Public summary of PhD-thesis of Juan Camilo Castellanos Rodriguez
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Drastic size reduction of LED driver by integration on chip

LED lighting is booming. However, a disadvantage of this technology is that it requires a separate driver unit to convert electrical energy into the right voltages and currents to control the brightness of the LEDs. Researcher Juan Castellanos succeeded in miniaturizing the LED driver components on a single prototype chip measuring only 14 mm^2, for which he explored new LED driver topologies. His driver is not only smaller, but also it can offer simpler and cheaper lighting solutions. Additionally, it enables integration of other electronics, like sensors, to include even more functionality.

LEDs require specialised devices (LED drivers) to regulate their brightness, while the supply voltage must be converted into a suitable LED voltage without waste of energy. The LED lighting market requires efficient, smart and compact LED drivers offering both low cost and long lifetime. These are clear motivations to look for an integrated on-chip solution with a minimum quantity of external components. However, power efficiency can easily be jeopardised when decreasing the size to on-chip dimensions.

This PhD research explored LED driver topologies, called *hybrid switched power converters*, to enable an integrated System-On-Chip (SoC) or System-In-Package (SIP) *LED driver* with: a *compact form factor,* minimum parts count, optimal *power efficiency* and *dimming* capabilities. Two different *LED driver* topologies were fabricated on-chip using 180nm CMOS technology, integrating capacitor, power switches and all the analogue and digital circuitry needed to work. The results materialized a compact on-chip LED driver able to *dim down* and with a 93% *power efficiency*, which is state-of-the-art.

Compared to commercial implementations we managed to decrease radically the size of the inductor, which is one of the critical components in terms of size and cost. To our knowledge, on-chip LED drivers using an inductance value less than 1 microhenry have been not reported before. The resulting inductor is so small that it can even be printed on the circuit board or implemented using off-the-shelf commercial components as small as 0.7mm^2.

Additionally, we implemented a self-resonant concept, where the LED driver is automatically adapted to variations due to parasitic components, tolerance of the components, inductor values and forward voltage variation from the LED load. This was possible without the need of an external intervention or synchronization signal. This concept provided the LED driver with a large versatility regarding manufacturing and component variations while holding its *compact form factor*, *power efficiency* and *dimming* capabilities.

Steps to be taken before the chip can be commercialised include further testing and approval in regulations for LED drivers. Also another module may be required for ac to dc conversion and the integration between LED die and silicon die has to be developed.

Title of PhD-thesis: HYBRID SWITCHED CONVERTERS FOR CMOS INTEGRATED LED DRIVERS. Promotor: Eugenio Cantatore, TU/e. Other main parties involved: Philips Lighting and NWO