New Generation of Fine Pitch Kelvin Spring Probes

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TECHNOPROBE

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MICROFABRICA

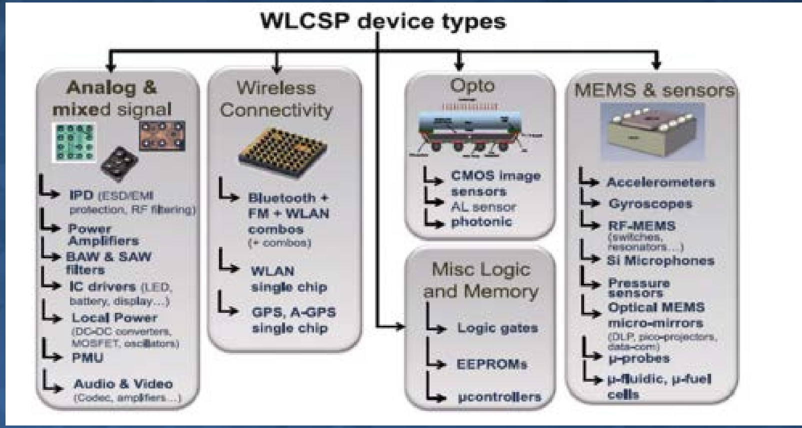
Hsinchu, Taiwan, October 26-28, 2022

Overview

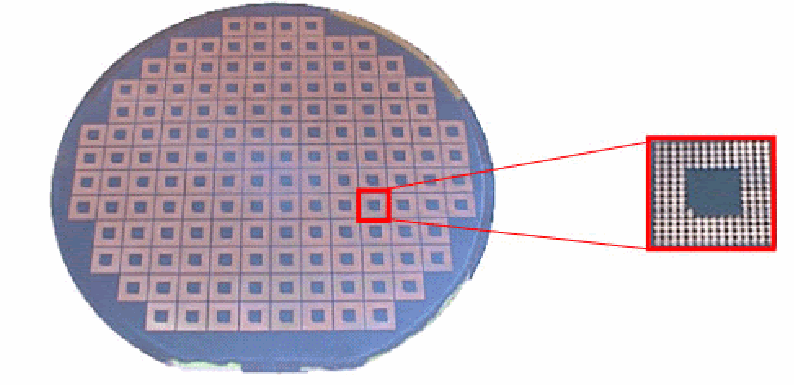
- Introduction / Background
- Goals & Objectives
- Why Kelvin Measurement?
- Design Criteria for True Kelvin Spring Probes
- MEMS Fabrication of True Kelvin Spring Probes
- Design Results
- Summary

Introduction

- **Wafer-Level-Chip-Scale-Package (WLCSP) is becoming packaging technology of choice across different applications**
- **Major trends in WLCSP**
  - Increasing wafer size
  - Shrinking die size
  - Tighter pitches
  - Increasing I/O counts
- **New generation of Kelvin contacting technology is required to support these immutable trends**
  - Scales down to very fine pitches and ball sizes
  - Highly precise and reliable
  - Easier to use and maintain (crucial for high I/O count applications that are cost sensitive)



Yannou, J-M.: Market dynamics impact WLCSP adoption, 3D Packages, No. 22, Feb (2012)



WLCSP wafer

Goals & Objectives

- **Goal:**
  - Advance True Kelvin Spring Probes for fine-pitch WLCSP
- **Objectives**
  - Enable True Kelvin measurement over full array at fine pitches
  - Enable capability to “mix and match” w standard spring probes for non-Kelvin test I/Os
  - Improve pointing accuracy for reliably hitting smaller targets
  - Make True Kelvin Spring Probes easier to use and maintain
  - Reduce the overall cost of Kelvin Test

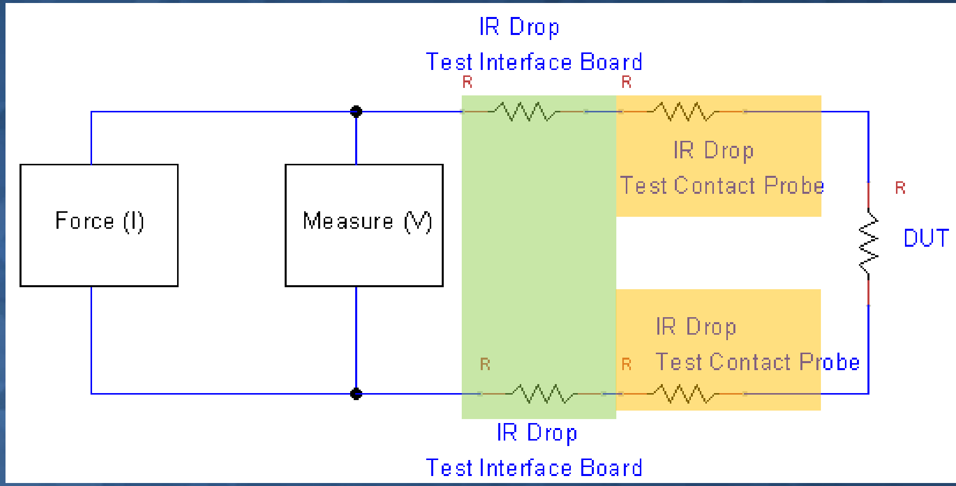
Why Kelvin Measurement?

Overview:

- **Test interconnect circuit**
- **Kelvin connection**
- **Evolution of resistance measurement**
  - Traditional Two-Wire measurement
  - Four-Wire measurement through two standard spring probes
  - Four-Wire measurement through two True Kelvin Spring Probes

Test Interconnect Circuit

- A test interconnect circuit includes test interface board, test contact spring probes, Device-Under-Test (DUT)
- The resistance of the test interface board and the contact probes are added into the resistance measurement, causing significant error in measurement of DUT

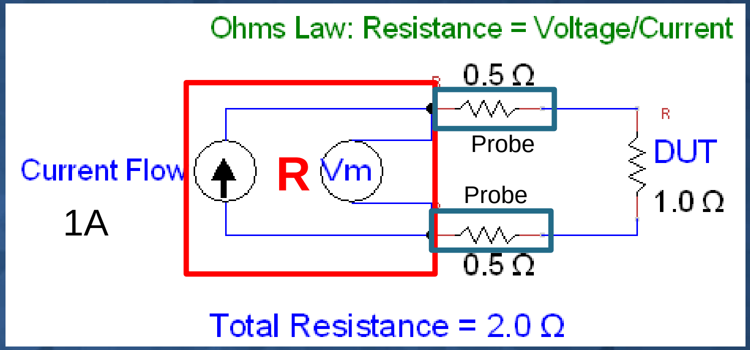


Improved Measurement Accuracy

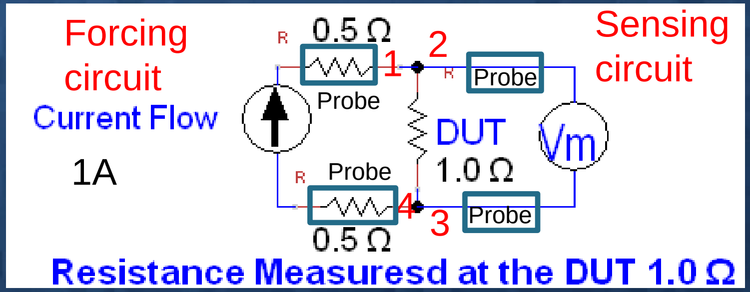
- **Direct Measurement vs. Kelvin Measurement**
- **Direct Measurement (2-wire)**
  - In the example, the measurement through one series circuit will measure the total resistance of 2.0 Ω which includes 1.0 Ω from the probes
- **Kelvin measurement (4-wire)**
  - The Kelvin connection separates the sensing circuit from forcing circuit to create a parallel connections, which measures the voltage with higher accuracy
  - In the example, this measurement correctly determines the resistance of DUT as 1.0 Ω

DC Measurement Accuracy at the DUT

Direct Measurement (2-wire) Setup

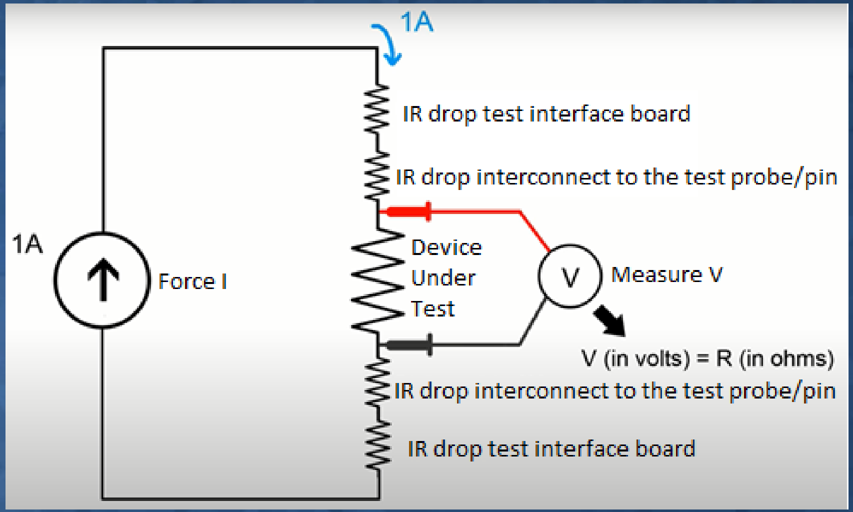


Kelvin Measurement (4-wire) Setup



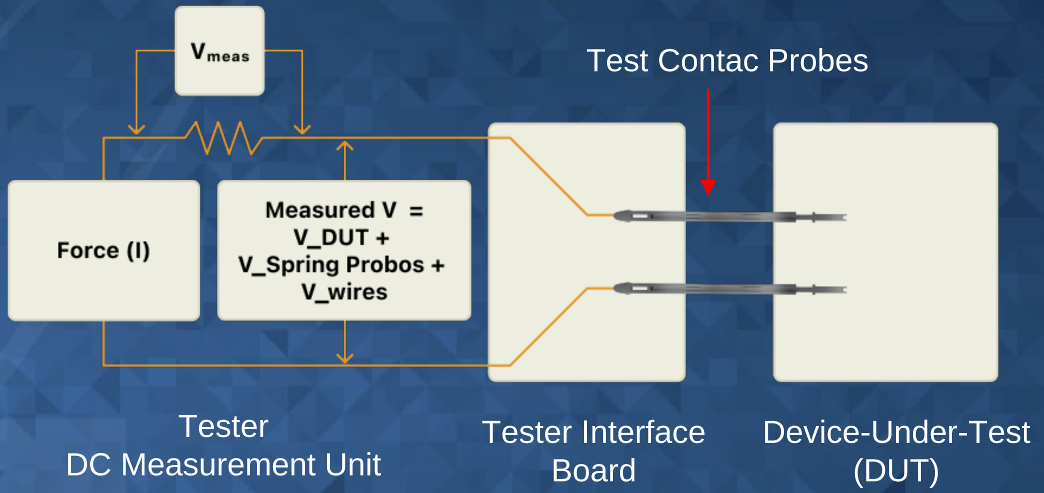
Sensing Circuit Is Not a Big Deal

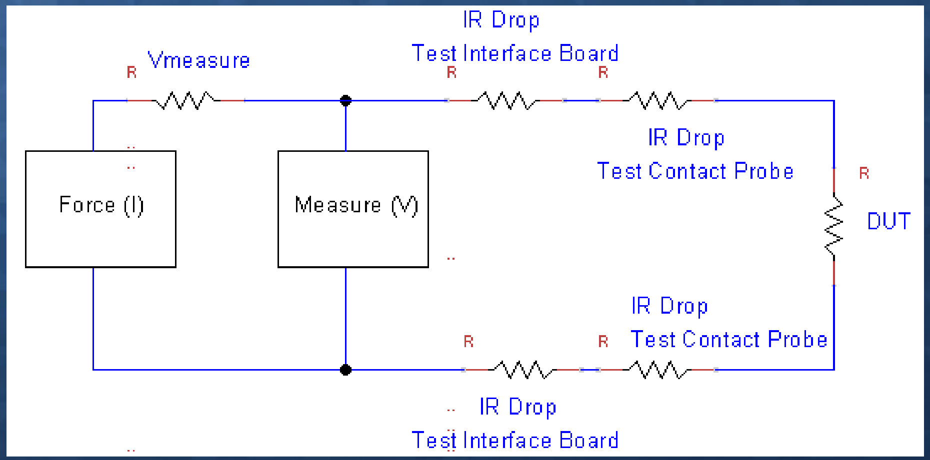
- The input impedance of the Multimeter is very high and negligible current flows into it
- Sensing circuit is parallel to forcing circuit
- Sense connections are very close to DUT



Traditional Two-Wire Interconnect

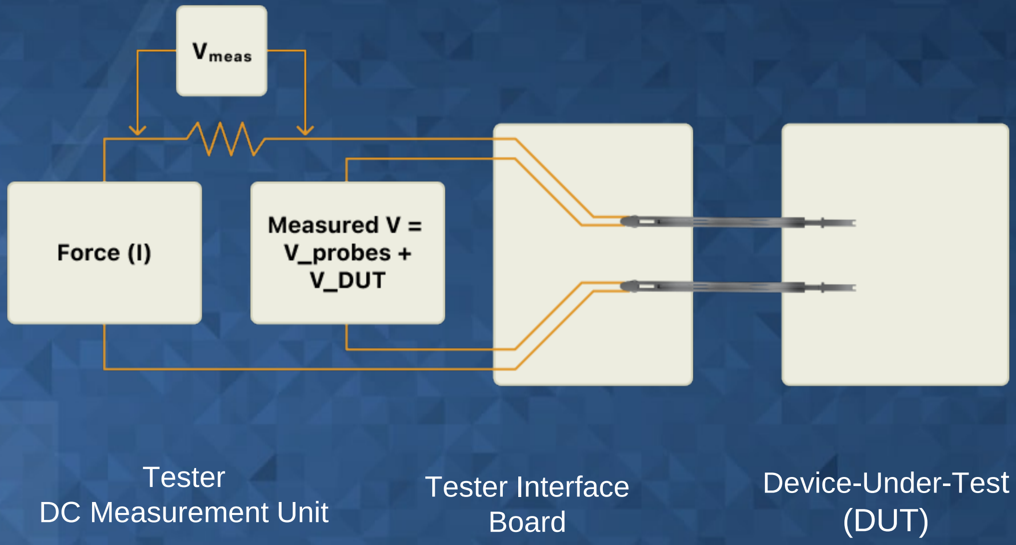
- **Shown here is a basic block diagram of an Automatic Test Equipment (ATE) measurement circuit with some of the interconnects to the DUT**
- **The total resistance measured will include the resistance of the test interface board, test contact probes and DUT because there is only one series path for current to flow**
- **The resistance introduced from the test board and the probes become unacceptable for many applications where DUT resistances are very low**

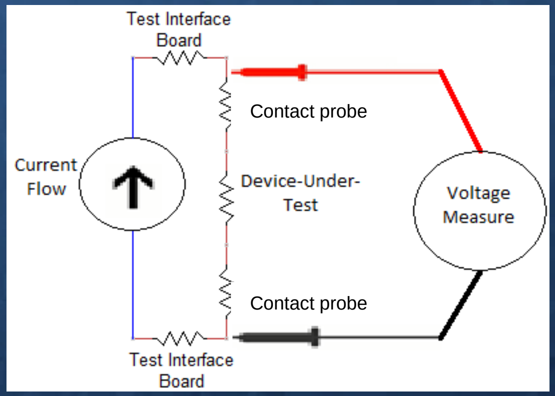




Four-Wire Measurement through Two Standard Spring Probes

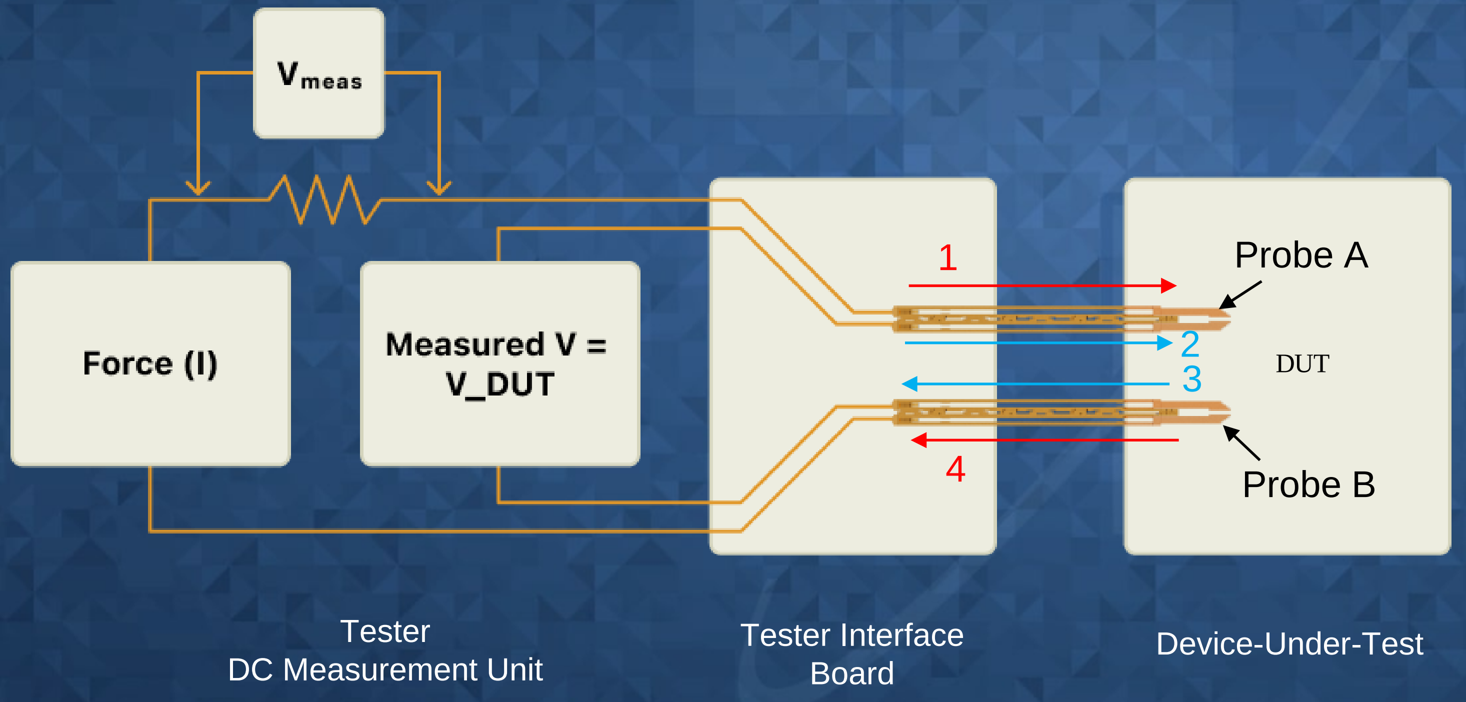
- Four-wire connection at the contactor involves shorting the force and sense lines via the spring probes at the test interface board
  - This method is used when an accurate measurement is desired, but Kelvin contacting at the DUT is not feasible.
  - The voltage and resistances measured are across the combination of contact probes and DUT





Four-Wire Measurement through Two True Kelvin Spring Probes

- **The True Kelvin Spring Probe consists of two isolated electrical paths in one probe, allowing accurate measurement right at the DUT**

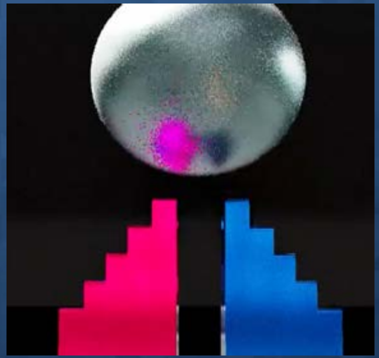


True Kelvin Probe A consists of
Force line 1 + Sense Line 2

True Kelvin Probe B consists of
Force line 4 + Sense Line 3

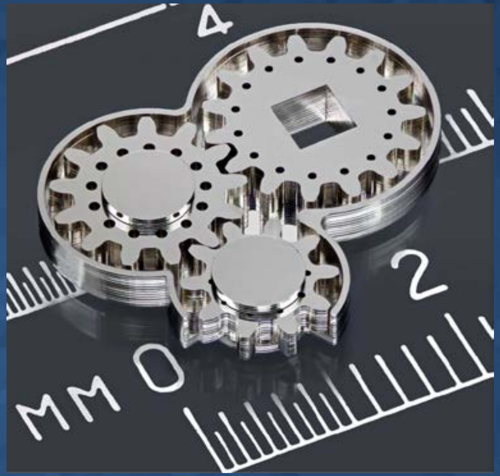
Design Criteria for True Kelvin Spring Probes

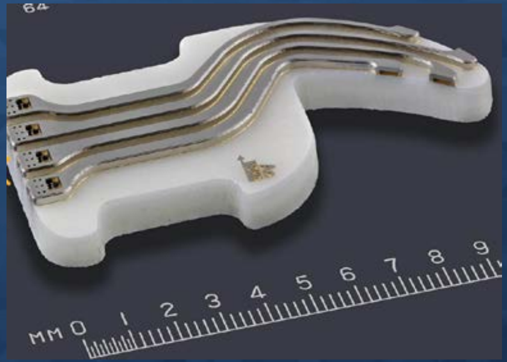
- True Kelvin spring probe should have force and sense paths integrated into a single probe
- Force and sense paths should be electrically isolated from one another
- Probe should have two tips - one for force and one for sense
  - Each tip is allowed to move mechanically independent of other so they can conform to ball non-uniformities
- Tip dimensions and probe pointing accuracy should allow hitting small targets (ball diameters < 200 µm)
- Electrical and mechanical performance should meet application specs



MEMS Additive Manufacturing Overview

Sample devices

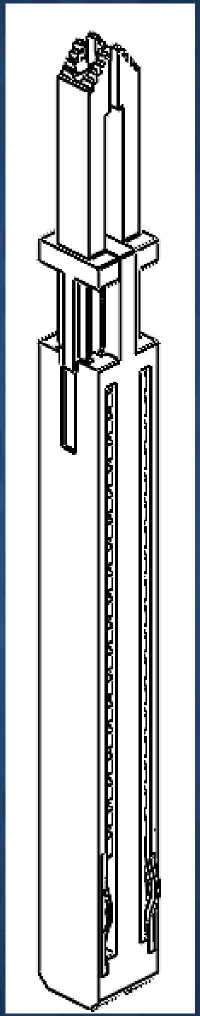




Mica-Freeform Video

Additive Manufacturing of Kelvin Probes

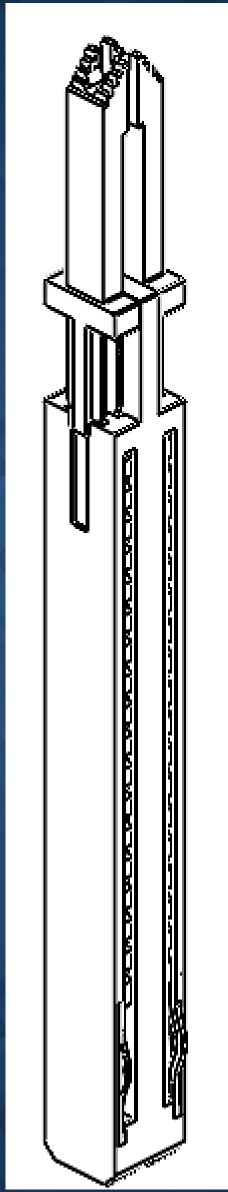
- **Complex 3D structure and assembly can be additively fabricated**
  - Enables fabrication of the full True Kelvin Spring Probe without the need of assembly
- **Different metals, metal alloys, and dielectric material can be combined into micro-composite structures**
  - Enables optimized electrical and mechanical characteristic for the True Kelvin spring probe
- **High accuracy and high precision achieved using MEMS processes**
  - Enables precise spring and tip geometry for advance pitch applications



Results

- **True Kelvin Spring Probes designed and fabricated using MEMS additive manufacturing technology**

- **Salient features:**
  - Designed for < 350 µm pitch
  - Spacing between tips: 40 µm
  - Force and sense paths verified to be electrically isolated
  - Tips verified to move independently
  - Demonstrated lifetime of probe > 1M cycles
  - Designed to require only 1 hole per probe in the socket



Summary

- **Kelvin measurement eliminates parasitic voltage drops which degrade the measurement accuracy when the user is seeking to calculate very low resistance values and obtain higher confidence in test data**

- **New Generation of Fine-Pitch True Kelvin Spring Probes provide a solution to meet the requirements advanced WLCSP applications**
  - Leverages highly flexible additive manufacturing technology
  - Enables Kelvin testing at fine pitches & high I/O count
  - Promises high performance, reliability at lower overall cost

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Thank You