LM-80 Best Practices



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www.vektrex.com

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LM-80 Best Practices Agenda

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Top 2 Success Factors	3
1. High Quality, Reliable System	5
2. Process/Proficiency	13
3. Performance Load Board	25
4. Control LED Testing Temperature	35
5. Optimize Light Measurement For Repeatability	43

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LM-80 Test Success – Top 2 Success Factors

1. High Quality, Reliable System

- Meets LM-80 Requirement
- Pass Audit

2. Process/Proficiency

- Pass Audit

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Success Key #1 – High Quality, Reliable System



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Example: SpikeSafe Based Test Systems

- Highly accurate drive current 0.2% typical
- STARS – SpikeSafe Test and Reliability Software Application
- Automatic current, voltage, temperature monitoring
- SpikeSafe protection ensure LEDs are not damaged by power loss, DUT failures, leakage
- Synchronization with oven to avoid overstress

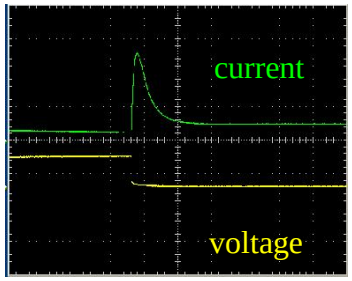


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SpikeSafe Rapid Shutdown Limits Current Spikes When Shorts/Opens Occur In Series Strings

Generation 1 (bulk power supplies)

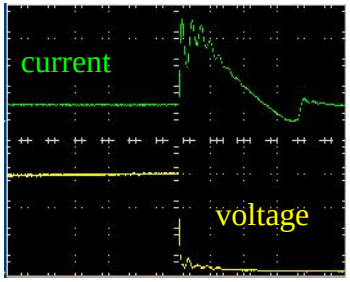
- **Typical Constant voltage sources run in constant current mode**



Current is green
See 2mS spike duration
1000% over current
All devices destroyed

Generation 2

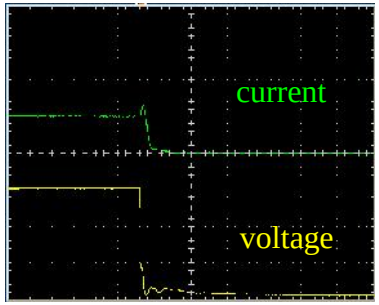
- **Low capacitance constant current sources**



400uS spike duration
400% over current
All devices destroyed

Generation 3 (SpikeSafe)

- **SpikeSafe; Digitally- controlled current sources with fast protection**



10uS spike duration
30% over current
One device failure

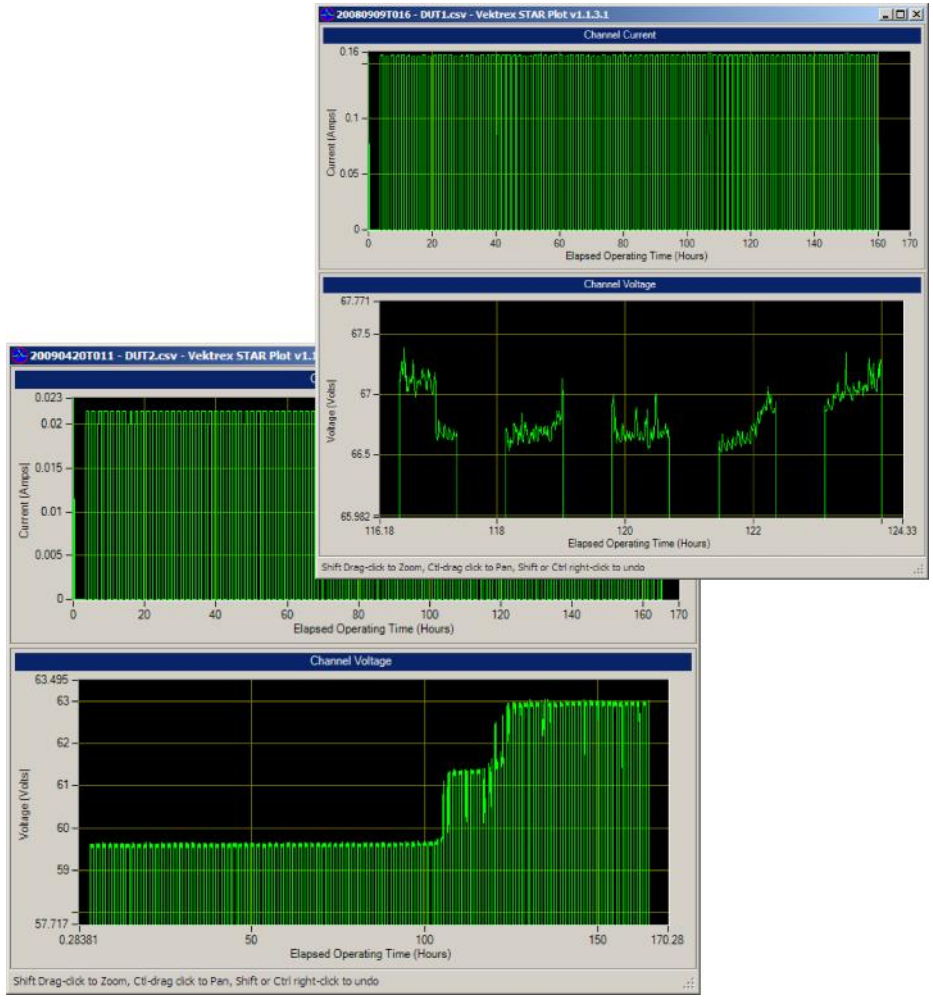
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SpikeSafe dV/dt Monitoring Can Detect Abnormal LED Vf Changes

- **Shuts down if dV greater than threshold in detection time (50mS to 1.5S)**

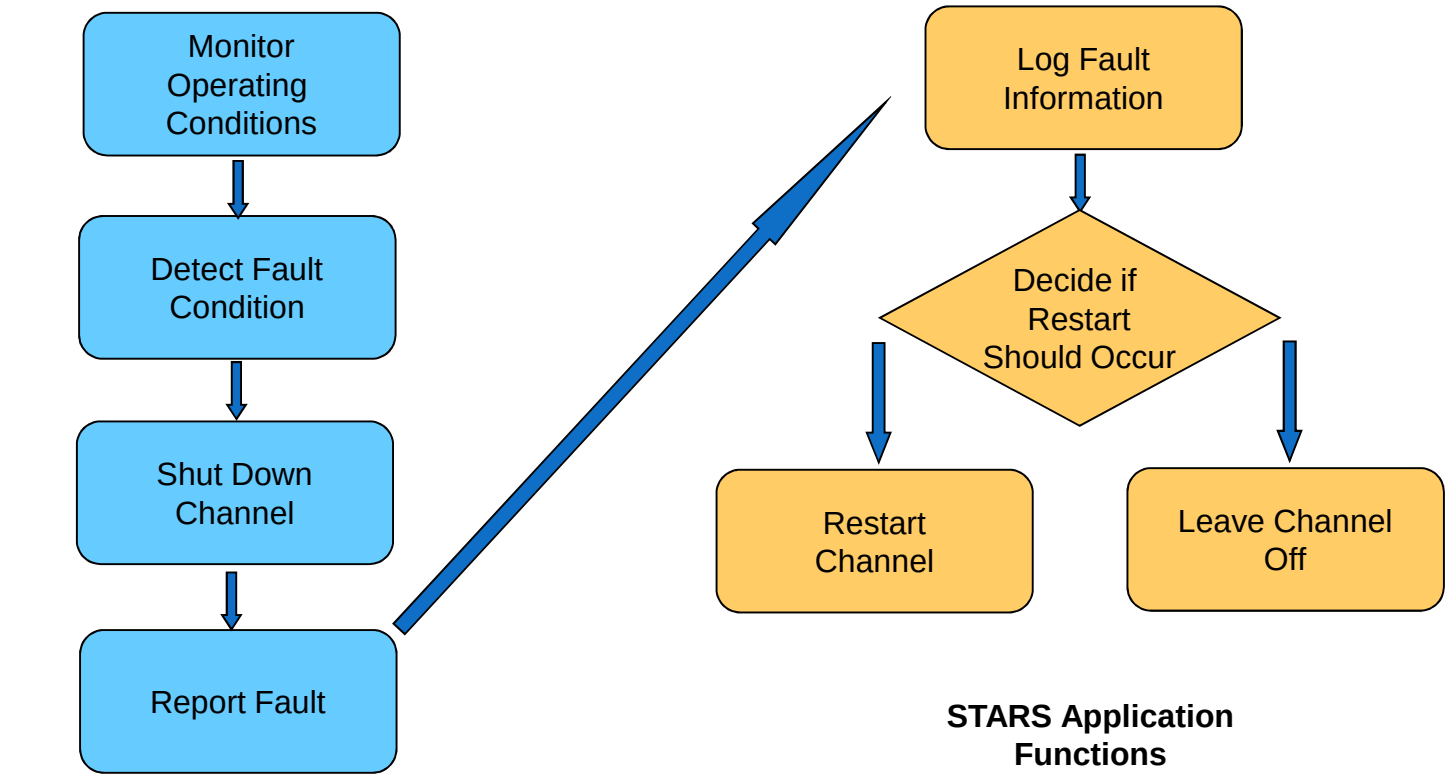
Detects:

- **LED array current path changes**
- **Connector contact issues**
- **Some rapid Tj changes**



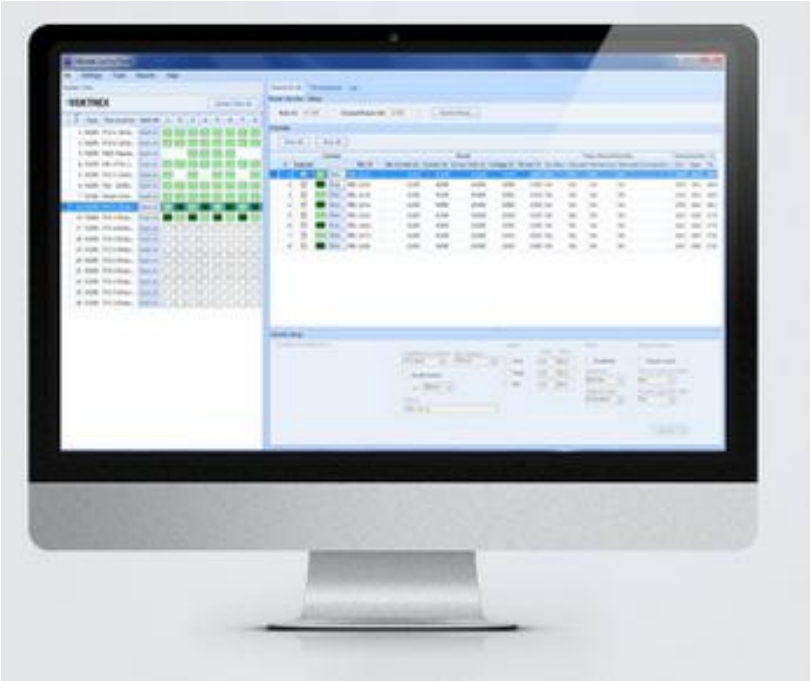
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SpikeSafe Fault Handling



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Ensure Monitoring/Control Software is Ready For Long Term



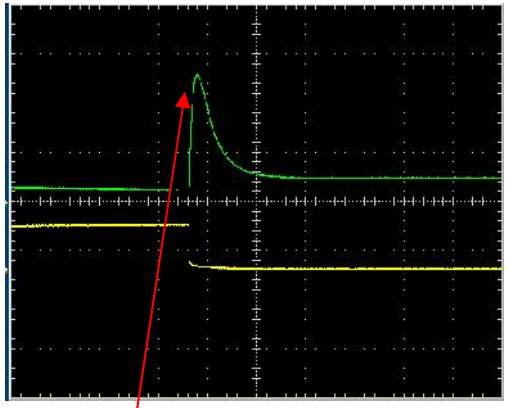
Vektrex STARS Application

- Continuous monitoring of voltage & temperatures
- Automatic shutdown if over temperature
- Clean handling of power outage
- Proven application, designed for long duration testing
- Software uncertainty timing report

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Summary: High Quality, Most Reliable System

- Use high quality current sources with spike protection
- Set up safety systems to prevent thermal overstress conditions that can damage LEDs
- Make sure all equipment has traceable calibration, ideally to ISO 17025
- Design fail-safes into system to protect data and load boards in the event of a power failure
- Choose modular systems that are upgradeable



13X Current Spike from unprotected current source

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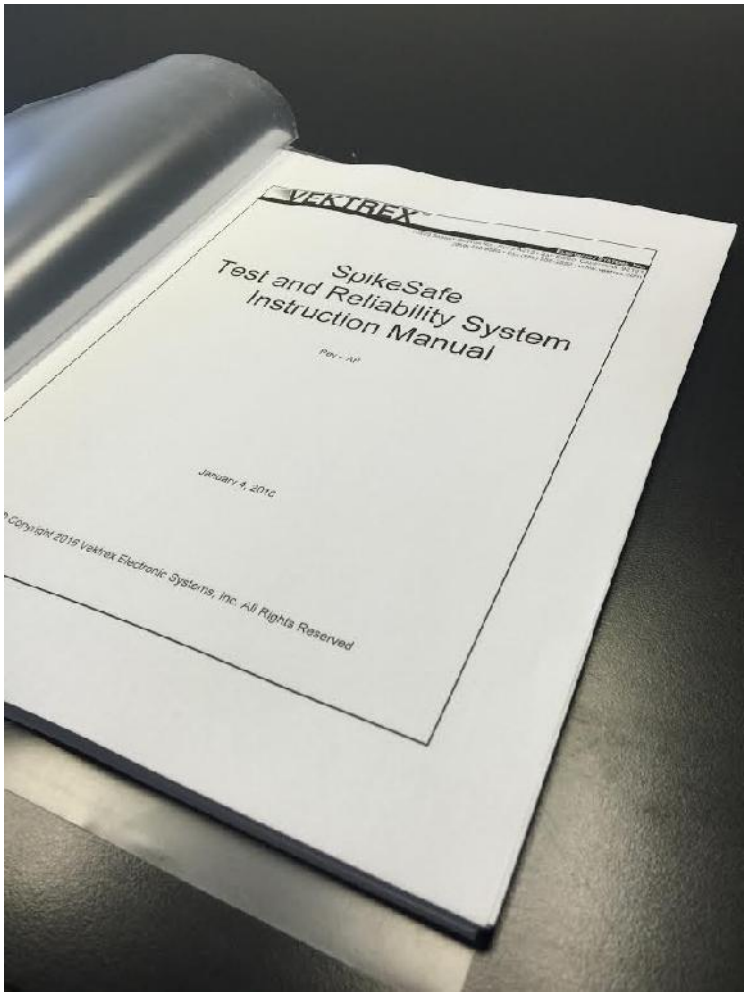
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Success Key #2 – Follow a Careful Process During Testing



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Set Up And Certify Equipment

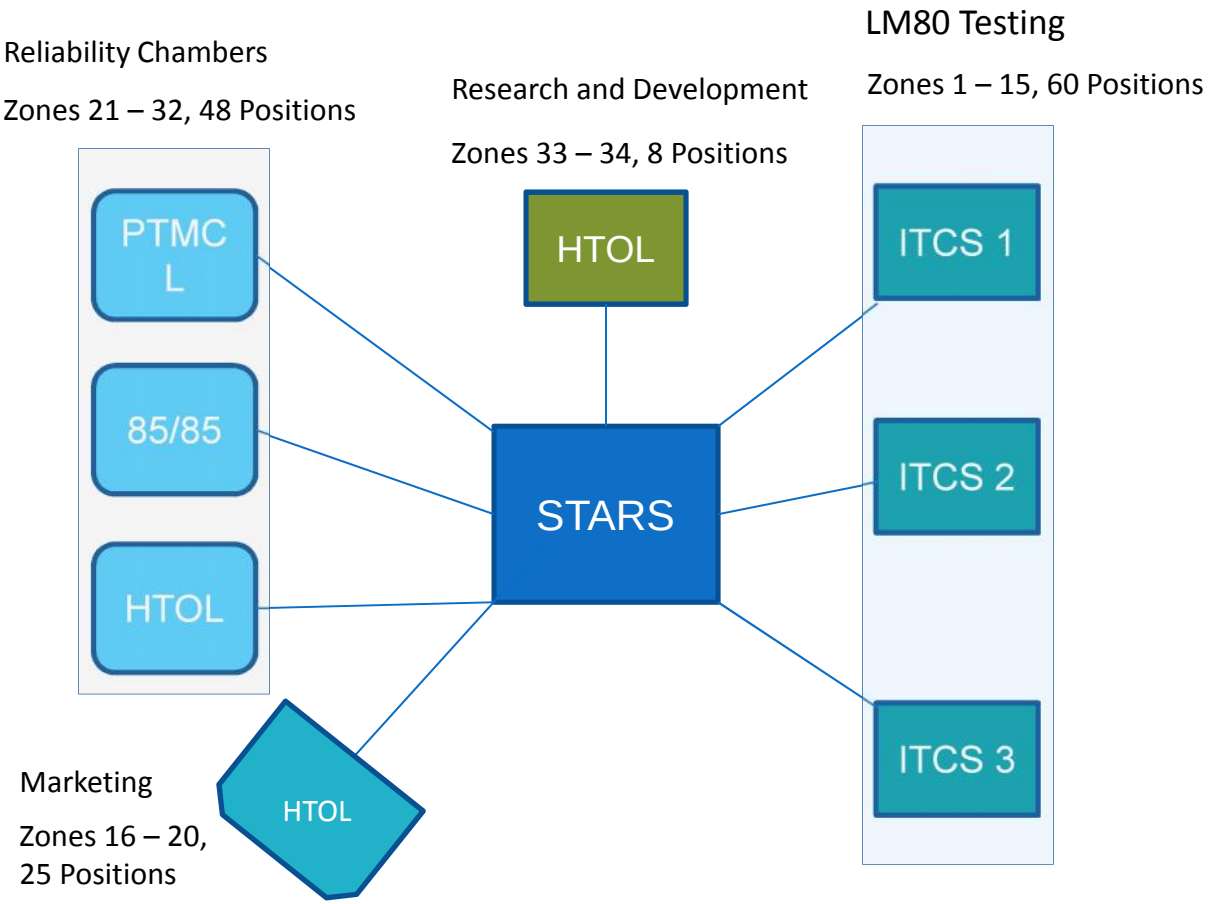
- **Prepare clean facility**
  - Low particulates
  - No chemicals that harm LEDs
  - Low EST
  - Adequate power and cooling water
  - Adequate air conditioning
  - Restricted access
- **Install equipment per manufacturer recommendation**
- **Perform steps for lab accreditation**
- **Conduct trial run tests to get familiar with equipment**

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Plan and Layout the Testing Facility

In this example layout:

- 4 Applications
- 8 Test chambers
- 34 Zones
- 141 Positions



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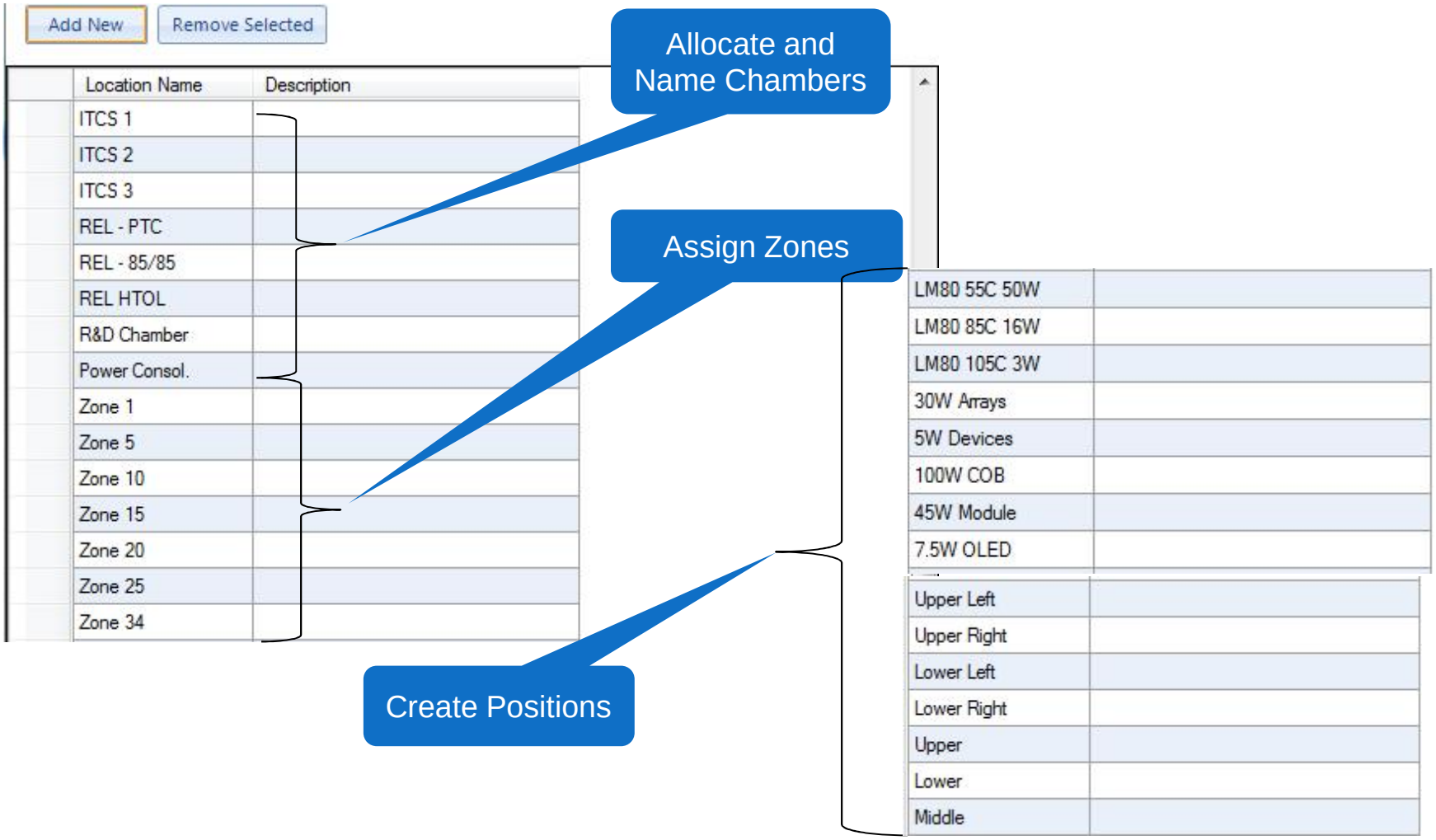
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Set Up Naming Conventions

- Name chambers and driver resources
- Make sure load rack slots are labeled
- Enter names into STARS software
- Develop meaningful load board naming numbering scheme

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STARS Resource Naming

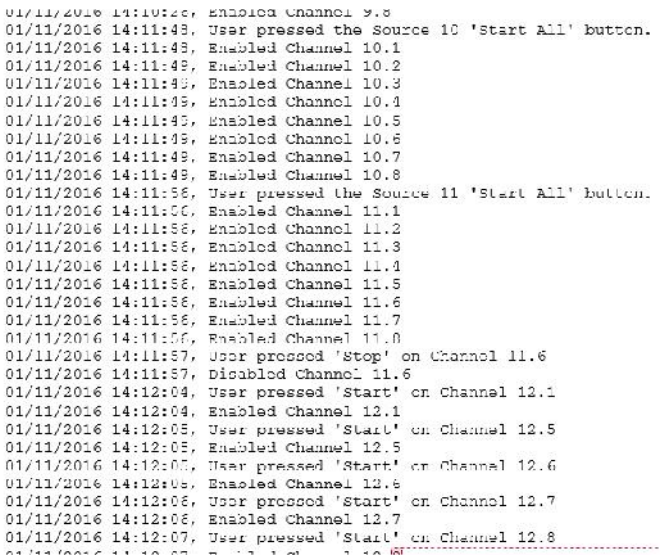


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Plan Data Collection/Storage

- LM-80 systems generate a lot of data, it must be managed
- Temperature and voltage monitoring data during operating intervals
- Photometric data at measurement points
- System status and action logs
- Maintenance information data



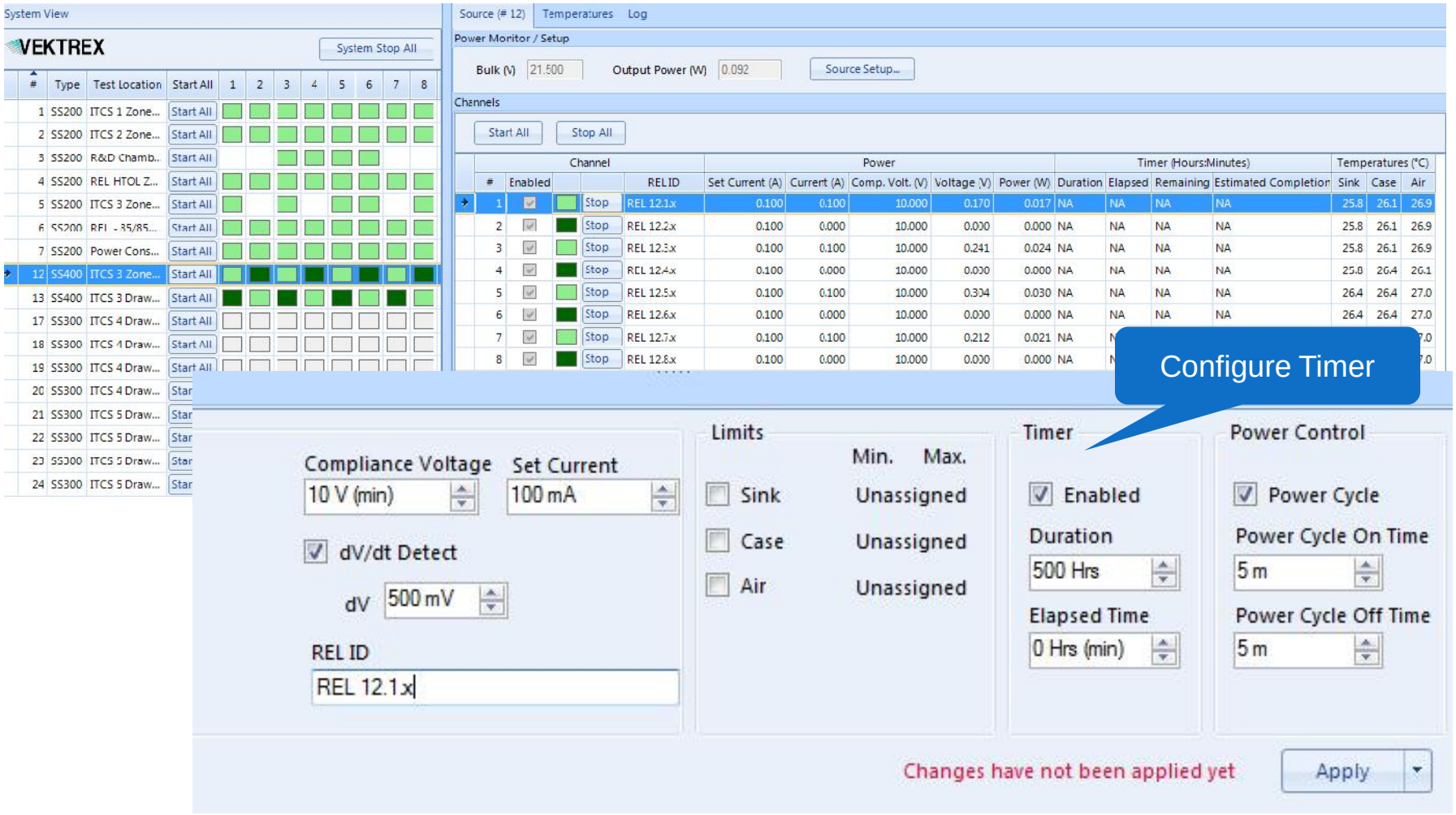
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Understand SpikeSafe Errors

- Errors are explained in STAR manual in section 8 along with possible causes
- STARS will try to restart after some errors, but not all
- Overcurrent at startup usually means a load board short
- For first few errors get in the habit of looking them up to make sure you understand them

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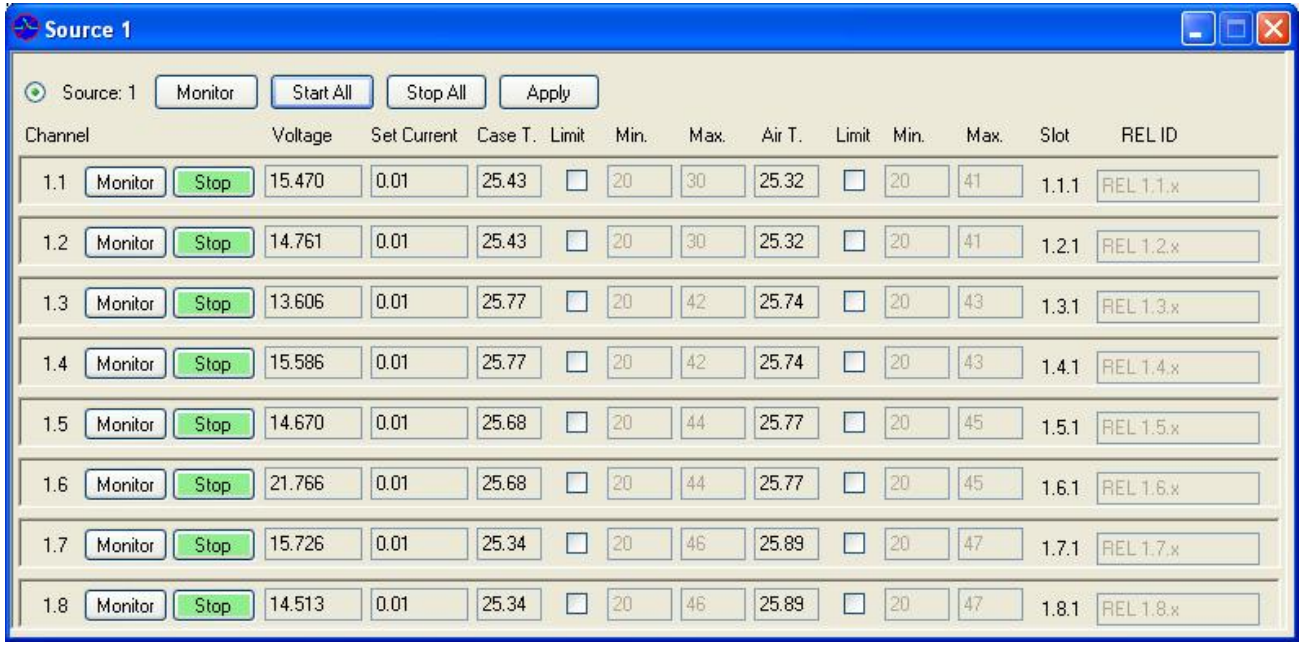
Use Timers & Take Frequent Measurements Early in Test



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Set Limits In STARS

- **Set limits in Stars config file**
- **Enable limits in the Source window in STARS**



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Audit Deadlines

- **Hire a LM-80 auditor to perform a pre-audit**
- **Contact Vektrex with any auditor question that you cannot answer**

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Summary: Follow a Careful Process During Testing

- **Plan and carefully setup system**
- **Create a data plan**
- **Build reference sample load boards**
- **Measure reference samples whenever optical system changes, also at measurement intervals**
- **Suggested measurement schedule:**
  - 24, 72, 168, 500, 1000, 1500, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000

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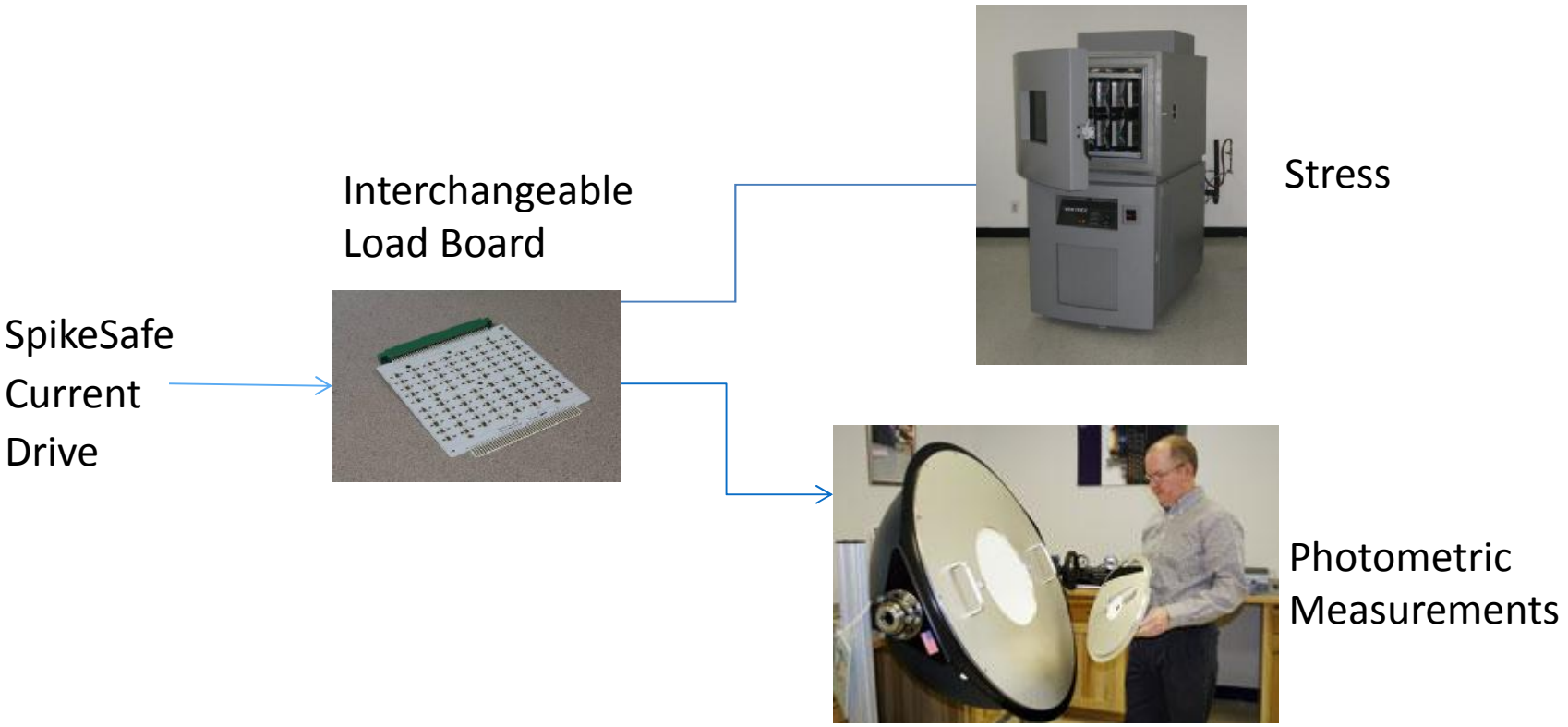
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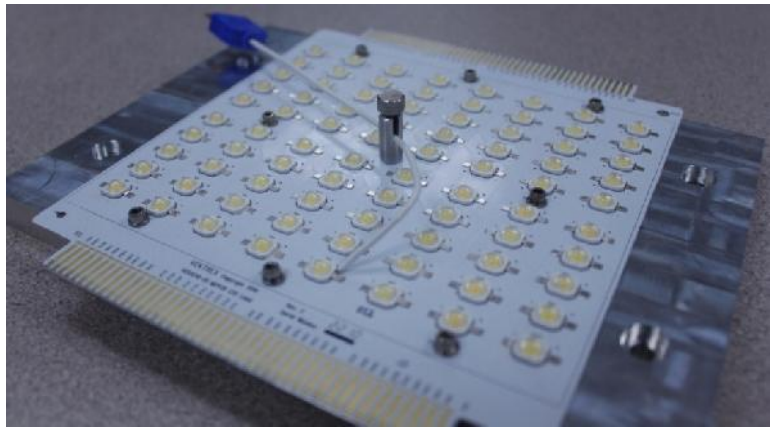
Success Key #3 – High Performance Load Boards



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Load Boards Serve Many Functions

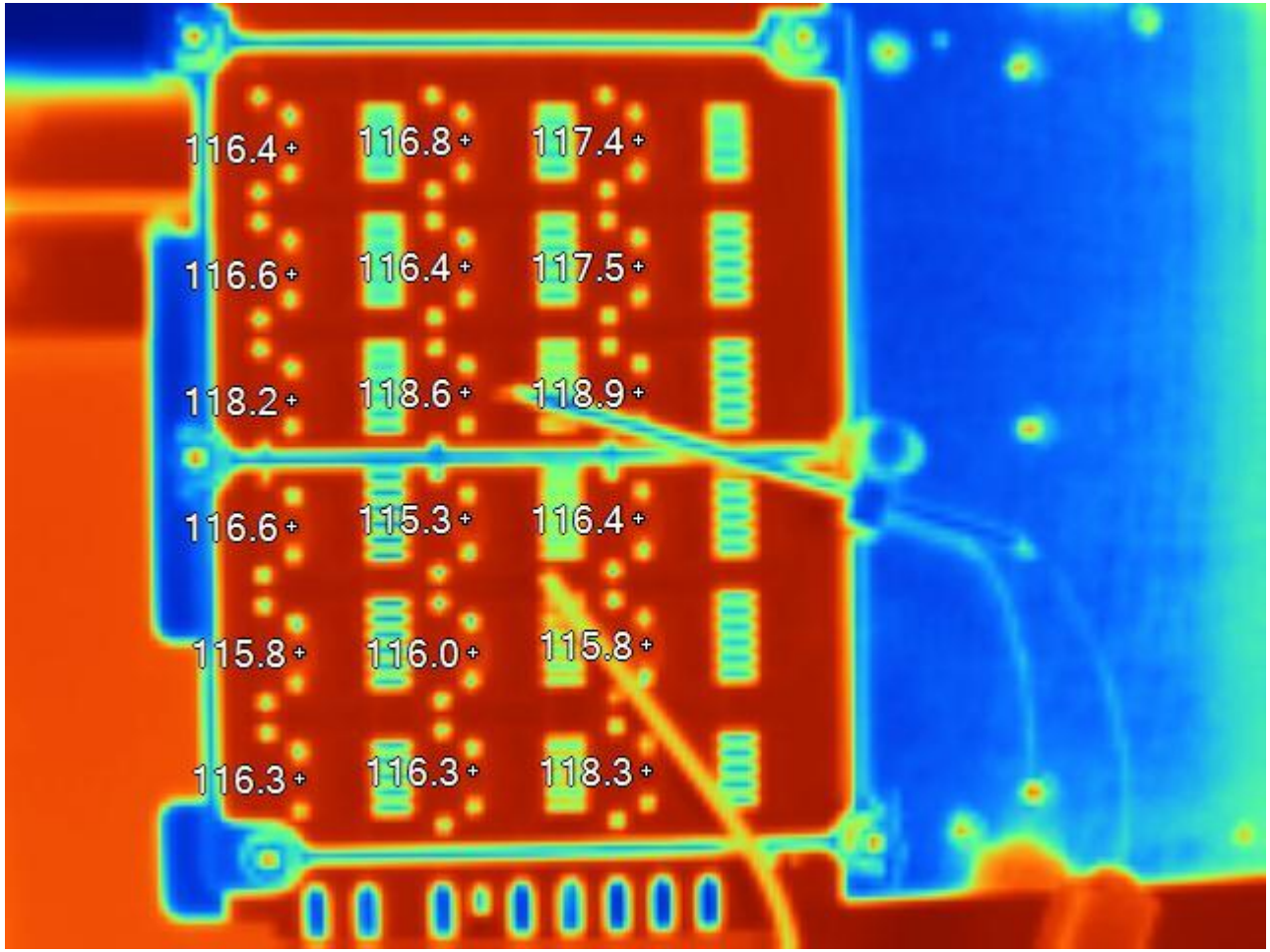
- Electrical connections during reliability test and photometric measurement
- Heat removal
- Physical LED attachment
- Test sample identification
- Platform for optical testing
- Temperature monitoring location



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Goal : Small Distribution of LED Temperatures

Good
Design
+
Good
Material
+
Flatness

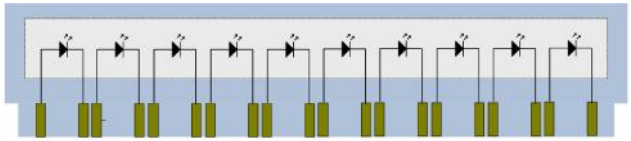


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Choose an Efficient Topology

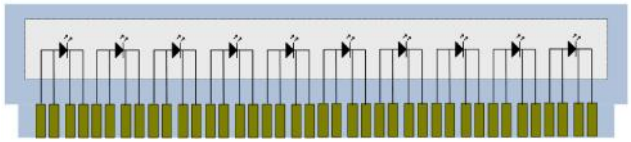
N+1, lowest number of connections to manage

2N



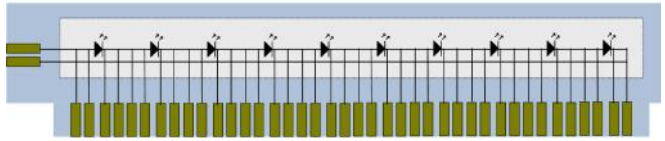
2N Type => 20 connections for 10 LEDs

4N



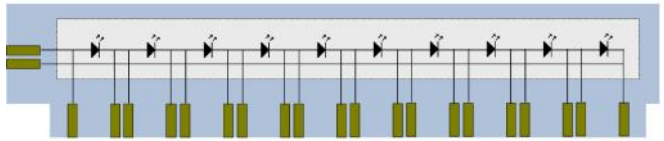
4N Type => 40 connections for 10 LEDs

4N+2



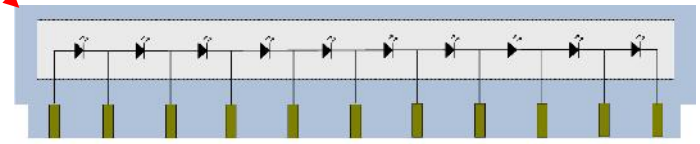
4N+2 Type => 42 connections for 10 LEDs

2N



2N+2 Type => 22 connections for 10 LEDs

N+1



N+1 Type => 11 connections for 10 LEDs

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Vektrex N+1 Load Board – An Industry Standard

- **Flexible 150x150mm, 75x150mm, 300x150mm size fits almost any LED/array application**
- **MCPCB for excellent thermal performance**
- **Disposable items**
- **One layer construction**
- **Reduced connections**



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Use Best MCPCB Materials to Reduce Temperature Rise

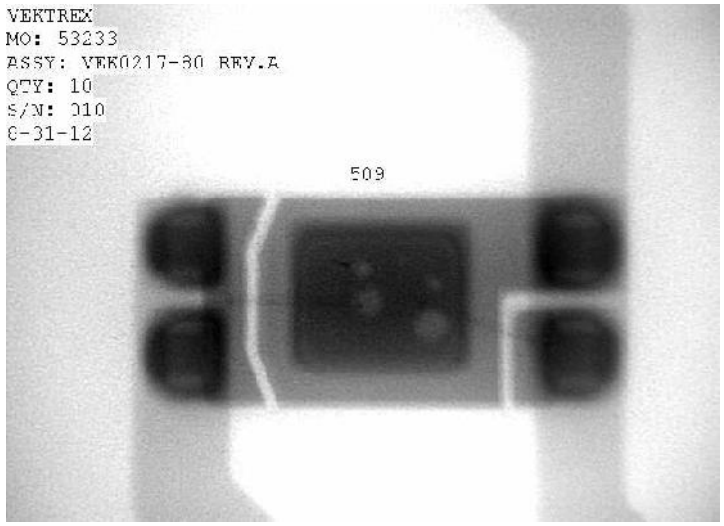
LED Information:							
LED dimension X, m	0.0023	Note: these are the dimension of the path heat takes under the LED. For a SMT LED this is the heat slug pad, for a COB it is usually the entire package					
LED dimension y, m	0.0033						
Forward Voltage, V	3.5						
Current, A	1						
Optical Power, %	20%						
Load Board Information:							
MCPCB Type	**Berquist CML 11006**	**Berquist HPL**	**Dupont Coolam LX**	**Laird T-Lam 1ka 04**	**Local Provider**	**Berquist HPL/Cu**	**Alternate Provider**
Aluminum thickness, m	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Aluminum conductivity, w/mk	140	140	140	140	140	400	140
Dielectric thickness, m	0.00015	0.000038	0.000017	0.0001	0.000095	0.000038	0.00004
Dielectric conductivity, w/mk	1.1	3	0.8	3	2	3	7.5
Copper thickness, m	0.00007	0.00007	0.00007	0.00007	0.00007	0.00007	0.00007
Copper conductivity, w/mk	390	390	390	390	390	390	390
LED Power, W	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Optical Power, W	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Power to MCPCB, W	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Heat Transfer Area, m^2	0.00000759	0.00000759	0.00000759	0.00000759	0.00000759	0.00000759	0.00000759
Temperature Rise, Copper Pad, C	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Temperature Rise, Dielectric, C	50.31	4.67	7.84	12.30	17.52	4.67	1.97
Temperature Rise, Aluminum, C	2.64	2.64	2.64	2.64	2.64	0.92	2.64
Temperature Rise, Load Board, C	**53.01**	**7.37**	**10.54**	**15.00**	**20.22**	**5.66**	**4.67**

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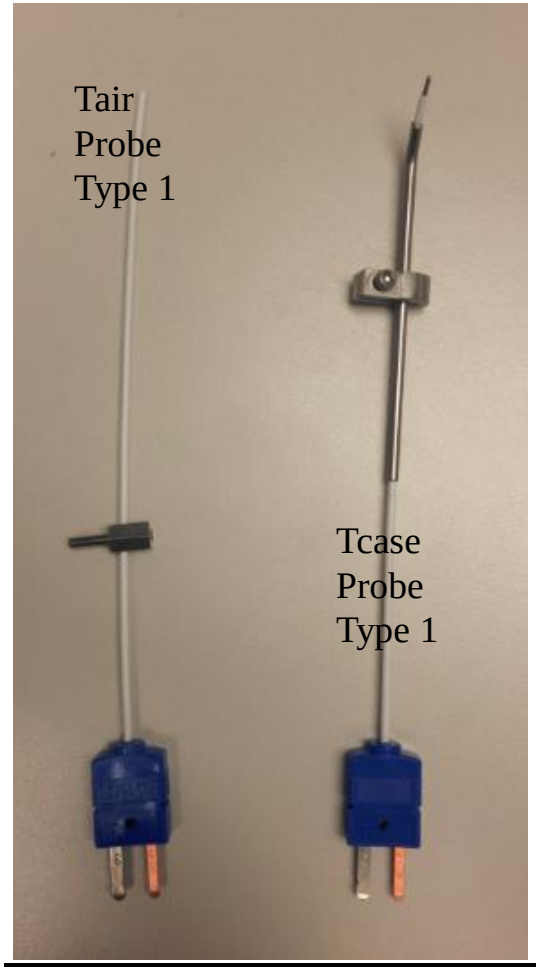
Load Board Assembly Tips

- **Follow manufacturer's soldering guidelines for assembly**
  - Pre-bake parts if necessary
  - Avoid hand assembly
- **Use solders and fluxes that minimize voids**
- **Keep everything very clean**
- **Perform x-ray inspection of parts**



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Pick Best Choice For Temperature Monitoring

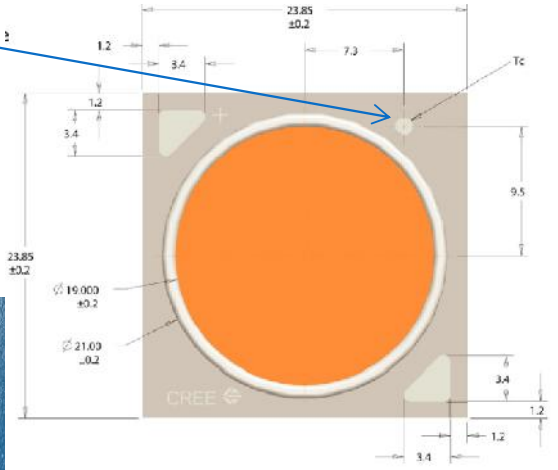


- **ITCS Temperature Monitoring**
  - Tsink – Thermocouples
    - Fixed Position
    - Integrated with thermal platforms
  - Tair - Thermocouples
    - User Positionable
    - Type 1 Generation 1 shown
  - Tcase – Thermocouples, RTD or NTC
    - User Positionable Thermocouple shown
    - Type 1 Generation 1 shown

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Use of Thin Wire Thermocouples for COB

- **Tcase to be monitored**
  - Use location specified by device manufacturer
  - For COB, thin wire is recommended
    - Use for Tair
    - Use for Tcase



Thin wire thermocouple





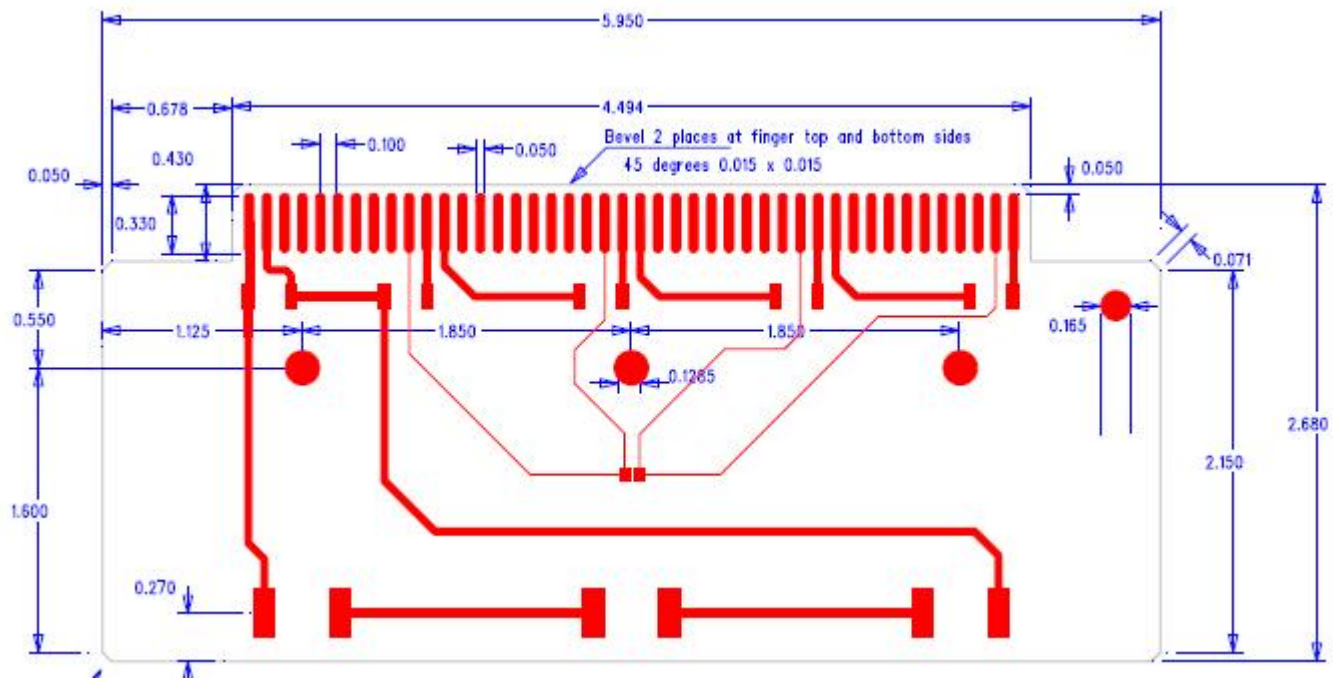
Thermocouple Isolator

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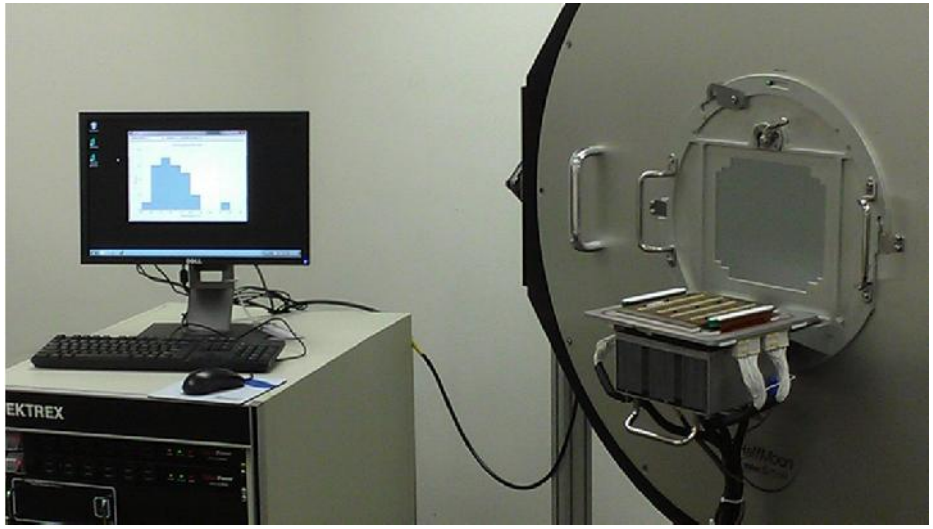
Use of RTD / PTC / NTC for packaged devices

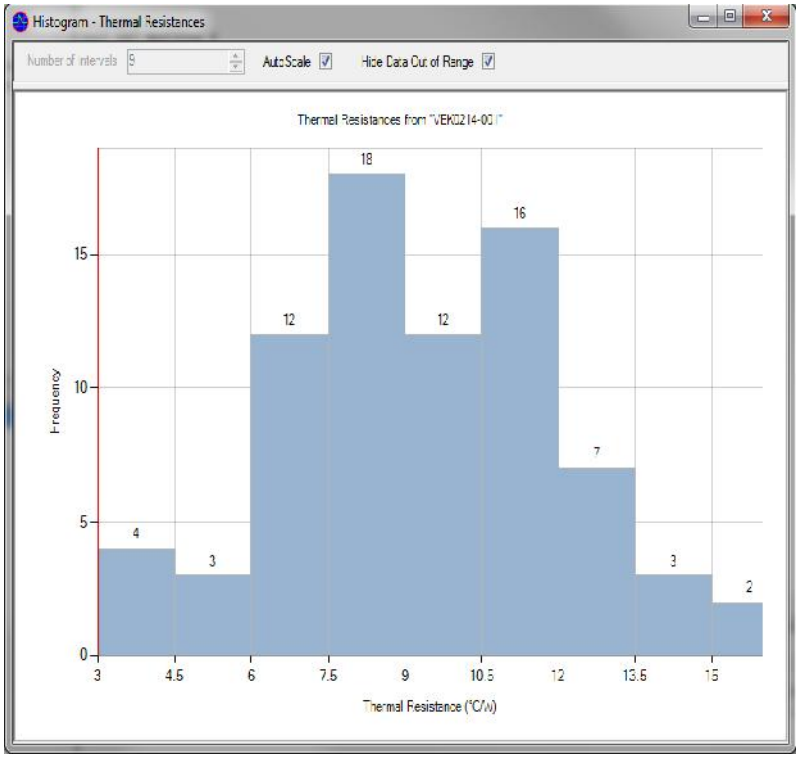
- Best for packaged devices
- Sensor integrated with load board
- Example ITCS Retention Board
- Note 0 ohm SMT resistors used to cross RTD traces



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Perform Thermal Resistance Test to Verify Thermal Mount





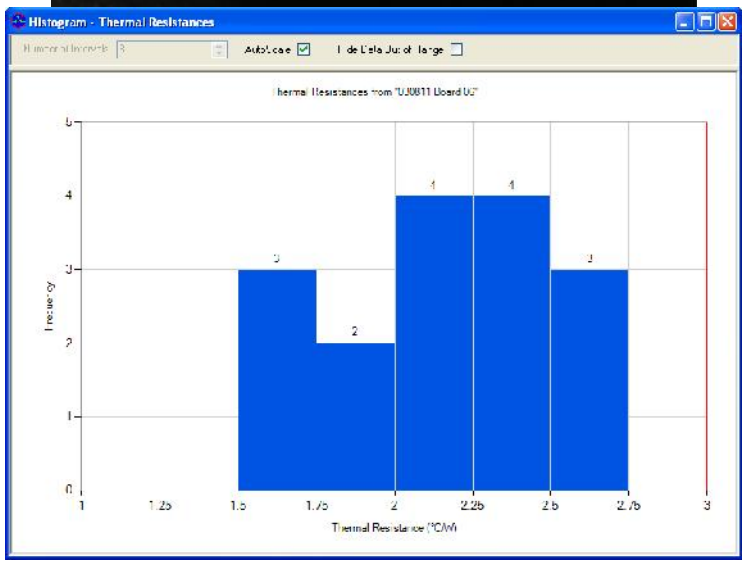
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High Performance Load Boards

- Use N+1 topology to minimize connections
- Use the best materials – high conductivity dielectric, copper or aluminum
- Avoid “no clean” flux
- Follow Vektrex design rules
- Check thermal resistance of load boards to ensure proper DUT mount
- Optimize normal force clamping load board down





Rth Histogram

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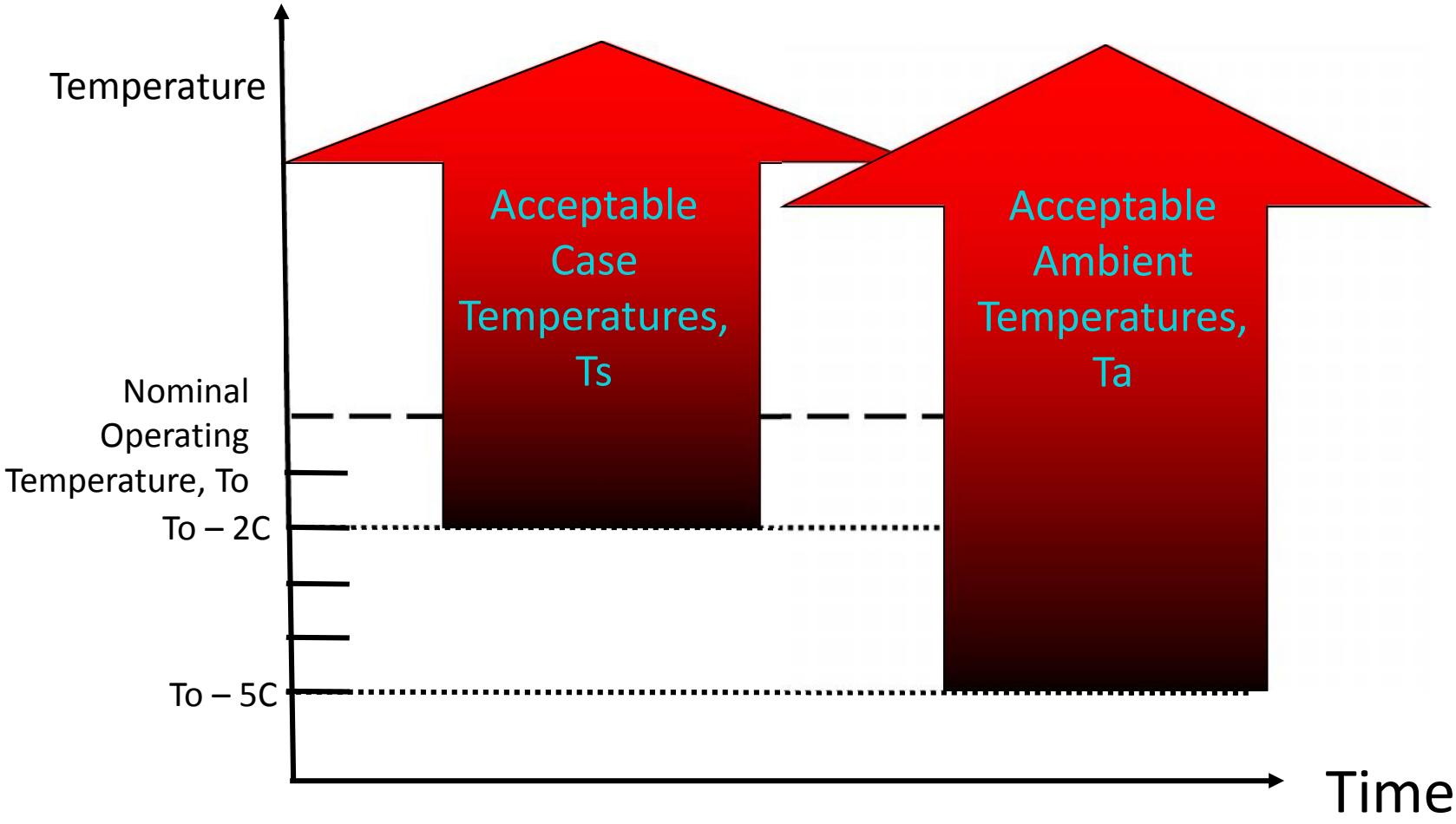
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Success Key #4 – Control LED Testing Temperature Carefully



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Example: Vektrex ITCS – High Performance Liquid Cooling

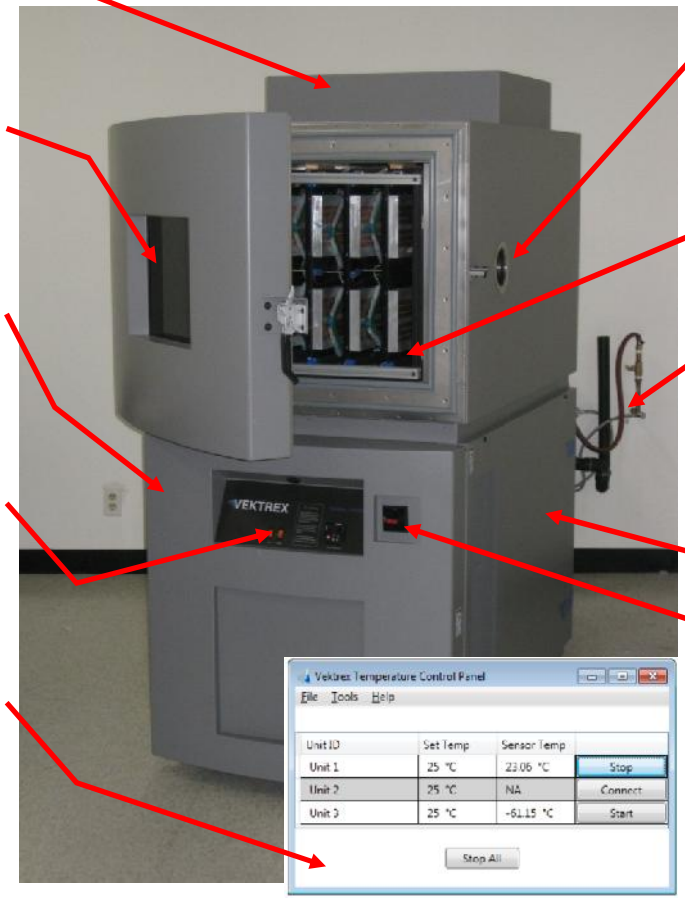
Variable Air Circulation

Light Protected View Port

Thermocouple Logging System

Settable Over Temperature Limit

Remote Control Software



Adjustable Vent Ports

Load Rack With Power & Thermocouples

Plant Chill Water Connections

Ts, Ta Thermal Control System

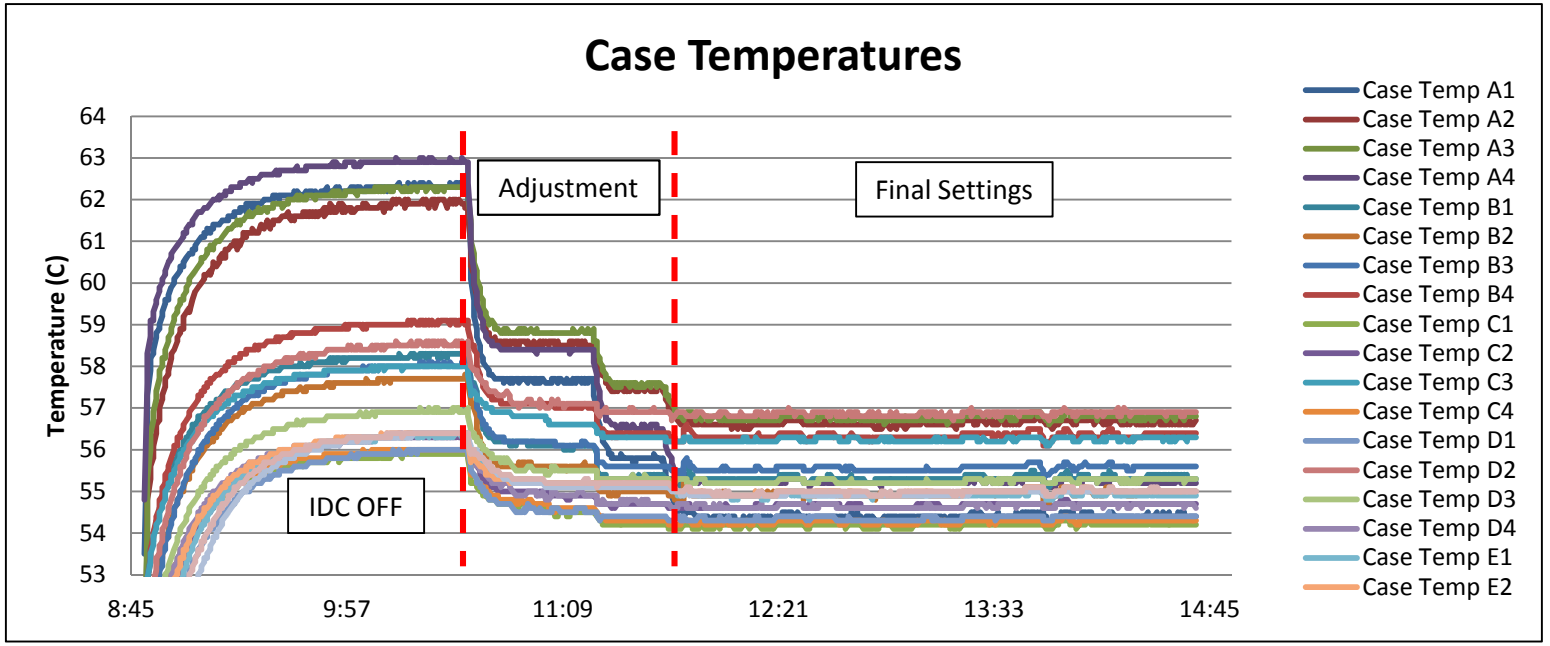
Configurable AC Input Power

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Minimize Temperature Spreads In Testing Chambers

- Adjust thermal control systems to reduce spreads
- Relocate load boards
- Utilize thermal shims



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Success Key: Good Thermal Management

- Specify a reasonable case temperature measurement location
- Pick operating To based upon worst-case case temperatures
- Control air temperature in the chamber with forced air movement
- Ensure air temperature thermocouples are shielded from radiation



Shielded Air Temperature Probe

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Use New Temperature Monitoring Techniques Outlined in LM-80-15

- RTD and thermistor sensors now allowed
- Profile a load board by comparing RTD sensor reading to thermocouple readings
- Determine worst-case offset from RTD and enter in logging system
- Monitor various LEDs, beware of systems that report perfect temperatures

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Set Up ITCS Thermal Protection

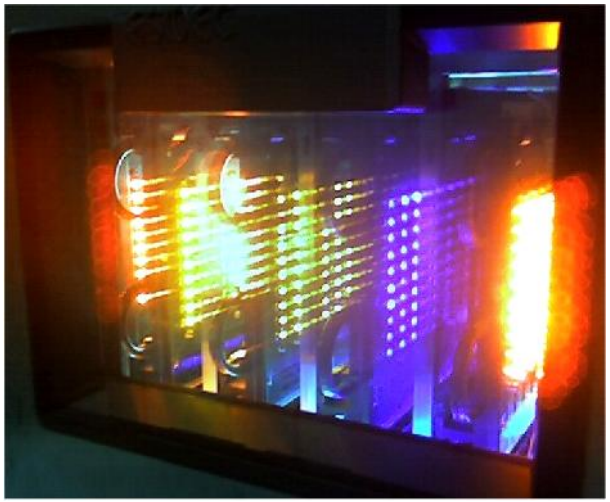
- **Thermal protection protects LEDs from run-away temperature conditions such as:**
  - Heater malfunction
  - Chiller malfunction
  - Operator error
- **ITCS limit controller cuts power to internal chiller in the event limit is exceeded**
- **Set limit to Tnominal + 10 or 15C**



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Summary: Control LED Testing Temperature Carefully

- Use liquid cooling to ensure uniform temperatures
- Size system for expansion, growth
- Carefully monitor and control case and air temperature
- Set thermal limits – most labs will eventually suffer a thermal runaway



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LM-80 Best Practices Agenda

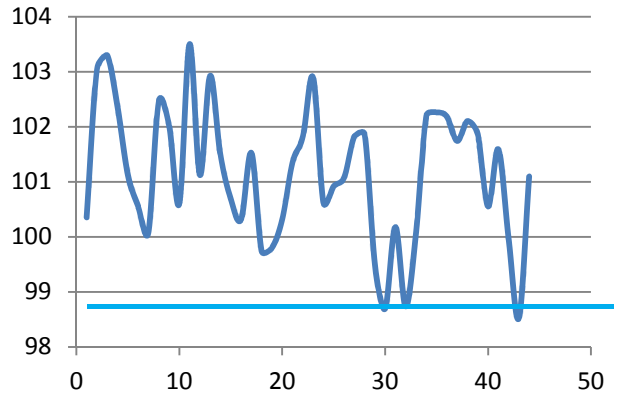
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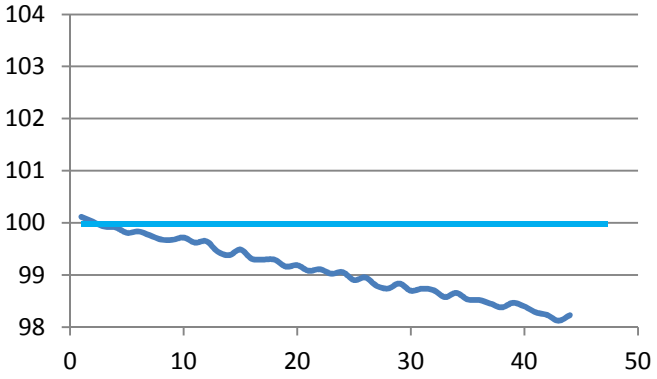
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Success Key #5 – Optimize Photometric Measurement System for Repeatability

- **Typical photometric systems have variability of 1-2%**
- **The variability makes it difficult to spot trends, requiring longer test times**
- **Example Optimized System: ALMS variability is 0.05-0.1%**
- **With lower variability you can see trends sooner allowing you to shorten test times and make more rapid process changes**



Non-optimized



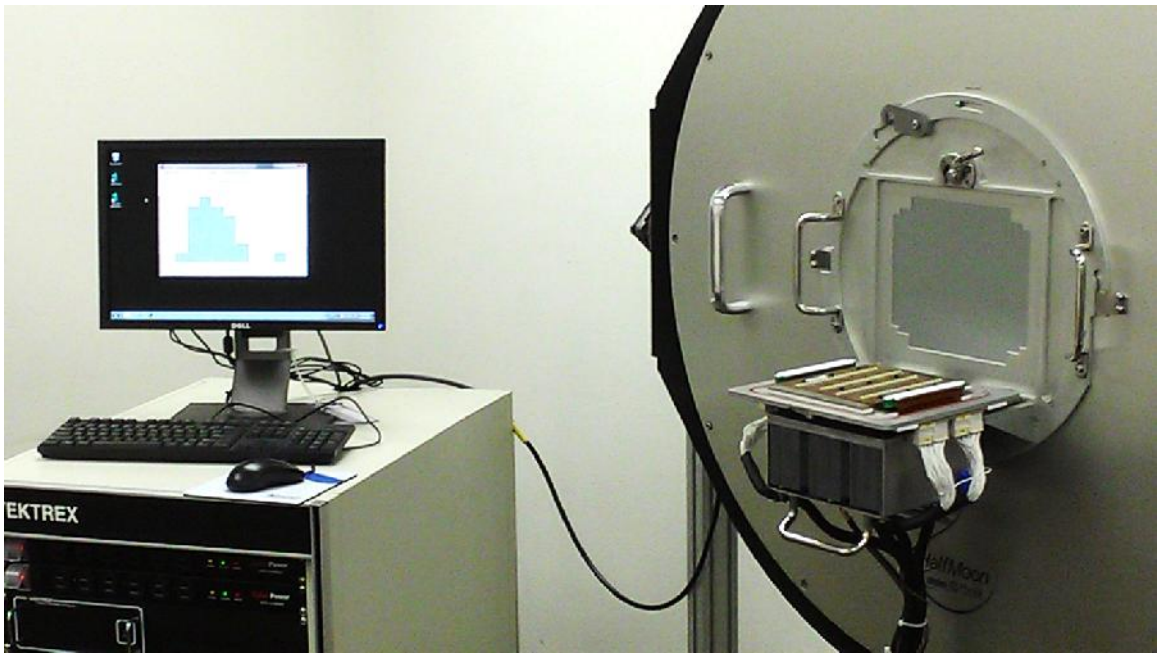
Optimized

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Vektrex Automatic Light Measurement System

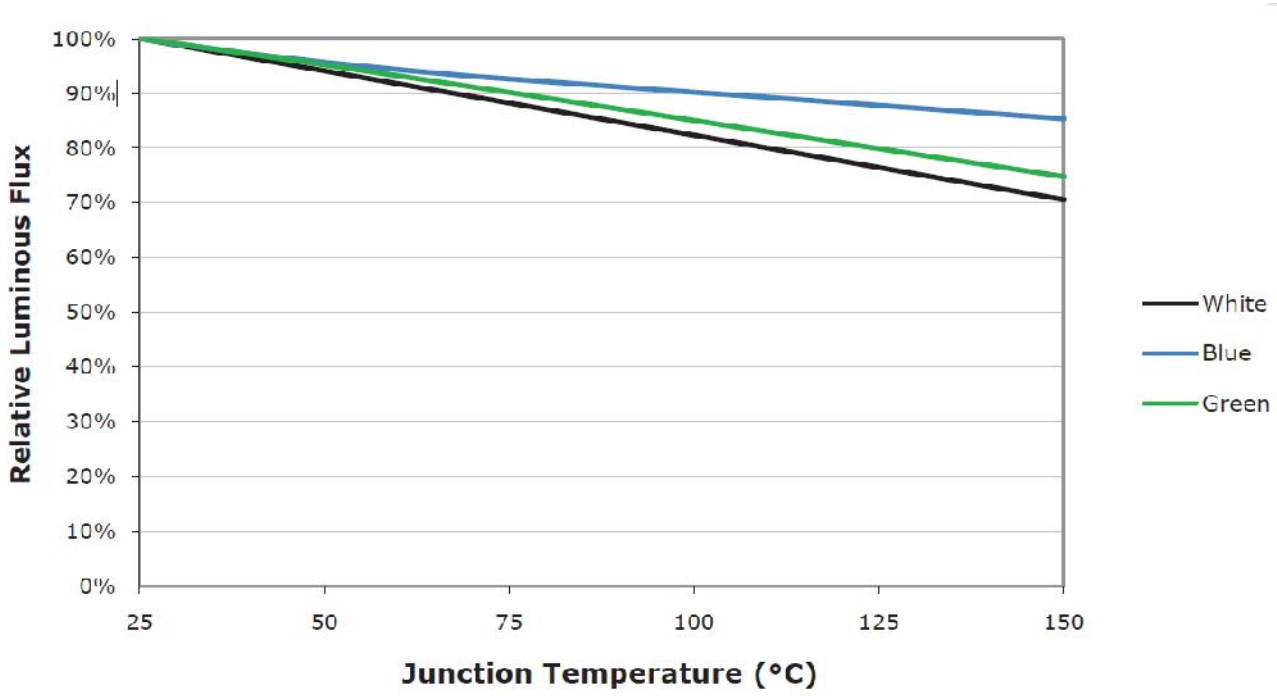
- **Automates measurements for N+1 load boards**
- **10 min/80 LEDs**
- **0.05% repeatability**
- **Simple loading**



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Temperature Should Be Controlled Much Better Than LM-80 +/-2C

- LED flux output changes with temperature
- Example: Cree White LED = -0.25%/degree C
- Worst-case 4C change = 1% difference

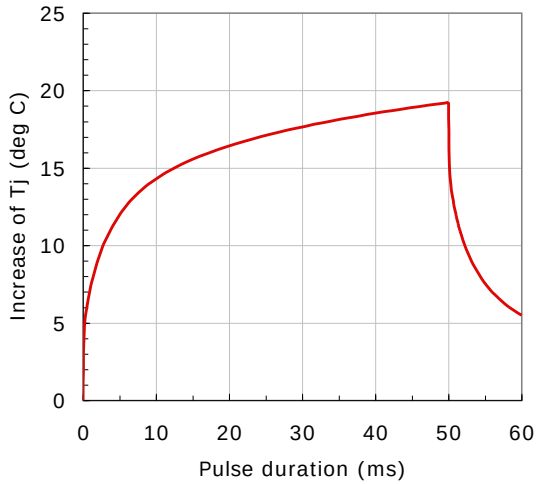


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Make Good Light Measurements

- **Calibrate the light measurement system**
- **Perform uncertainty analysis for system**
  - required for LM-80
- **Use self absorption corrections for each type of load board**
- **Keep load boards clean**
- **Maintain uniform measurement temperature to +/- 0.25C if possible**
- **Use pulsed measurements**
- **Make sure LED is re-stabilized before repeating measurements**

3W LED temperature rises 19C in 50mS



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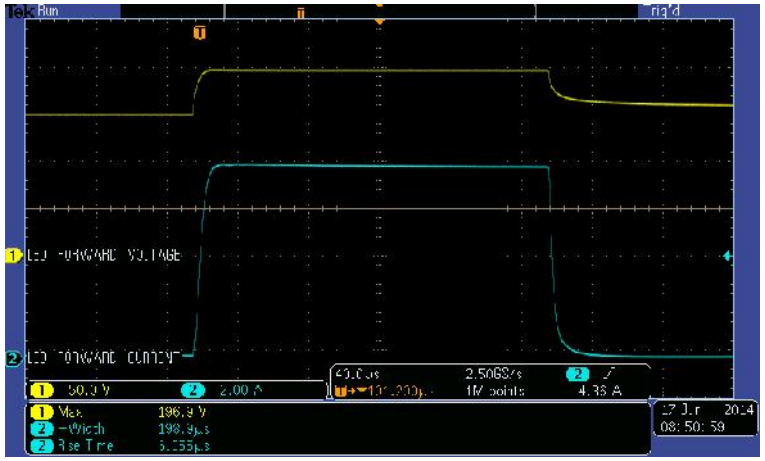
Maintain “Golden” Samples To Track System Drift

- Prepare load boards with stable LEDs
- Measure these before starting test and at measurement intervals
- Between measurements store in low humidity clean environment
- Use readings to correct for sphere drift, operator errors, etc.

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Ensure Pulsed Current Source Performance

- **High power LEDs require high peak power levels**
- **LM-85 and TC2-63 require microsecond rise time current for pulsed measurements**
- **Pulsing/triggering should be stable with minimal jitter**
  - Error due to jitter = 0.2%/1ms of jitter for average LEDs, higher for higher power LEDs

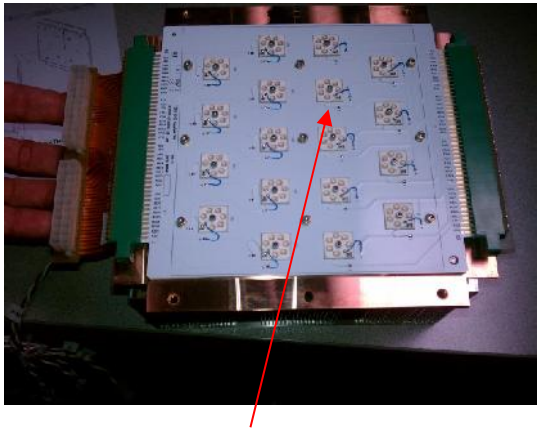


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Summary: Optimize Photometric Measurement System for Repeatability

- Design photometric system for automated measurement of one load board
- Make absolute optical measurements with a high quality spectrometer-based system
- Use stable calibration artifacts to correct long-term changes in photometric system
- Follow new LM-85 or TC2-63 high power LED test methodology
- Maintain constant Ts during photometric testing



Load Board Installed On Photometric Temperature Platform

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Thank you



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