

Design Challenges

- Standard & Agency Requirements
- Design Complexity
  - Power Factor Correction
  - Safety and Protection
  - Constant Current (CC) Tolerance
- Reliability
- Lifetime

- Thermal / Efficiency
- Cost
- THD / Standby power

Standard and Agency Requirements

Sample of Worldwide Agency Programs

Agency	Location	Voluntary vs. Mandatory
Energy Star - US	United States	Voluntary
California Energy Commission	United States - California	Mandatory
European Commission ErP Ecodesign Directive	Europe	Mandatory

LED Driver Specific Standard and Agency Requirement

Item	Reference	Criteria
Power Factor (PF)	Energy Star Program Requirements for Integral LED Lamps Version 1.1 (Amended – Mar. 22, 2010)	≥ 0.7 for >5W
	Energy Star Program Requirements Product Specifications for Luminaires (Light Fixtures) Version 1.0, (Effective date: Oct 1, 2011)	Residential ≥ 0.7 for >5W Commercial ≥ 0.9 for >5W ≥ 0.5 for ≤5W
Total Harmonic Distortion (THD)	EN(IEC)61000-3-2 Class C (Lighting)	Class C (>25W) ≤ 30%THD Class D (≤25W)
	KS C7651/2/3 (IEC61000-3-2)	Class C (>25W) Class D (≤25W)
Dimming	Energy Star Program Requirements Product Specifications for Luminaires (Light Fixtures) Version 1.0, (Effective date: Oct 1, 2011)	Continuous dimming from 35% to 100% of total light output
Operating Voltage	NEMA SSL 1-2010	120, 127, 208, 220, 230, 240, 277, 347, 480 V_{AC} at 50 or 60 Hz, 12 or 24V_{AC} or V_{DC}

Key Elements of LED Lighting Designs

- PFC
  - General Requirement :
    - Line voltage input application : ≥0.9 for >5W at rated input voltage
    - MR16 lamp (low-voltage input) application : No regulation
  - Market Trends & Design Challenges:
    - Increasing PFC demand although ≤5W application ; save input electrolytic capacitor

- THD
  - General Requirement :
    - <25% THD >25W (<10% for Russia market)
  - Market Trends & Design Challenges:
    - No severe requirement for “bulb” application

Key Elements of LED Lighting Designs

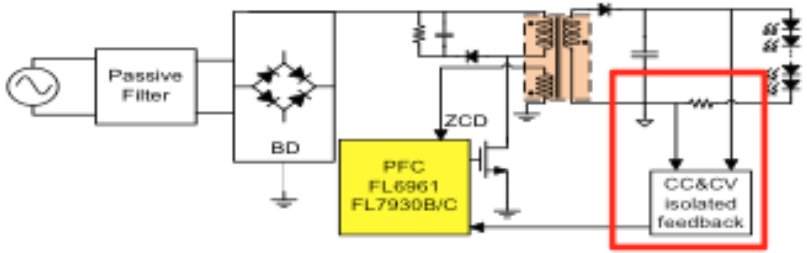
- LED Driver Board Power Efficiency
  - General Requirement : (Low-power applications only)
    - Non-dimming board : >85%
    - Dimming board : >80%
  - Market Trends & Design Challenges:
    - Increasing higher efficiency requirement but related with BOM increment

- Dimming Compatibility
  - Dimmer type :
    - Phase cut dimmer (leading edge type & trailing edge type)
    - 0-10V, DALI (Digital Addressable Lighting Interface)
  - Market Trends & Design Challenges:
    - No flicker/shimmer for phase-cut dimmer
    - New interface dimmer

Traditional Single-Stage Flyback PFC Solution

Using Critical Conduction Mode (CRM) Power Factor Correction (PFC) Control IC

- CRM PFC control IC is designed for a boost PFC application and not a single-stage flyback application, but with some circuit modifications it will work well
- Good high efficiency, but needs fast turn-on circuit or V_{CC} start up resistor incurs losses
- High PF/ Low THD
- Accurate constant current (CC) incurs sensing loss

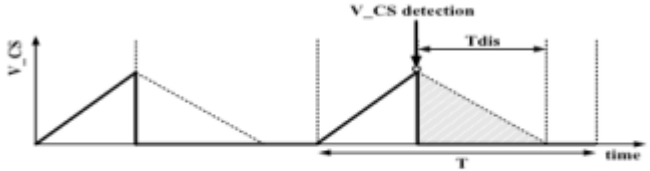


CRM PFC PWM IC

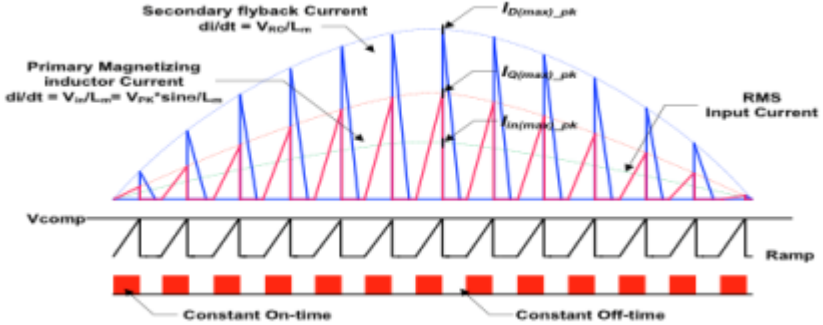
Discontinuous Conduction Mode (DCM) Single-Stage Power Factor Correction (PFC) Primary Side Regulated (PSR) Flyback for LED Applications

- PFC & THD Operation (Constant On, Constant Off control)
  - Excellent PF ≥ 0.9 and THD < 10% under 85-305VAC conditions
  - Removing Input Electrolytic Capacitors
- Various Protection
  - Open / short LED protection
  - Thermal shut down
  - Cycle by cycle current limit
- TRUECURRENT® calculation

$$I_{IN} = I_{P\_AVG} = \frac{T_{ON} \cdot (V_{IN}/L_m) \cdot T_{ON}}{2T} \propto V_{IN}$$



$$I_O = \frac{1}{2} \cdot \frac{T_{DIS}}{T} \cdot V_{CS} \cdot \frac{N_P}{N_S} \cdot \frac{1}{R_{SENSE}} \qquad V_{REF} = \frac{1}{2} \cdot \frac{T_{DIS}}{T} \cdot V_{CS}$$

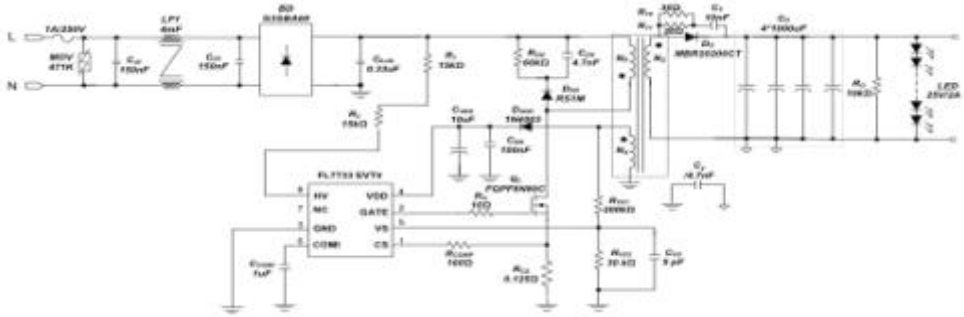


New Product – FL7733A

Single-Stage PSR Fixed-Frequency Discontinuous Conduction Mode (DCM) PFC

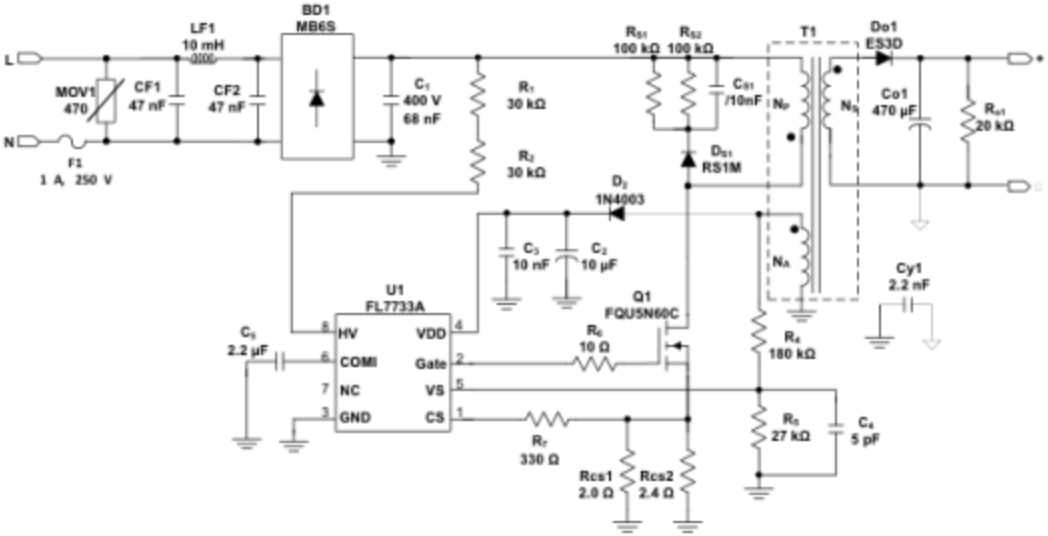
- Suitable for PSR single-stage flyback PFC constant current regulated LED applications, provides:
  - Accurate constant current (CC) tolerance : <±3%
  - High PF/ Low THD (>0.9/ <10% @ universal input)
  - High efficiency with linear frequency control & DCM mode operation
  - Ultra-wide output voltage operation from 10% to max VOUT
  - Fast start up : <0.3S (@85Vac) with internal start up JFET
  - No overshoot/ undershoot – VCOMI steady state prediction
  - Low BOM : single-stage PSR
    - No input E_Cap.
    - No optocoupler & regulator
  - High reliability
  - Non phase cut dimming applications up to ~100W
    - A19/ PAR30/38 bulb
    - Down lighting driver
    - Flat lighting driver
    - Indoor / outdoor lighting driver

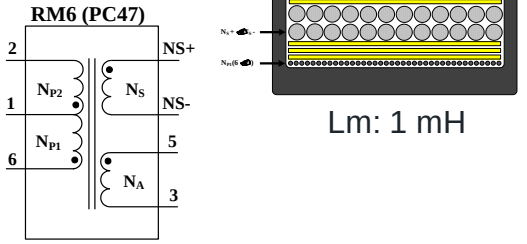
DCM PFC PWM IC



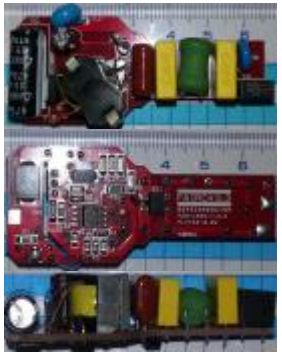
FL7733A Performance Test Platforms

Reference Design: 8.4 W (24 V, 0.35 A), Universal Input





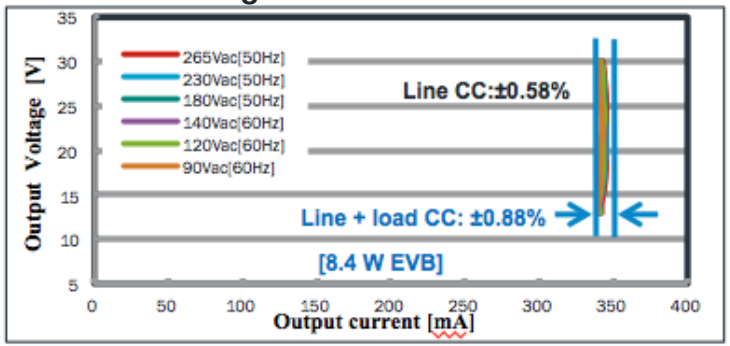
Lm: 1 mH



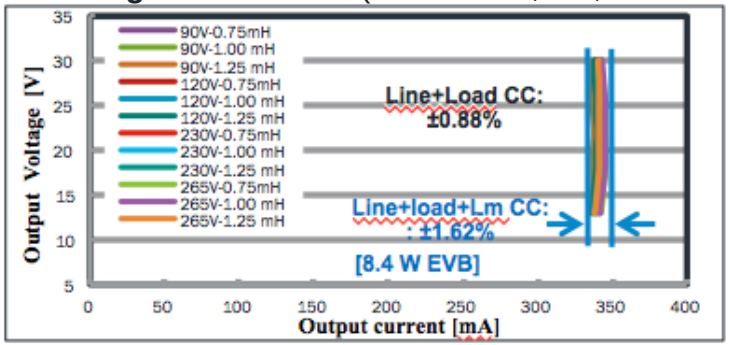
Dimensions:
64 (L) × 26 (W) × 26 (H) [mm]

Accurate Constant Current (CC) Tolerance
FL7733A Device

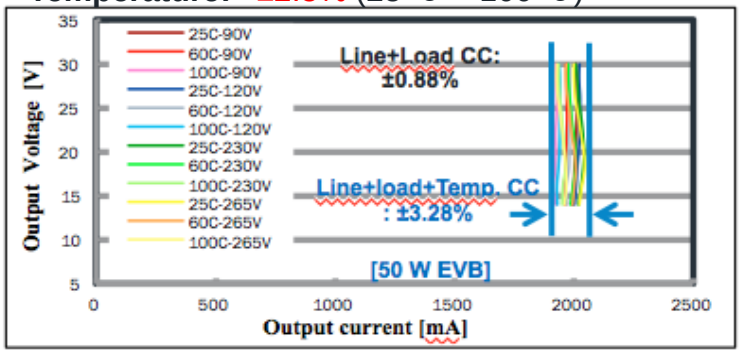
Line & Load Regulation: <±1%



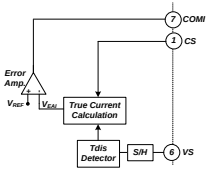
+ Lm Regulation: <±1% (±25%: 0.75, 1.0, 1.25 mH)

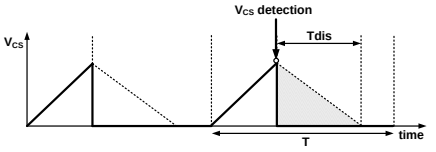


+ Temperature: <±2.5% (25 ℃ ~ 100 ℃)



IC to IC Variance: (KEAI / Vref): <±2%





TRUECURRENT® calculation

$$I_O = \frac{1}{2} \cdot \frac{T_{DIS}}{T} \cdot V_{CS} \cdot \frac{N_P}{N_S} \cdot \frac{1}{R_{SENSE}}$$

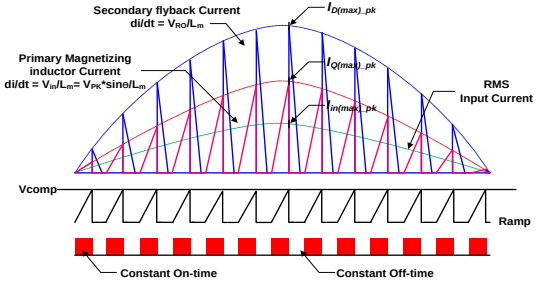
Trimming: <±2%

$$V_{EAI} = K_{EAI} \cdot \frac{T_{DIS}}{T} \cdot V_{CS}$$

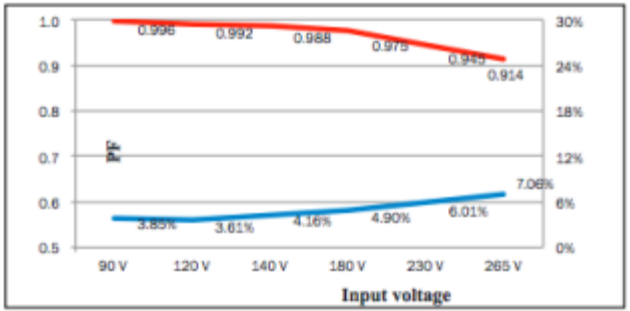
Power Factor (PF) and Total Harmonic Distortion (THD) – FL7733A Device

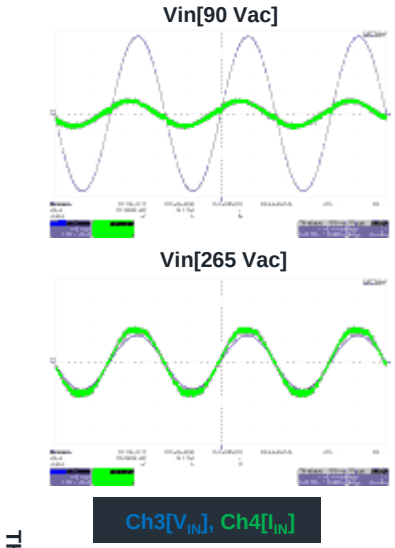
PFC and THD Operation: Fixed On-Time, Fixed Frequency

$$I_{IN} = I_{P\_AVG} = \frac{T_{ON} \cdot (V_{IN}/L_m) \cdot T_{ON}}{2T} \propto V_{IN}$$

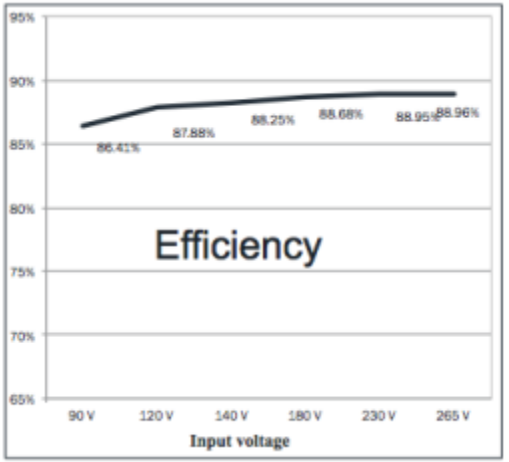


8.4 W Flyback PF and THD





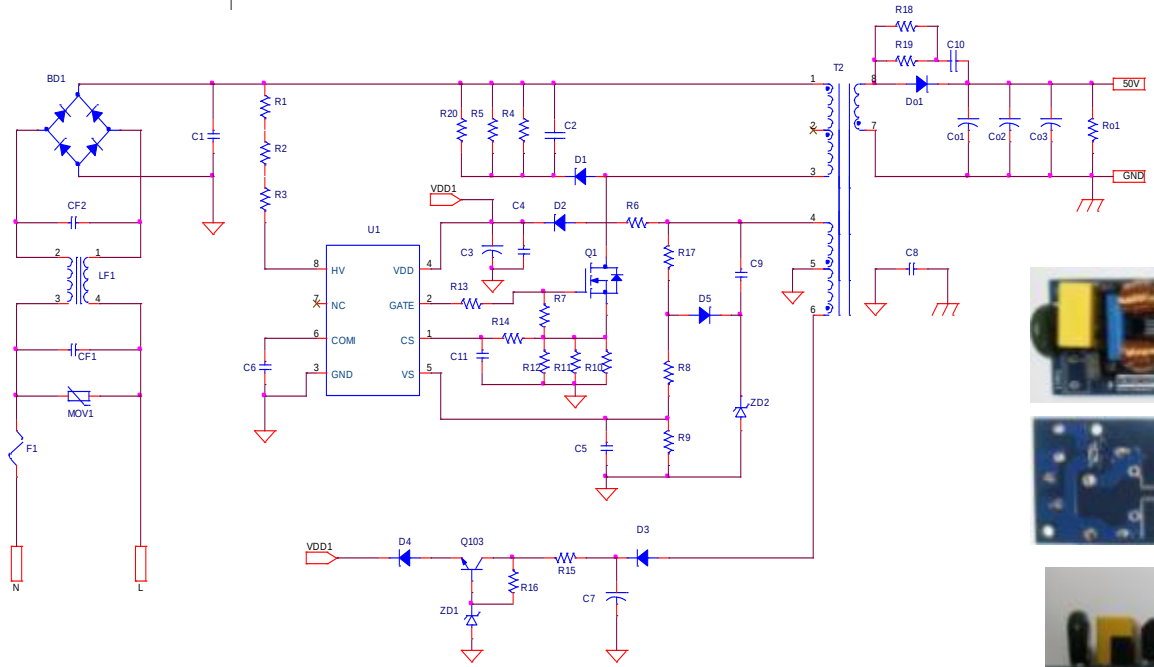
Optimized zero crossing distortion: THD: <10%

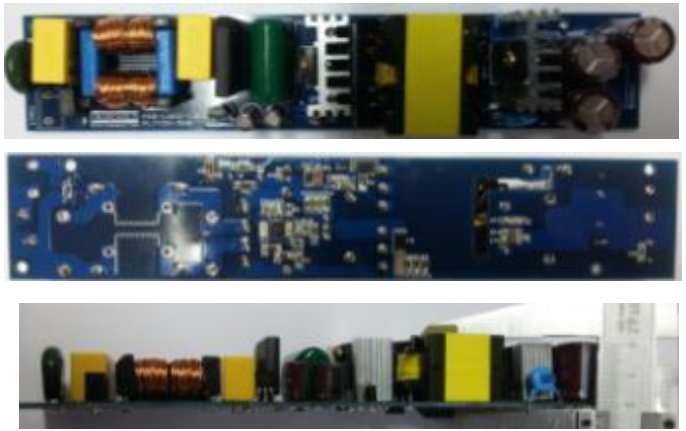


8.4 W – Mainly DCM Operation

FL7733A Circuit and Layout Unmodified

Reference Design: FEBFL7733_L52U050A 50 W (50 V, 1 A), Universal Input

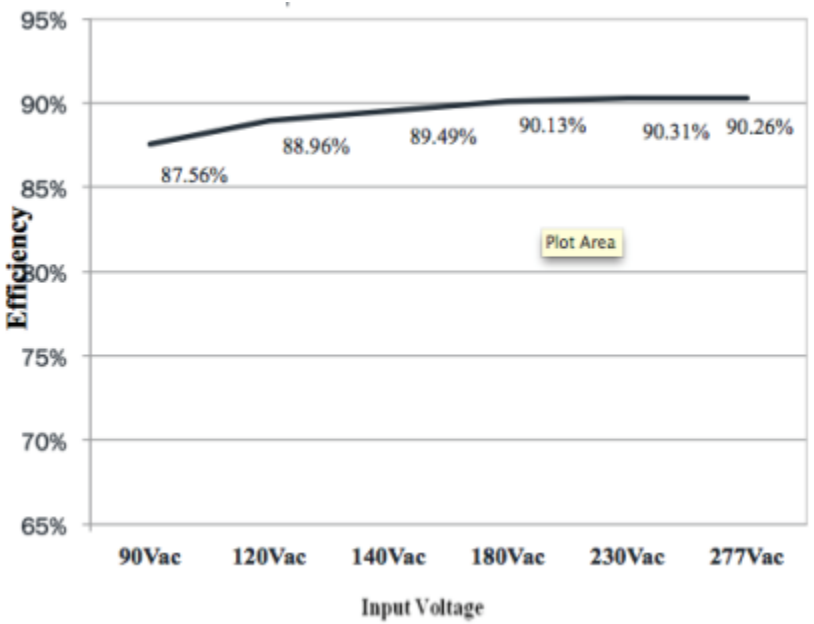


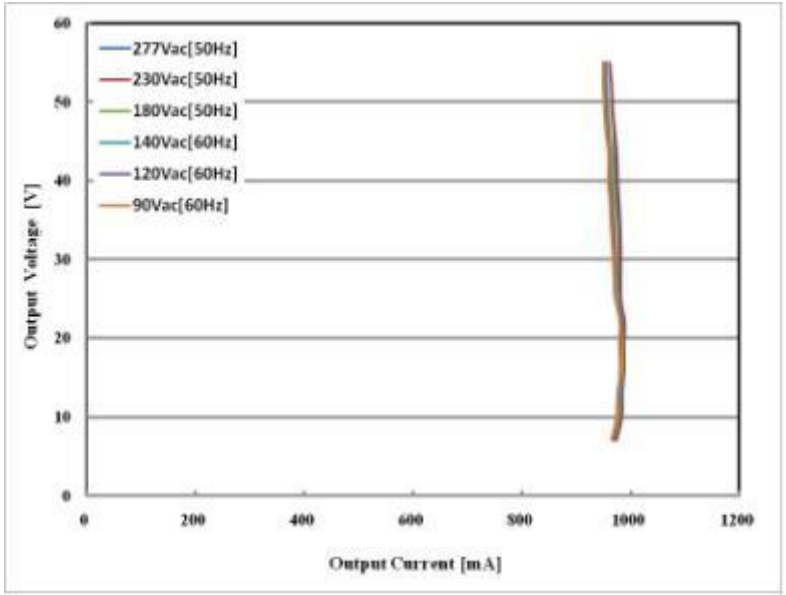


Dimensions: 168 (L) × 35 (W) × 25 (H) [mm]

Performance Test Platforms Unmodified

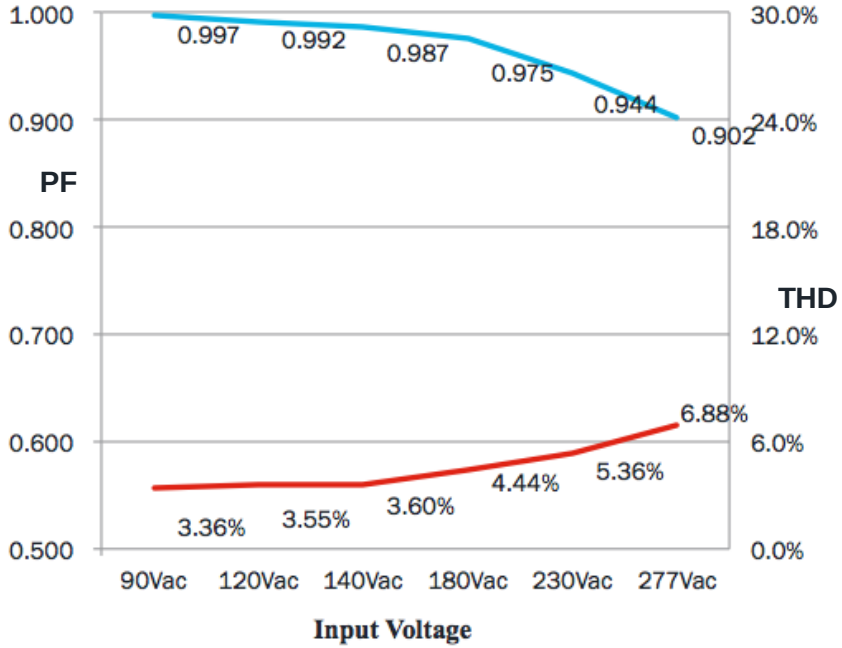
Reference Design: FEBFL7733_L52U050A 50 W (50 V, 1 A), Universal Input

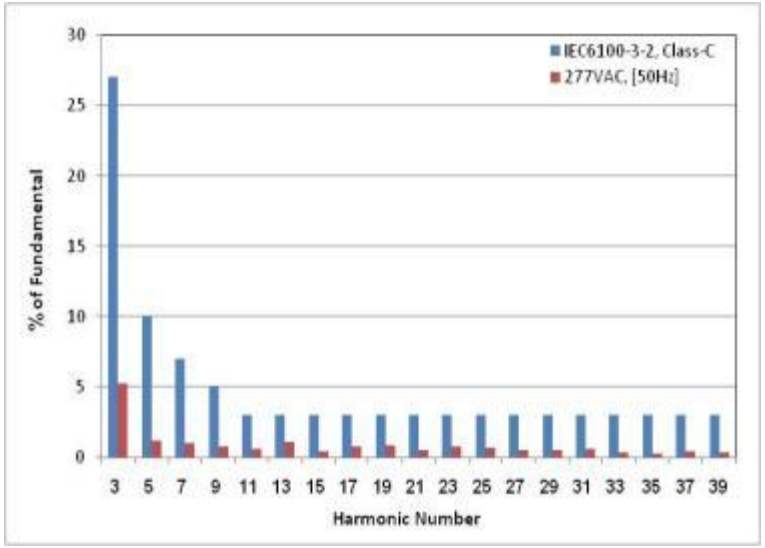




Performance Test Platforms Unmodified

Reference Design: FEBFL7733_L52U050A 50 W (50 V, 1 A), Universal Input

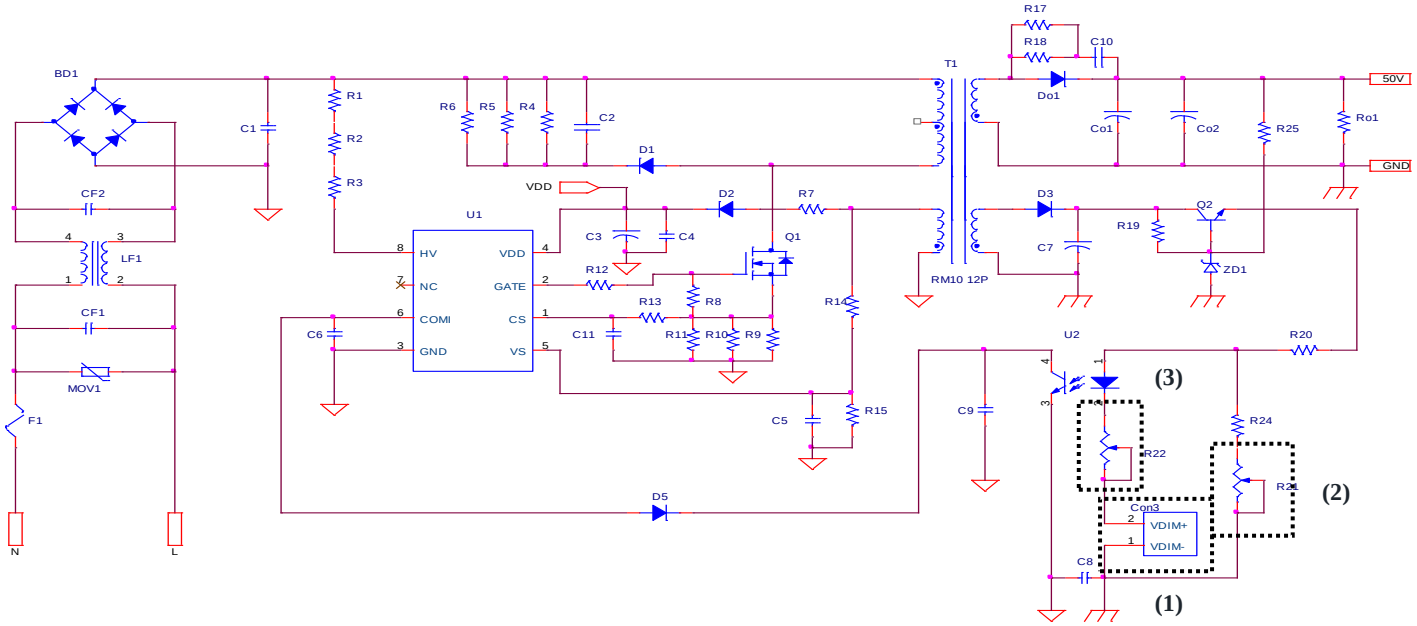




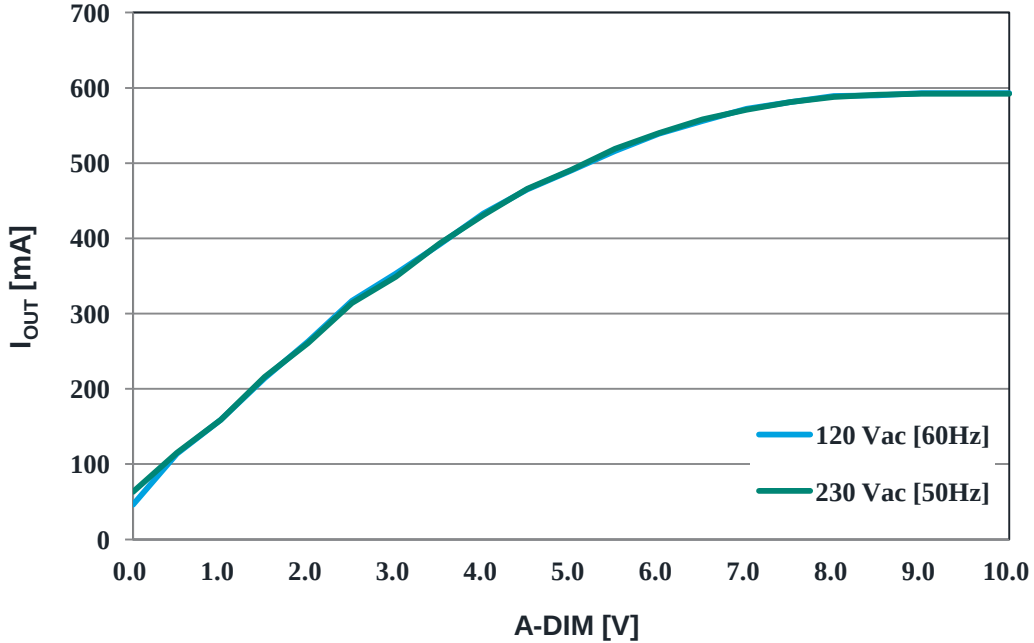
FL7733A Analog Dimming

0-10V Dimming Modification From Secondary Side

Reference Design: 30 W (52 V, 0.58 A), Universal Input



Analog Diming Test Results 0-10V



FAIRCHILD™

The Power to Amaze.

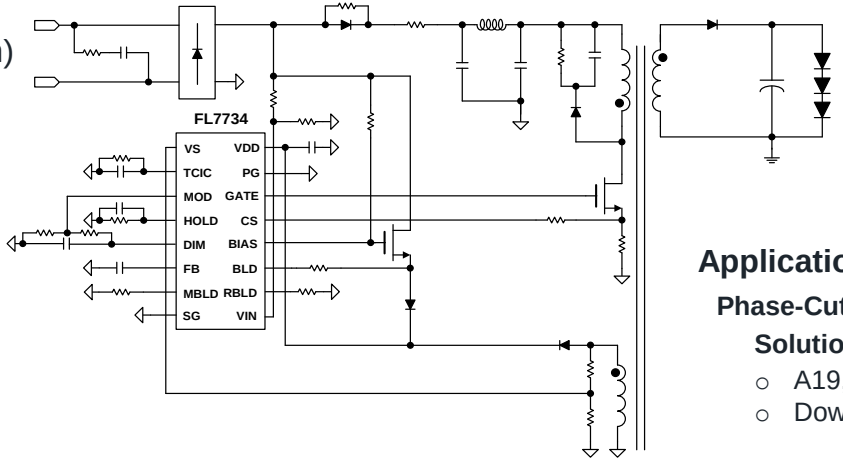
FL7734

PHASE-CUT DIMMABLE SINGLE-STAGE PSR CONTROLLER WITH PFC

New product– FL7734

Phase-Cut Dimmable Single-Stage PSR Controller with PFC

- ***High Performance***
  - Excellent Dimming Performance with Active dimmer control technique
    - High dimmer compatibility
  - High PF, Low THD: >0.9 / <20%
  - Fast < 0.2 s Start-up
  - Good CC tolerance: <±1% (Line Regulation)
- ***Low BOM Count: Single Stage PSR***
  - No Input E-Cap.
  - No Boost PFC circuit block
  - No Photo-Coupler and Regulator
- ***Design Flexibility***
  - Controllable Minimum input current
  - Controllable Dimming curve
- ***High Reliability***
  - LED Short Protection (SCP)
  - LED Open Protection (OVP-VS, OVP-VDD)
  - Output Diode Short Protection (OCP)
  - RCS Short and Open Protections (SRSP, SROP)
  - Over Temperature Protection (TSD)



Applications

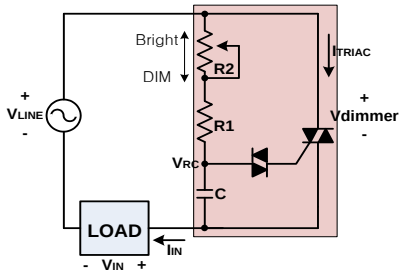
Phase-Cut Dimmable Lighting Solutions

- A19, PAR30/38 Bulbs
- Down Light Driver

Understanding Phase Cut Dimming – 1

Issue in LED Lamp

TRIAC Dimmer

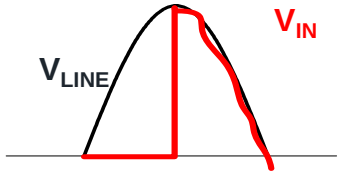


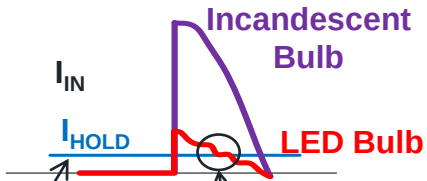
TRIAC

Turn On: $V_{RC} > V_{BO}$
(DIAC Breaks Over Voltage)

Turn Off: $I_{TRAC} < I_{HOLD}$
(TRIAC Holding Current)

Problem in LED ?



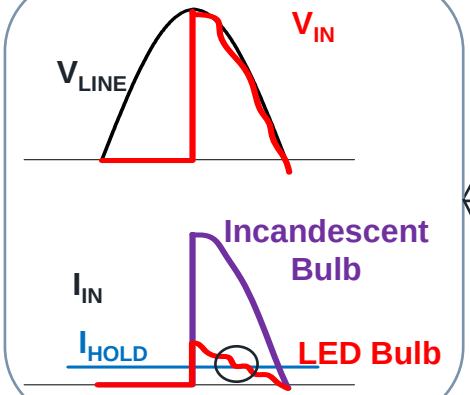


Different I_{HOLD} by dimmers
➔ Compatibility

Fluctuation by Line voltage distortion or Ringing of EMI filter
➔ Lighting Flicker with unstable TRIAC turn-off

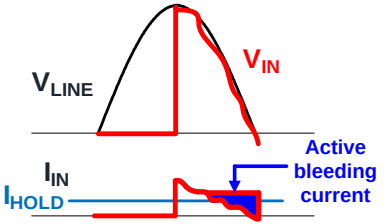
Understanding Phase Cut Dimming
Existing Active Dimming Control Solutions

Problem in LED ?



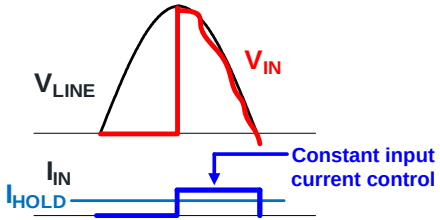
Active Bleeding Control

- Maintaining I_{IN} over I_{HOLD} by active bleeding
- Power dissipation in the active bleeding circuit is higher as LED lamp power is reduced.



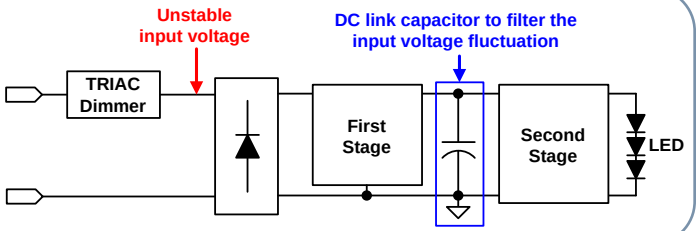
Constant Input Current Control

- Maintaining I_{IN} over I_{HOLD} by controlling constant input current
- Min. output current is high and dimming range is narrow, especially with high-line dimmers.



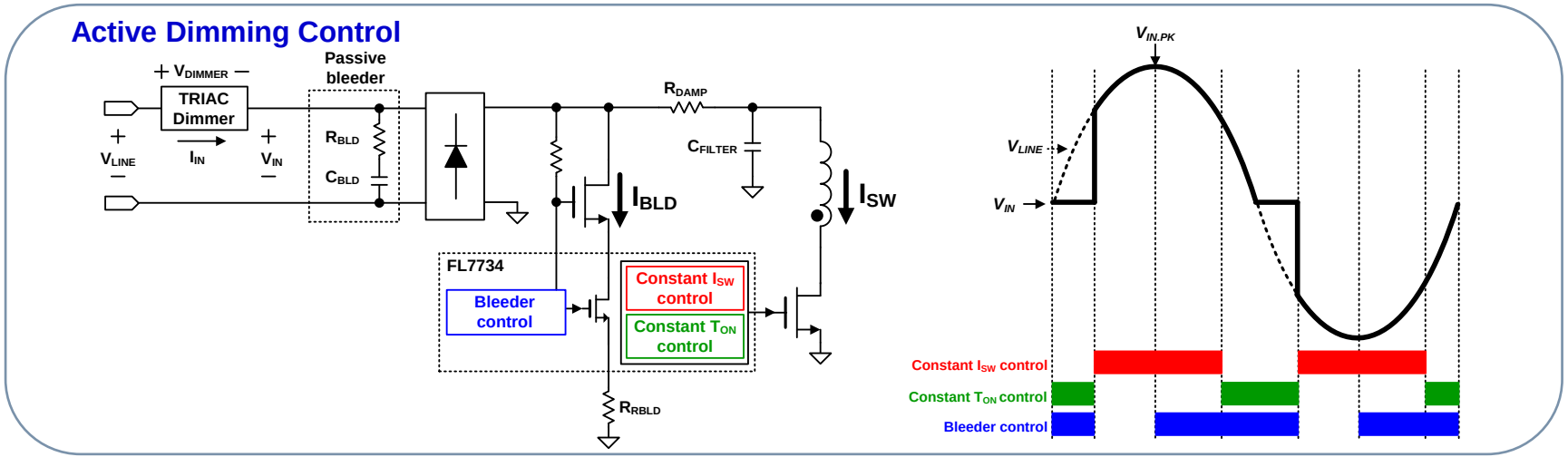
2 Stage Solution

- DC link cap. and digital control manages stable LED current.
- Cost and size are the bottle neck at low power LED lamp.



FL7734 Active Dimming Control

Fairchild solution



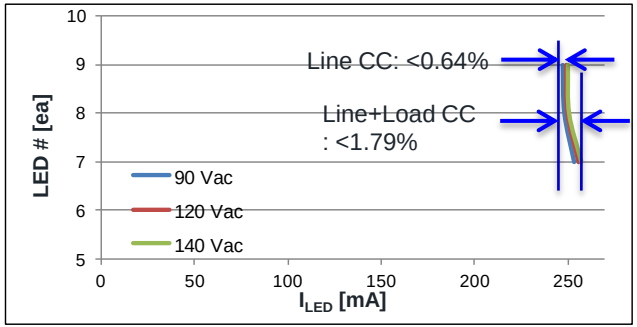
- Main switching current (I_{SW}) is constantly controlled to maintain input current (I_{IN}) higher than TRIAC holding current (I_{HOLD}).
- Bleeder current (I_{BLD}) helps to keep I_{IN} higher than I_{HOLD} and stabilizes dimmer when constant T_{ON} control is enabled.

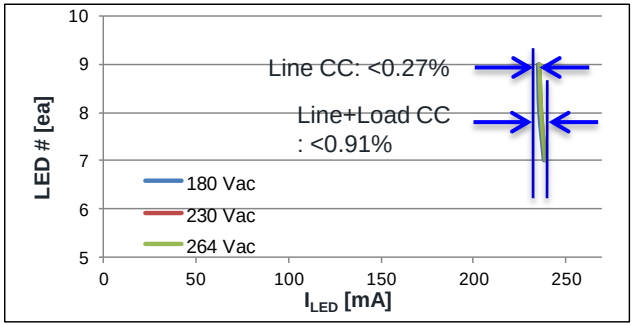
Low power dissipation in bleeding circuit !
Wide dimming range !
Low cost and system compactness !

FL7734 Electrical Performance

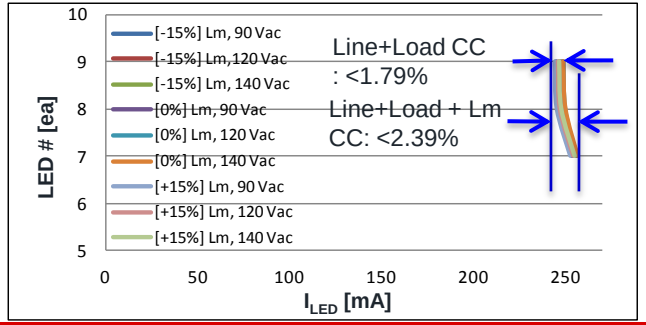
CC Tolerance (250 mA / LED 7~9 each)

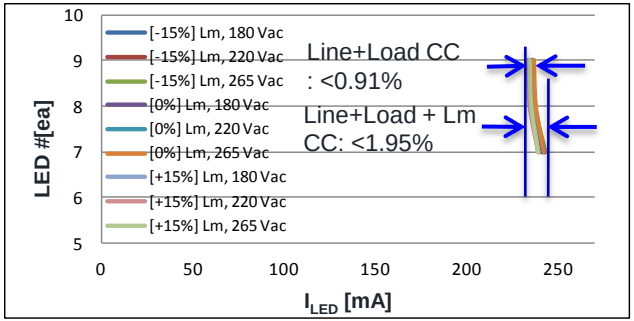
Line/Load Deviation: < ±2%





Line/Load/Lm Deviation: < ±3%



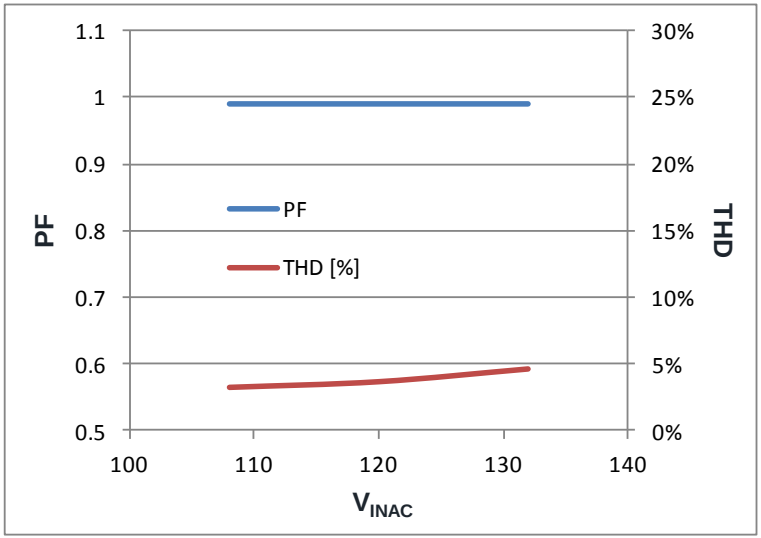


FL7734 Electrical Performance

PF/THD – (250 mA / LED 8 each)

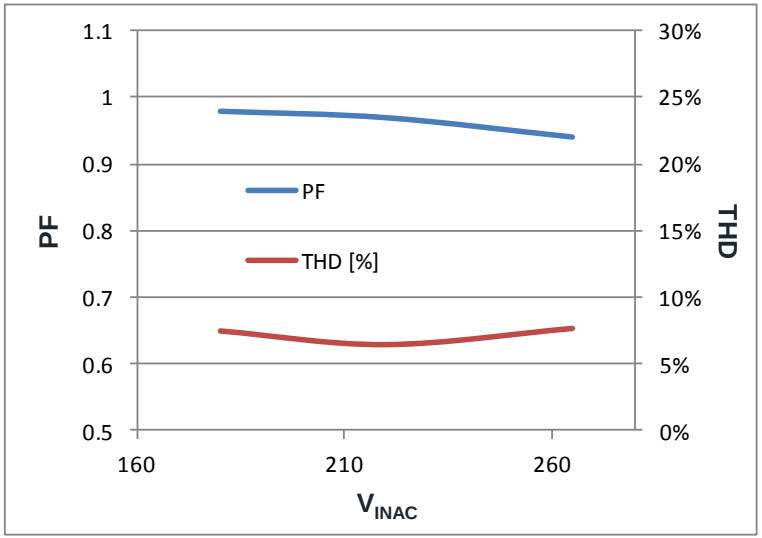
Low Line

[120 V_{AC}/60 Hz, 5 minutes aging]



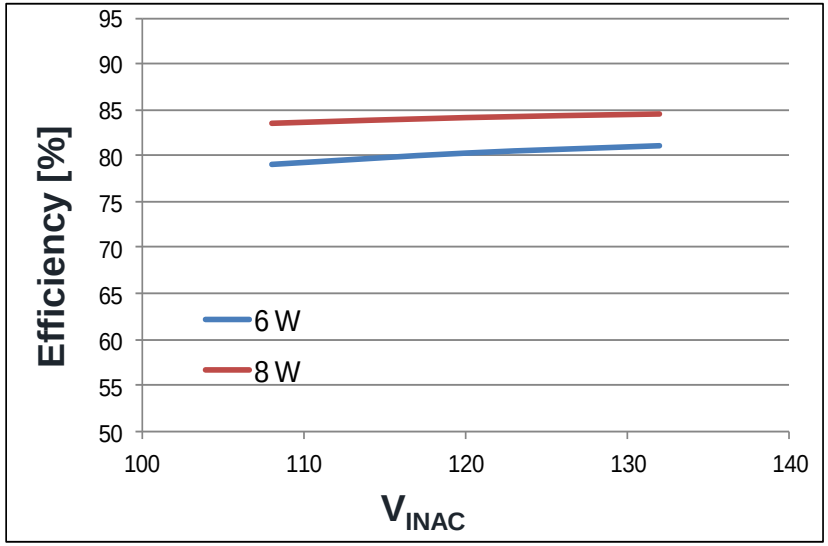
High Line

[220 V_{AC}/50 Hz, 5 minutes aging]

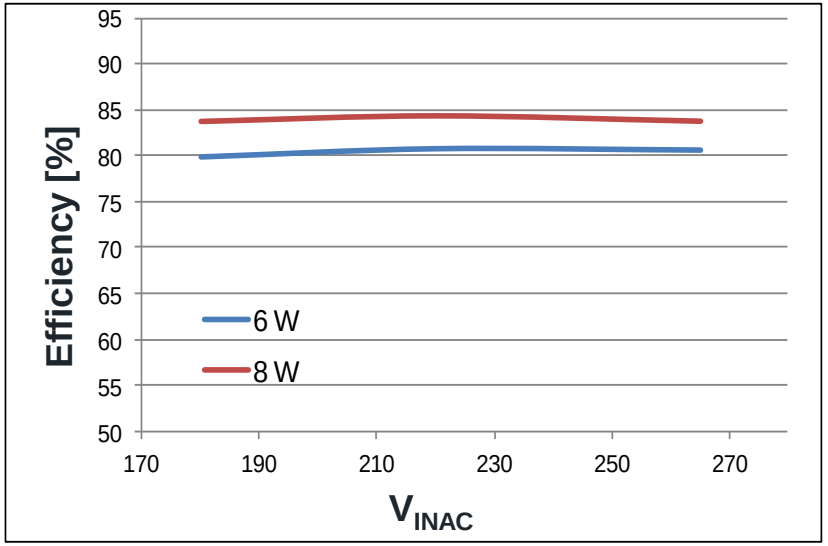


FL7734 Electrical Performance
Efficiency

Low Line



High Line

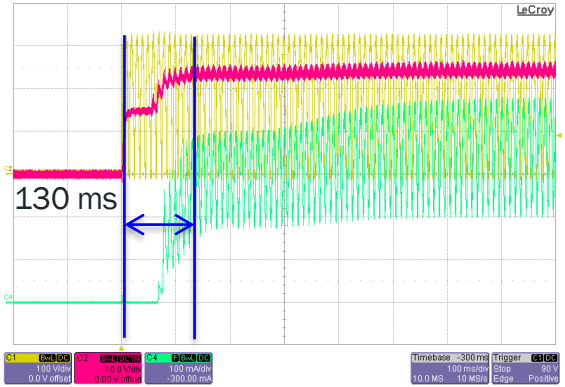


6 W (24 V/ 250 mA, without active damper circuit)
8 W (24 V/ 350 mA, with active damper circuit)

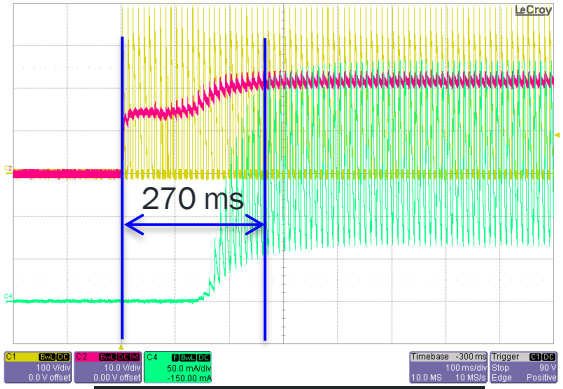
FL7734 Electrical Performance

Fast start up time (8 W / 220V_{AC})

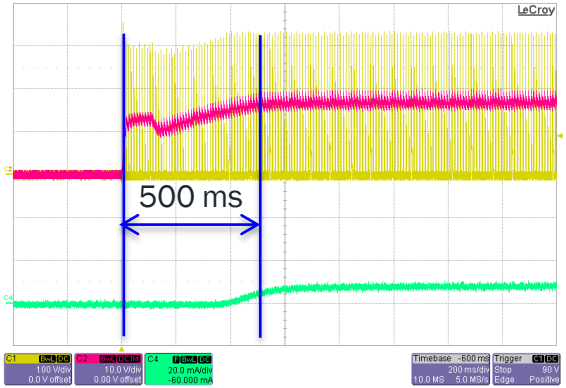
Max. Angle



Half. Angle



Min. Angle



C1[V_{IN}], C2[V_{DD}], C4[I_{OUT}]

Below 0.2 s start up, below 0.5 s start up even at min. phase angle condition.

Summary

- New LED lighting designs request for :
  - Higher compatibility to various LED module
  - Good lighting quality with constant brightness and instant turn on
  - Meet global regulations and standards
- Fairchild's new generation of LED lighting driver (FL7733A) provides
  - Ultra wide Vout range of 10%~100% / Up to 100W driving capability
  - <±3% constant current (CC) / turn on time < 0.2s
  - THD < 10%
- Fairchild's new generation of Dimmable LED lighting driver (FL7734) provides
  - Excellent dimmer compatibility and adjustable dimming curv
  - High efficiency, high PF with lower THD

- For more information, please visit : http://goo.gl/KuqePu

THANK YOU