OLED Integration and Manufacturing Challenges

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OLED and LED

- Compares
  - Solid state components
  - Electrically modelled as diodes
  - Convert electrical power to light
  - Low voltage DC power
- Contrasts
  - OLED emits light over broad surface; LED is a point source
  - OLED light spectrum closer to sunlight
    - Inorganic - LED uses blue source and phosphors to create white light
    - Organic - OLED do not require phosphors – OLEDs create white light by mixing primaries
  - Forward current and voltage
    - Typical LED < 6 VDC @ 350 mA; OLED <24 VDC @ 215 mA
    - LED’s specifications standardized on 350 mA, 700 mA, 1000 mA, and 1400 mA

Infrastructure and support

- LED industry is well established
  - Specifications standardized forward currents on 350 mA, 700 mA, 1000 mA and 1400 mA
  - Numerous competitive suppliers
  - Performance and cost are mature and are becoming commodities
  - Mature technology; established standards
    - IES
      - LM-79-08 Electrical and Photometric Measurements of Solid State lighting
      - LM-80-08 Measuring Lumen Maintenance of LED Light Sources
      - TM-21-11 Projecting Long Term Lumen Maintenance of LED Light Sources
    - SAE
      - ARP5873 LED Passenger Reading Light
      - ARP6253 LEDs and Aircraft Applications
      - ARP6259 LED Replacement for incandescent and fluorescent lamps
- OLED still the wild west
  - Few suppliers
  - No standards
  - Performance still improving and costs high

The promise of OLED Technology

- Why pursue OLED?
- Homogenous light output across entire surface
- Low profile; panels ≤ 2mm thick
- Mirrored and transparent versions
- Flexible versions
- The future possibilities
  - OLED as paint

OLED System cost is the dominant barrier to adoption

- OLED System (and cost basis) consists of:
  - OLED Panel
  - Driver
  - Mounting bracketry
- Acquisition cost much higher than LED
- Operating cost – higher than LED
- Replacement cost – shorter life and higher lumen depreciation
- Result – OLED applications tend to be niche applications that are not price sensitive

Cost comparison

Component	OLED	LED
OLED Panel Light Source (200 lumens)	$30-$35	
Electronics Drivers (8 Watts)	$15.00-$20.00	
Mounting bracketry	$5.00	
*7 watt, A19 LED Lamp (with integrated electronics)		$2.95
Total	~$50	$2.95

*Source: https://www.superiorlighting.com/

Note: The LED bulb requires a fixture whereas the OLED could be a stand alone light source

LED and OLED; Low voltage power -> Installation Flexibility

- OLED Panels are low voltage devices, and therefore lend themselves to open power distribution networks (≤48 VDC)
- Low voltage distribution networks do not require licensed electricians for routing or connecting to light sources
- Low voltage distribution networks are easily reconfigurable
    - Easily change wiring and light source location in a room

WPE – Wall Plug Efficiency

Illuminator	Light source	LUMENS	OLED Panel input power (w)	*System Electrical input power (W)	Light source efficacy (lm/W)	Power Supply efficiency
LED	90+ LIGHTING : SE-350.034	250		5	70	
OLED	OLEDWorks Brite 3	300	4.02	4.73	63	85%
OLED	OLEDWorks Brite 3	300	4.02	4.37	68.6	92%

*Assumes an OLED driver efficiencies of 85% and 92%

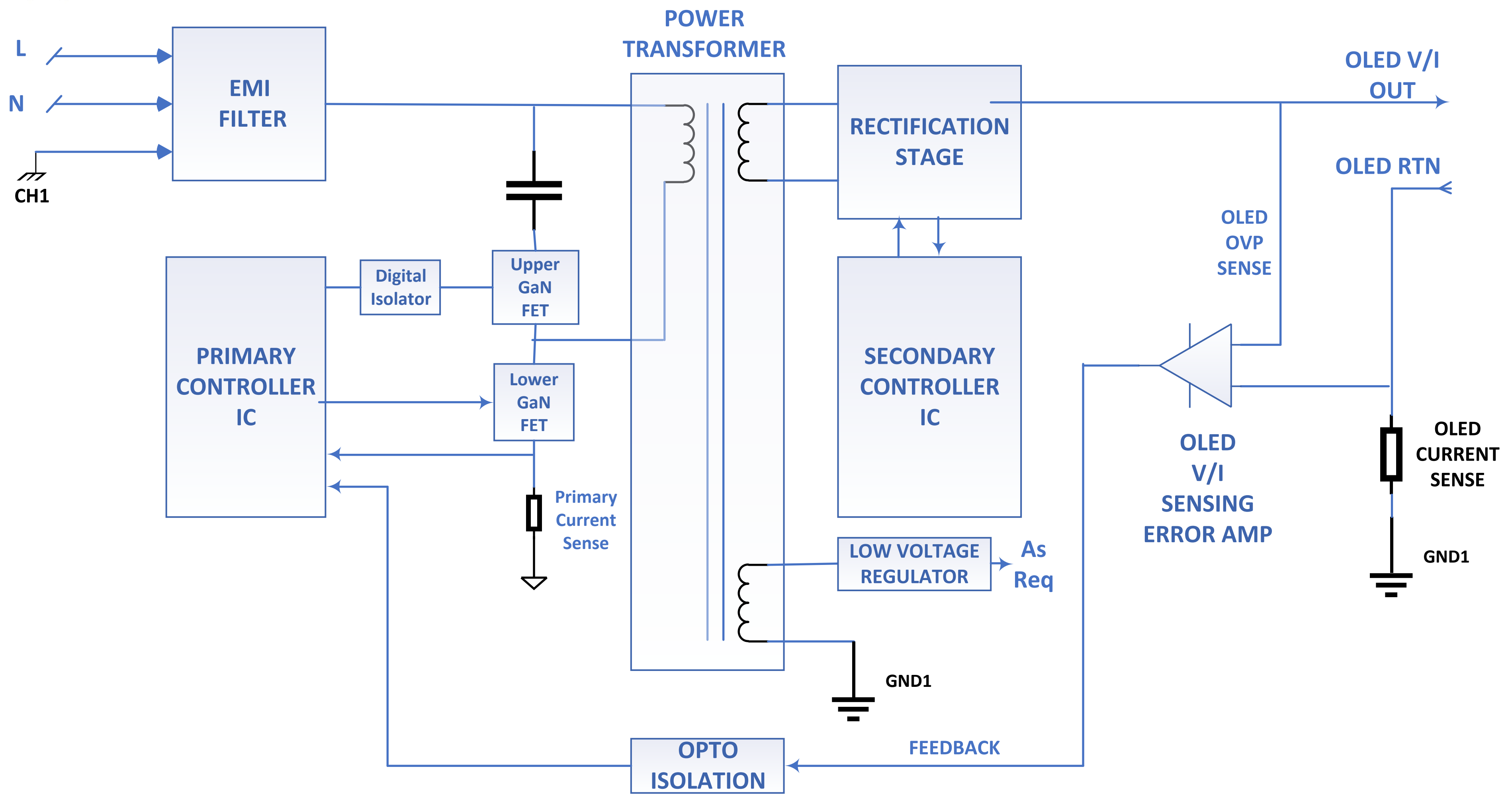
Benefits of an High Efficiency OLED Driver

Some of the benefits of increasing the efficiency of OLED driver circuit

- Reduce the total cost of ownership of OLED fixtures and propagate their use in the lighting market place
- Reduces overall energy consumption and commensurately pollution and greenhouse gasses.
- Advances the state of the art in OLED Drivers by applying new techniques and technologies in low power line voltage applications

LED Specialists DOE Project

- Advance the state of the art in OLED driver technology
- Increase typical 8W driver efficiency from current 85% to over 90%
- Approach
  - Select most efficient topology for 8 Watt design – Active Clamp Flyback
  - Address highest loss areas and minimize
    - Magnetics (reduce leakage inductance – selection of core materials)
    - FET and diode switches;
      - use wide bandgap technologies
      - Use synchronous rectification
    - Linear regulators; employ Low Dropout regulators



Active Clamp Flyback - OLED High Efficiency Driver Block Diagram

Wide bandgap (WBG) electronic switches

- The efficiency of the power switches can be increased through the use of wide Bandgap materials such as Gallium –Nitride (GaN) transistors
- Wide bandgap (WBG) semiconductor materials allow power electronic components to be smaller, faster, more reliable, and more efficient than their silicon (Si)-based counterparts
- Eliminates up to 90% of the power losses that currently occur during AC-to-DC and DC-to-AC electricity conversion
- Higher-temperature operation: Operates at temperatures over 300°C (twice the maximum temperature of Si-based devices). This tolerance for higher operating temperature results in better overall system reliability, enables smaller and lighter systems with reduced lifecycle energy use, and creates opportunities for new applications

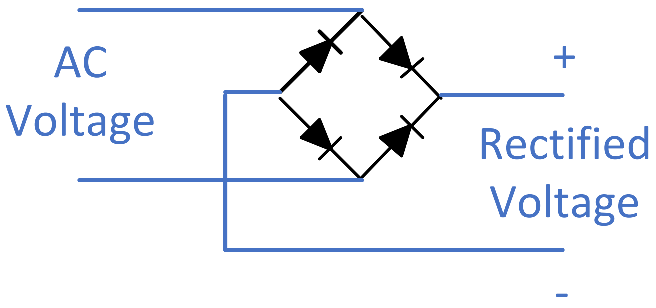
Source: Department of Energy Advanced Manufacturing Office: Wide Bandgap Semiconductors: Pursuing the Promise.

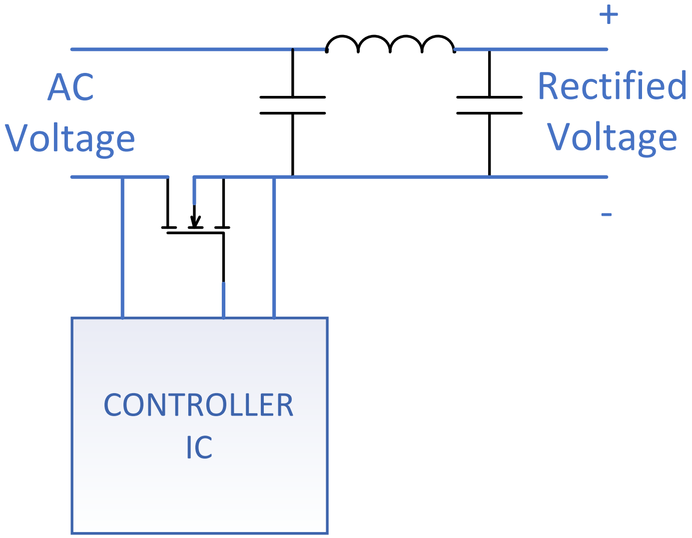
Magnetics

The transformer is one of the most critical components in the design

- Provides safety (galvanic) isolation between line voltage input and the output
- Contains multiple secondary windings to optimize operational voltages for each section of the driver
- High efficiency is driven by low interwinding capacitance and low leakage inductance
- Design approach
    - Optimize selection of transformer configuration and core materials

Rectification Stage





Traditional Full Wave Diode Rectifier

- Simple, but less efficient

Synchronous (Active) Rectifier

- More complicated, but very efficient

Low Voltage Regulator

LOW VOLTAGE REGULATOR

Produces supply voltages (Vcc) required for driver operational ICs

- LDO Low drop-out operation minimizes wasted head-room voltage
- Multiple transformer windings may be used to feed multiple sections, as required
- Downstream operational IC's are selected for low quiescent operation to minimize overall power dissipation

Summary

LED Specialists is in the process of designing, prototyping and debugging a high efficiency (>90%) OLED driver circuit in the 5-8 Watt range utilizing many of the features identified in this presentation

- Reconcile actual results with theoretical and analytical values
- Identify trade-off decisions made in the design and component selection criteria – if things don't go exactly to plan
- Identify cost drivers for a future cost reduction initiative

Program Logistics

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