BiTS™

Burn-in & Test Socket Workshop

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Mesa, Arizona

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Burn-in & Test Socket Workshop

Technical Program

Session 4
Tuesday 3/09/04 8:00AM

MEASURING CURRENT CARRYING CAPACITY

"Study Of Current Carrying Capacity Measurement"

Jiachun (Frank) Zhou – Kulicke & Soffa
Uyen Nguyen – Kulicke & Soffa **Alberto M. Campos** – Kulicke & Soffa

"Current Rating For Contacts - Time To Standardize The Test Method"

Qifang (Michelle) Qiao – IBM Microelectronics **Karl Schoenfeld** – Gonzer Associates

"Socket Current Carrying Capacity (CCC) Characterization"

Victor Henckel – Intel Corporation
Glenn A. Cunningham – Intel Corporation **Hongfei Yan** – Intel Corporation

Study of Current Carrying Capacity Measurement

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Overview

Introduction & Objective

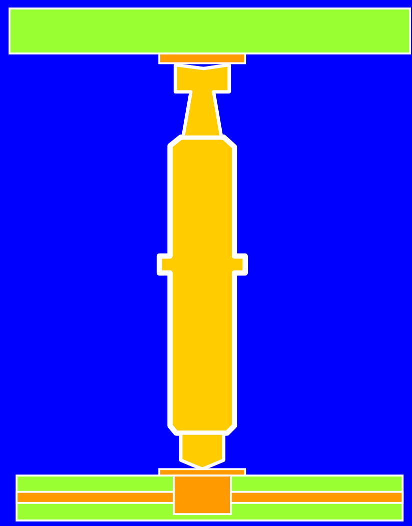
Test Set Up

Test Results and Discussions

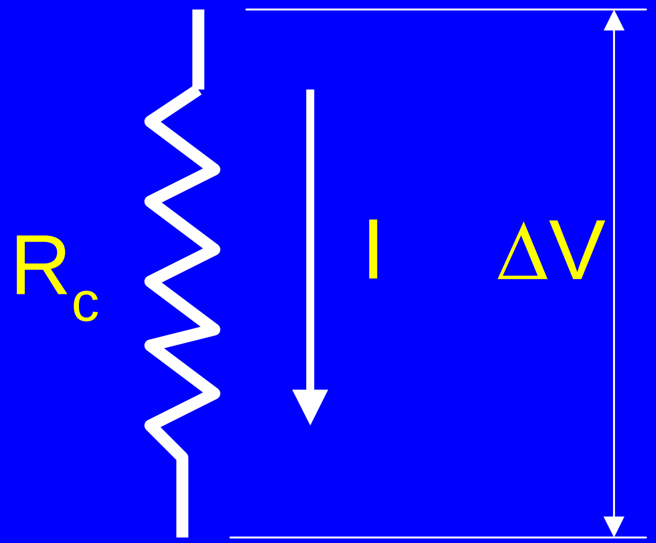
Summary

Introduction

Inter-connector



Electrical Model



R_c: **Total Resistance in connector**

I: **Current through connector**

Introduction

Total power loss in connector: $P = I^2 \times R_c$

Heat generated in connector: $Q_g \sim P$

Heat released to heat sink: Q_l

Temperature rise in connector at steady state:

$$\Delta T \text{ a } (Q_g - Q_l)$$

Current Carrying Capacity (CCC) - max current allowed for inter-connector to function without failure due to ΔT.

Technical Challenges in determining CCC

Heat sink by device, PCB, and socket to affect measurement accuracy.

Temperature measurement of inter-connector when it is placed inside socket.

Objectives

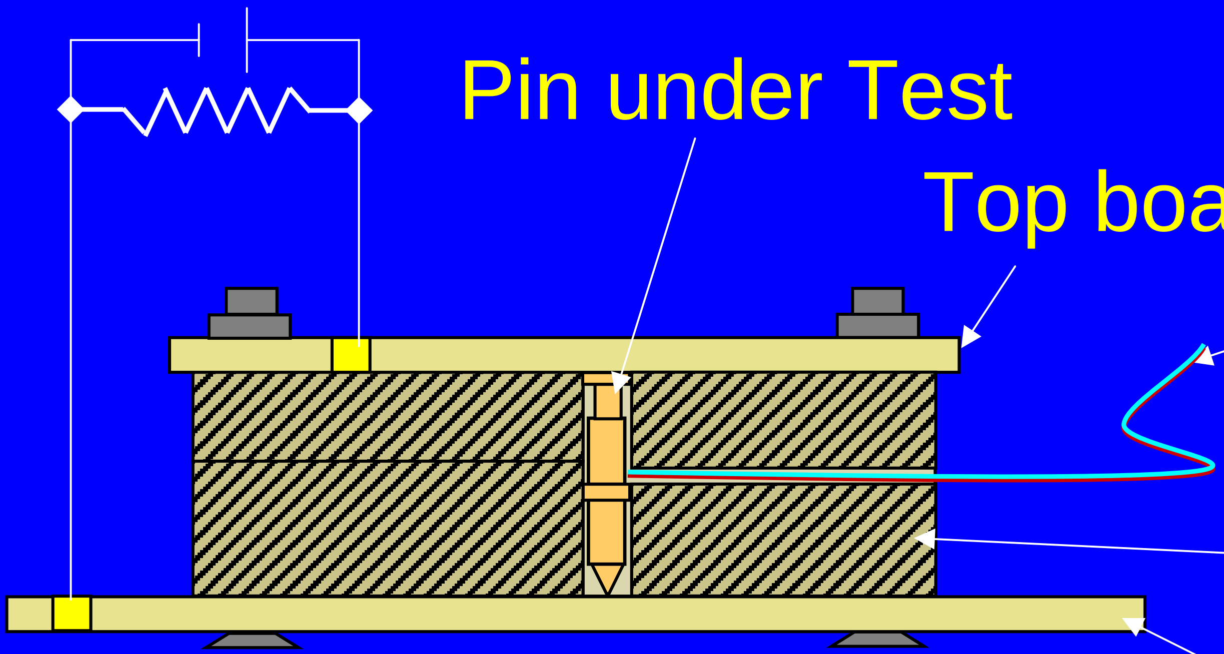
Investigate the effects of selected methodologies on measurement of current carrying capacity

- Thermocouple
- IR contact-less (thermal imager)

Set up suitable methodology and instrumentation in house to measure current carrying capacity of inter-connector.

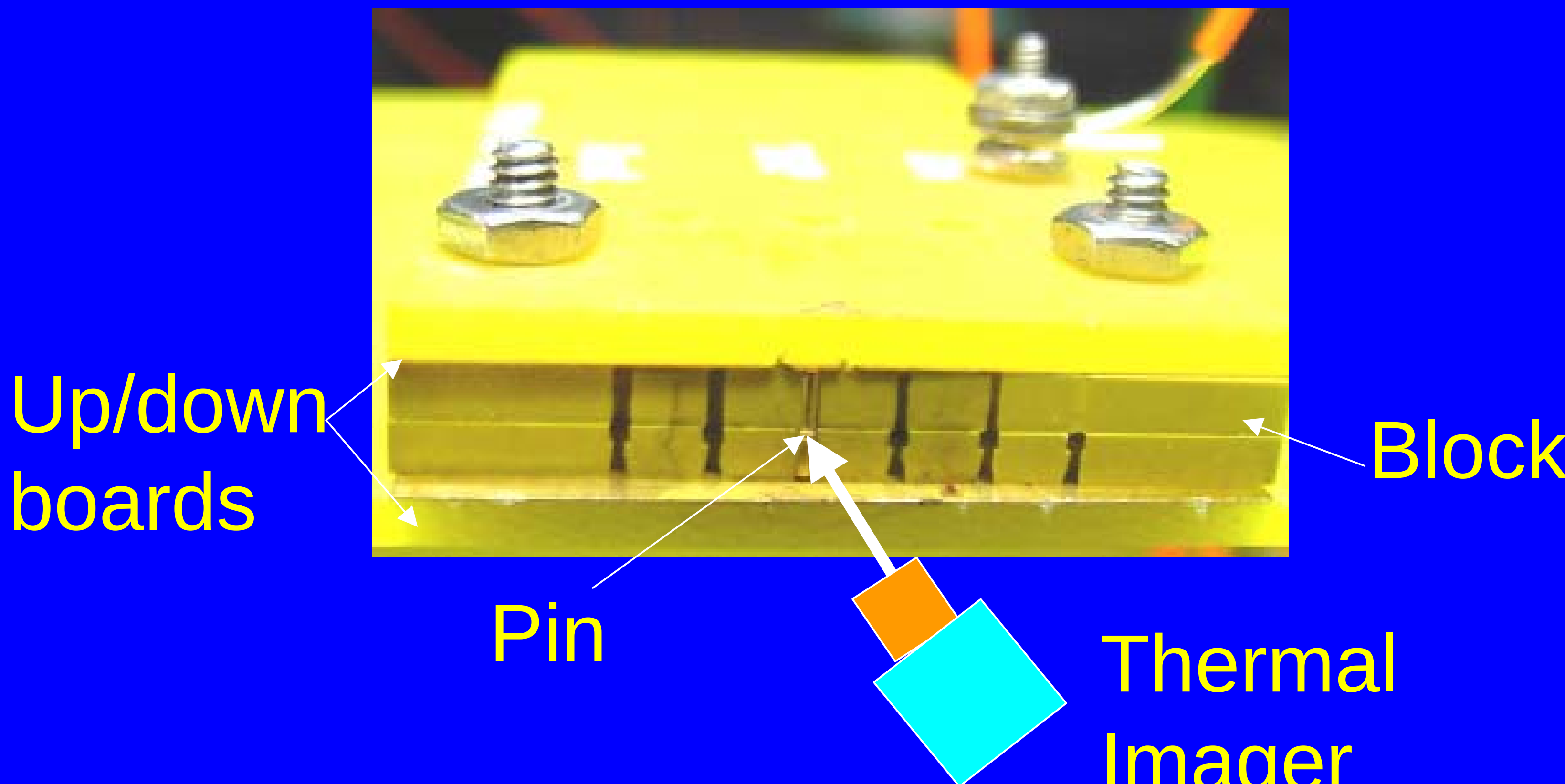
Test Setup – Thermocouple Method

Use thermocouple to measure the temperature rise in spring pin due to current flow.

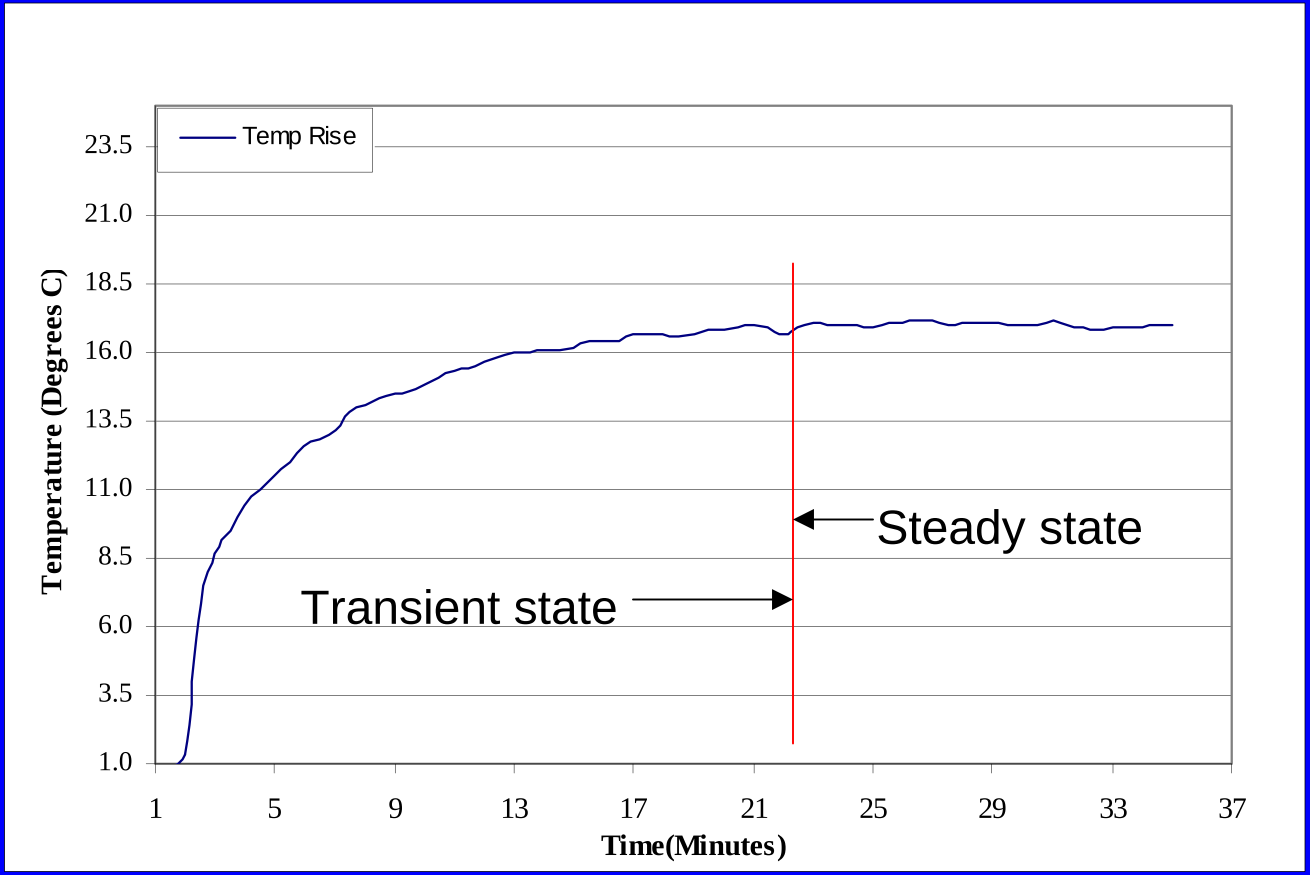


Test Setup – Thermal Imager Method

Use thermal imager to measure the temperature rise in spring pin due to current flow.

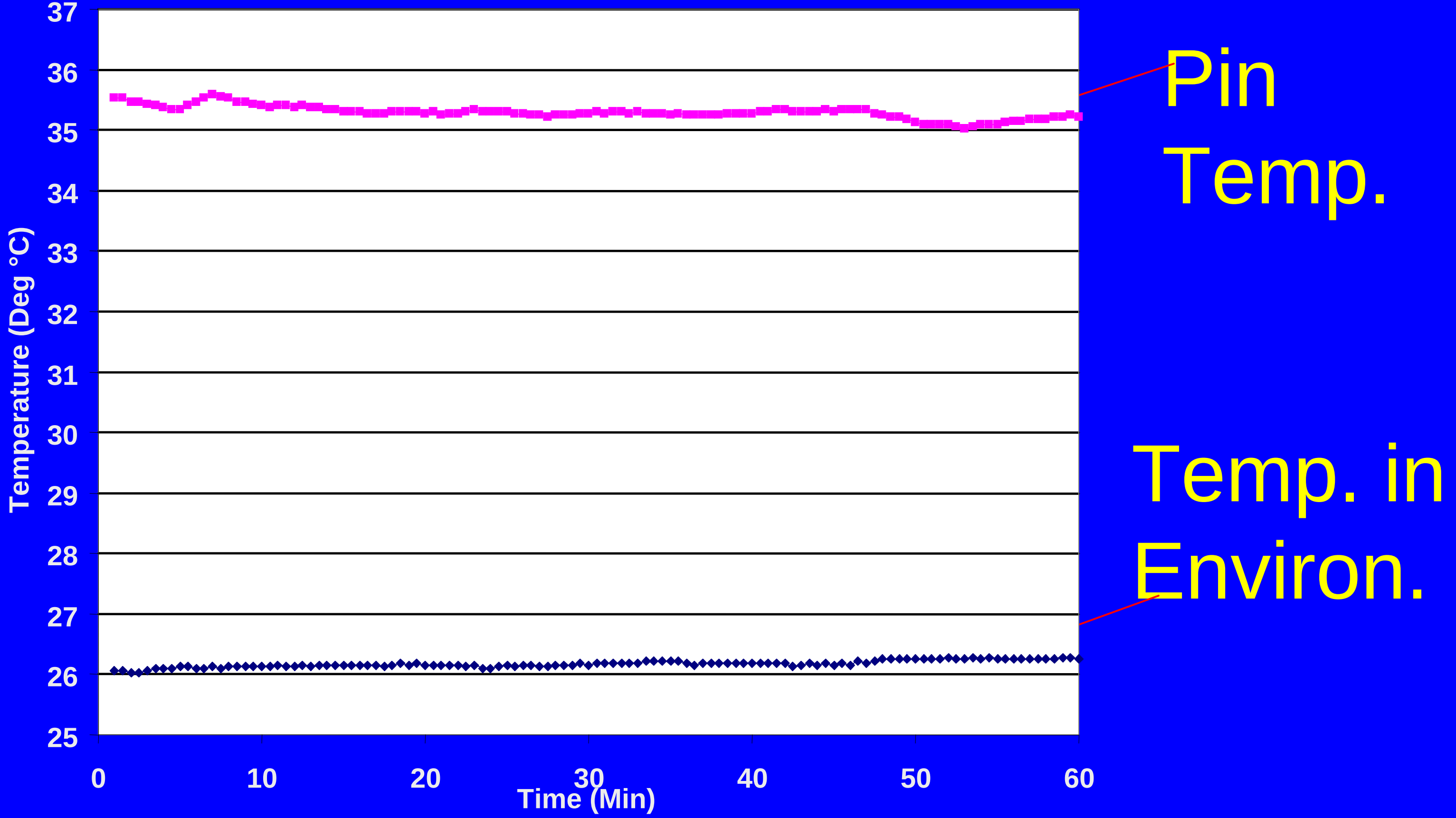


Measurements - Stability



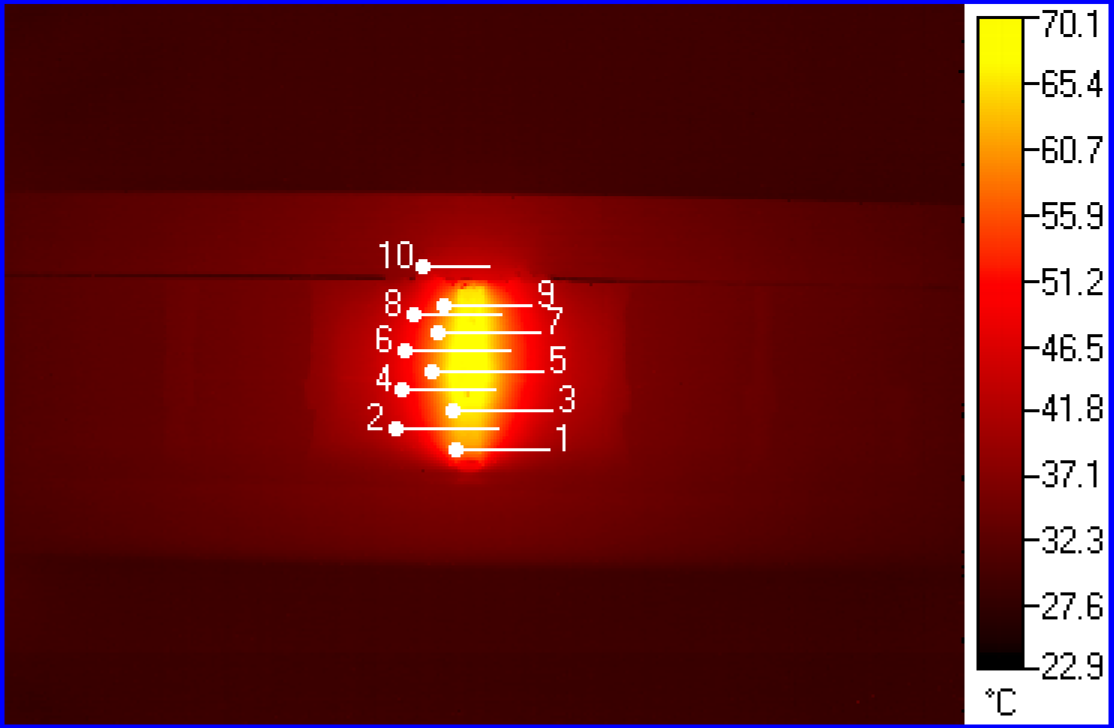
Temperature stability: T-Rise < ± 1°C over 15 minutes.

T-Rise Determination – Thermocouple Method



T-Rise is determined at one position reading over time @ fixed current.

T-Rise Determination – Thermal Imager Method



10 temp readings are used to determine T-distribution, maximum temperature and T-rise.

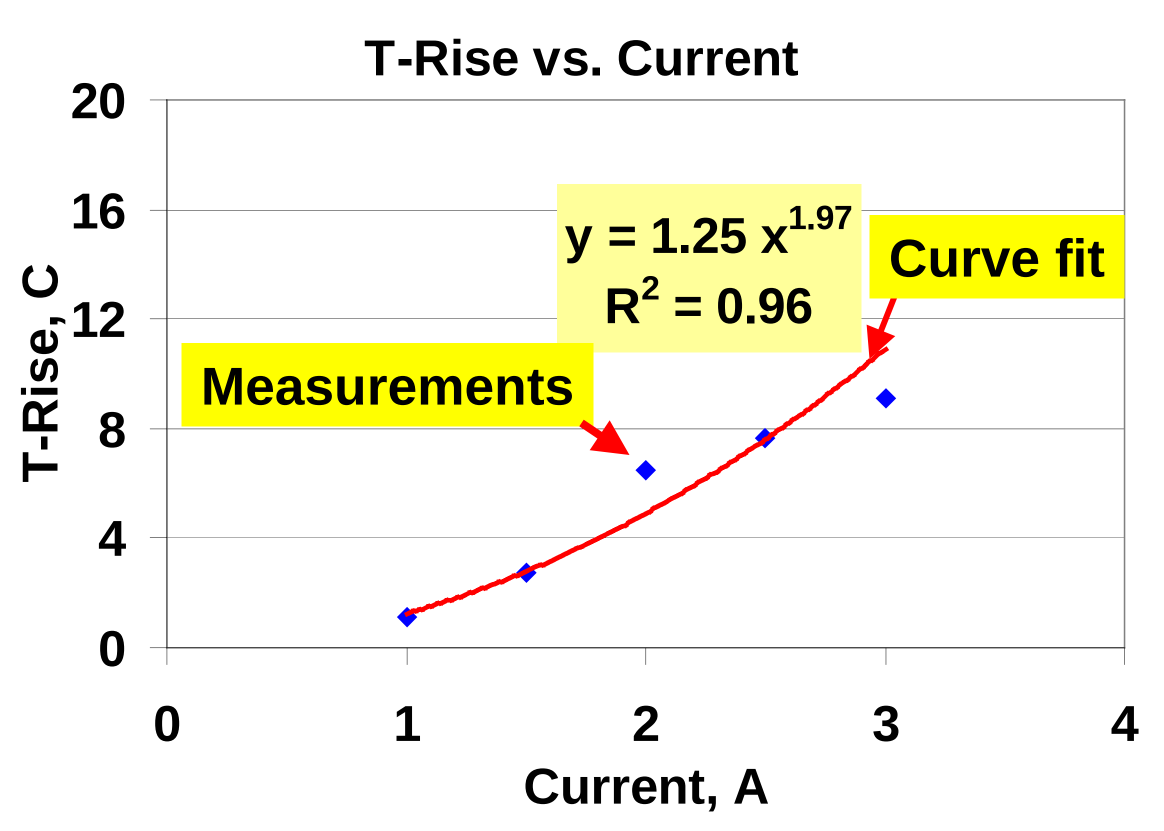
T-Rise Determination – Thermal Imager Method

3.0A	Line1	Line2	Line3	Line4	Line5	Line6	Line7	Line8	Line9	Line10
Max °C	38.2	40.8	41.8	43.3	43.6	43.3	43	42.5	42.2	31.7
Max °C	38.4	39.1	39.6	40.9	41.2	41.1	41.1	40.8	41	32.7
Max °C	40.1	41.1	42	42.9	43.5	43.3	42.5	42.1	41.8	32.3
Average	**37.0**	**40.3**	**41.1**	**42.4**	**42.8**	**42.6**	**42.2**	**41.8**	**41.7**	**32.2**
Stdev	**1.0**	**1.1**	**1.3**	**1.3**	**1.4**	**1.3**	**1.0**	**0.9**	**0.6**	**0.5**

T-rise is determined with measurements of temperature over time @ 10 pin positions.

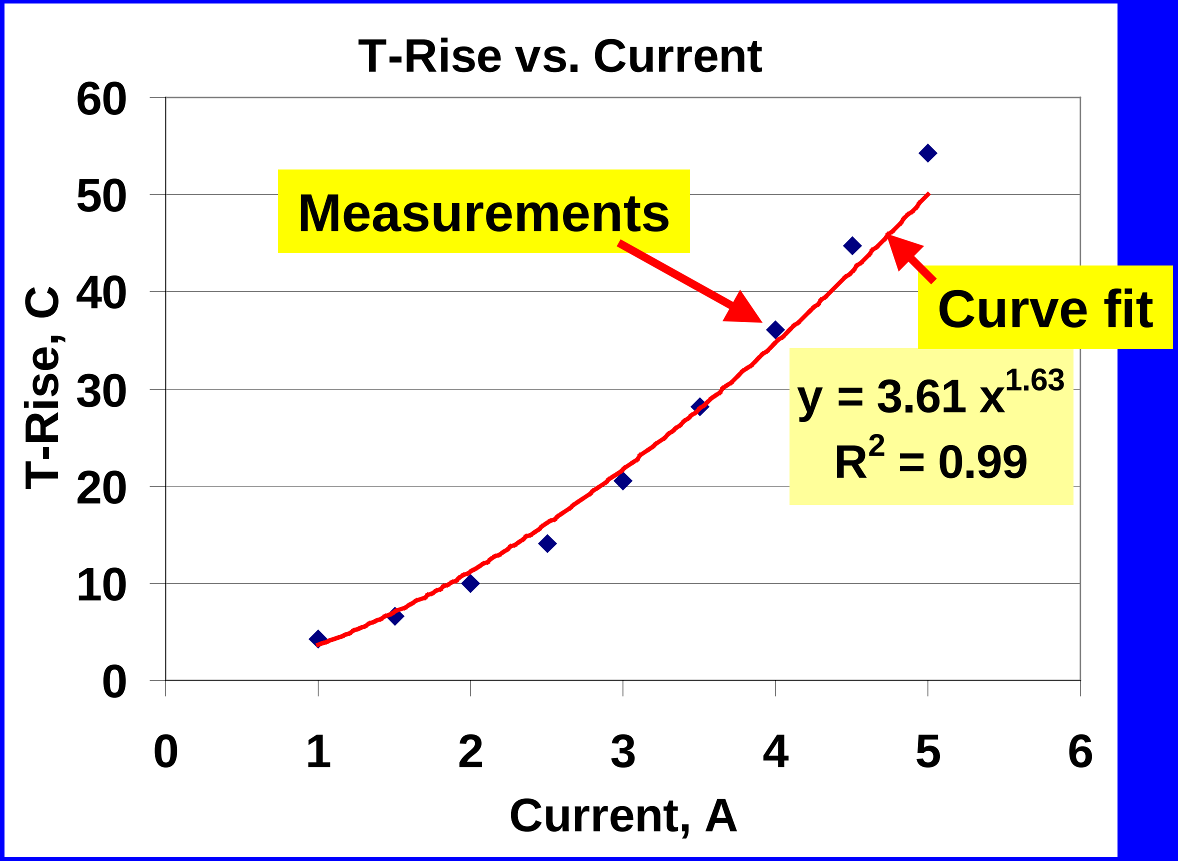
Measurements of 3 pins are in above table. Stdev is < 1.5°C among pins.

One Pin Measurement–Thermocouple Method



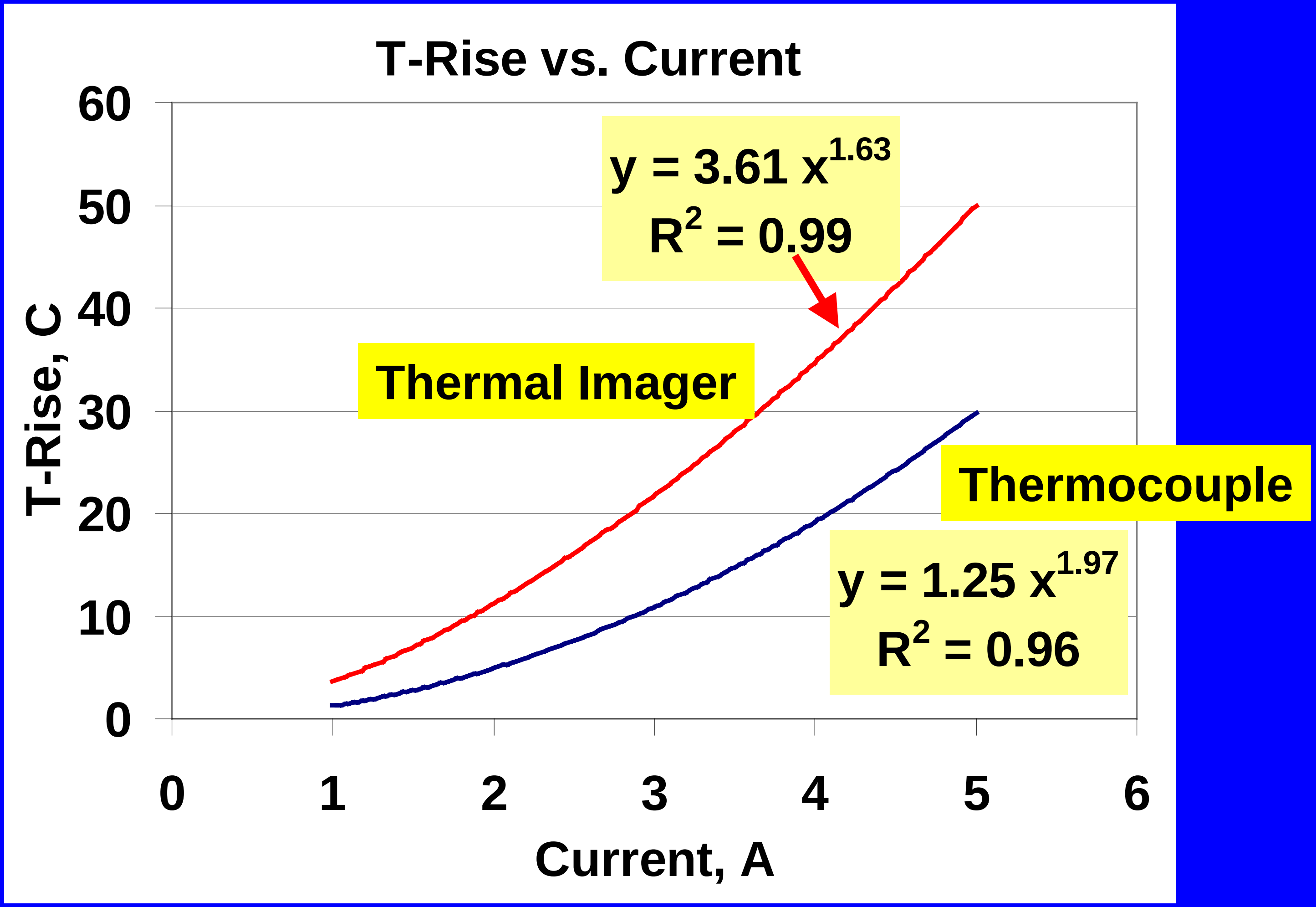
Curve fit function is based on T-Rise measurements at steady state.

One Pin Measurement– Thermal Imager Method



Curve fit has same trends as thermo-couple method but less diversity.

Comparison–
Thermal Imager vs. Thermocouple



Comparison– Measurement Results

- T-rise vi thermal imager method is larger than thermocouple method.
- Thermal imager measurements have less diversity (R^2=0.99) than thermocouple method (R^2=0.96).
- Operation of thermal imager system is easier and has better repeatability (stadv < 2°C).

Comparison– Measurement Accuracy

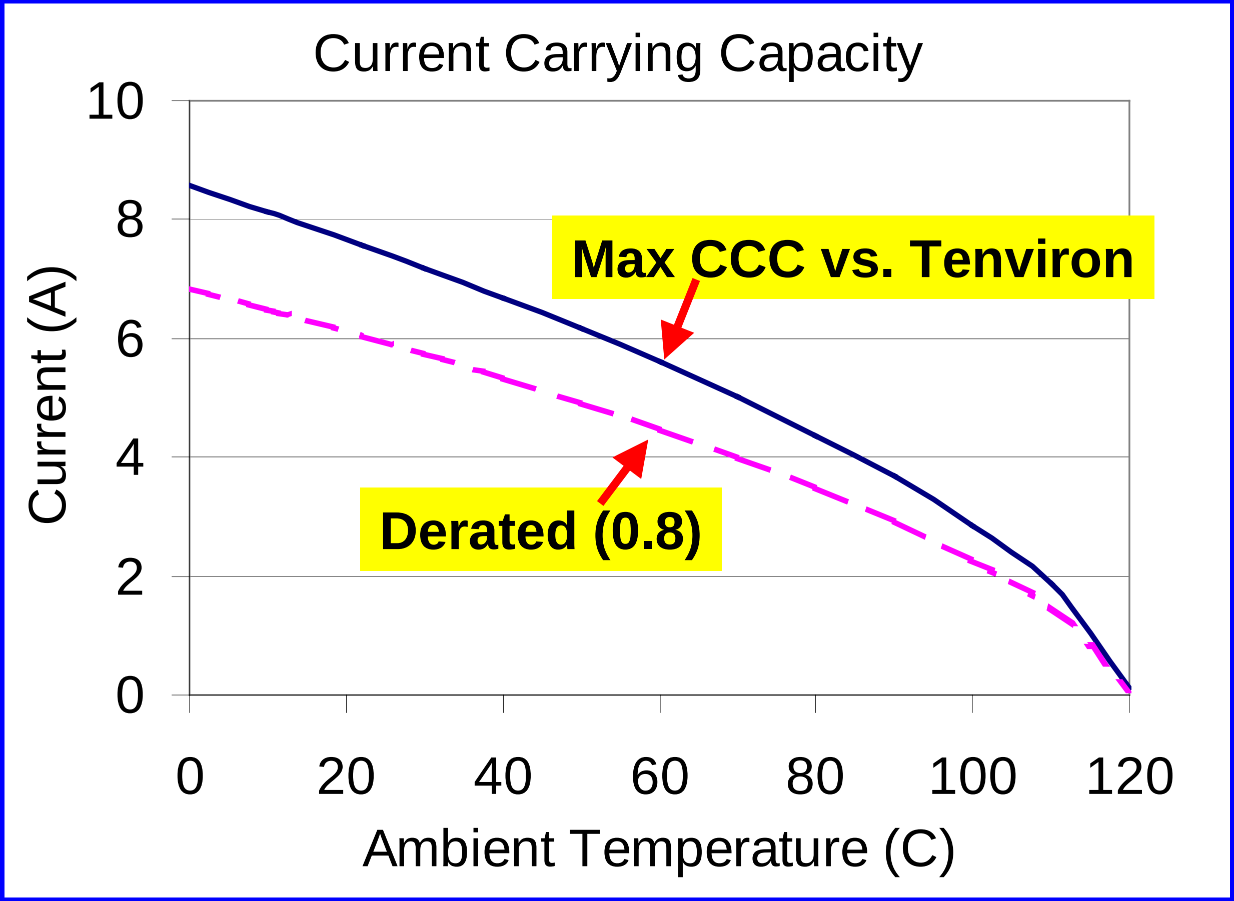
Thermal Imager:

- Calibrated with high-end block-body calibration source
- System accuracy of +/- 2°C
- Accuracy of measurements +/- 2°C

Thermocouple:

- Measure system accuracy of +/- 2°C
- Uncertainty on accuracy of measurements:
  - Thermal contact barrier between pin and thermocouple
  - Heat sink function of thermocouple
  - May not at max temperature position

Determination–
Current Carrying Capacity



Assumed max temperature = 120°C

Summary

Two measurement systems, thermocouple and IR, were established in KNS to measure the current carrying capacity of inter-connector.

Measurements with IR system are more stable and have better repeatability and accuracy (+/- 2°C).

Accuracy of using thermocouple is affected by thermal contact barrier, heat sink, and one point only measurement.

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Current Rating for Contacts Time to Standardize the Test Method

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Introduction

- Higher current requirement in Burn in and functional test at smaller "real estate" area
- What is current carrying capacity of the contact
- Could we borrow the evaluation standard from connector industry
- Need to have customized test methods for socket application
  - Test Method A (single contact, ambient)
  - Test Method B (cluster of contacts, oven environment)

Background

- Electronic packaging design puts more power in less pins in smaller “real estate”
- Industrial standard EIA-364-70 is only a good reference point for contacts
- Current rating should be related to the application of the contacts in Burn in and Test socket

Criteria for Contacts

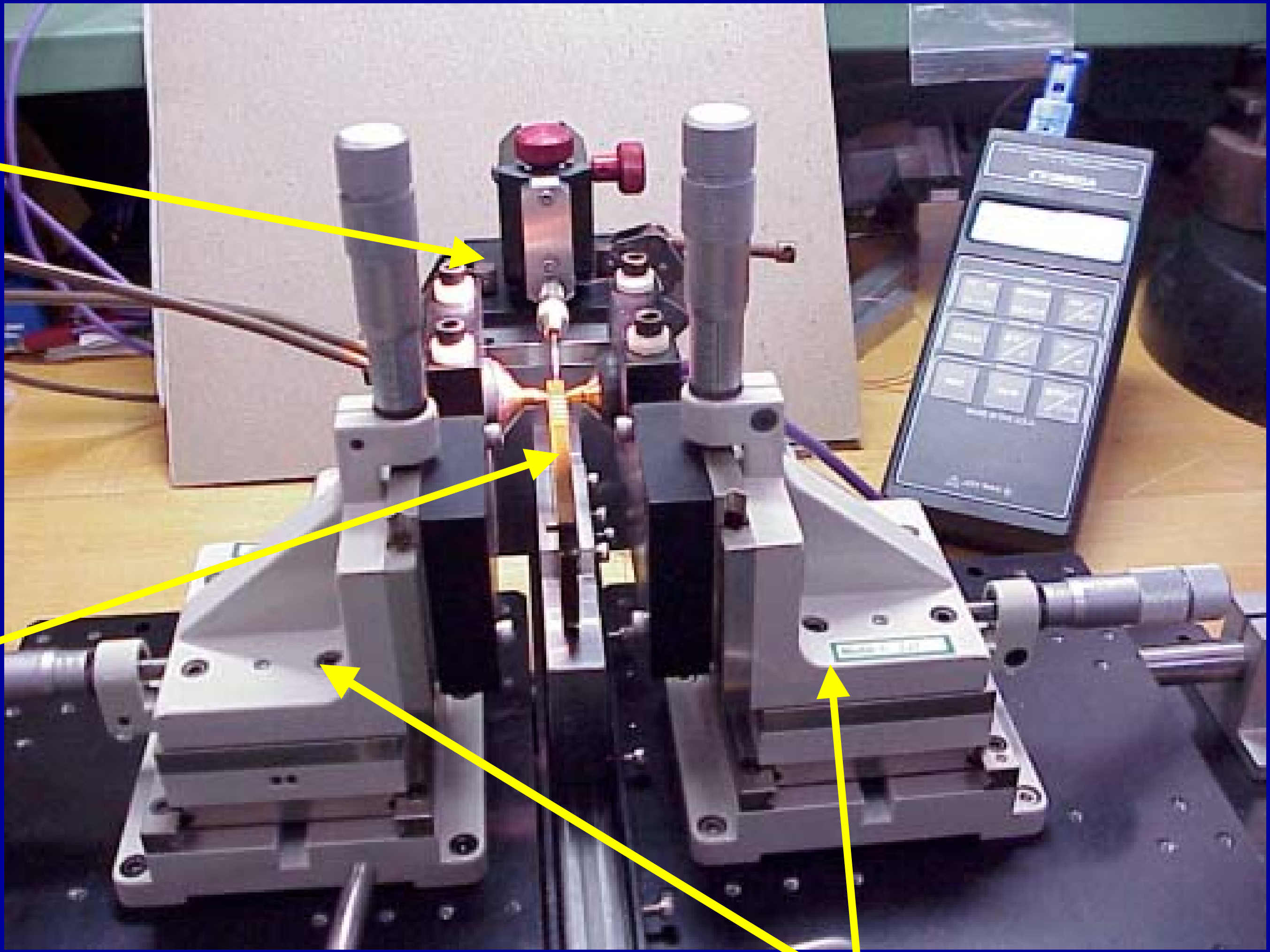
- Compliance range (i.e. > 0.2mm @1mm pitch)
- Before and after the test:
  - Check for changes in dimension and appearance (such as plating)
  - Check force-deflection-resistance
- Performance over current cycling (power on/off) and durability at elevated temperature

Test Method A

- Temperature Rise vs. Current of a single contact (similar to EIA-364-70)
  - Ambient, still air
  - Contact is held at operating length with minimum constraint from the fixture
  - 0.005” thermocouple is placed at the hottest spot of contact under test
  - Used for contact selection pre-screening

Test Method A Setup

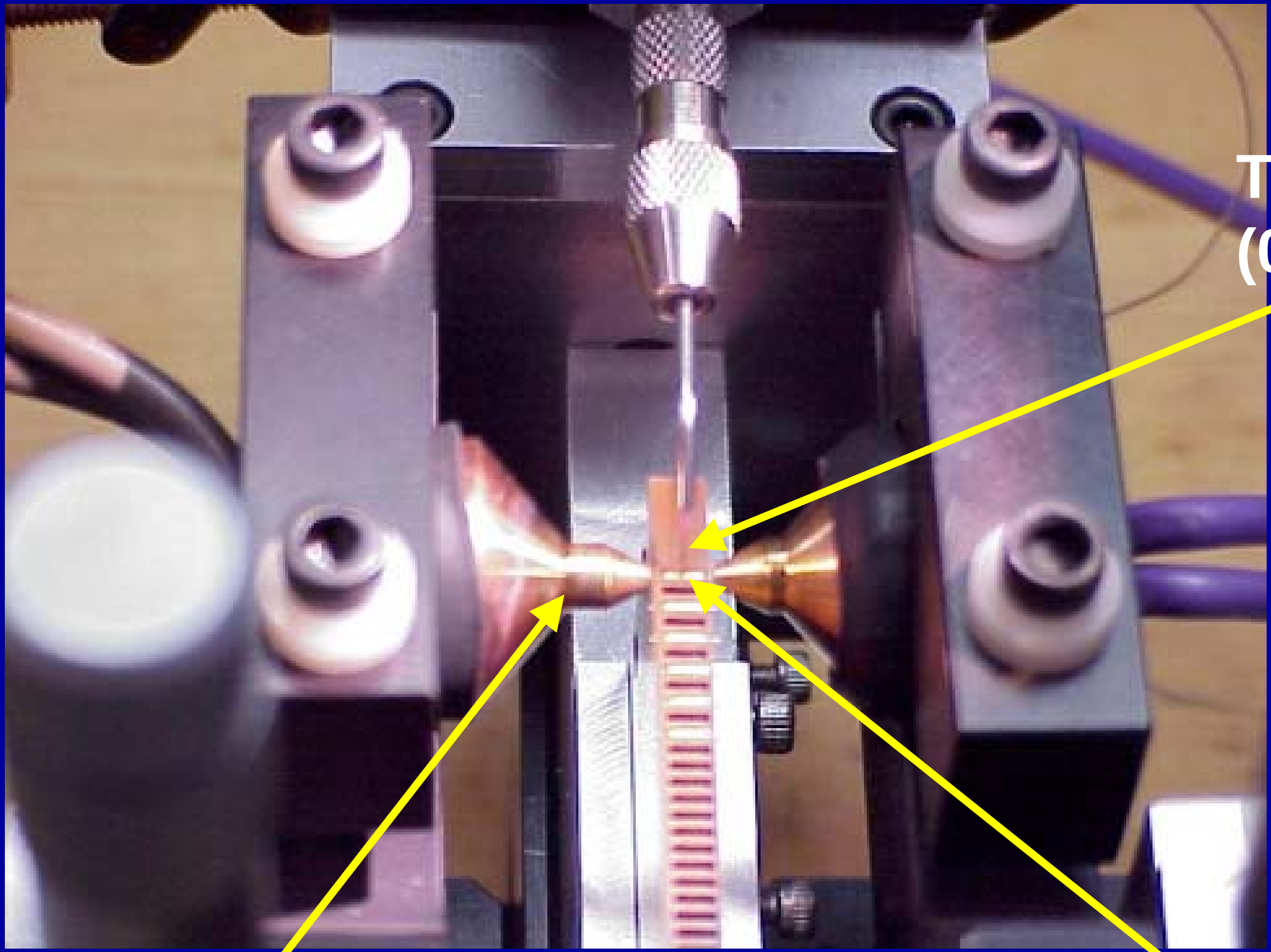
Mini X-Y-Z stage



Modified interposer

X-Y-Z micrometer stage

Test Method A Setup (Cont'd)

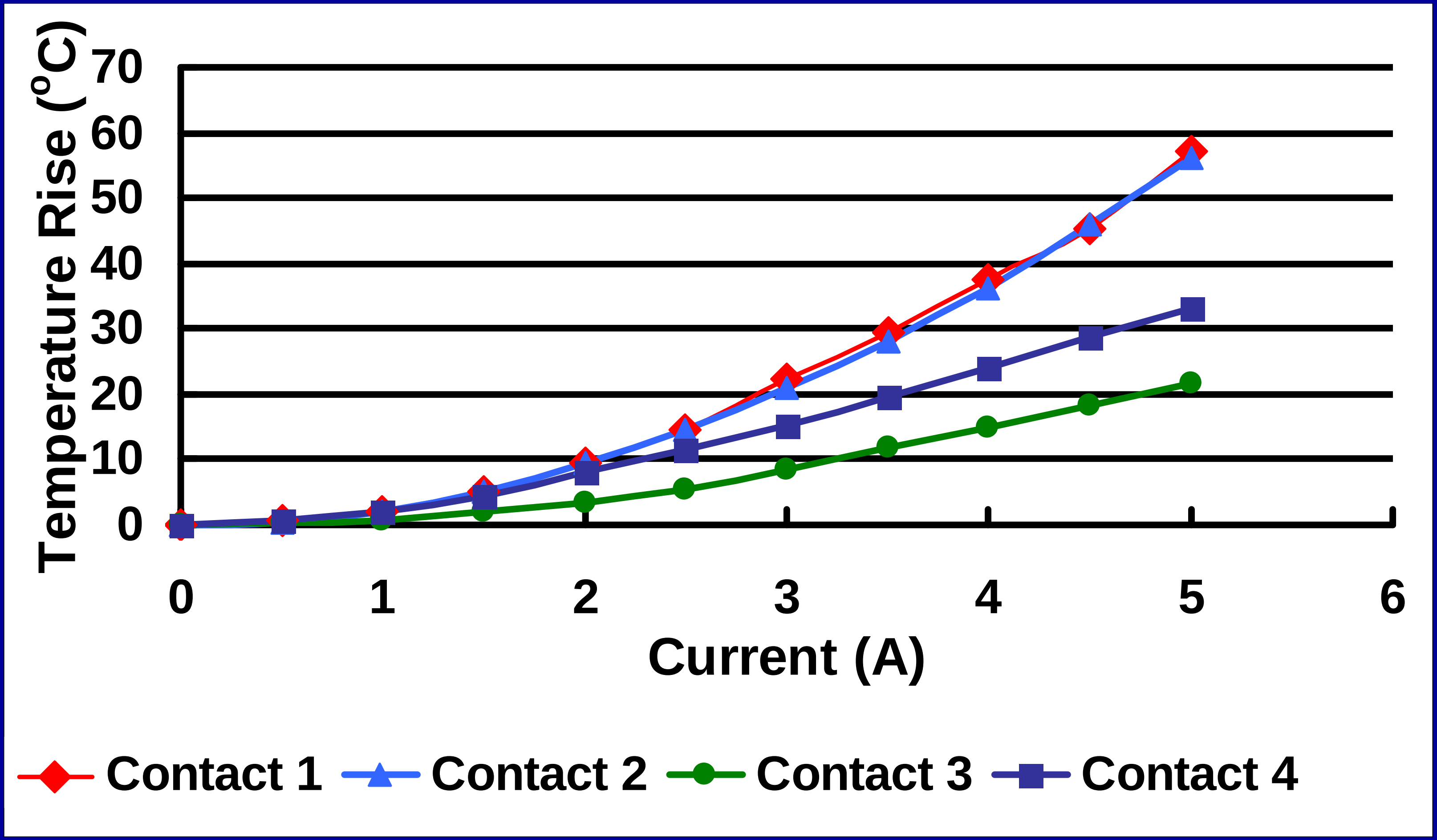


Thermocouple
(0.005" Dia.)

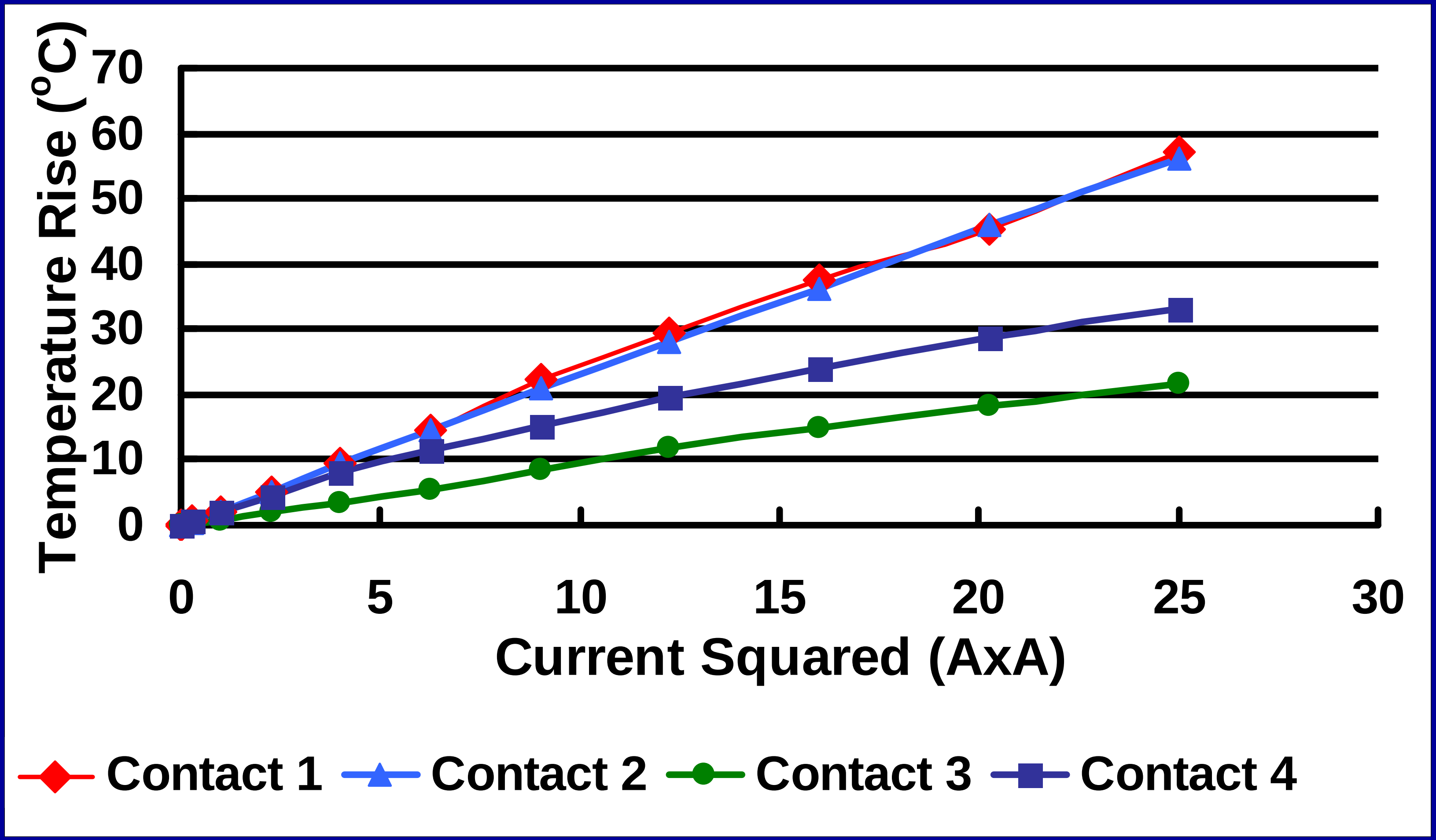
Copper Electrode
(Au plated)

Contact
under Test

Comparison of Commercial Contacts from Test method A



Current Squared vs. Temperature Rise



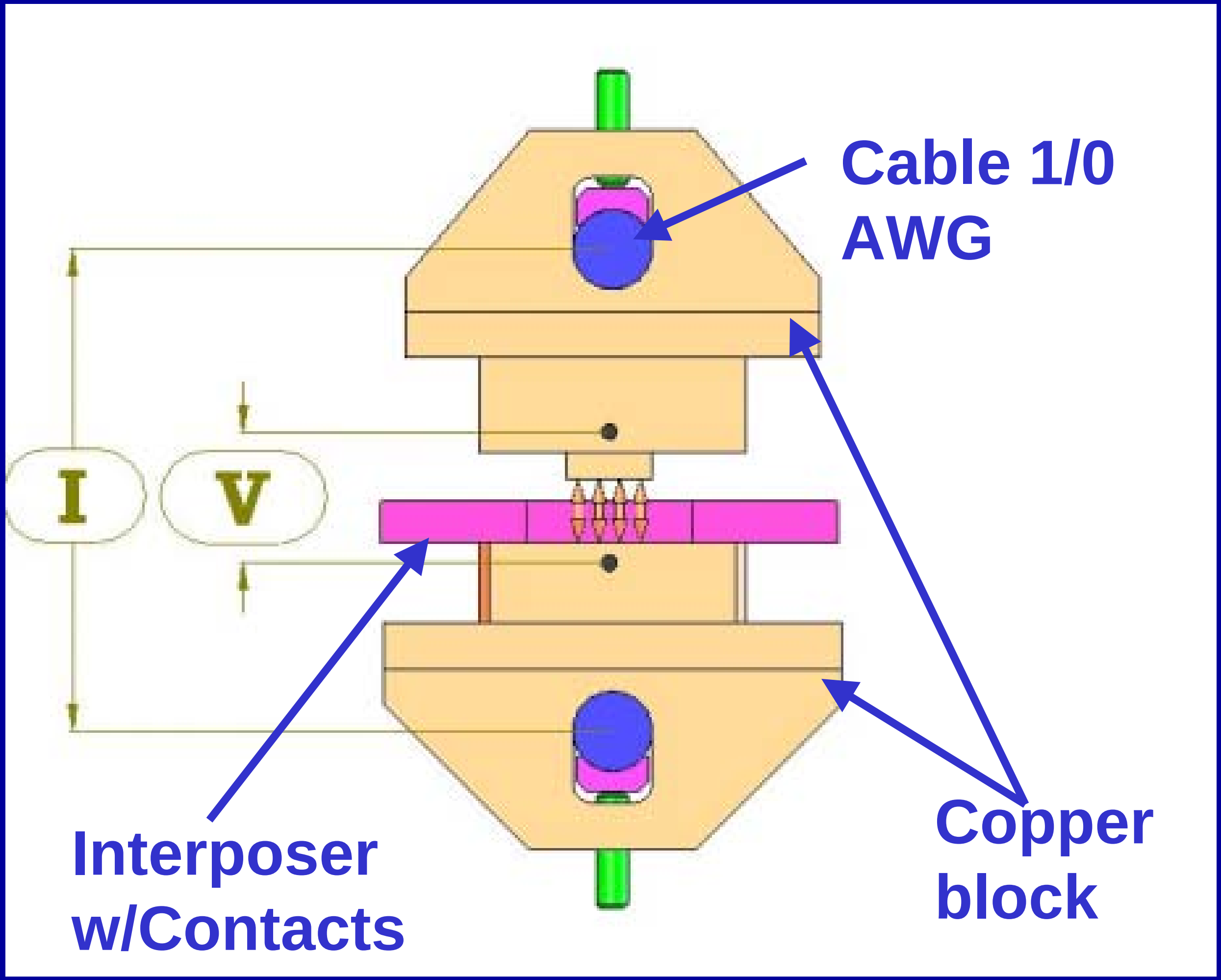
Test Method B

- Cluster of contacts
  - held in socket interposer
  - sandwiched between two Au-plated copper blocks
- The entire test setup
  - placed inside a convective oven (temperature precisely controlled and not influenced by the heat dissipated from the contacts)

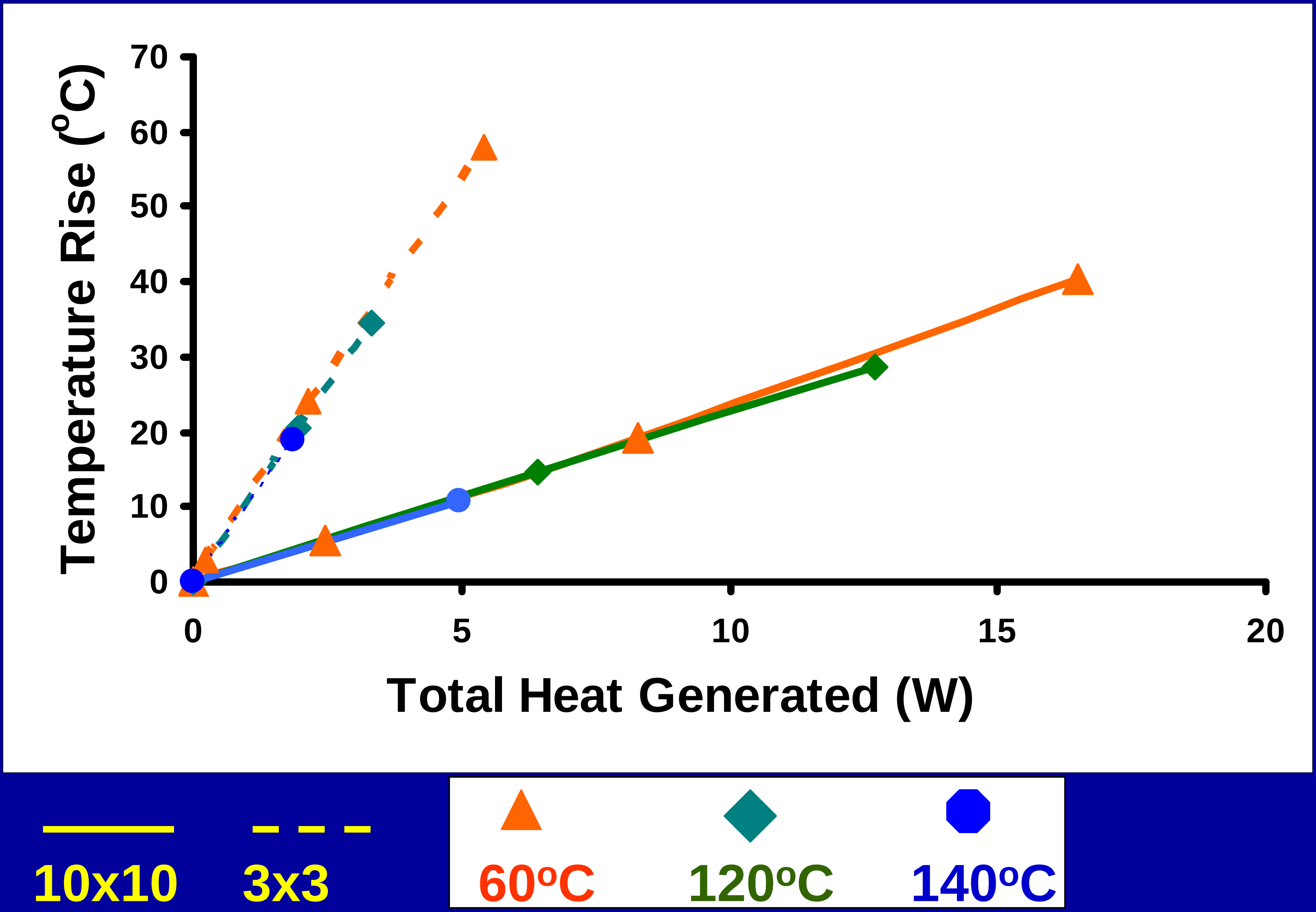
Test Method B (Cont'd)

- Temperature rise (Delta T)
  - T (air in the center of the area array) – T (air close to the socket body)
- Voltage drop
  - across the two copper blocks
- Average resistance
  - Voltage Drop / (Current / pin)

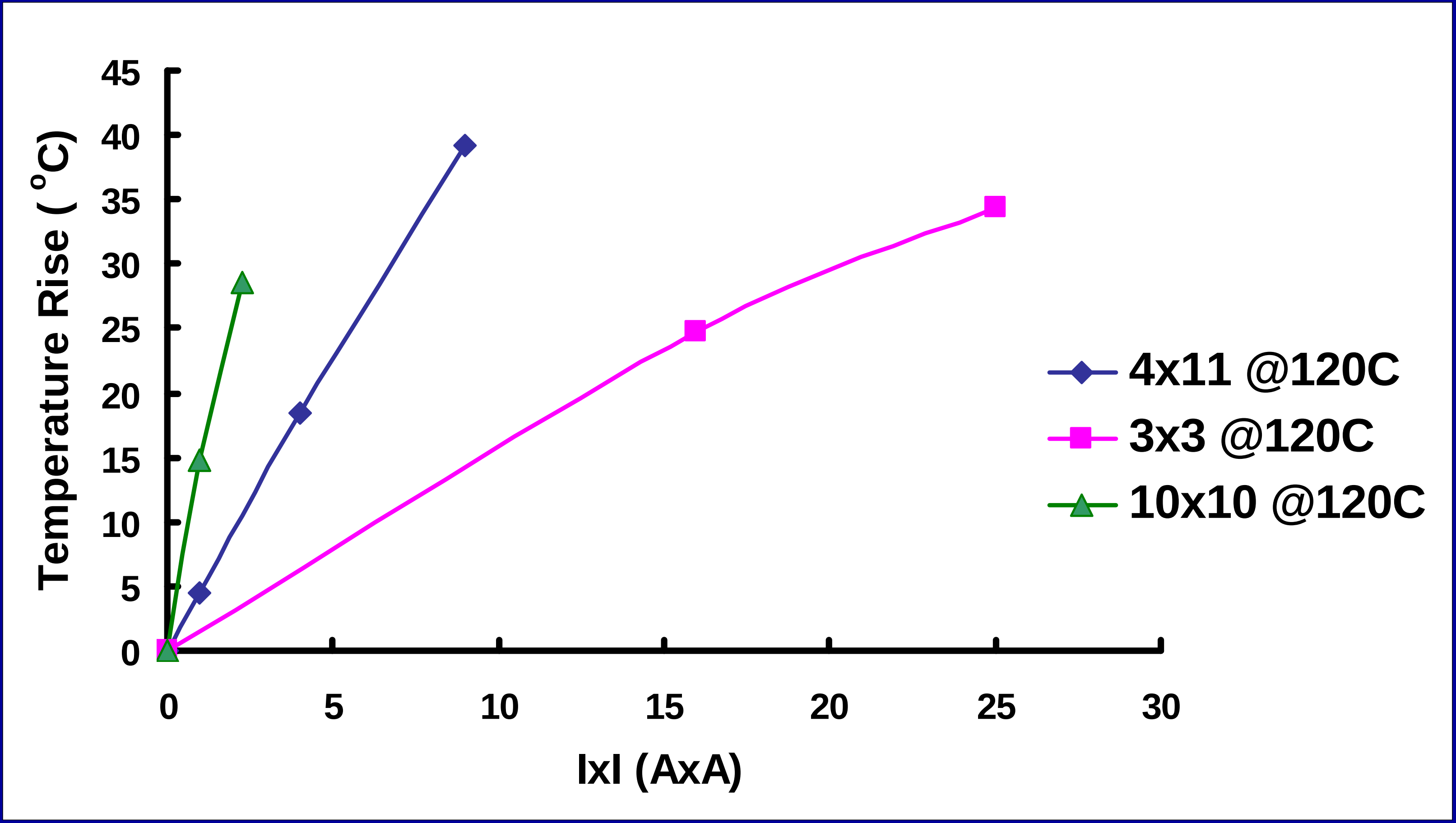
Test Method B Setup



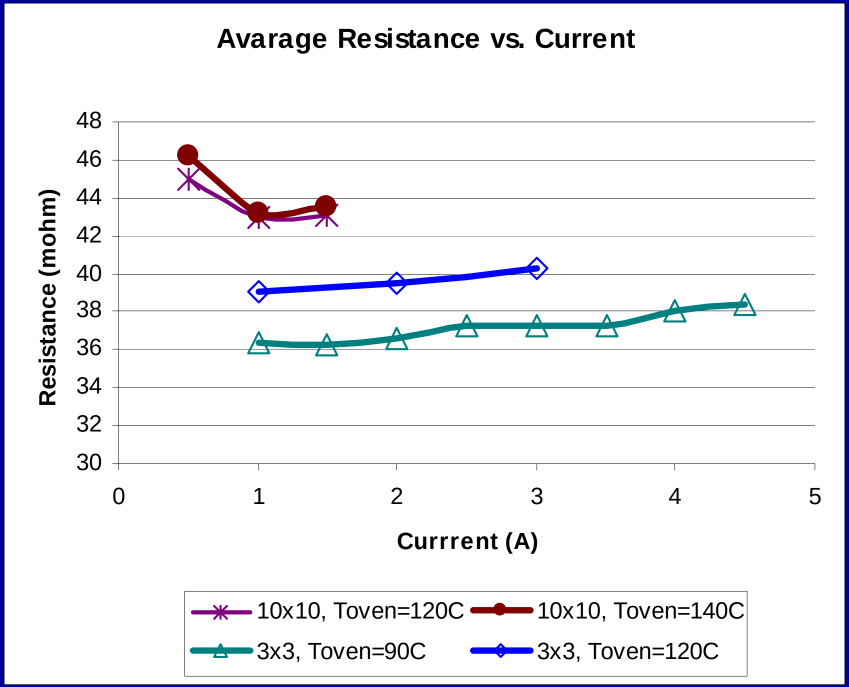
Comparison of IxIxR vs. Delta T at Various T_{oven}

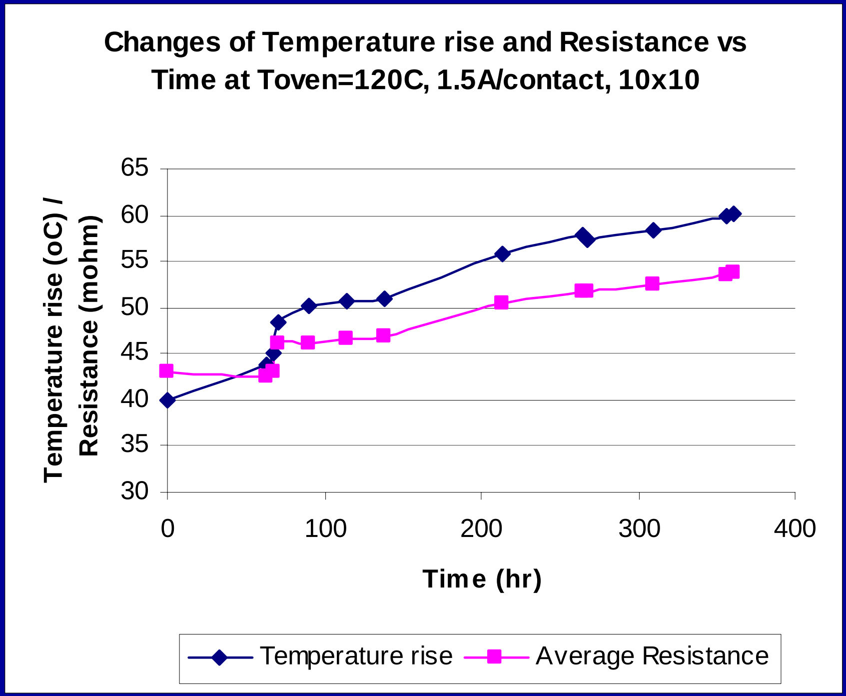


Comparison of IxI vs. Delta T at Various Area Array Size



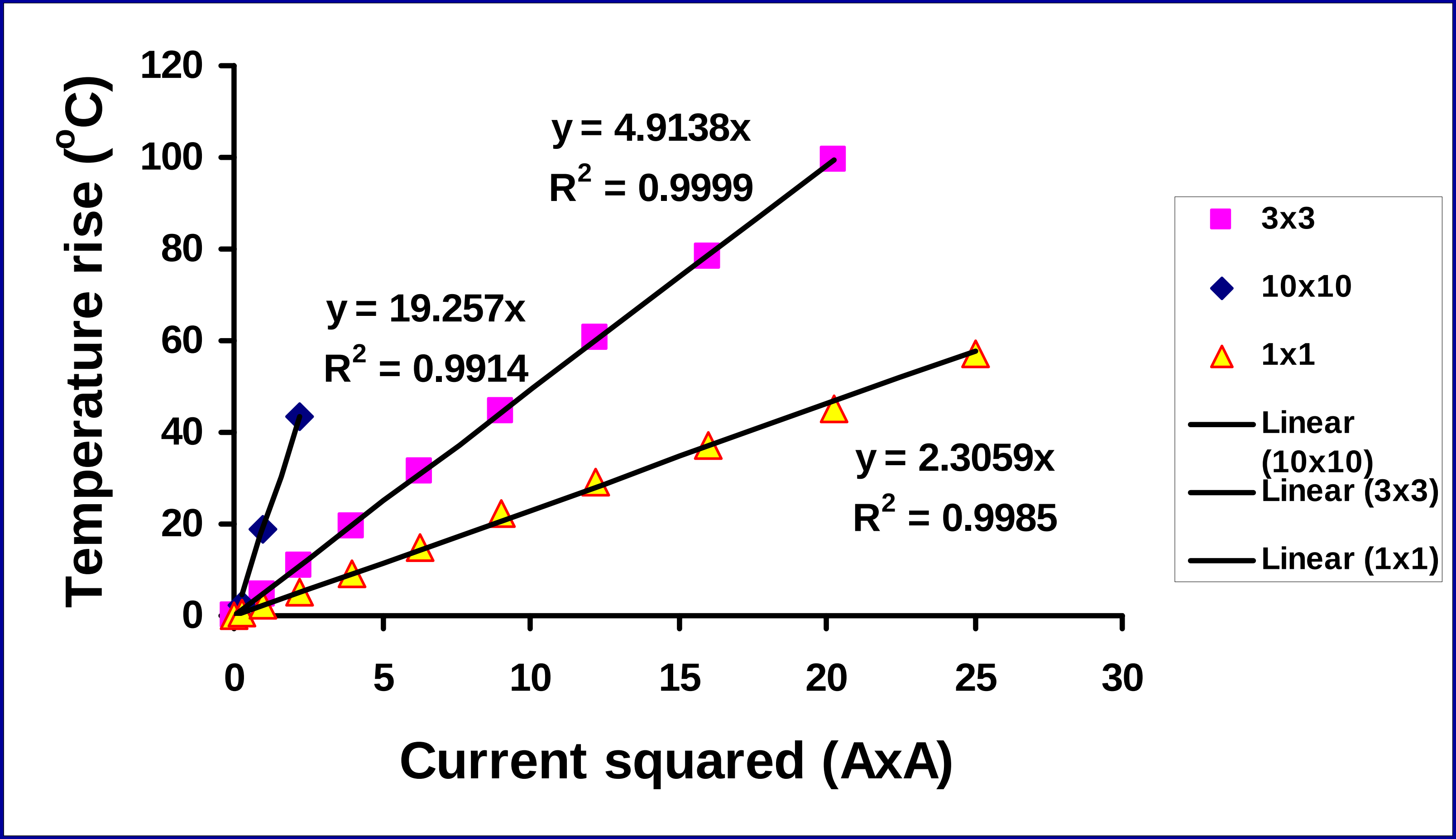
No Significant Changes in Average Resistance





- Average Resistance varies little versus Current
- Average Resistance changes less than 20% over 360hrs Burn in

How Test Method B Can Help Predict Other Cases



How Test Method B Can Help Predict Other Cases (cont'd)

- **Only 1 test point is needed for a new contact at each area array size**
- **Temperature rise can be predicted for other area array size by plotting a straight line in the curves within 1x1, 3x3, 10x10**
- **Observed from experiments, set $T_{array,\ max}$ = 170°C, I.E.**
  - **5x5 array is between 10x10 and 3x3 (4.9 vs. 19.2), say 10**
  - **at T_{oven}=120°C, Y=170-120=50°C**
  - **X=50/10=5, and I_{max}=2.2A**

Simplified Prediction Agree with Test Results

Case #	Test parameters	Predicted Imax	Test results	
1	10x10 @ 140°C, 1A	Y=19.257X Y=170-140=30C Imax=1.25A	120hrs OK	✓
2	10x10 @120°C, 1.5A	Y=19.257X Y=170-120=50C Imax=1.61A	120hrs Ok	✓
3	3x3 @90°C, 4.5A	Y=4.914X Y=170-90=80C Imax=4.03A	12hrs Burned	✓

Summary

- Two step approach to standardize current carrying capacity for contacts
  - Method A to screen potential candidates
  - Method B to determine current carrying capability at a given array
- Developed a simplified model to predict I_{max}

References

EIA-364-70:
“Test Procedure for Current vs. Temperature Rise of Electrical Connectors”

http://global.ihs.com/

Socket Current Carrying Capacity (CCC) Characterization

Victor Henckel
Glenn Cunningham
Hongfei Yan

Intel Corporation

Agenda

- Problem Statement
- Industry Methodology
  - Definitions for Use Condition
  - Comparison with Use Condition
- Proposed Methodology
  - Definitions
  - Test Setup
  - Pin Design Temperature
  - Specification
- Test Description and Result
- Conclusions

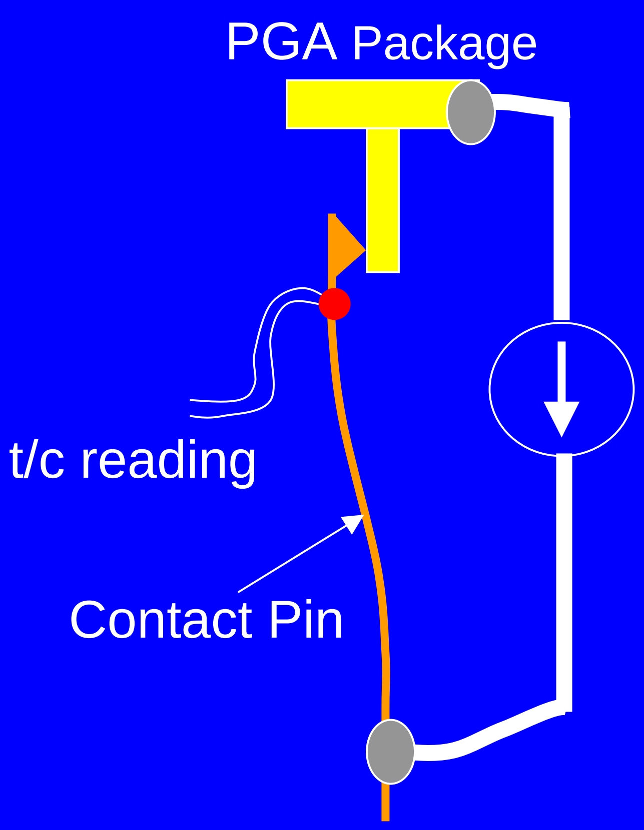
Problem Statement

Contact pin CCC (current carrying capacity) methodology does not predict performance in use condition.

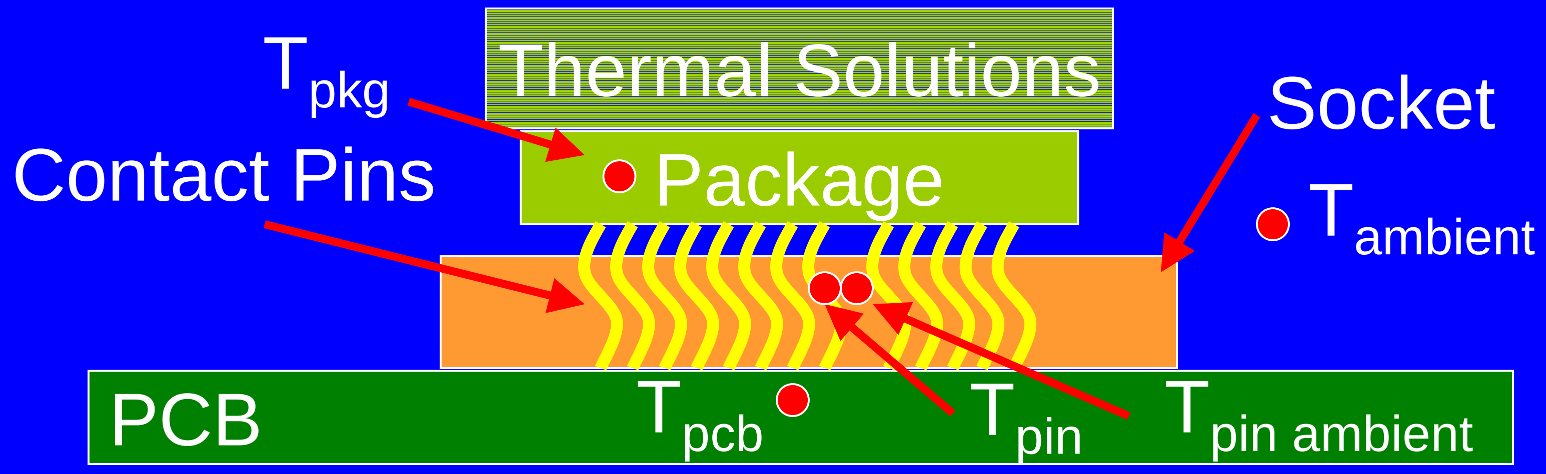
Industry Methodology

- The industry standard for current rating of sockets is to measure temperature at the individual pin level including package pin contact.
  - The temperature rise of the pin is plotted versus current.
  - The CCC is plotted on a de-rated curve to determine the max current load for a given ambient temperature.
- What is the CCC for a pin array? BIS?

Test Setup Illustration



Key Parameters Identified From Use Condition

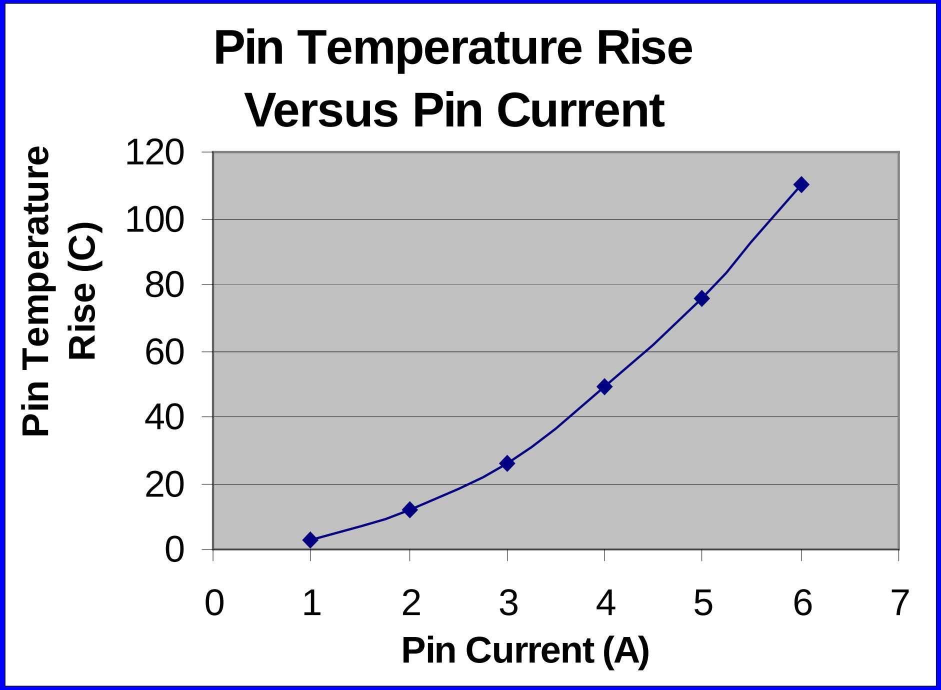


List of parameters impacting socket CCC.

- Ambient temperature
- Package temperature
- PCB temperature
- Pin ambient temp.
- Pin temperature
- Contact pitch
- Total number of power and ground pins
- Power and ground pin pattern
- Steady state or transient with duty cycles
- End of life testing post stress relaxation
- Minimum allowable displacement

Industry Method
Compared to Use Condition

- Does not include the effects of current density or the contact pin thermal environment.
- Actual industry data shown below for pin level.
- How do we estimate BIS CCC?

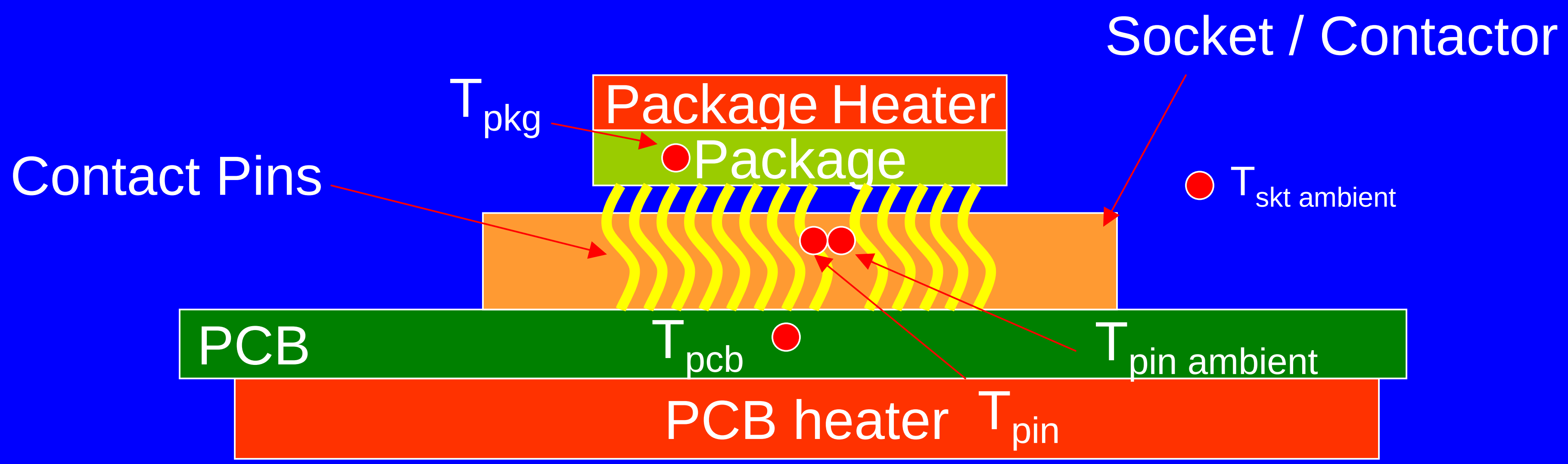


- **Given:**
  - **60C Ambient**
  - **300 Power Pins**
  - **Max operating temp of pin is 110C.**
- **Answer:**
  (4.0A)(300)=1200Amp?
  WRONG!!!

Proposed Methodology

- Socket assembled to PCB with actual power/gnd pin map of use condition (or range of pin arrays).
- Control $T_{substrate}$ and T_{pcb} with heaters to simulate use condition.
- Control $T_{ambient}$ with oven/enclosure or use correction factor for room temperature.
- Measure the pin temperature through a range currents and plot CCC.
- Socket CCC = current load through contact pin array if Tpin is not exceeding pin design temperature.

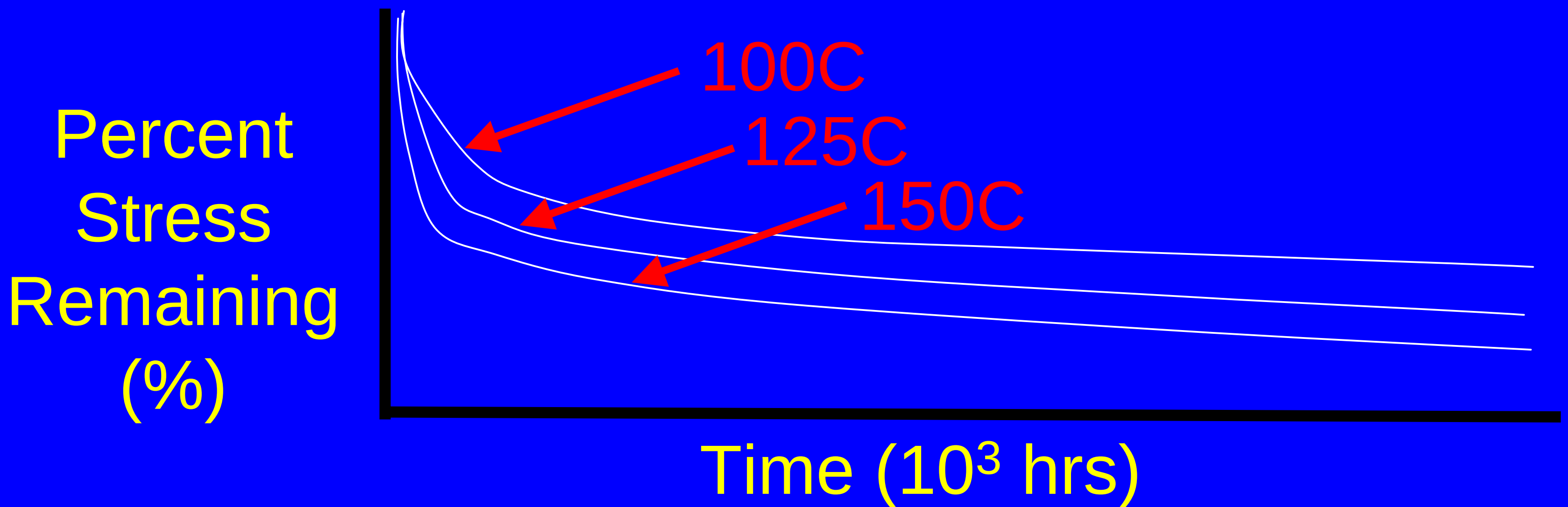
Proposed Test Setup



- Measure critical temperatures (shown above).
- Two heaters to control $T_{substrate}$ and T_{pcb} per the use conditions.
- Heaters controlled via feedback loop from thermocouple attached to substrate and PCB.

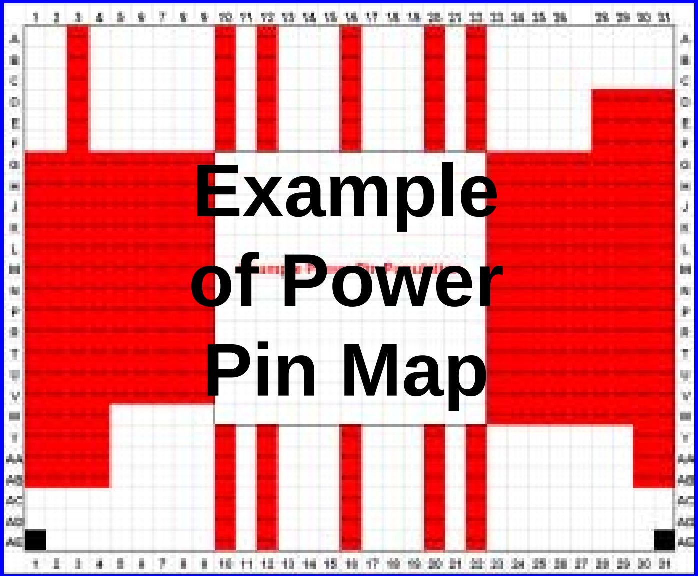
Contact Pin (C/P) Design Temperature

- C/P design temperature or maximum operating temperature can be chosen based on the stress relaxation curves.
- Percent stress remaining plotted over time can be used to predict the service life for a given temperature.



Specification (Example)

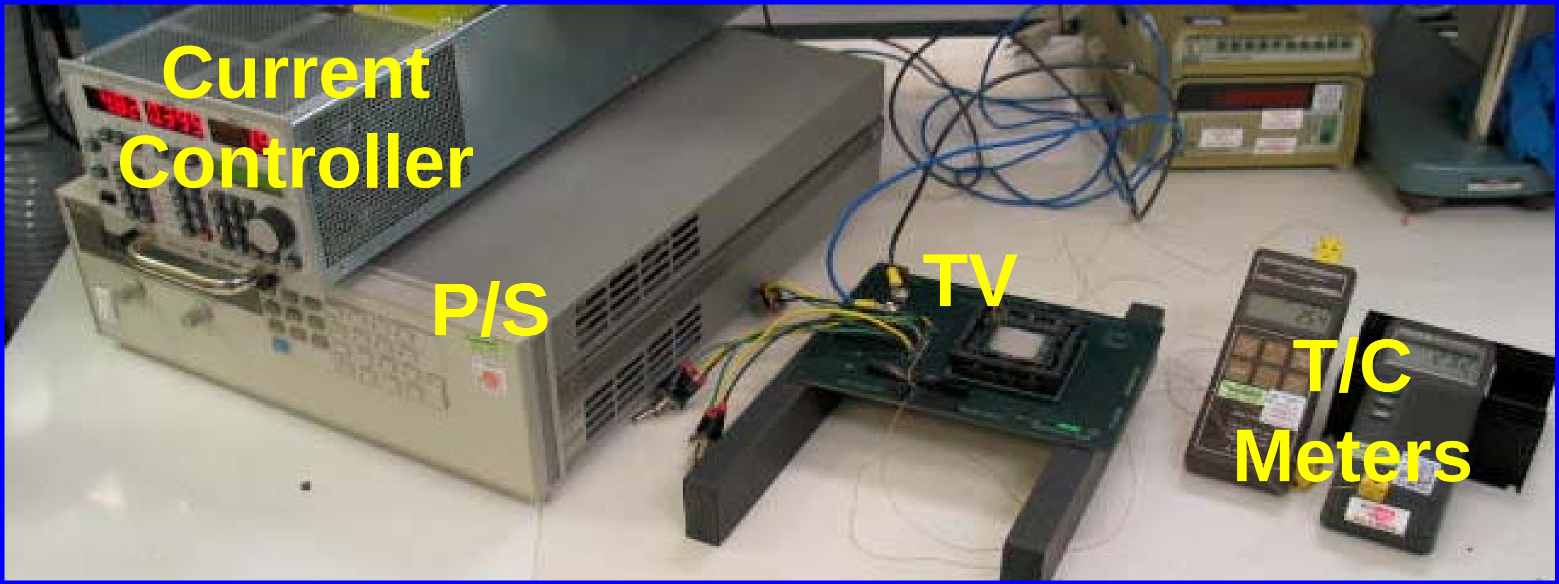
- Service life at test condition: 5000hrs.
- Socket environmental conditions:
  - Substrate temperature: 100C
  - PCB temperature: 50C
  - Ambient air temperature: 25C



- Socket CCC: 100 Amp supplied through 100 power pins and 100 ground pins
- Contact pin CCC: 2 Amp.

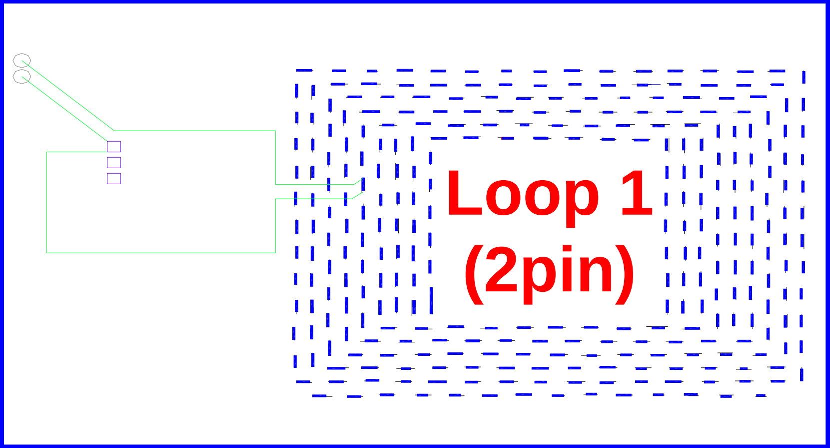
Details Of Test Setup

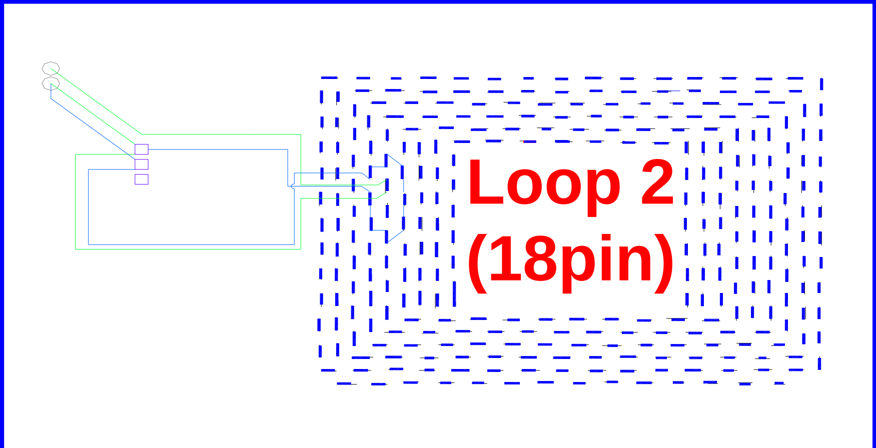
- Hardware: Power supply (P/S) with current controller
- Test Vehicle (TV):
  - Daisy chain package.
  - Daisy chain PCB with toggle switches to direct current through various pin populations.
- Thermocouples & t/c meters.
- Not Included in this setup (Enclosure/Oven & Strip Heaters)

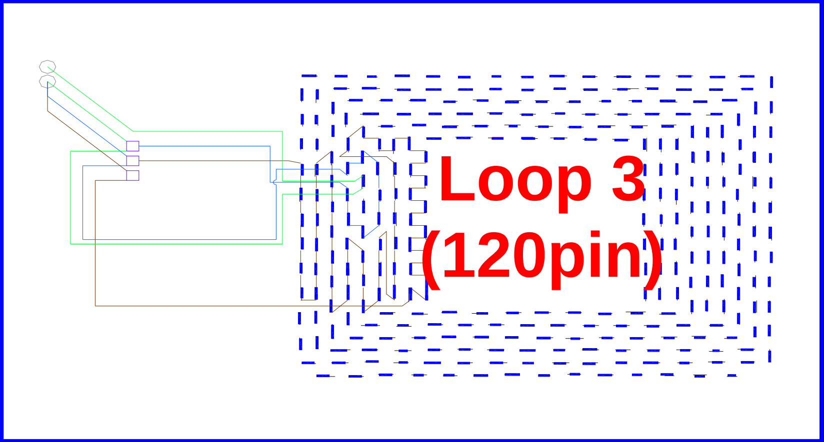


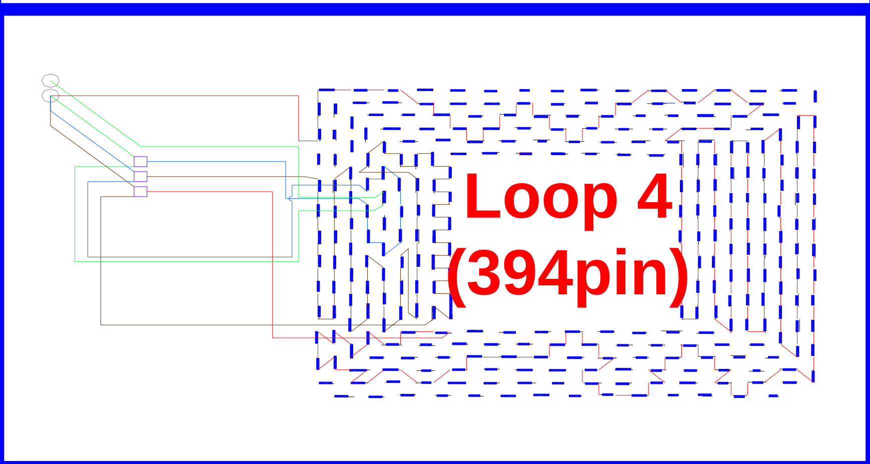
Details Of Test Setup

- Schematics: PCB & Package daisy chain routing.
- 4 loops with cumulative counts of 2, 18, 120, and 394.



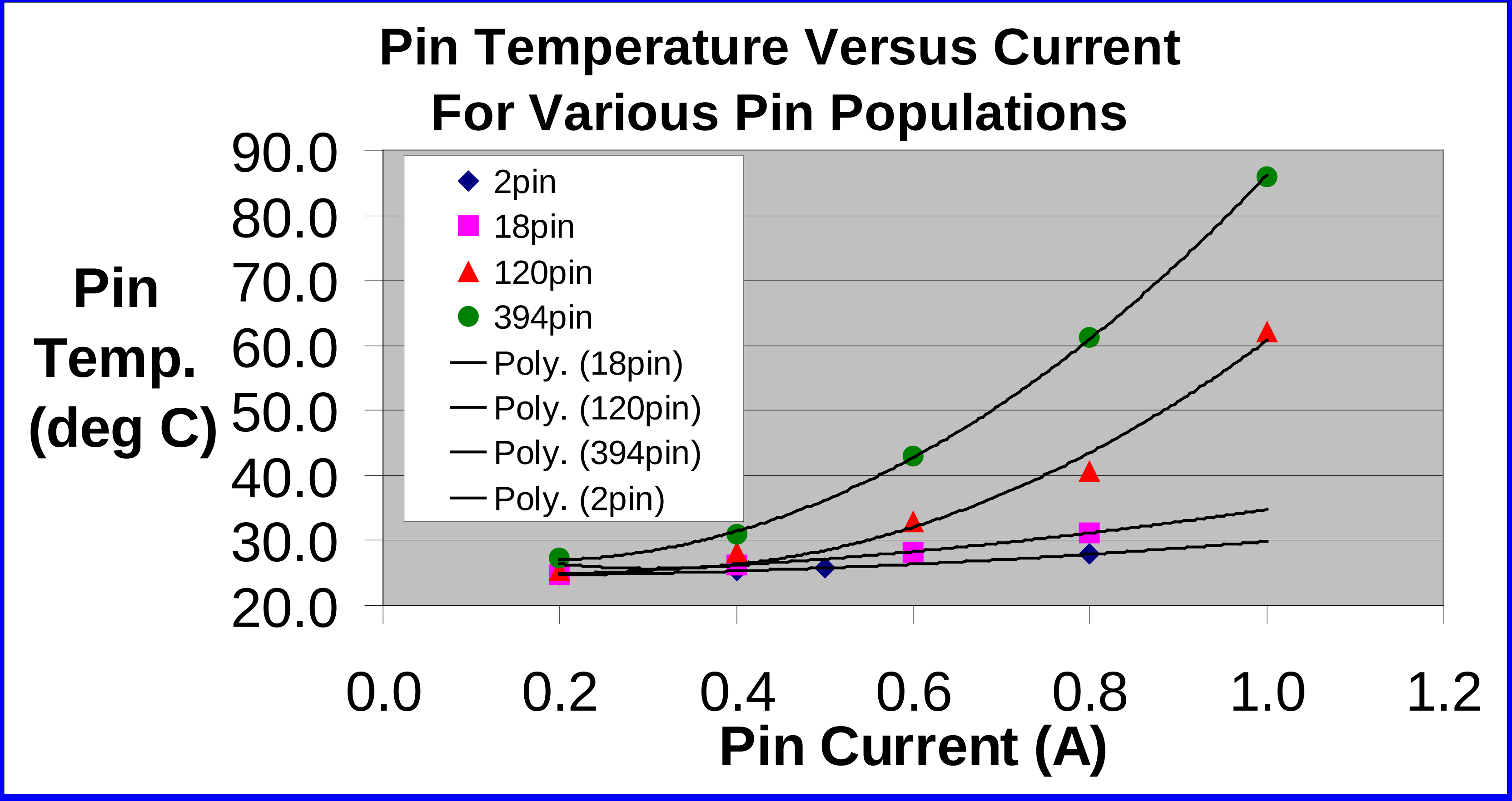






Test Result

- Test performed at room temperature (23C).
- T_{pin}, $T_{substrate}$, and $T_{pintail}$ at current levels.
- Below is the T_{pin} for various pin populations.
  - Steeper Trise for increasing pin density.



Conclusion

- CCC methodology does not predict performance in the use condition.
- Need socket level CCC which includes the thermal environment.
- Materials industry needs to provide data for contact pin design based on initial stress and service time.
- Suppliers and end users need capability to predict the CCC of a particular pin design.