

Maury Wright Editor-in-Chief LEDs Magazine

An Overview of LED Drivers: AC/DC & Dimming

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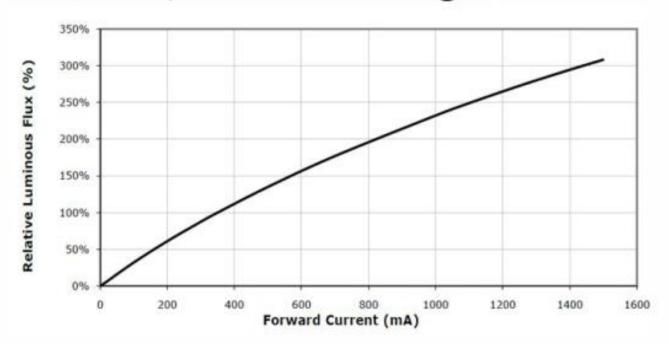
Today's Agenda

- LEDs
 - Overview of their characteristics.
- Power Sources
 - Introduction to the AC power line.
- SMPS
 - Many of the issues involved with design of off-line drivers.
- Dimming
 - Why your light should dim, and how.

LEDS

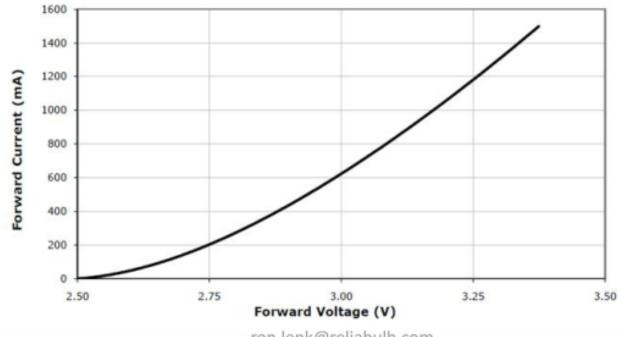
LED Characteristics

- LED stands for Light Emitting Diode.
- Like other diodes, their performance is set by their current, not their voltage.



LED Characteristics

- Once you know the current, that determines the voltage.
- Thus you need a current source, not a voltage source, to drive the LEDs.



LED are Complicated Systems!

- Technical details:
 - Raising the die temperature decreases the light output for a given current.
 - Raising the die temperature decreases the forward voltage of the LED.
 - And the die temperature depends on the power dissipation, which is the current x voltage.
- We usually build complicated Spice models, including temperature effects and optical output.

LED Strings

- Putting LEDs in parallel can be a problem.
 - Very high currents at low voltages, lots of loss.
 - Currents don't share well.
- Series is better.
- In practice, strings of LEDs are put in parallel.
 - Long strings have less variation in voltage, and thus better output matching.
 - String length may be limited by maximum voltage or reliability.

AC LINE POWER

Power Sources

- In addition to the familiar 120VAC and 240VAC, the US also has 277VAC.
 - "Universal Input" has a different meaning than for power supplies.
- Another difference from standard power supplies is that not all power sources for lighting are 3-wire---the light bulb in your ceiling is only 2-wire.
 - Affects EMI and lightning.

Power Sources

- +10% isn't good enough! What should your light do at 85VAC? Or 175VAC?
 - Shouldn't burn up!
 - Maintain constant light, or dim? Dim linearly?
 - Turn off between 132VAC and 250VAC?
- Should your light have a disconnect if it is designed for 3-wire, but only 2-wire is attached?

Lightning

- Power lines have very high voltage surges from lightning.
 - Class 'A' is a 100KHz ring going to 2-4KV at 500A.
 - Class 'B' is a spike going to 6KV at 3000A.
- Class 'A' lightning protection is suitable for home use...commercial needs Class 'B'.
 - And there's a Class C for outdoors!
- Just sticking an MOV across the line may not be enough....

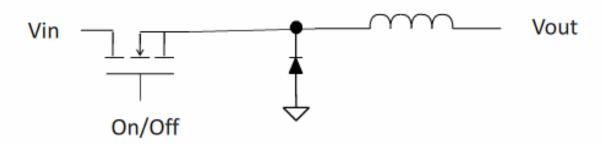


SMPS

SMPS

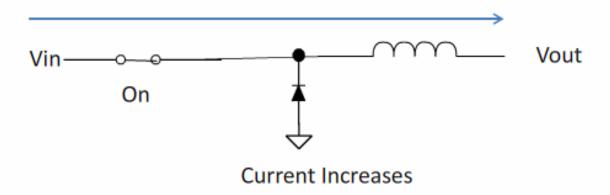
- Most off-line power supplies these days are Switch-Mode Power Supplies.
 - High efficiency.
 - Wide input and output ranges of both current and voltage.
 - BUT can involve complex engineering decisions.
 - And can be costly.
- Two most basic topologies: buck and boost.

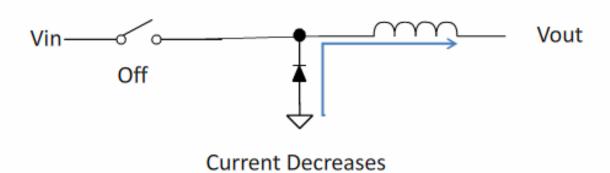
Buck



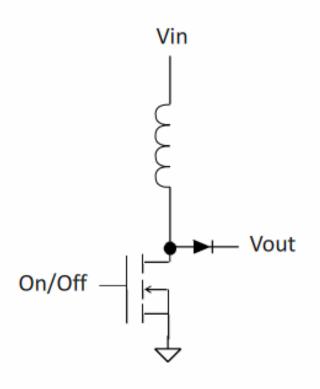
- Buck can only produce output voltage lower than input.
- MOSFET and diode must be rated to take highest input voltage.
- Inductor must be rated to take highest output current.

Buck



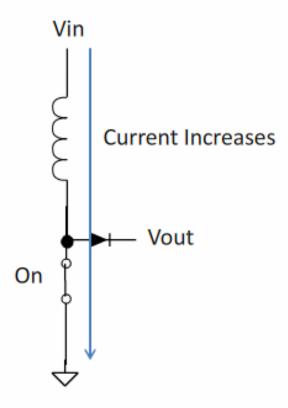


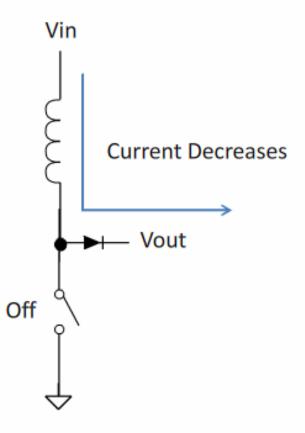
Boost



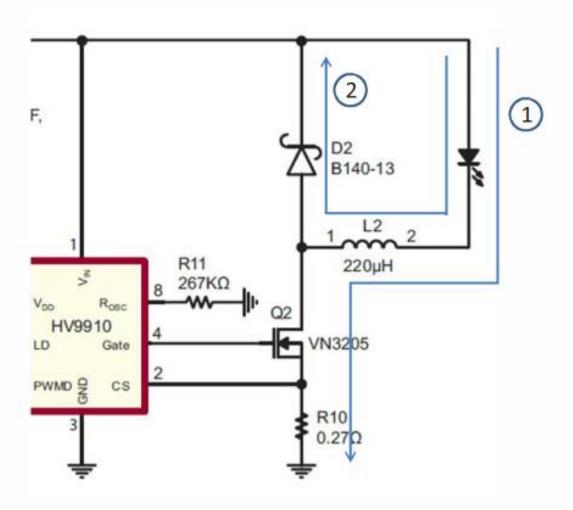
- Boost can only produce output voltage higher than input.
- MOSFET must be rated to take highest input voltage.
- Diode must be rated to take output voltage.
- Inductor must be rated to take highest output current.

Boost

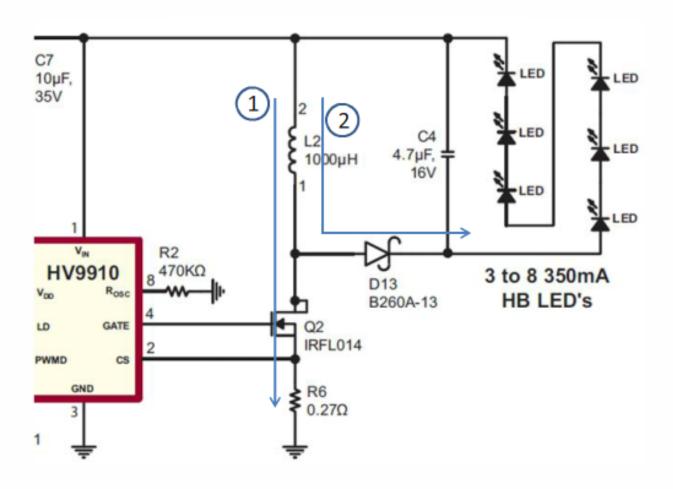




Buck Example

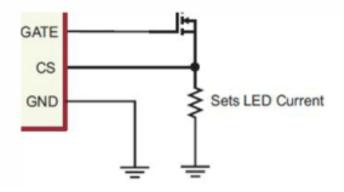


Boost Example

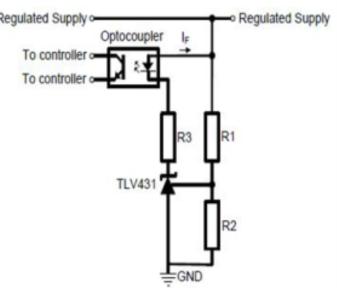


Feedback

 For non-isolated drivers, feedback is straightforward. The peak current is set by the feedback voltage of the IC divided by a resistor value.



- Isolated feedback is much more complicated. Typical construction involves a 431 error amplifier + an optocoupler.
 - Optocouplers age faster than any other component in a driver, and so must be very carefully specified and shielded from high temperature.



COMPONENTS AND PARAMETERS

Switching Frequency

- "Switching frequency" is how often the transistor turns on and off per second.
- Higher switching frequency generally translates to smaller inductors = lower cost for low volume production.
- BUT higher switching frequency makes passing EMI harder, and may translate to larger filters = higher cost.
- Good compromise = ~100-300KHz.

Selecting an IC

- Choose an IC specifically designed for driving LEDs. Some of the things to look for:
 - Should control current, not voltage.
 - Should have a very low feedback voltage, say 100mV.
 - High voltage IC convenient, otherwise need startup circuit.
 - High gate drive current only for high power units;
 may make EMI unnecessarily hard!

MOSFET vs. IGBT

- Almost all LED circuits use MOSFETs. They are available in 600V (for 120VAC) to 1000V (for 277VAC), and a huge range of resistance.
- But, as power / voltage gets higher than ~500W, it pays to consider IGBTs, which are available in even higher voltages.
- Note: For very low power levels, bipolar transistors can sometimes be the cheapest alternative.

Capacitors!

- There have been a LOT of bad LED driver designs because of misuse of electrolytic capacitors.
- Proper use requires attention to
 - Ripple current rating;
 - Lifetime at temperature rating.
- Lifetime increases x2 for each 10° drop.
 - Example: 5000 hrs. at 105° C → 20,000 hrs. at 85° C.

OTHER CONSIDERATIONS

Isolated or Not?

- Essentially all off-line power supplies (for things other than LEDs) are isolated, so users can't be electrocuted (UL, VDE).
- BUT...there are other choices...if the output can't be accessed, isolation is not needed.
 - Many manufacturers are doing non-isolated these days because it's cheaper.
 - Have to work very closely with mechanical engineering.
 - Getting UL involved from the beginning is a very good idea.

Power Dissipation

- Even though drivers are efficient, they still dissipate significant power.
 - Example: 2000 Lm lamp, at 100 LPW needs 20W.
 At 85% efficiency, the driver dissipates 3.5W.
 - Much of this power is in the MOSFET, diode and inductor...relatively small components.
- May need significant heatsinking for the driver.
 - Or thermal isolation from the LEDs.

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PEAK

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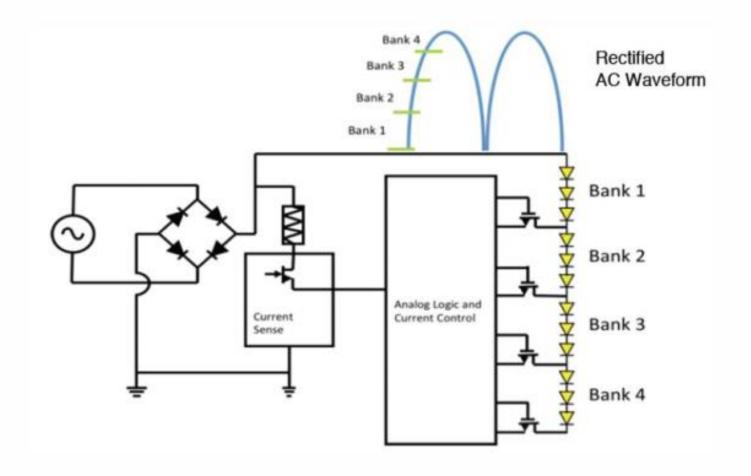
EMI

- Government dictates how much electrical noise your LED driver can put out.
 - Class A for residential, Class B for commercial---not really that much difference practically.
 - Conducted noise can be suppressed with filters...but not making the noise in the first place, using a careful design, is better.
 - Radiated noise depends on careful component placement on the PCB.
- Don't expect to pass the first time.
 Passing EMI can frequently be faster by getting advice from an expert!

"AC LEDs"

- Connect a string of LEDs directly to the output of a bridge.
 - No SMPS cost.
- Common problems:
 - Current goes up exponentially with voltage, high peak currents.
 - Line frequency ripple.
 - Lightning!
- Takes very careful design to make a survivable product.

"AC LEDs"



DIMMING

Why Dim?

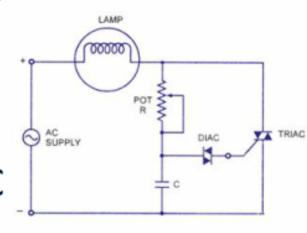
- About 150 million dimmers in US---but this is only 10% of total sockets. Maybe just ignore them?
- All incandescents dim. Np dimming is one of the major frustrations with CFLs.
- People don't have to pay extra to get an incandescent that dims. Therefore, all LED lights should dim, and must have zero pricedifference.

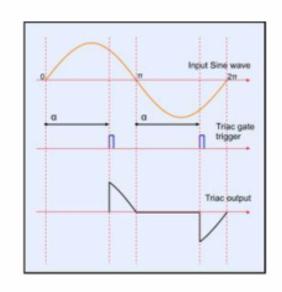
Incandescent Dimming

- Human eyes are non-linear. Fortunately, so are incandescents. An incandescent bulb at halfpower is noticeably dimmer than at full power.
 - The few present-day LED bulbs that dim tend to be linear---they look like "bright, bright, bright, full dim".
- Incandescents change CCT as they dim, from 2800°K down to ~1800°K.
 - The market is just beginning to think about practical ways to do this with LEDs.

Triac Dimming

- Most dimming circuits use triacs.
- Chop off beginning or end of AC line.
- Require minimum current to keep triac on. Problem for LED bulbs!
- Several sophisticated ICs--expensive.





0-10V Dimming

- Some dimming is done with 0-10V (0V off, 10V full brightness).
- Unfortunately, some are 1-10V!
- Easy for LED drivers with an IC that has a linear dimming pin.
- BUT...harder if the 0-10V signal has to be isolated from the AC line.

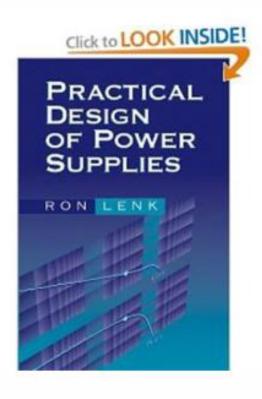
PWM vs. Analog Dimming

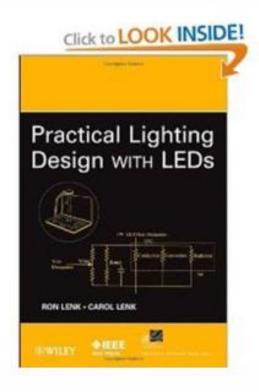
- Analog dimming seems natural. Decreased current = decreased light.
- PWM dimming turns them on and off at full current.
 - Many ICs support this because LEDs tend to have (some) color shift at low currents.
 - But newer LEDs have much less shift. Analog may be a good choice for most applications.
 - Exception: If you need a huge dimming range, may need to use both!

Dimming Problems

- Flicker is the most common LED dimming problem. Line voltage goes to zero every 8.3msec, so unless you store energy, lights turn off every cycle.
 - Low dim is harder than moderate dimming.
- Have to use special techniques to prevent triac from turning off.
 - Easy technique: Throw away power when dimming.

For More Information





For your next lighting project: ron.lenk@reliabulb.com.