Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Dimming considerations for visible light communication]
Date Submitted: [9 May 2009]
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Re: [TG7 Call For Contributions]

Abstract: [Dimming has been presented as an issue for investigation in previous TG7 meetings. This contribution is to help provide more background and discussions on dimming and its relevance to TG7 standardization]

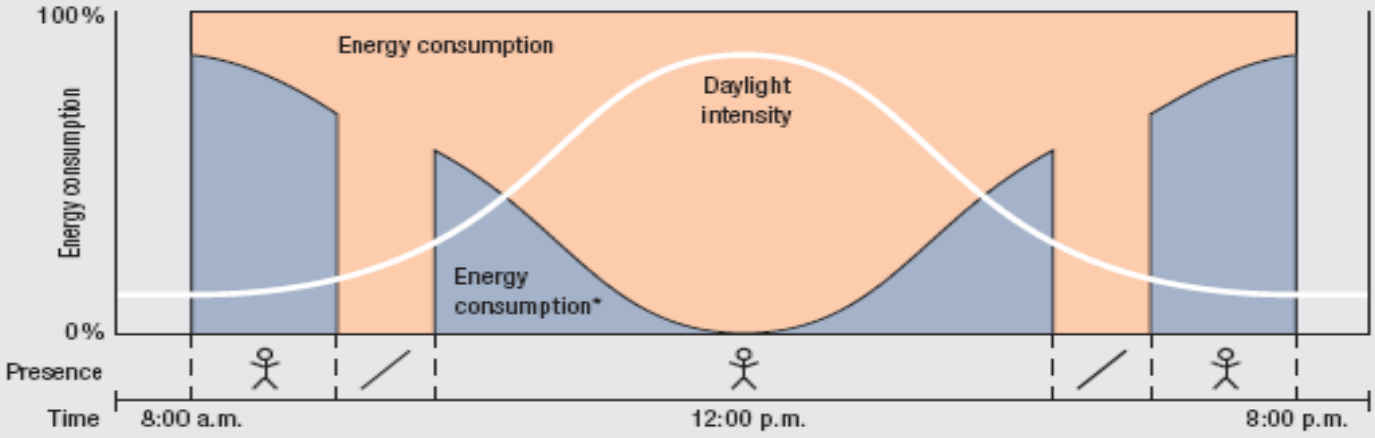
Purpose: [To trigger discussion with other group members of TG7]

Dimming for green energy

Dimming is one of the requirements proposed for Energy Star certification

Advantage of LEDs over CFLs

- CFLs do not support dimming well



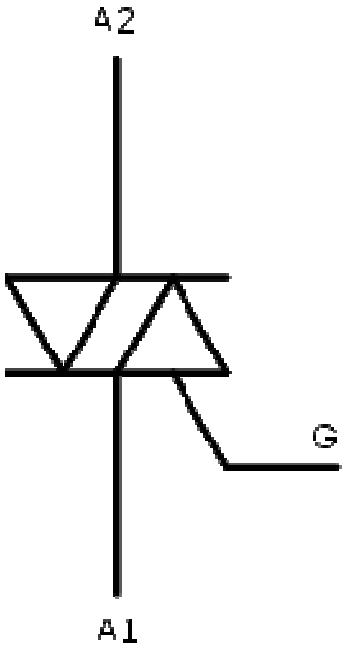
→ *Up to 80 % energy savings with daylight-dependent and presence-dependent lighting control*

** with daylight-dependent and presence-dependent lighting control*

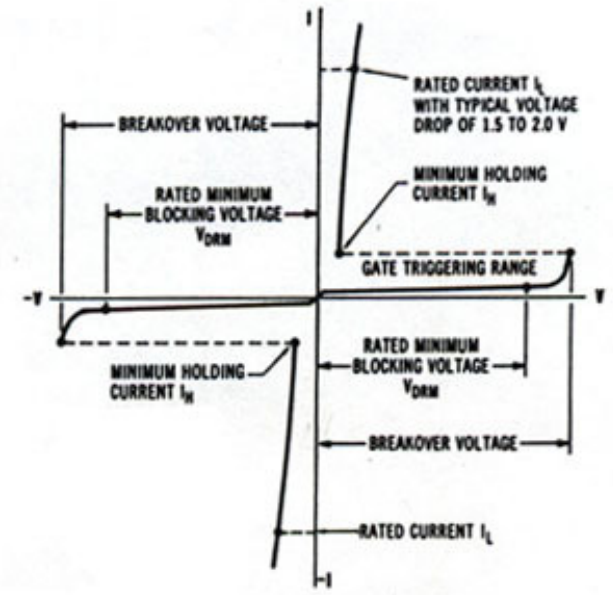
Source: Visions turn to light, Osram brochure

Background: Triac (TRIode for Alternating Current)

bidirectional electronic switch which can conduct current in either direction when it is triggered

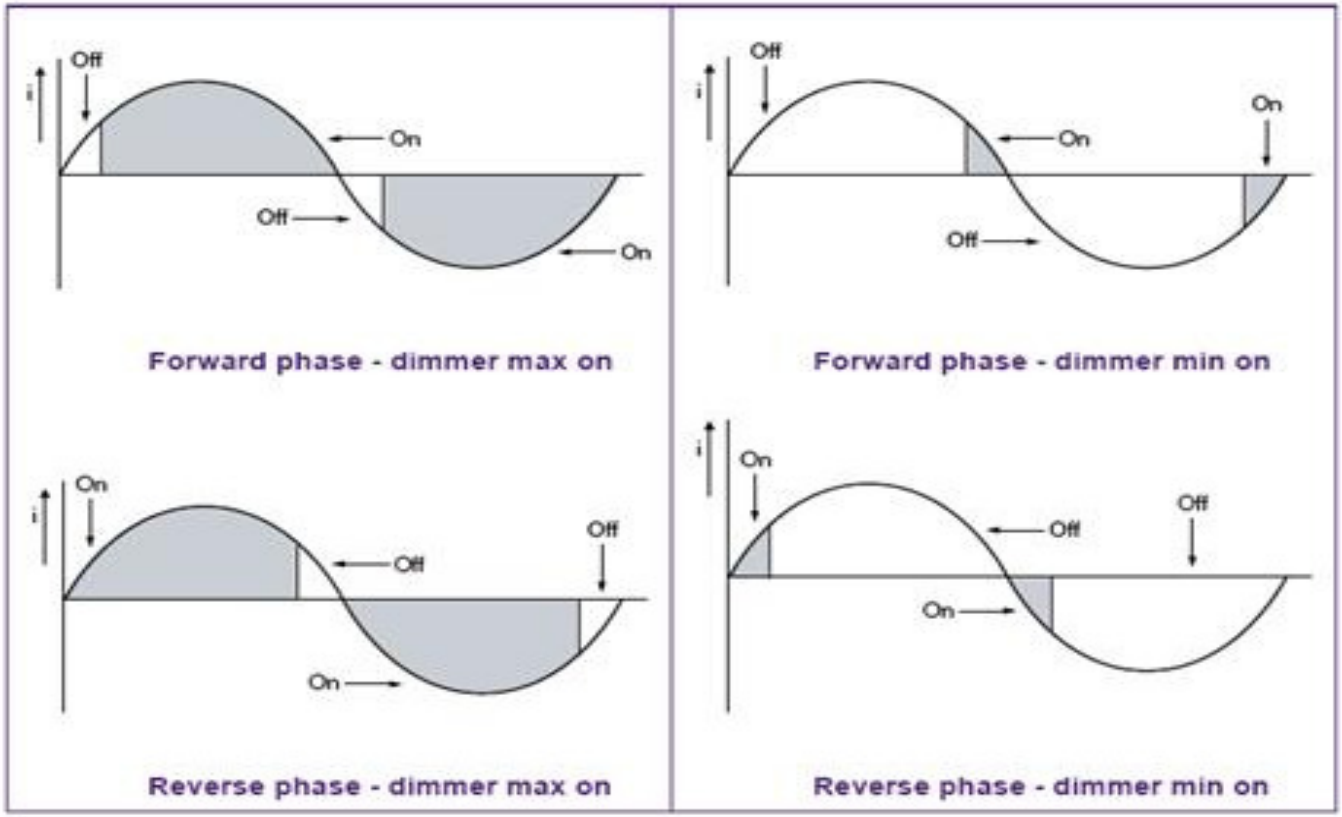


http://en.wikipedia.org/wiki/TRIAC



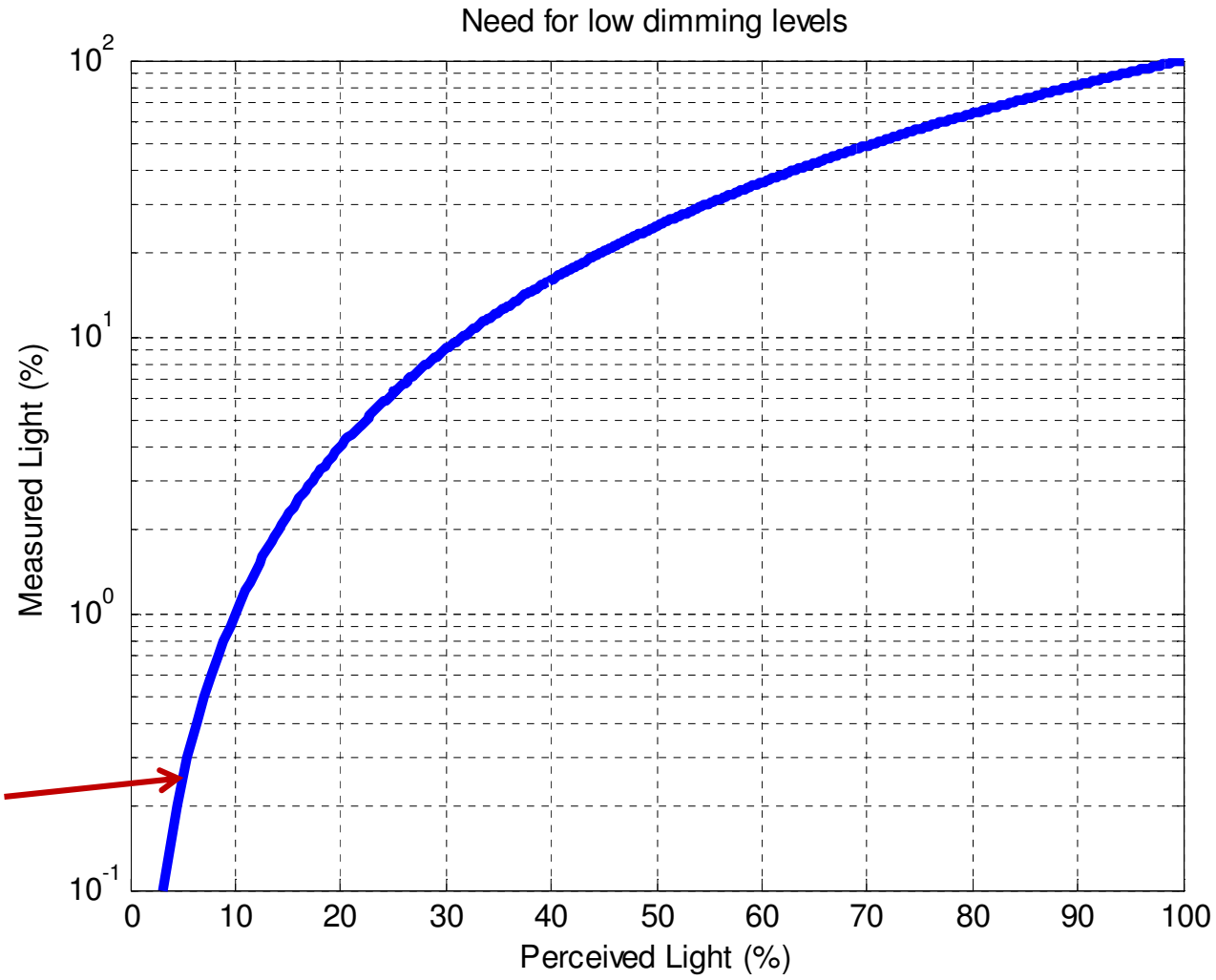
Typical triac VI characteristic curves.

Triacs used for incandescent bulbs



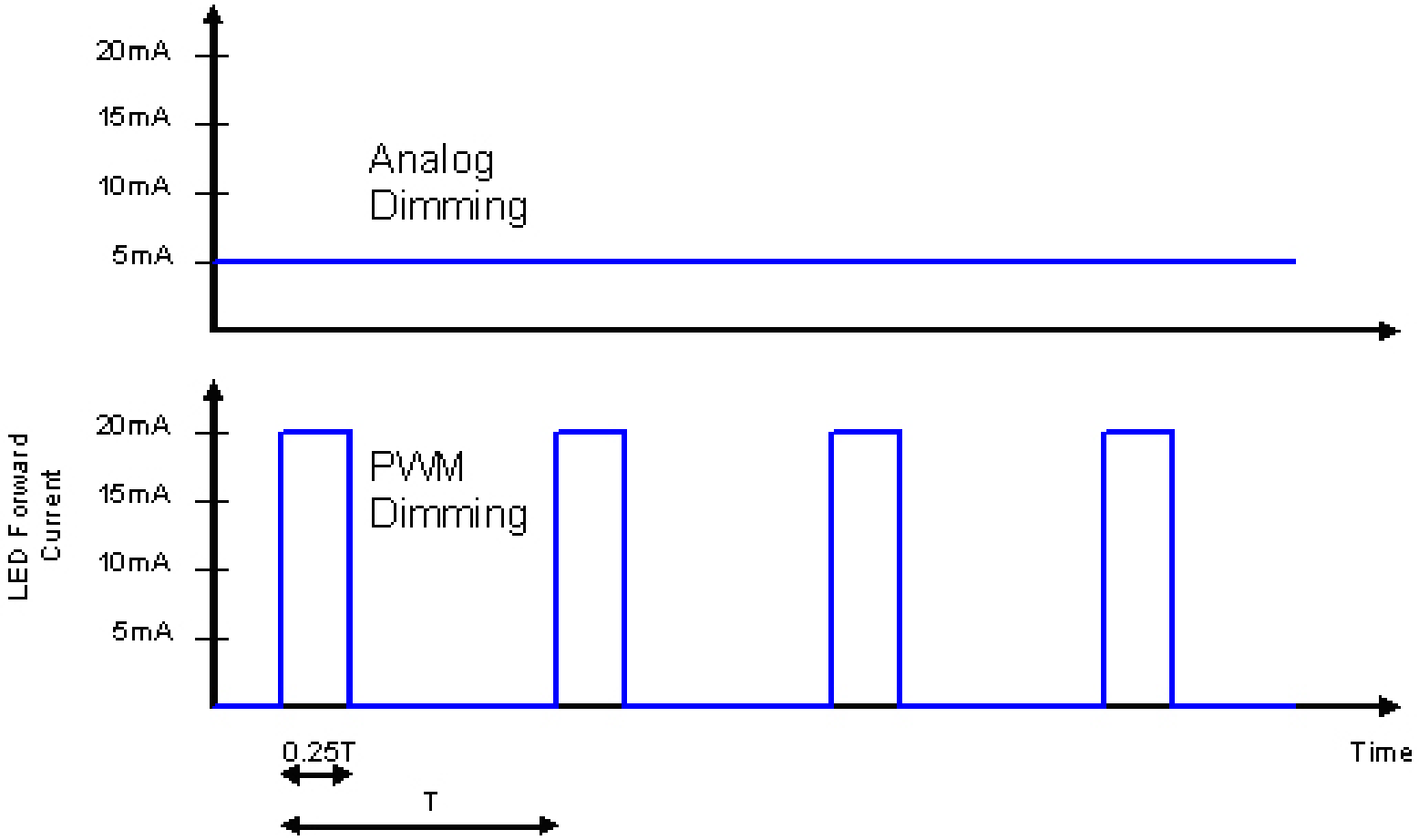
SSL2101 dimmable mains LED driver, Application note, NXP semiconductors

Human eye : non-linear sensitivity to brightness



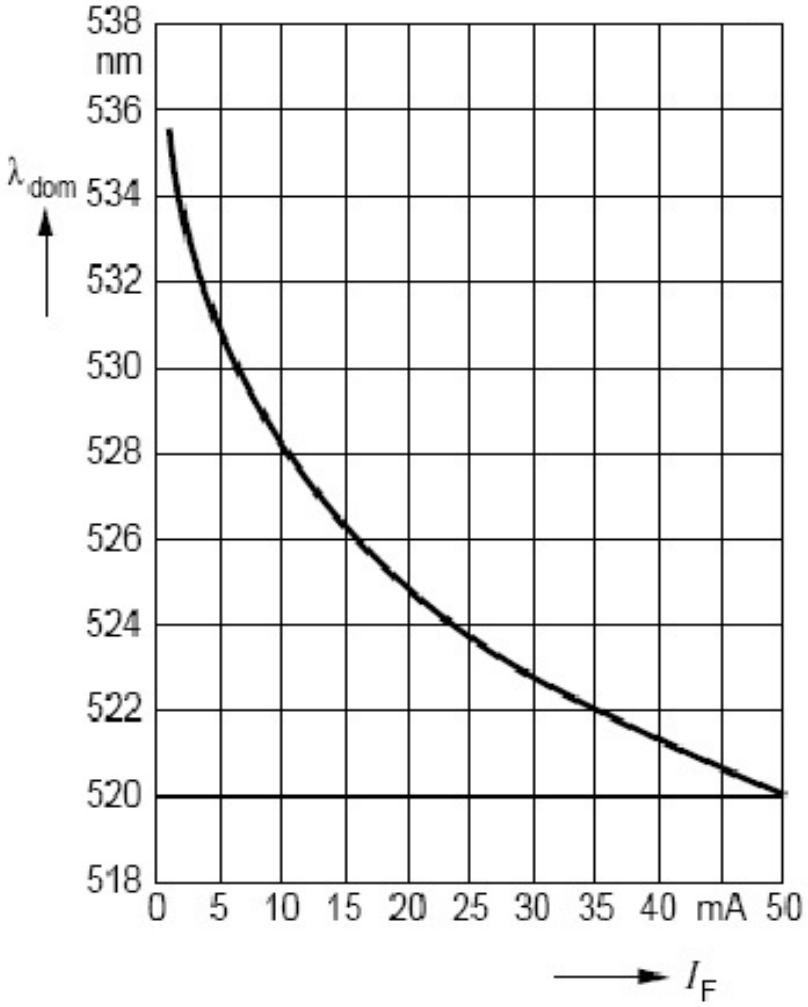
Need to dim as low as 0.1%

Analog vs. PWM dimming



http://www.eeproductcenter.com/passives/showArticle.jhtml?articleID=173401243

Color shift due to analog dimming



True "Green" LED (20 mA nom)

25% reduction from 20 to 5 mA causes λ to move from 525 to 531 nm

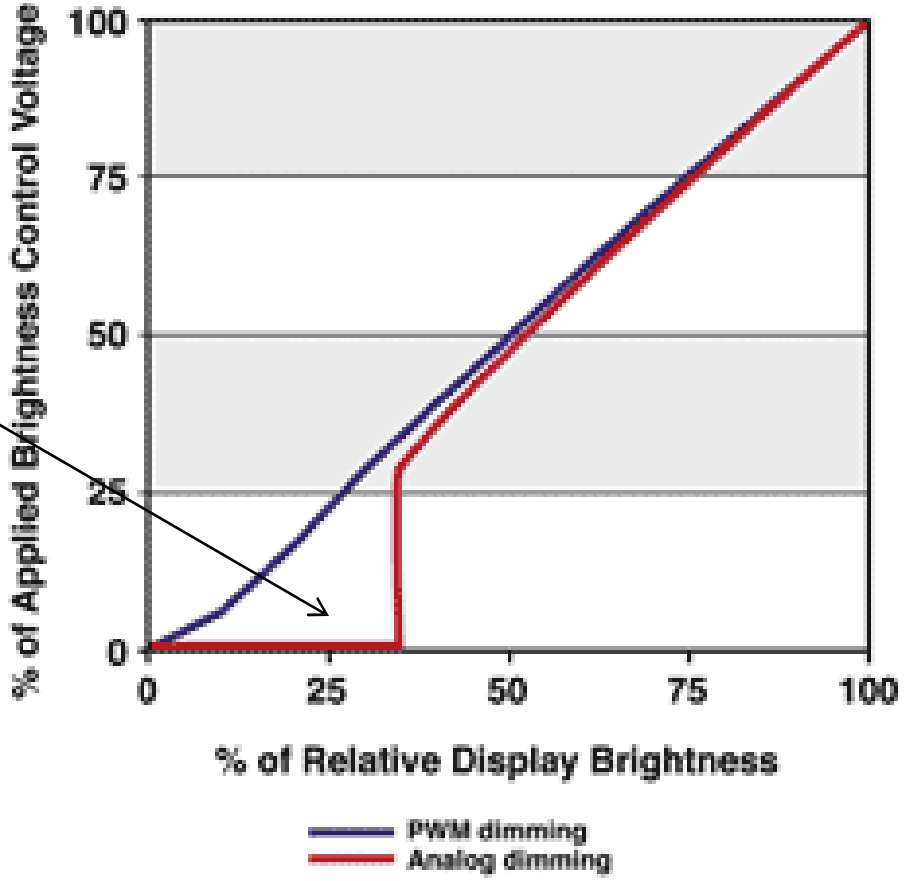
Not acceptable in many applications that use true color representations

http://www.eeproductcenter.com/passives/showArticle.jhtml?articleID=173401243

http://focus.ti.com.cn/cn/lit/an/slyt238/slyt238.pdf

PWM vs. analog dimming (LCDs)

Difficult to achieve fine dimming factor control for low brightness using analog dimming



http://www2.electronicproducts.com/Dimming_options_for_LCD_brightness_control-article-erg-mar2004-html.aspx

Other dimmer control interfaces

Isolated low voltage link for dimmer setting

- Can interface to various type of devices

0 – 10 V analog control (IEC 60929)

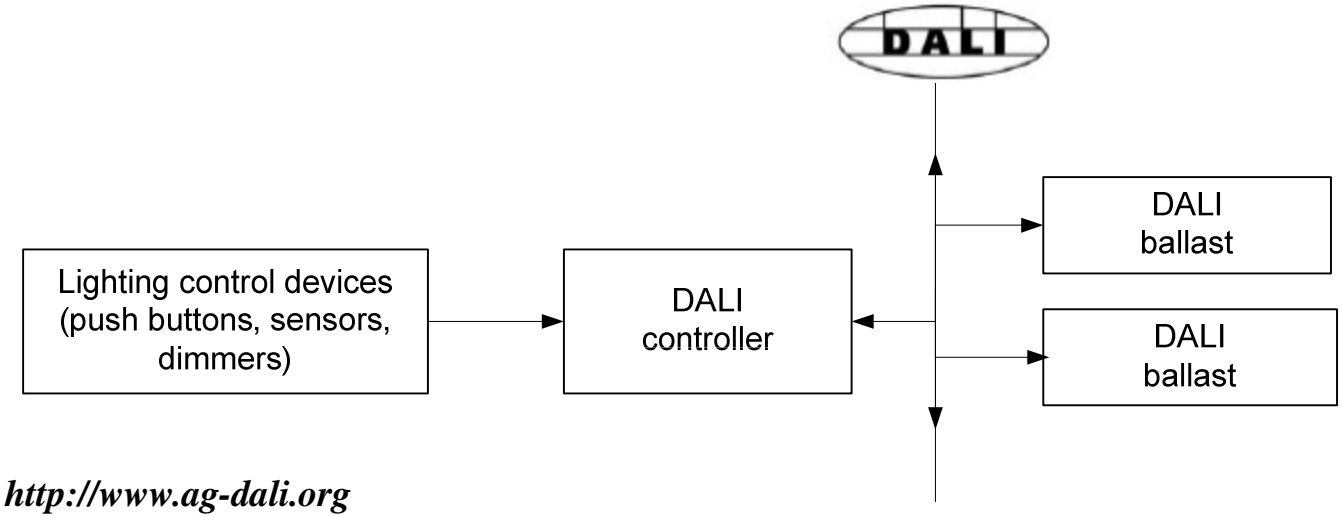
DALI: Digital Addressable Lighting Interface control

DMX: Stage lighting control

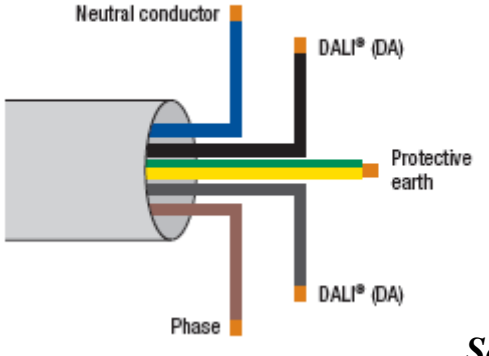
DALI messaging

- Software solution
- Allows digital setting of dimming
- Operating parameters such as min/max light level, fade time and rate can be stored in ballast memory
- Allows setting to some predefined levels
- Allows queries to get dimming factor (0.1% - 100%) and variety of status messages

DALI standard interface



http://www.ag-dali.org



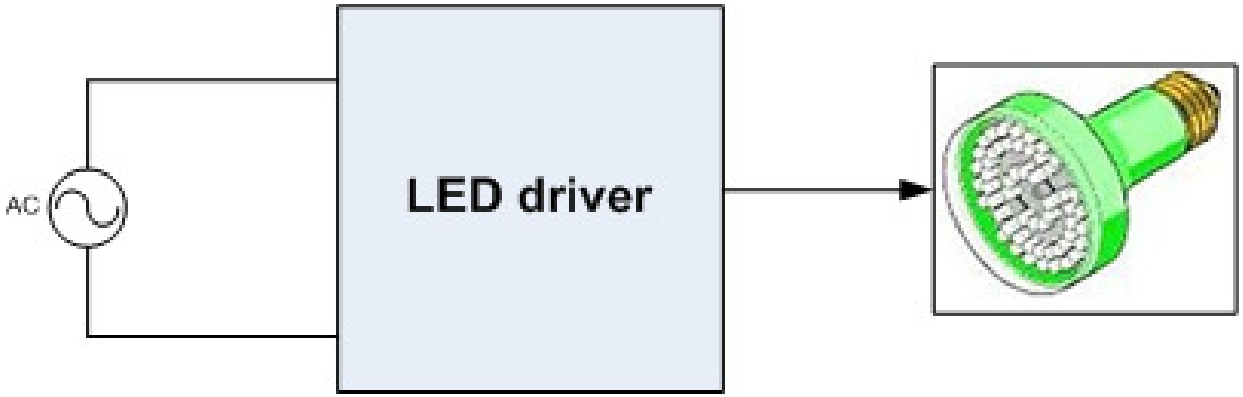
Source: Visions turn to light, Osram brochure

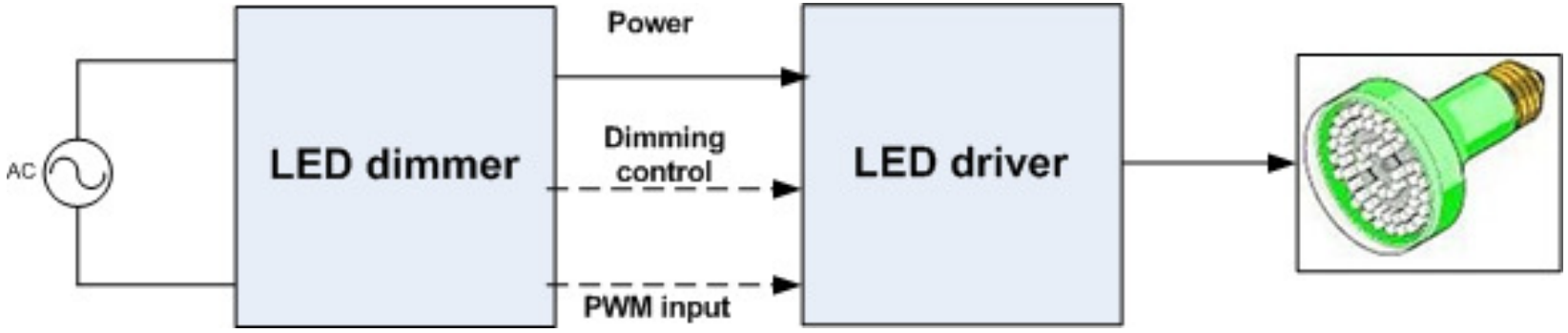
DALI messaging

Typical DALI Message	Description
Go to light level xx	Sets light level from 0.1% to 100.0%
Go to minimum level	Set light level defined as lowest for this situation or setting
Turn lamp off	Turns the light off
Go to level compliant with situation xx	Sets light level at a predefined level
Query: What light level are you on?	Returns a number from 0.1% to 100.0%
Query: What is your status?	Returns a variety of status messages

Technical Paper: The Digital Addressable Lighting Interface (DALI) : An Emerging Energy-Conserving Lighting Solution, Odile Ronat

LED bulbs with dimmer options





VLC issues for dimming

Communication affected by PWM-based drivers

- Will affect modulation and TX output from LED

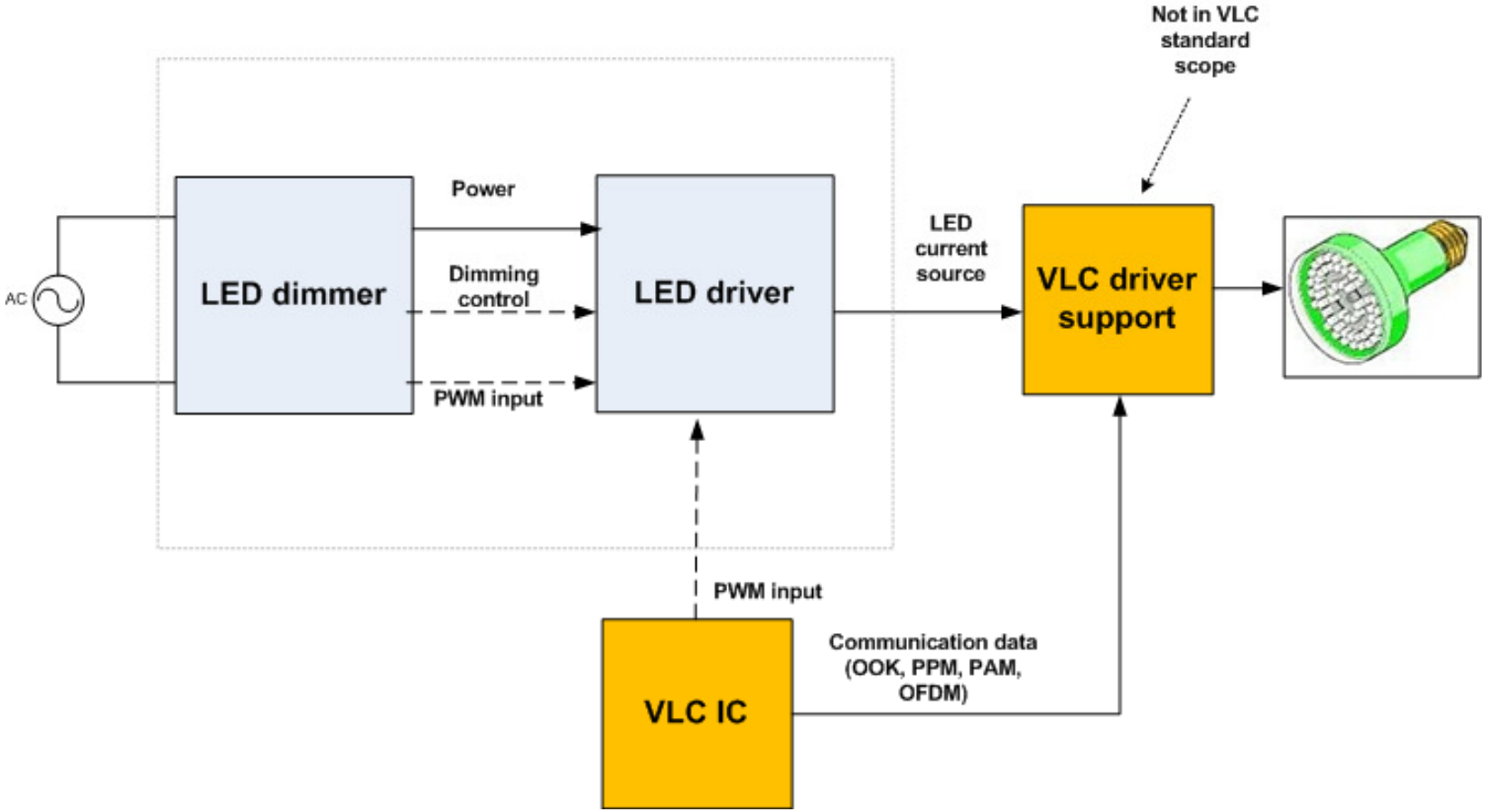
Loss in performance

- May be acceptable to increase light output temporarily during communication (external dimmer override)

Maintain visibility (light brightness) during VLC

Perception of flicker due to VLC

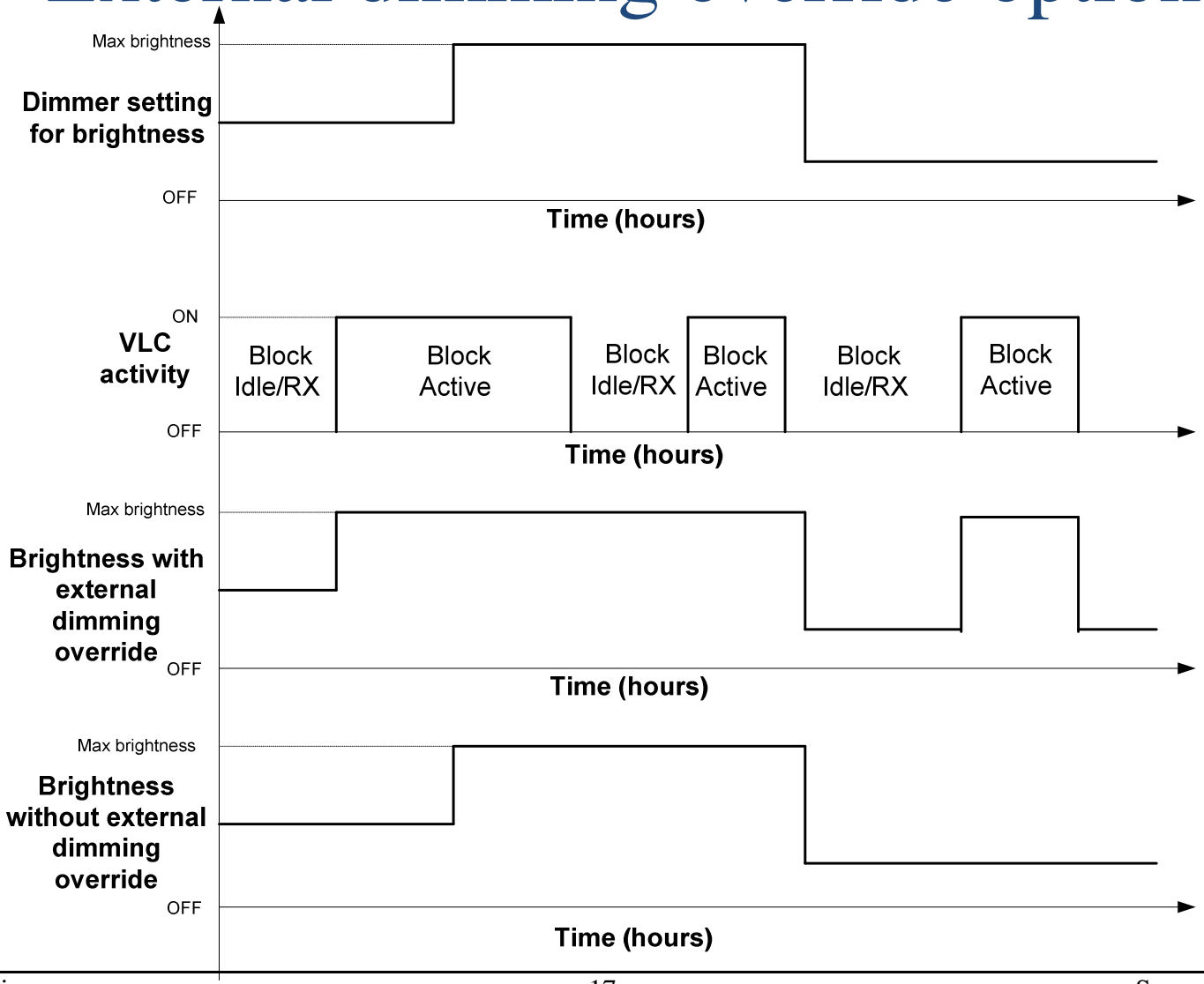
VLC-enabled LED bulbs



Need for separate VLC driver

- Accounts for duty cycle reduction due to modulation, if any and adjusts TX light intensity accordingly so that user does not perceive difference in light output.
- Supports multiple current level switching dynamically (OFDM, PAM)
- Out of scope for VLC standard (similar to antenna spec for RF)

External dimming override option



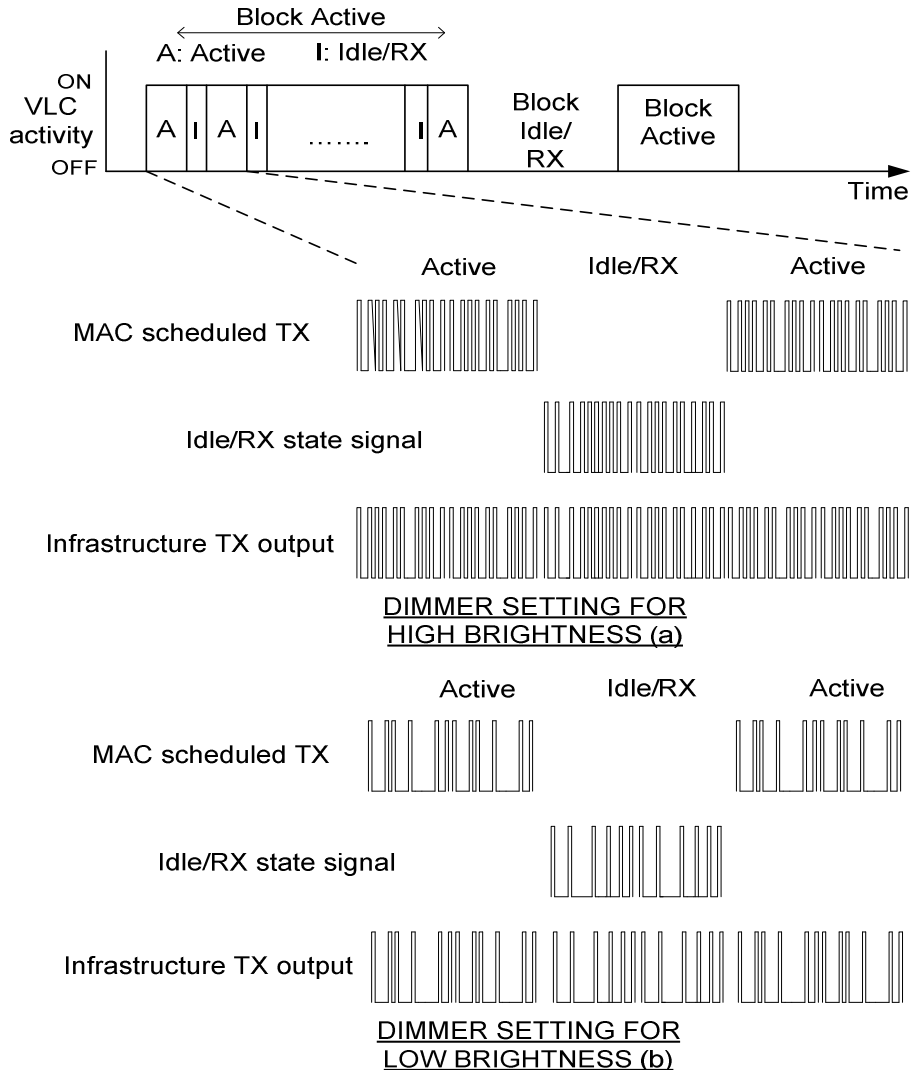
Idle/Rx state signal for dimming

Idle//Rx state signal for visibility and for flicker-free operation

Same duty cycle as that of dimmer setting

Can be used for other communication purposes than just dummy signal

- Synchronization, channel estimation, timing, beaconing, …



Other issues: Programmable dimmers

Many PWM dimmers allow the user to program the dimming pattern/switching frequency

Analog dimmers do not need any user programmable patterns/switching frequency

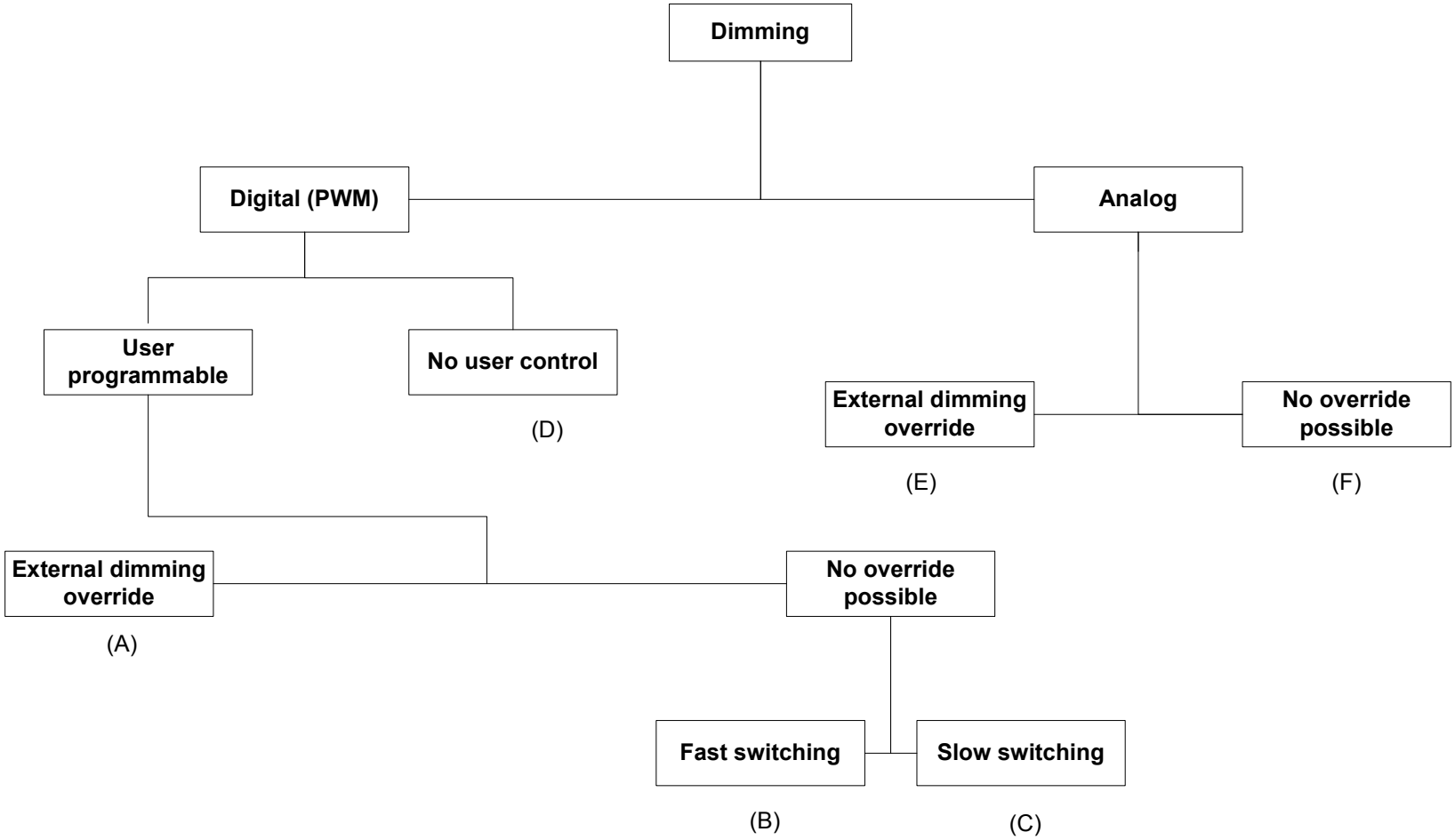
Other issues: Driver switching frequency

LED can switch at modulation rate

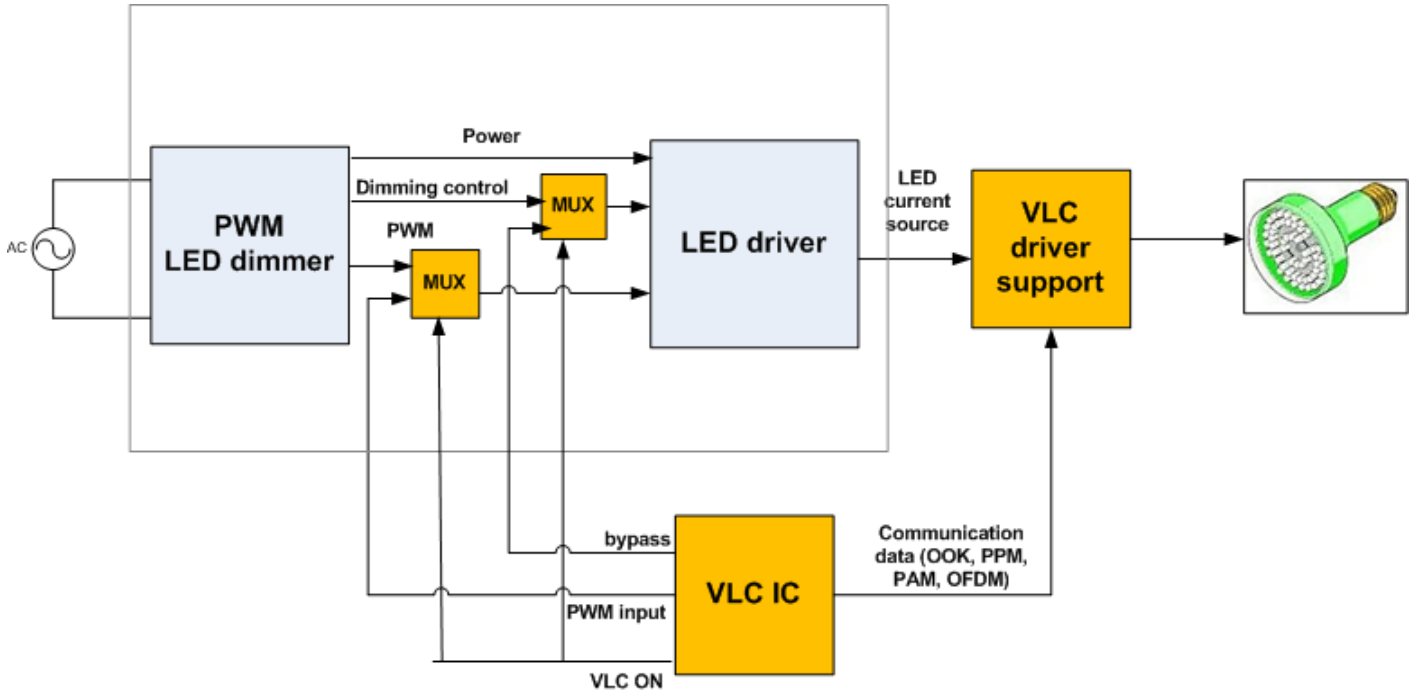
LED driver+ PWM dimmer may or may not be able to switch at modulation rate

- Slow switching: PWM dimmer rate < modulation rate
- Fast switching: PWM dimmer >= modulation rate

Dimming options



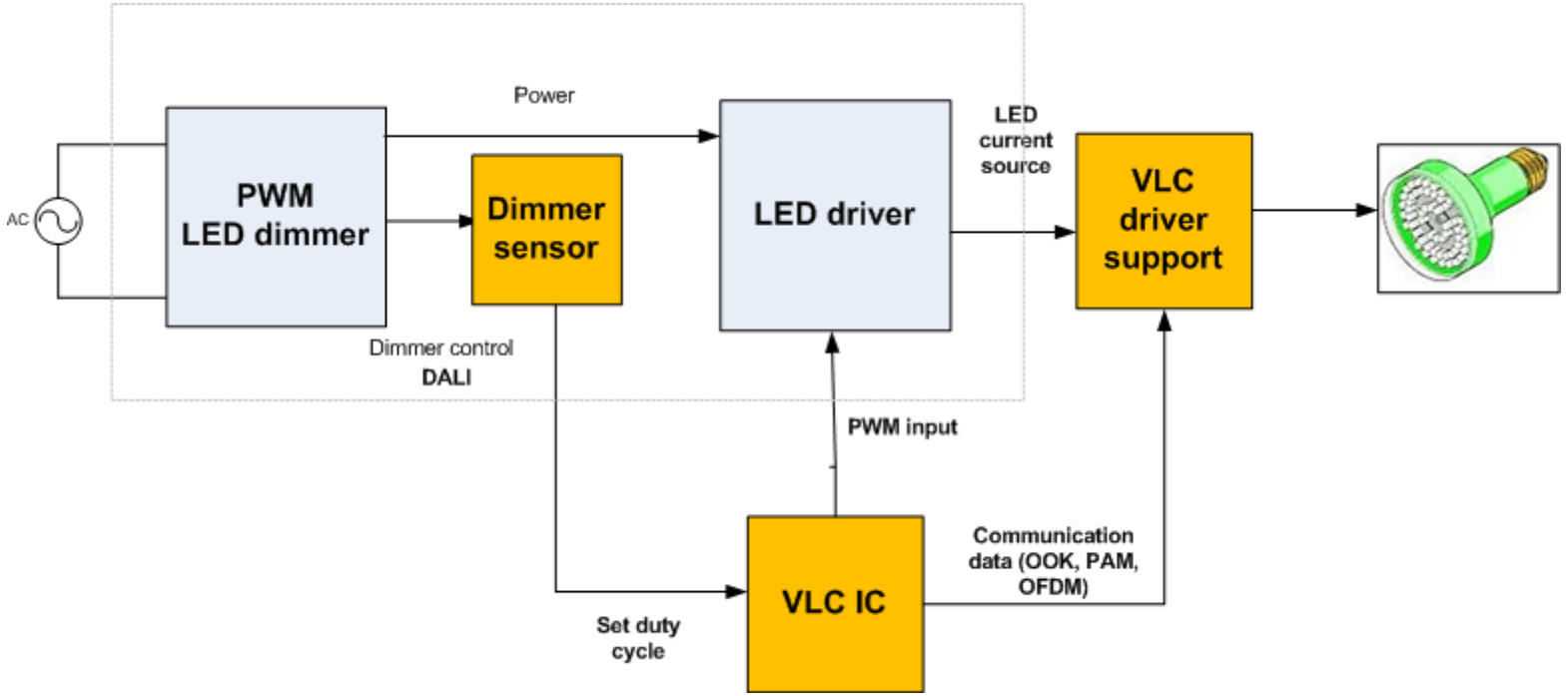
Case (A) – external dimming override



Bypass dimmer settings and regain control of driver via override signal

MAC should send random data or preamble data at same duty cycle to ensure no flickering when no TX data

Case (B,C) – no dimming override

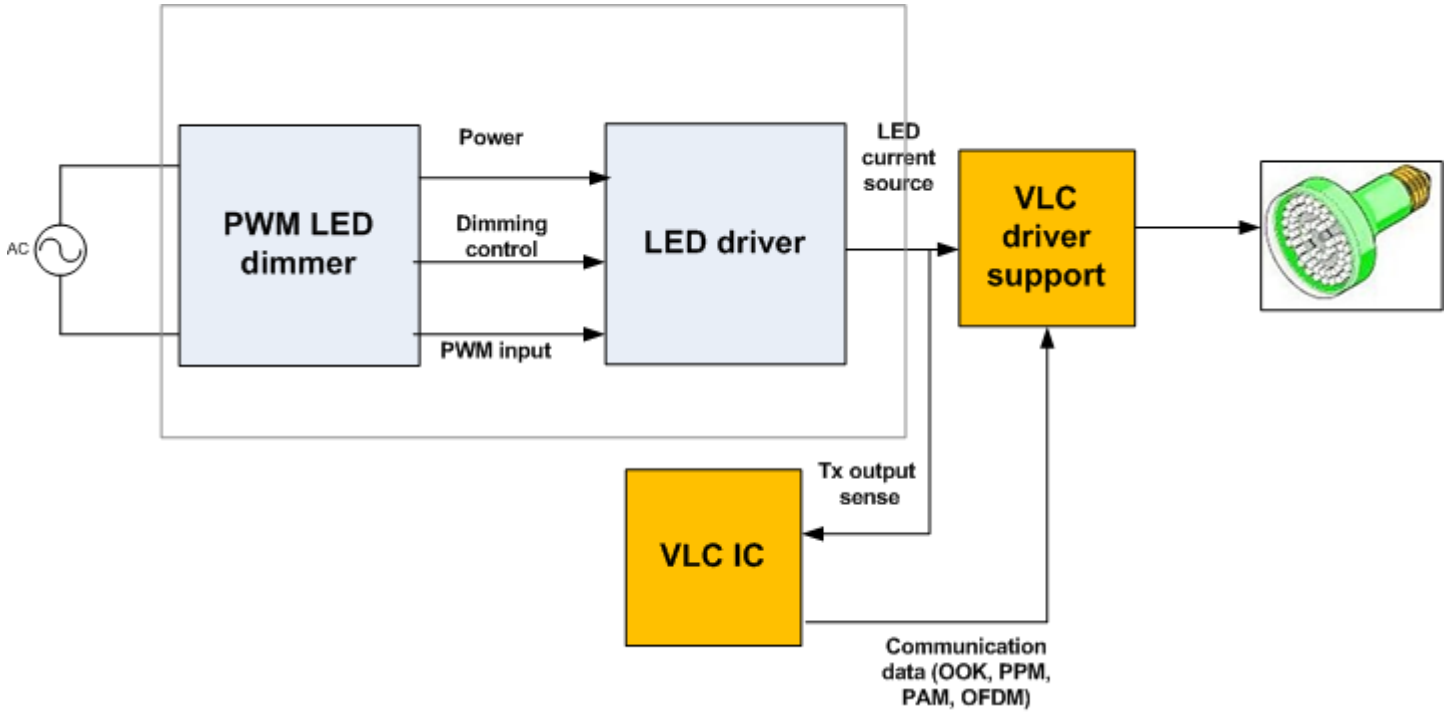


(B) PHY layer data rate with OOK can be set using dimmer sensor output

- Lower dimmer settings can cause lower data rate selection in the PHY

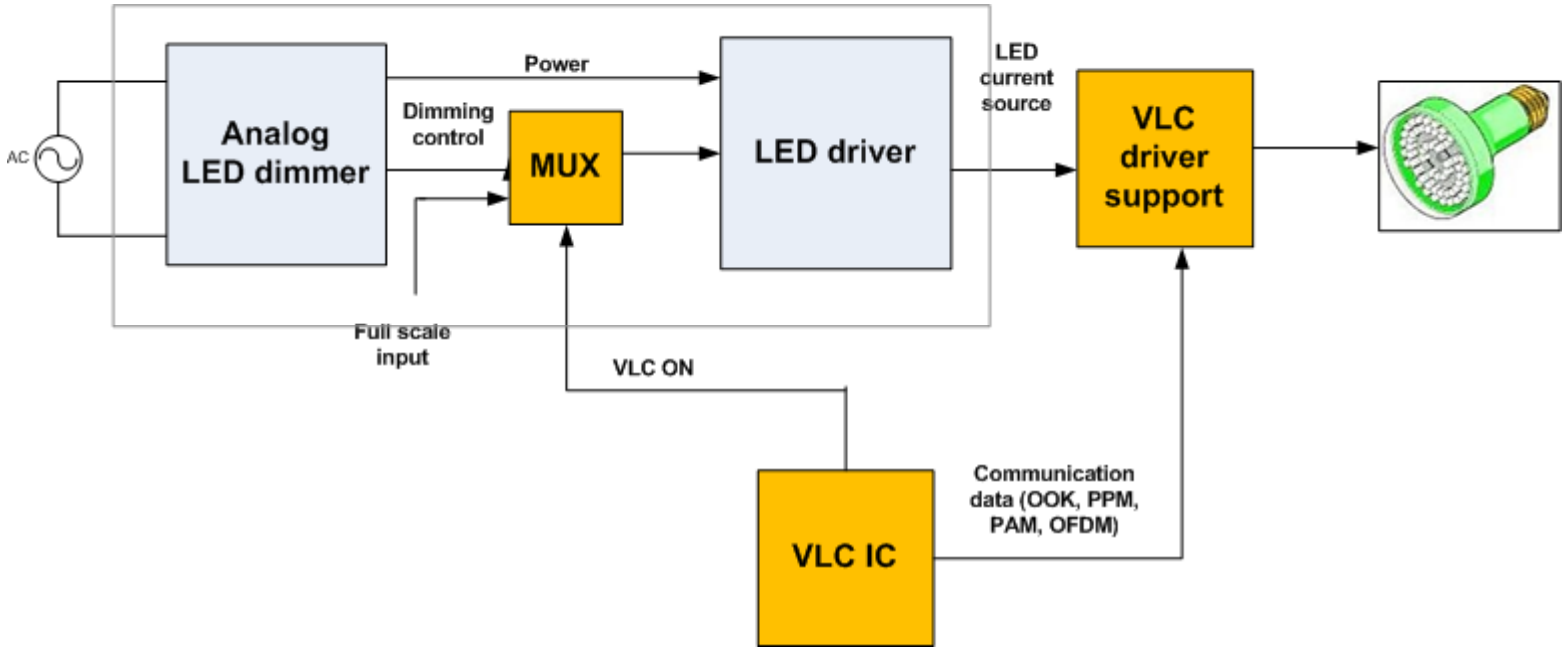
(C) MAC schedules sleep/transmissions with duty cycle set by dimmer sensor

Case (D) – no driver/dimmer control



- VLC IC scans/senses the output of the LED driver to obtain the PWM information
- Uses that information to set data rate, symbol time and/or sleep cycles
- MAC can communicate the PWM information to the receiver

Case (E, F) – analog dimming



(E) Bypass dimmer logic when VLC operation is ON and resume full brightness

(F) Use rate adaptation mechanism to lower rate if override not possible

Summary

- Dimming is an important consideration for infrastructure applications for VLC
- Different options possible by manufacturers (analog/PWM) with different levels of control
- Methods proposed for various dimming options to help integrate with the VLC standard

References

Energy star criteria, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/lighting/ESIntegralLampsCriteria_Draft1.pdf

Visions turn to light, Osram brochure

http://en.wikipedia.org/wiki/TRIAC

http://www.ag-dali.org

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