Accelerated Life Testing Results for SSL Luminaire Electronics

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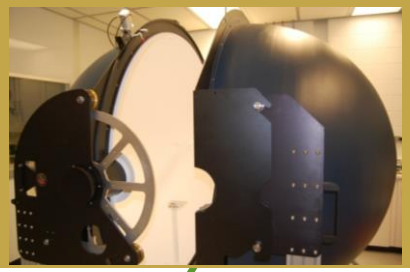
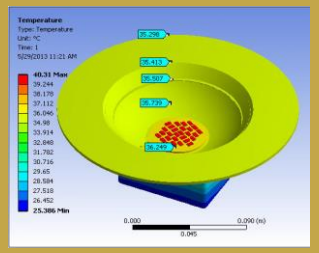
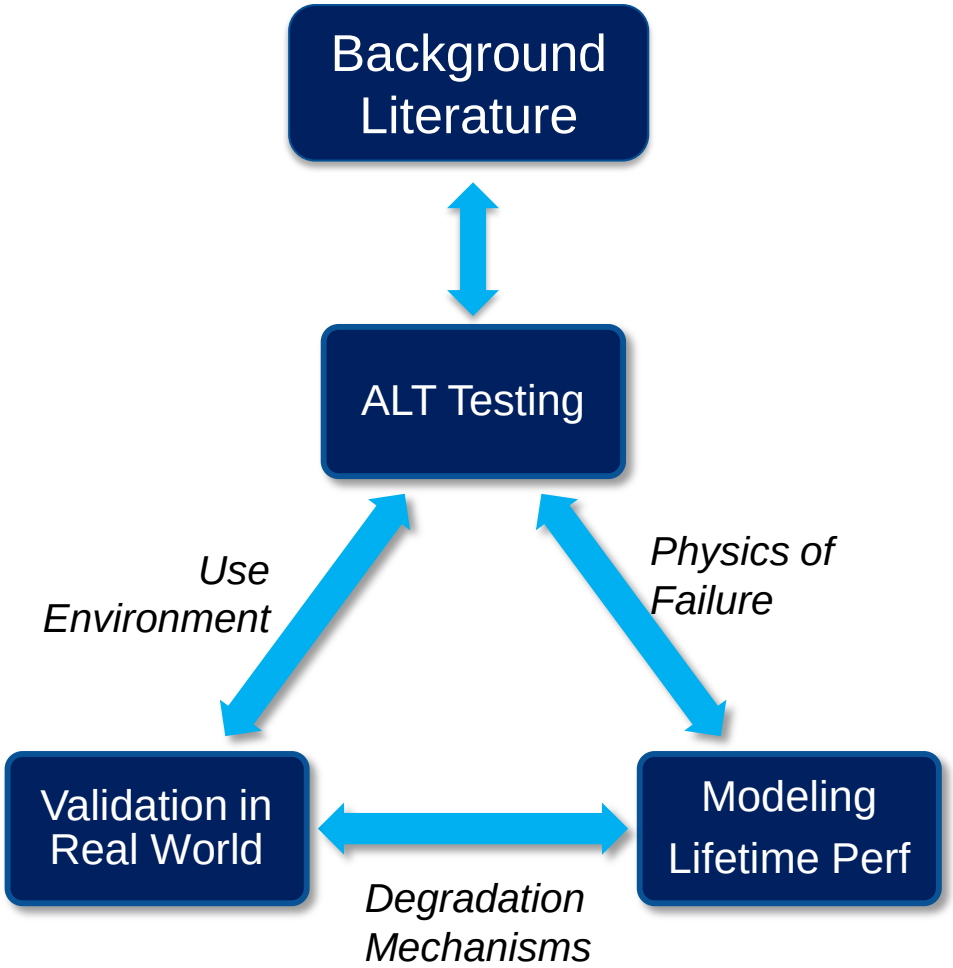


Approach

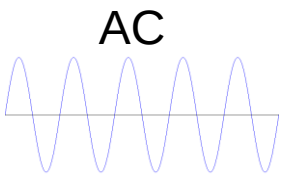
A**ccelerated life tests (ALT)** and **modeling** of both entire luminaires and key system components such as LEDs, drivers, and optical elements



6” downlights have been chosen as representative luminaires because they combine several desirable attributes:

- Low cost & readily available
- Multi-generational products
- Incorporate many design features
  - HBLEDs, mid-power, and hybrid LEDs
  - Different driver typologies

Generalized LED Driver



Filter and Condition

Components
Fuse
Capacitors
Inductors

Rectify

Components
Diode Bridge
Capacitors
Resistors
Diodes

Shaping and PFC

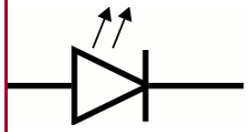
Components
Control IC
Capacitors
Inductors
Resistors

Switched Mode Control

Components
Control IC
MOSFET
Inductor
Capacitor
Diodes

Final Filtering

Components
Electrolytics
Film Caps
Inductors
Transformer
Opto-Isolator



Common Driver Typologies

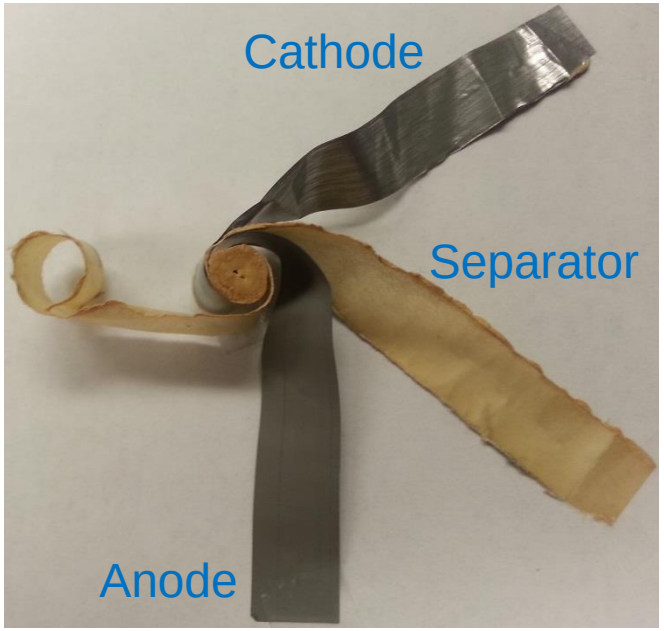
Boost
Voltage Step-up
Used with COB Arrays

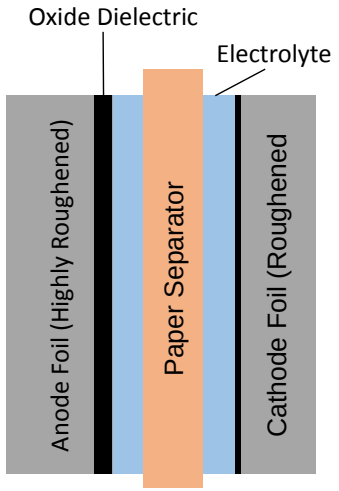
Flyback
Buck-Boost Converter
Electrical Isolation
Various LEDs

Buck
Voltage Step-Down
Used with HBLEDs

Electrolytic Capacitors

- Electrolytic capacitors offer high capacitance per volume ratio. Capacitance values > mF common.
- Electrolytic capacitor failure is often easy to spot, so they are often cited as a source of failure in SSL drivers.
- Failure modes
  - Degradation or loss of electrolyte
  - Increase in ESR leads to more heating and ultimately bulging & venting
  - Electrolytic capacitors are highly sensitive to in-rush currents.
  - ESR generally decreases with cap diameter



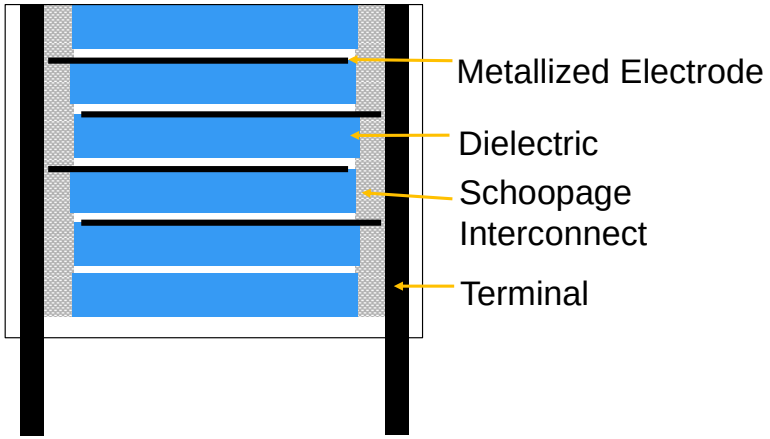


Electrolytic Capacitors, continued.

- Common failure models for electrolytic reliability include
  - Voltage stress (V_{op}/V_{rated})
  - Temperature
- Driver manufacturers are aware of the limitations of electrolytic capacitors and take appropriate actions
  - Derating of T & V (often 2X or more)
  - High quality caps (105 C rating min.)
  - Use in low voltage and/or low ripple circuits. Use film caps where possible.
  - Avoid placement near heat sources on either side of the board.

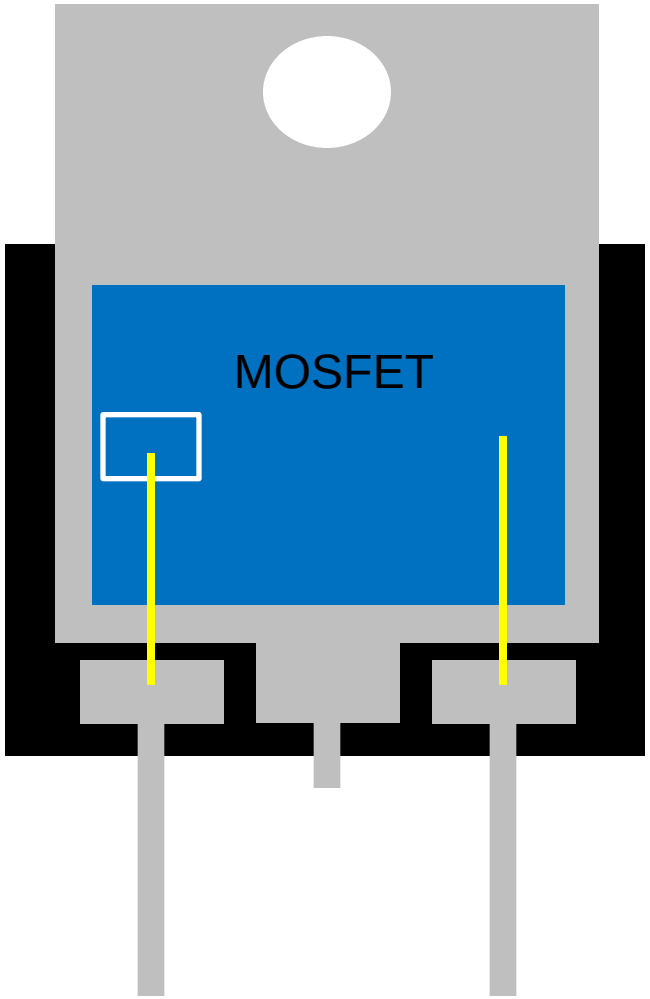
Film Capacitors

- Offer high storage capacity per unit area. Difficult to achieve very high capacitances (>10s μF). Increased use throughout in lower power (< 100 W) drivers.
- Often viewed as more reliability and more robust than electrolytics.
- Can handle surges and ripple well due to “self-healing” properties.
- “Self-healing” mechanism actually drops capacitance and raises ESR. Failure rate depends on dielectric thickness.

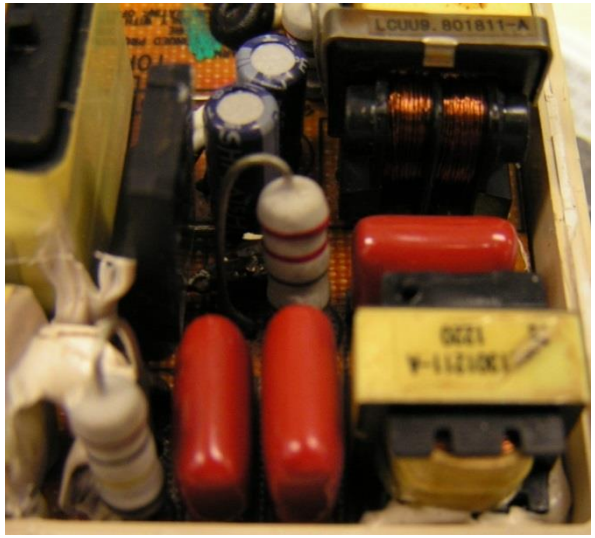


MOSFETs

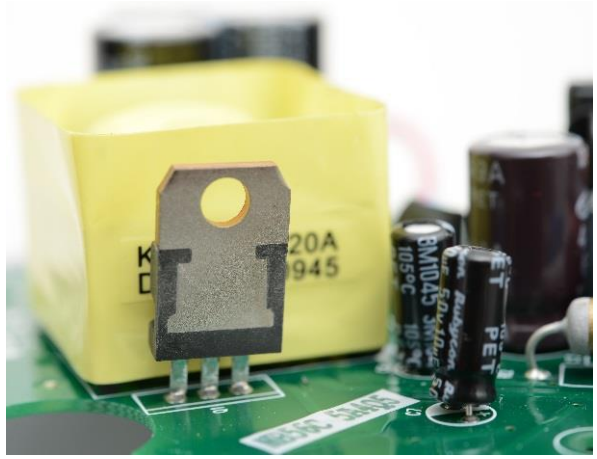
- Significant amount of variation in practices among manufacturers
  - Type of MOSFET package
  - Other heat sources nearby
- In our testing, MOSFET failure is a leading cause of device failure and has been observed to fail as quickly as 250 hours.
- Junction temperature is known to be a leading cause of MOSFET failure.
  - T_j depends on current to junction & heat conducted away ($R\Theta_{jc}$ & $R\Theta_{ca}$)



Addition Insights in MOSFETs



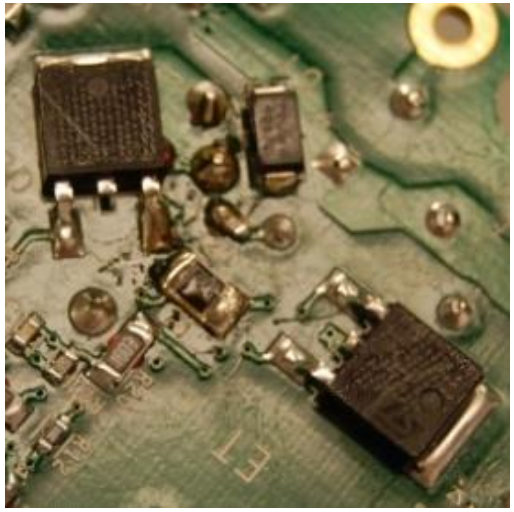
TO-220FP Θ_{jc} = 5 K/W



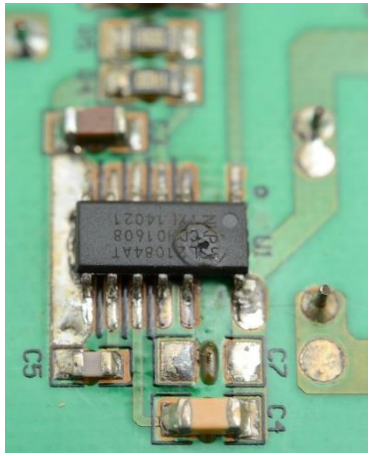
TO-220 Θ_{jc} = 1-2 K/W

Junction Temperature depends on

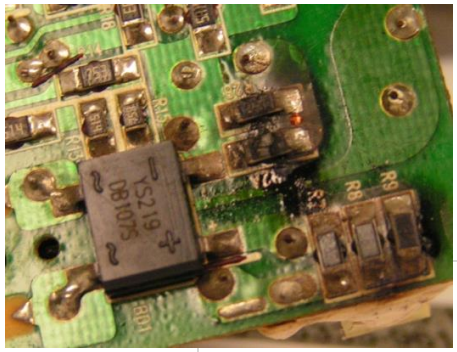
- Input power
- Heat removal
  - Junction to case
  - Case to ambient



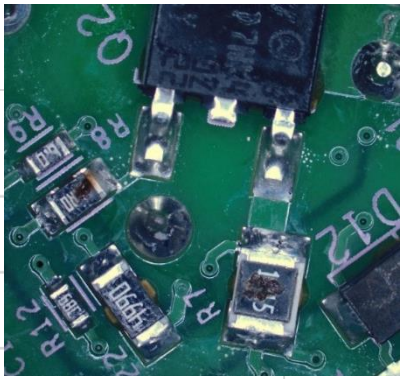
DPAK $R\Theta_{jc}$ = 1-2 K/W



DIP Θ_{jc} = 3-5 K/W



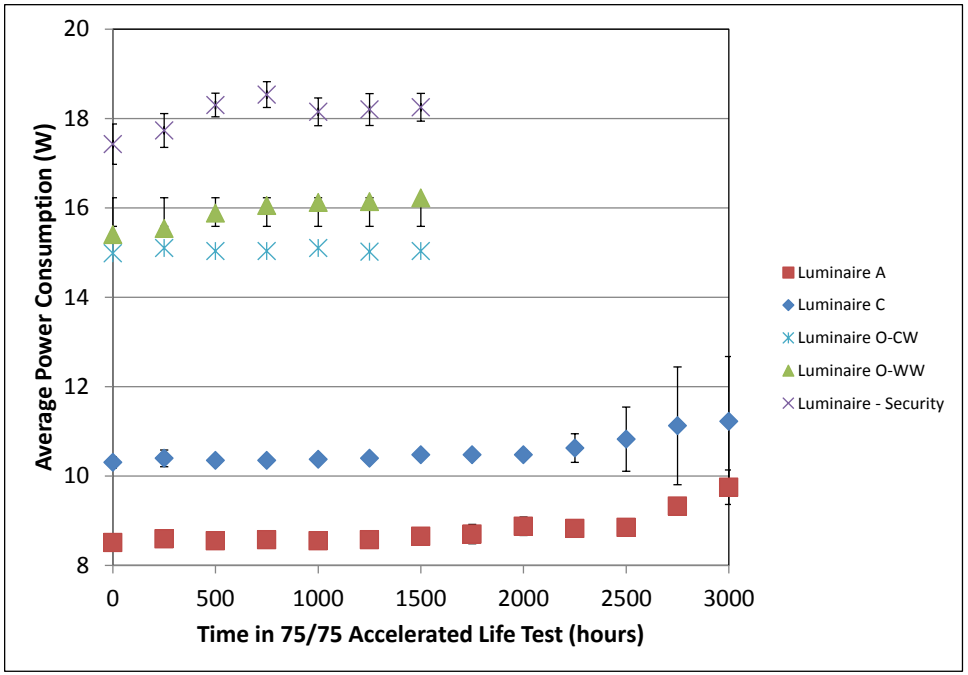
Other Components Can Fail as Well



Some failures are obvious, others are not

Effect of 75/75 Aging on Luminaire Power Consumption

- In general, luminaire power consumption tends to increase with time in 75/75.
  - Luminaires will consume more power as they age and efficiency will suffer.
- Some luminaires show the increase right at the beginning. Others stay flat for a period of time and then start to increase.
- Power factor also starts to increase with time. But at failure, power factor can drop significantly.



Conclusions

- Any electronic component can fail either due to overstress (temperature or voltage) or manufacturing defects.
- Some driver components leave visible evidence of failure. While others are more stealthy. It is easy to jump to a conclusion on cause of failure.
- Full failure analysis is required to understand the cause of failure, especially in multi-component failure cascades.

Acknowledgements

- This material is based upon work supported by the Department of Energy under Award Number DE-EE0005124.

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