



# Manufacturing LED Lighting Products Employing FDM 3D Printing Technology

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# About Tempo

- Founded in 1986
- Headquartered in Irvine, CA
- Harnessing the benefits of LED technology for lighting solutions since 1997
- Vertically integrated-design to manufacture
- Made-to-order operation
- Offer high configurability on most products

DOE SSL R&D Workshop Jan 28-30, 2020

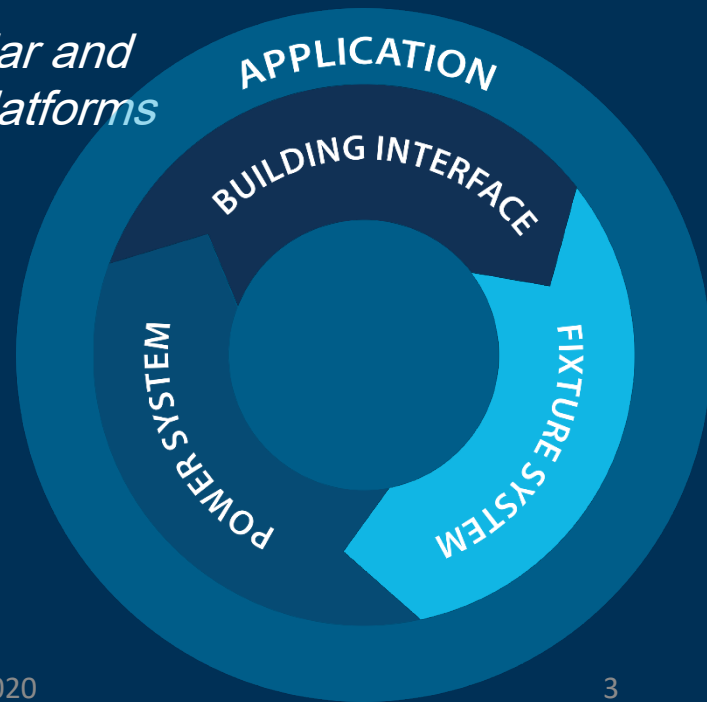


## Competitive Advantage - Design

### CLiP<sup>®</sup> – Configurable Lighting Platform

*Design philosophy of developing modular and interchangeable components across product platforms*

- Configurable NOT Custom
- Enables application specific requirements without custom solutions
- High commonality yields better inventory management
- Micro-maintainable modules for true sustainability





## Rapid Prototyping → Additive Manufacturing

- Concept developed-1980
- Chuck Hull invents SLA-1983
- Commercial SLS machines-1992
- Mid-2000's broad emergence in industry



Image courtesy of <https://3dinsider.com/3d-printing-history/>



## Why Additive Manufacturing for Lighting Products

- Enable more product performance options
- Unique designs
- Reduce parts count=lower assembly complexity and cost
- Ease of product lifecycle management (more change, shorter)
- Change in component lifecycle cost

# What about cost?

## New Cost

- Machine expense
- Post processing equipment
- Service package for machine
- Material cost
- Facilities cost

## Eliminate Cost

- Tooling
- Tooling modifications
- Expedited freight for 1<sup>st</sup> articles
- Cycle counting/inventory
- Phase in/phase out issues
- End of life scrap inventory

*AM requires a lifecycle cost perspective*



# AM Technologies

- Plastic/Composites (FDM, SLA, DLP, SLS, PolyJet, etc)
- Metal (melt or sinter technologies)
- Electronics





## State-of-the-Art Production 3D FDM Printing





# Uses of 3D Printed Parts

- Engineering “first of a kind” assemblies for testing
- Sales mockup/Customer validation
- Pilot production
- Low volume, high mix components
- Custom parts for specifics jobs
- Manufacturing aids



# Types of Parts Manufactured by FDM

- Baffles
- Optics holders
- Mechanical accessories
- Jigs for manufacturing
- Low voltage splice boxes



# Benefits

- Make samples for testing beyond mechanical design validation
- Customer validation samples, mock-ups
- Pilot production while tooling is fabricated
- Job specific components
- “Temporary parts”
- Digital Inventory; zero obsolesce and scrap cost

# Design

## Opportunities

- Part Thickness
- No draft angles required.
- No fillets or radii required.
- Undercuts permissible.

## Challenges

- 3D printed design and tooled design not exactly the same
- Size of part (small features)
- Snap features
- Texture and finish
- Materials selection (UL)
- UV stability



## pr1meFX™

US Patent 9,841,153

US Patent Pending



## C6 Series

US Patent 9,458,995

US Patent 9,803,807



## House Lighting System(HLS)

US Patent 9,596,740

European Patent 2993386



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## Customer MockUp

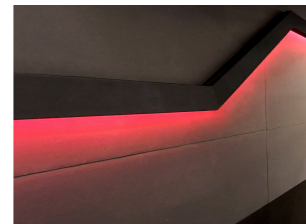


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PROJECT: \_\_\_\_\_  
TYPE: \_\_\_\_\_

### Soft Graze

WALL MOUNT LINEAR LED ACCENT LIGHTING



#### APPLICATION

The Soft Graze is a low voltage linear LED lighting system for theatres that provides a soft graze of light on acoustic wall panels. PVC construction is ready for fabric application to match acoustic panels or use contrasting fabric color for a stripe affect. Mix and match straight or angled runs to create unique lighting affects.

#### HOUSING CONSTRUCTION

- Extruded black PVC mounting bracket and cover can be field cut for precise installation.
- Sold in 8 foot sections only.
- Miter cut to length in field and to create angles.
- Matching End Caps available.

#### LINEAR SC3R LED CONSTRUCTION

- 12" linear modules
- Designed with lightweight polymeric components.
- Lightly frosted acrylic lens/diffuser.
- Quick wire connect system (no cutting, stripping, crimping required)
- Dense pack LED spacing for uniform illumination.

#### POWER SYSTEM

- Utilizes remote, Class II low-voltage 24VDC power supply.
- Power supply Total Harmonic Distortion <20%, Power Factor >0.9

#### PERFORMANCE

- 2 watts per foot - static colors
- 6 watts per foot - RGB color changing
- 2 circuit design allows for longer runs.
- Triac dimming to 1% DMX/RDM dimming to 1% 0-10V dimming to under 10%
- Operating temperature range of -20°C to 50°C
- Expected life (L85) 86,000+ hours of operation

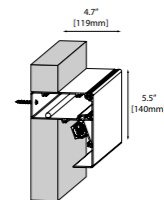
#### LIGHT CHARACTERISTICS

- Available in static Red, Green, Blue and Amber.
- Consult factory for custom LED colors
- RGB color changing also available

#### MAXIMUM RUN LENGTHS\* (2 CIRCUIT)

24V Driver	Watts/ft	Max Distance*
100W	2.0	100ft
60W	2.0	60ft
40W	2.0	40ft

\* Distance shown is for 2W/ft white and static colors.



**WARRANTY**  
Tempo provides a 5-year limited warranty.

**86,000 HOURS**  
**L85 LUMEN MAINTENANCE**  
LED Luminaires will reach 85% of initial lumen output at or beyond 86,000 hours at 25°C.

**MADE IN USA**  
ORIGINALLY IMPORTED COMPONENTS





# High-Mix, Low-Volume Production

- 21 different types of baffles
- Average about 110 parts/mn
- Runtime of 5-12 hrs/part
- Average about 500 other parts/mn
- Runtime of 0.5-3 hrs/part

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## HLS Cross-Aisle, Stairs & Landing

SURFACE MOUNT, 2-CIRCUIT  
REMOTE POWER SUPPLY

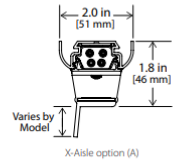


### APPLICATION

This revolutionary lighting system reduces or removes safety lighting products and wiring from the heavily trafficked floor environment. An extension of the multi functional House Lighting System (HLS) that delivers a targeted, narrow beam of illumination designed for cross aisles, stairs, walkways and landings. Precision optics paired with collimating slot micro-baffles and/or shields create a confined pathway of light with no visible source reference.

The Cross-Aisle/Stair option (Attribute A) utilizes a 4ft wide beam spread that can be installed in succession to provide continuous, even light along cross-aisles or stairs. The Landing option (Attribute B) utilizes a 3ft x 5ft or 3ft x 3ft beam pattern that provides a targeted block of illumination for landings.

Surface mounted with exclusive T-Bar ceiling mount clips allows for straight or curved illumination patterns. Tempo will assist in selecting the ideal optical configuration for your application based on layout and ceiling height.



Varies by Model

X-Aisle option (A)

### CONSTRUCTION

- Extruded aluminum channel
- Thermally optimized die-cast aluminum heat sink
- Plug and play connectors for simplified installation
- CSA damp location listed

### OPTICS / LENS / DIFFUSER

- Precision optics paired with a collimating slot and micro-baffles configured for the mounting height
- Side shield provides complete light block designed for auditorium applications

### POWER SYSTEM

- Utilizes a remote, low voltage DC power supply (24V, 120V input)
- Triac dimming (100-1%)

### PERFORMANCE

- Light output varies by configuration

### LIGHT CHARACTERISTICS

- Available in 2200K, 2700K, 3000K, 3500K, 4000K correlated color temperature. Static colors (i.e. Red & Blue) also available, consult factory for additional color options.
- Typical CRI of 80+
- Color variations confined to a 2-step MacAdam ellipse

### WARRANTY

Tempo provides a 5-year limited warranty. A 10-year warranty will apply when installed by a Tempo Certified Installer.



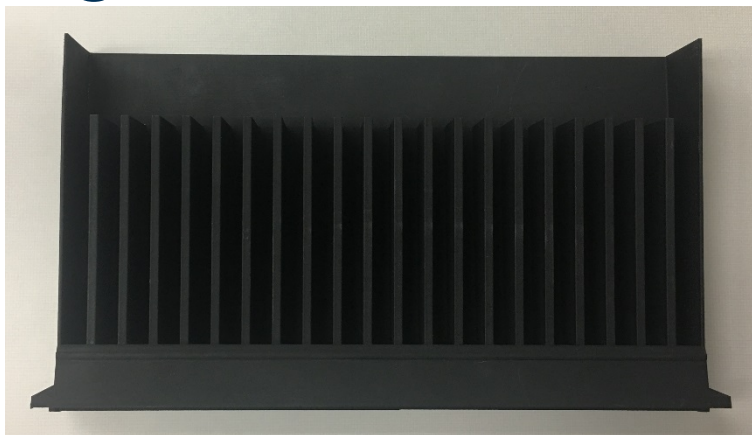
### PERFORMANCE SUMMARY

Attribute	Type	Application	Watts/Module
A	E	Cross Aisle/Stairs with nominal 4ft beam width at 10ft to 45ft height	~12 W
B	F	Landing with 3ft x 5ft beam pattern at 10ft to 35ft height	~12 W
B	G	Landing with 3ft x 3ft beam pattern at 25ft to 35ft height	~12 W



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## Light Baffles



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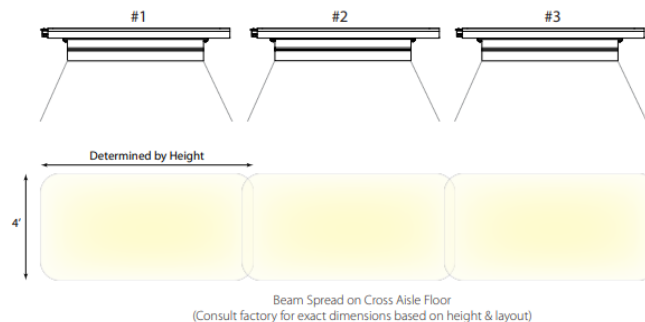
### HLS Cross-Aisle, Stairs & Landing Lighting

SURFACE MOUNT, 2-CIRCUIT

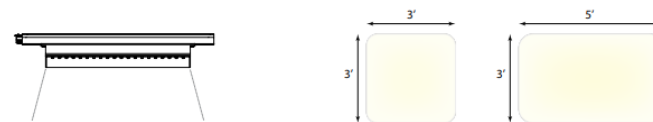
REMOTE POWER SUPPLY

#### SAMPLE CONFIGURATIONS

CROSS-AISLE/STAIRS BEAM SPREAD (Attribute A) shown with three modules



LANDING BEAM SPREAD (Attribute B)





## Operations- Overall Equipment Effectiveness

- Availability >98+%
- Quality (Yield) >95+%
- Performance - 30-85%; mainly effected by parts demand



# Operations– Impacts on OEE

- Filament feeding
- Cross-spooled containers
- Canister switch over
- Support material removal
- Solution tank-fluid changes, messy
- Loss of building power

