

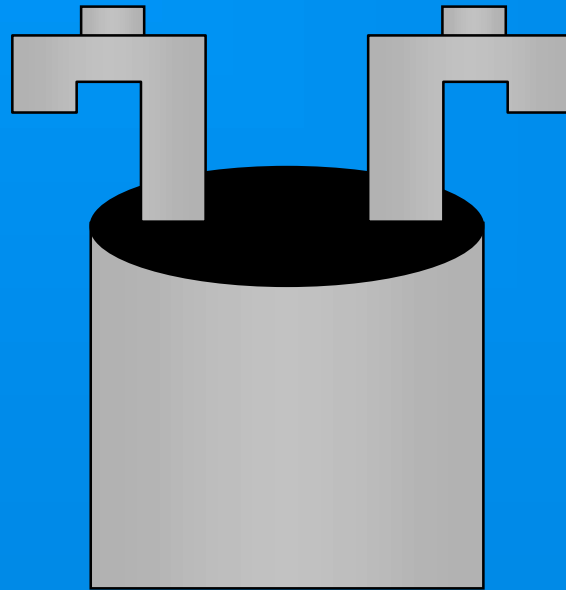
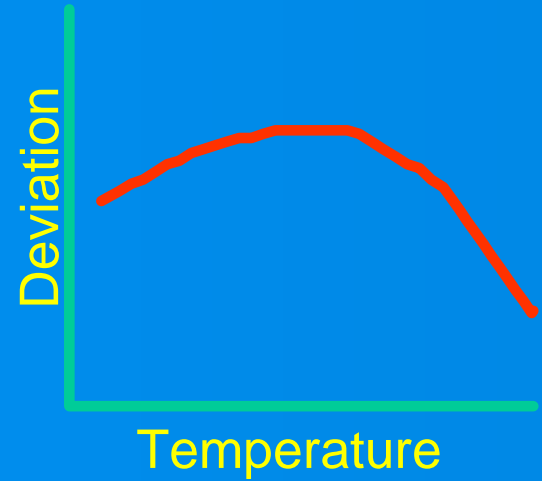
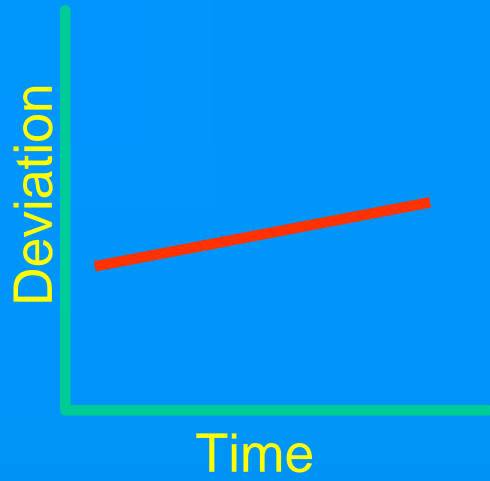
Automated Resistance Measurement Systems w/ Sub-PPM Accuracies



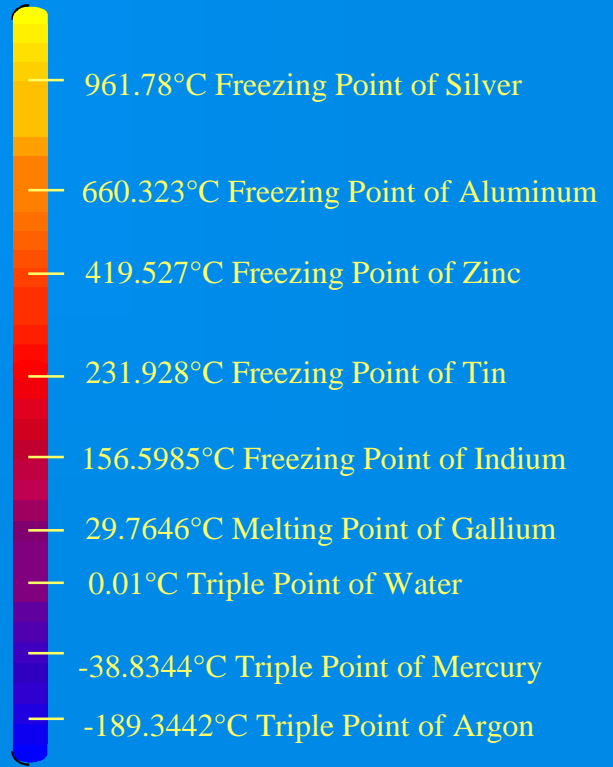
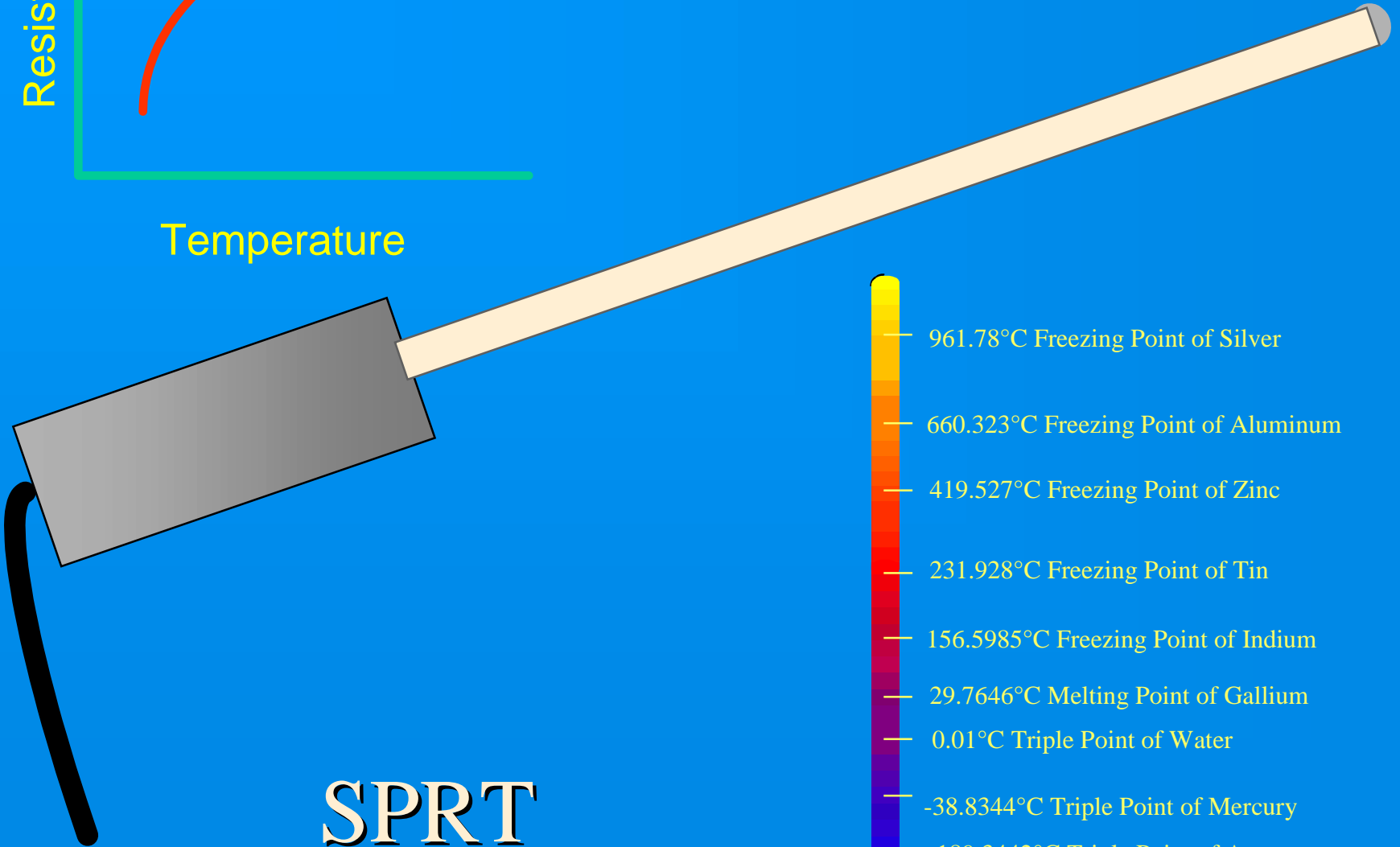
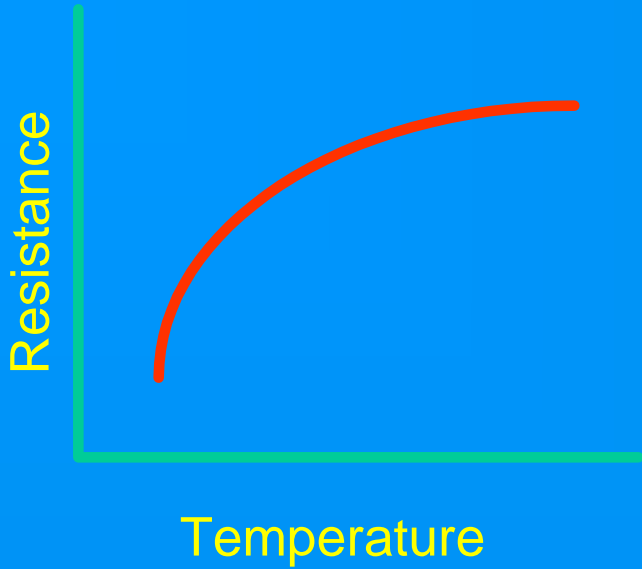
Jeffrey S. Willey

Measurements International

$$E(\text{Volts}) = \mathbf{R(\text{Ohms})} \times I(\text{Amps})$$



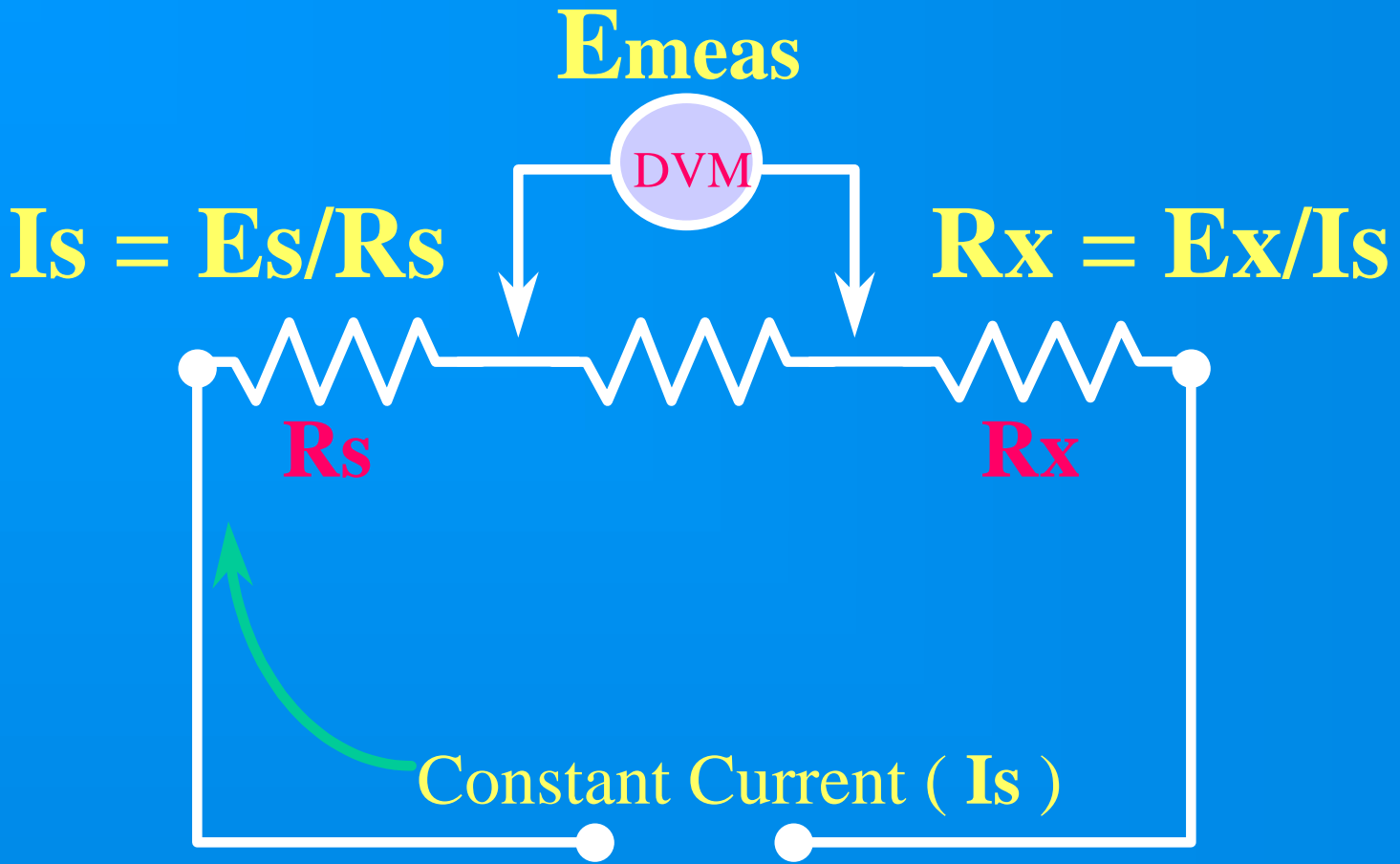
Standard Resistor



Measuring Resistance Ratios:

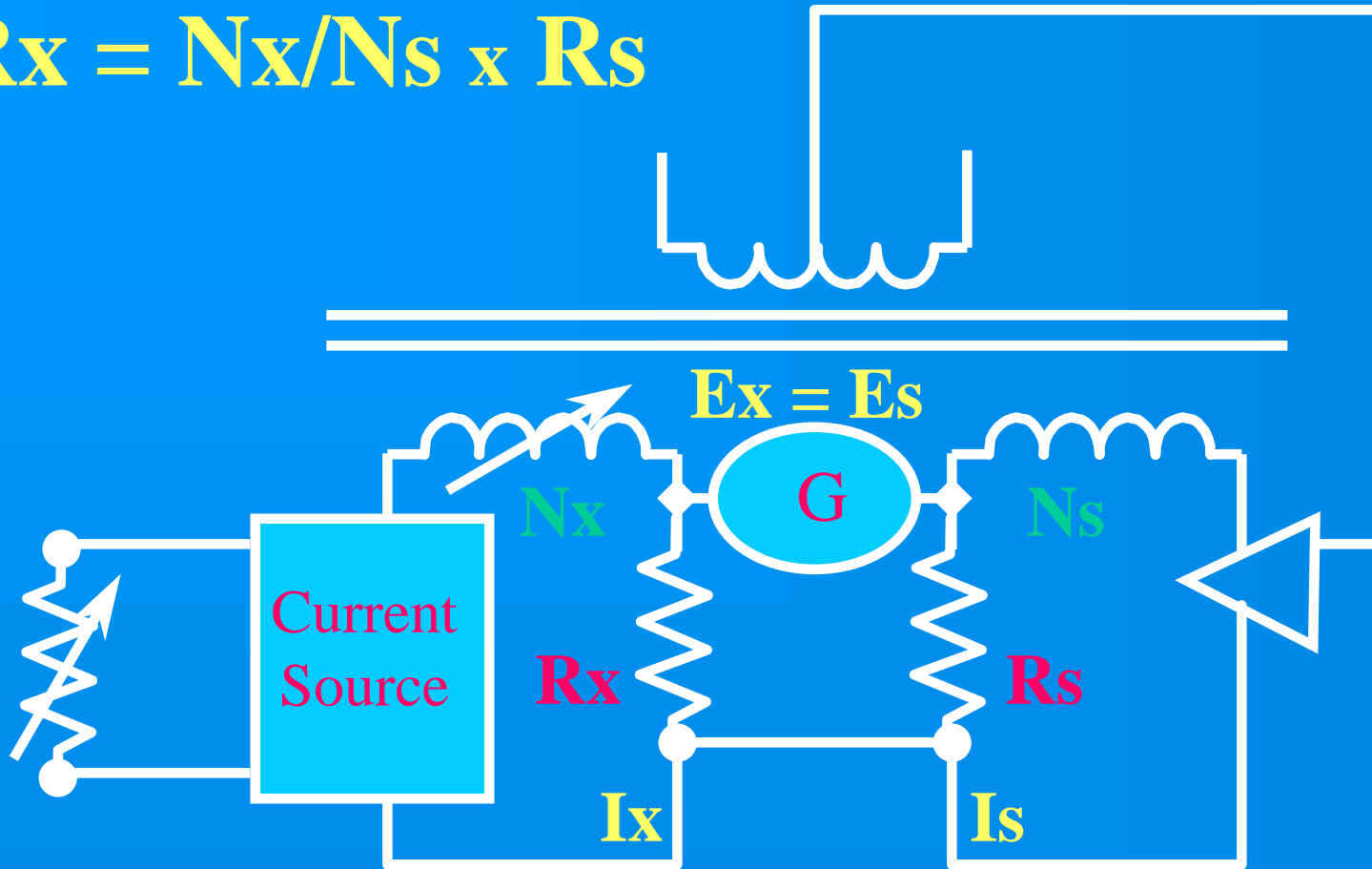
Passing a current through two or more resistors in series and measuring the ratio of voltages developed across the resistors

Passing known ratios of current through each pair of resistors until the voltage drop across each resistor is equal



Voltage Ratios:

$$R_x = N_x/N_s \times R_s$$

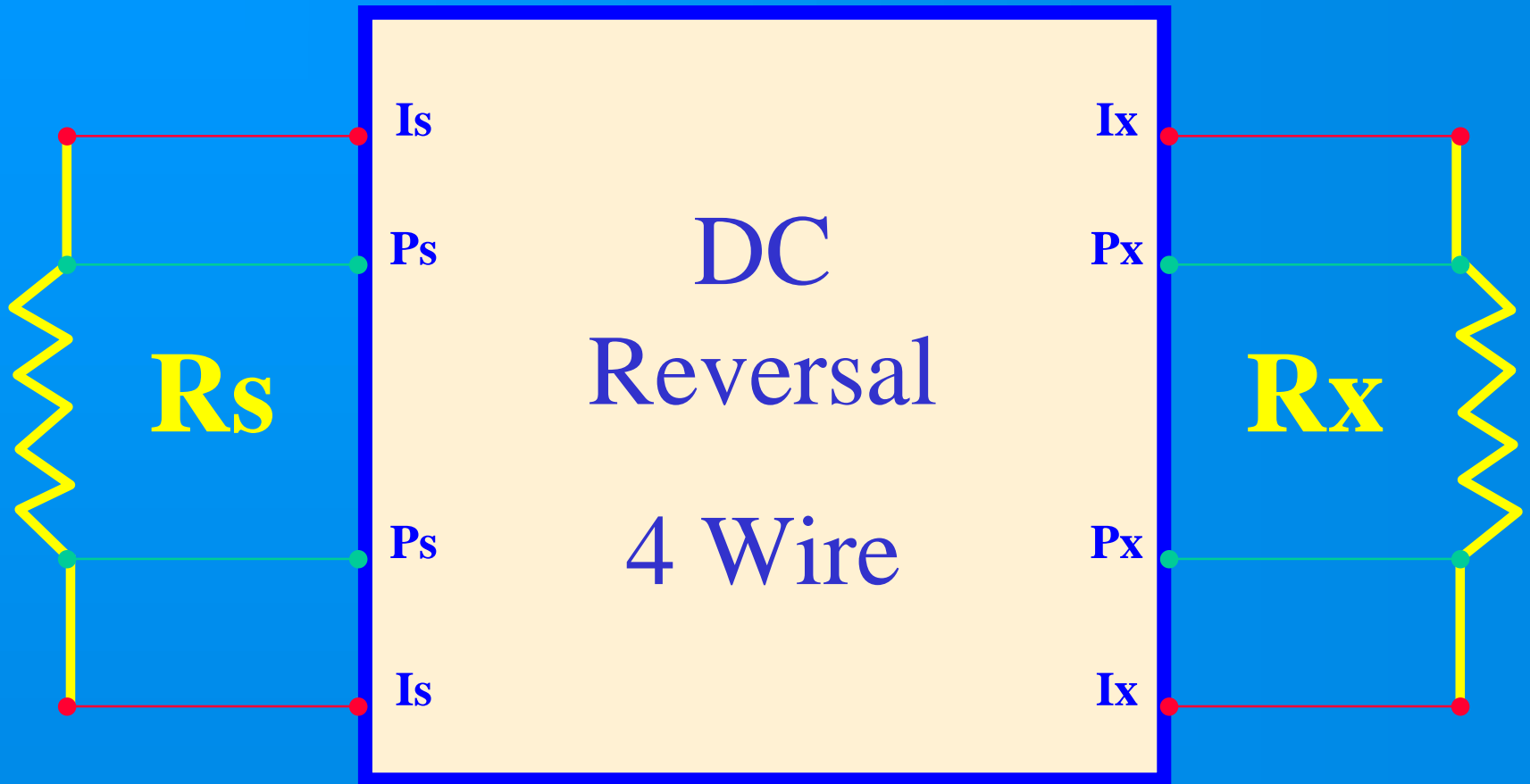


$$I_s R_s = I_x R_x$$

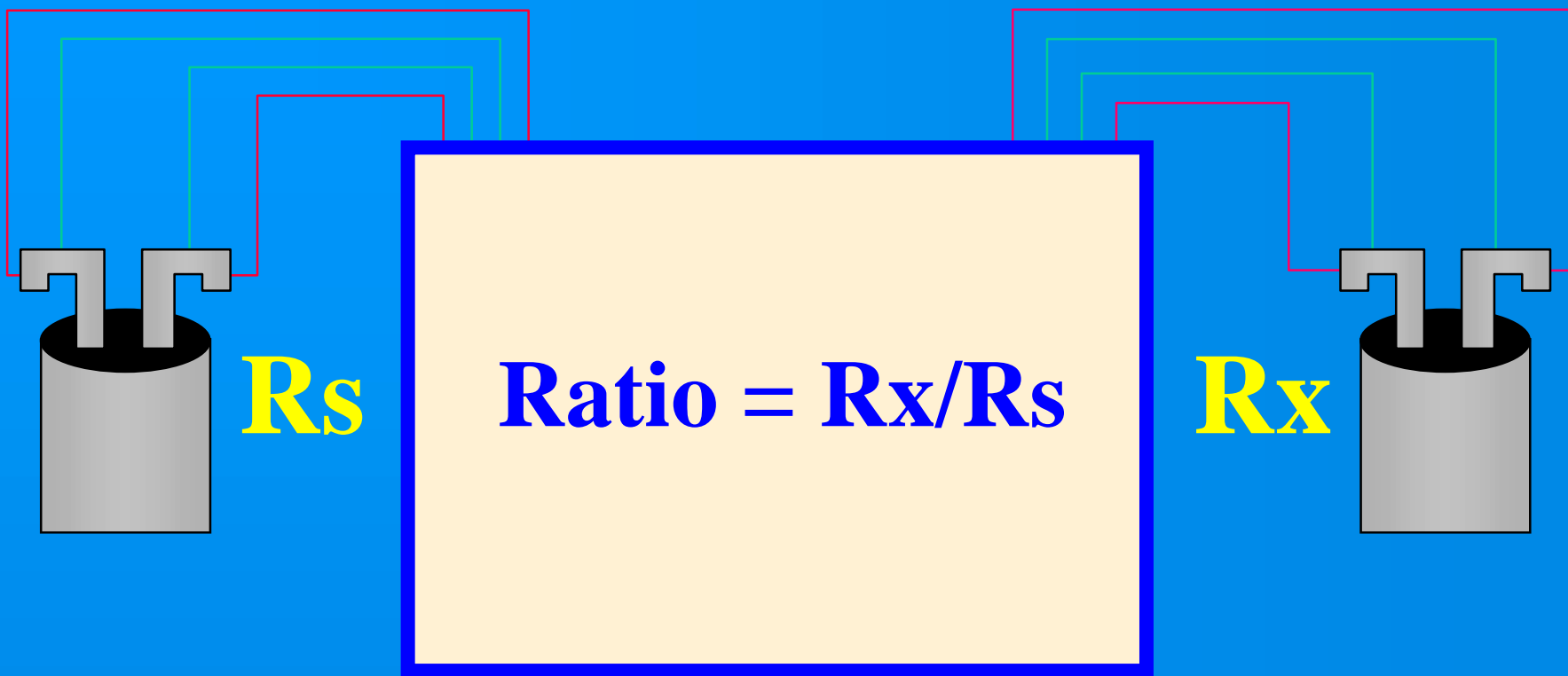
$$I_s N_s = I_x N_x$$

Current Ratios:

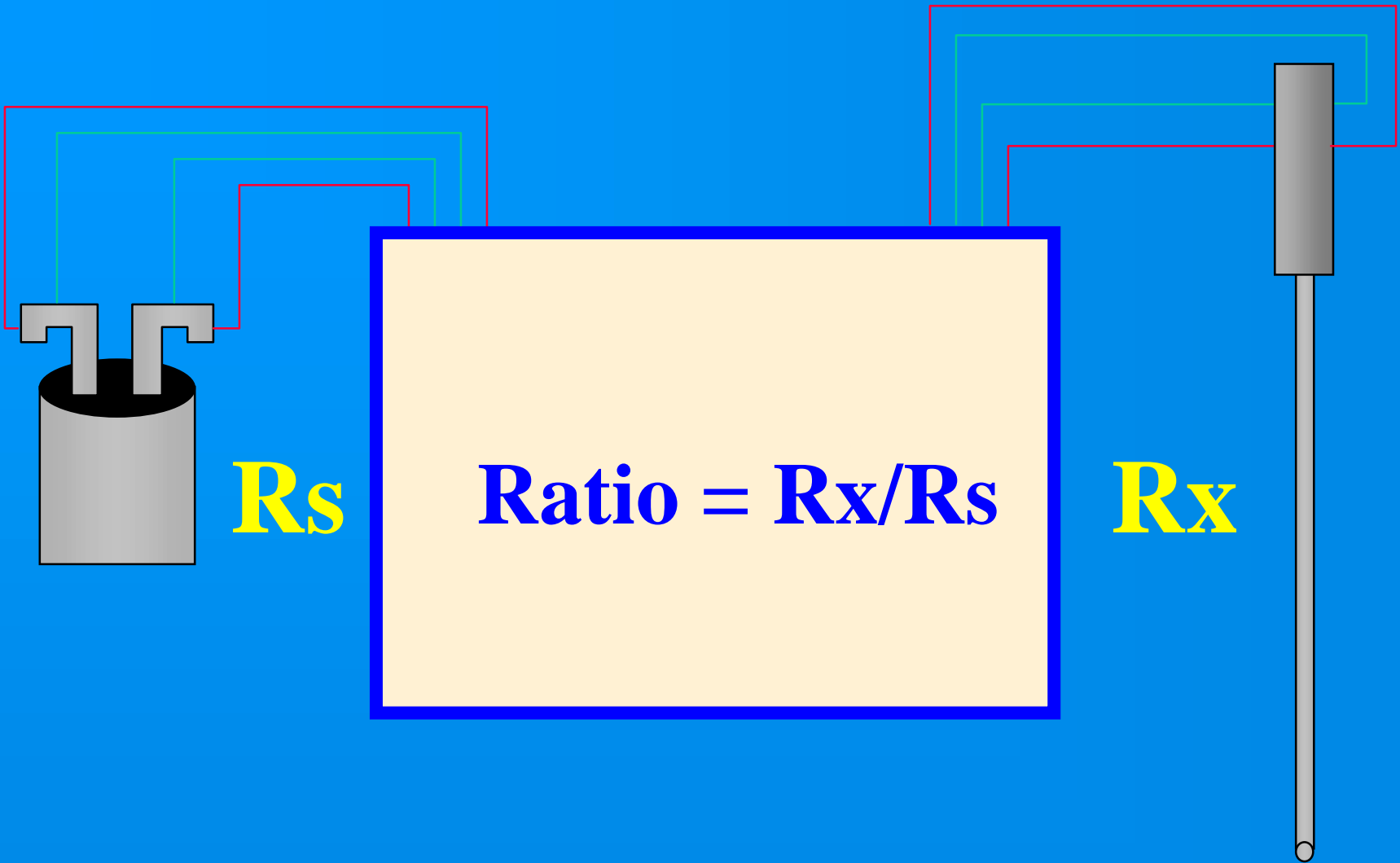
$< .1 \text{ ppm}$



Ratio Measurement Device



Resistor Ratio Measurement



SPRT Ratio Measurement

Two New Technologies:

< .1 PPM Measurement Systems

High Resistance: 1000 Ohm - 1G Ohm

Binary Voltage Divider Technology

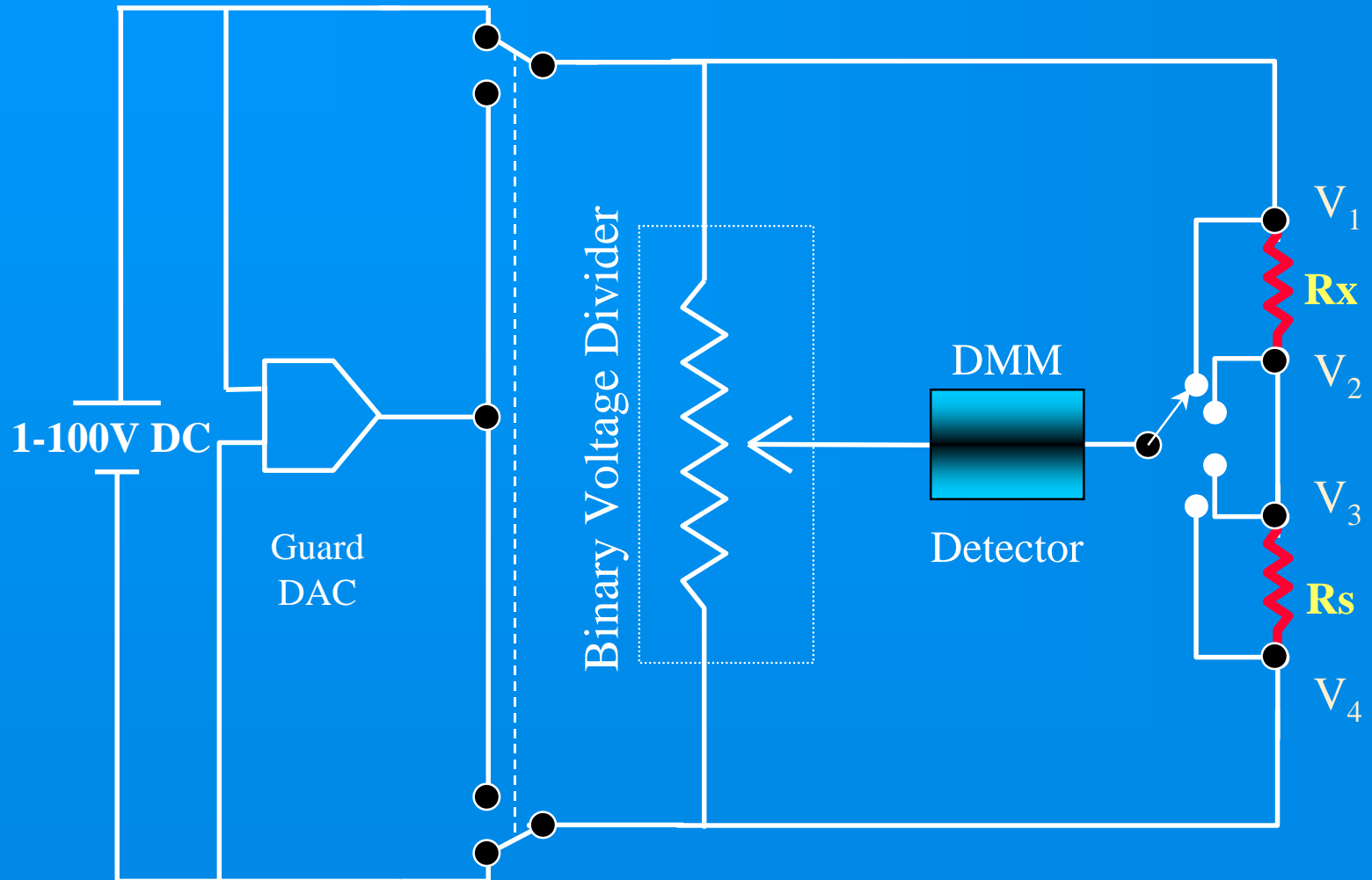
Low Resistance: .001 Ohm - 10K Ohm

Binary Wound Direct Current Comparator Technology

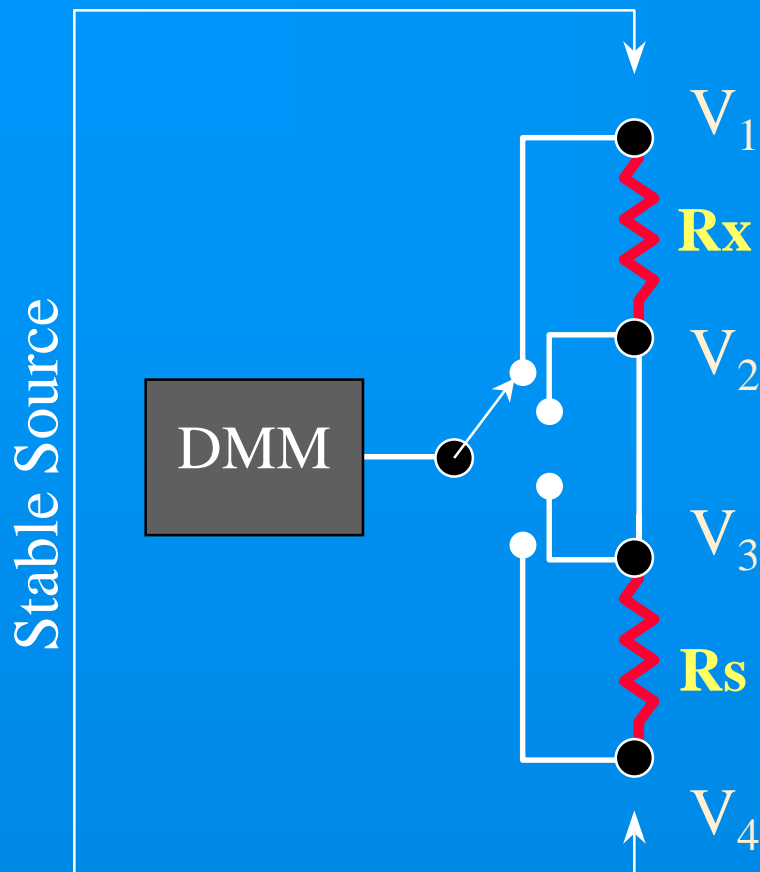
Binary Voltage Divider:

- History
- Limitations
- Advantages
- Applications
- Block Diagram

Binary Voltage Divider:



Ratio Measurement Calculation:



$$R = \frac{R_x}{R_s}$$

$$R = \frac{V_1 - V_2}{V_3 - V_4}$$

$$R = \frac{V_1/E - V_2/E}{V_3/E - V_4/E}$$

$$R = \frac{r_1 - r_2}{r_3 - r_4}$$

$$R_x = R_s \times \text{Ratio}$$

Binary Voltage Divider:

1K to 10M Ohm: <0.1 ppm

10M to 100M Ohm: <0.5 ppm

100M to 1G Ohm: <5 ppm

All Four Wire Measurements @ 1-100 Volts DC

Range: 1K to 1G Ohms

Resolution: DVM / Detector Dependant

Ratio: 1:1, 10:1, 100:1, 1000:1

Linearity: Self Calibration to ± 0.01 ppm

Binary Voltage Divider:

- Source Voltage: 1 to 100 Volts
- 4 - Four Terminal Inputs via Rear Panel
 - All Communication over IEEE488
 - Windows Operating Software
- Self Calibrating - *w/ stored corrections*

Binary Voltage Divider:

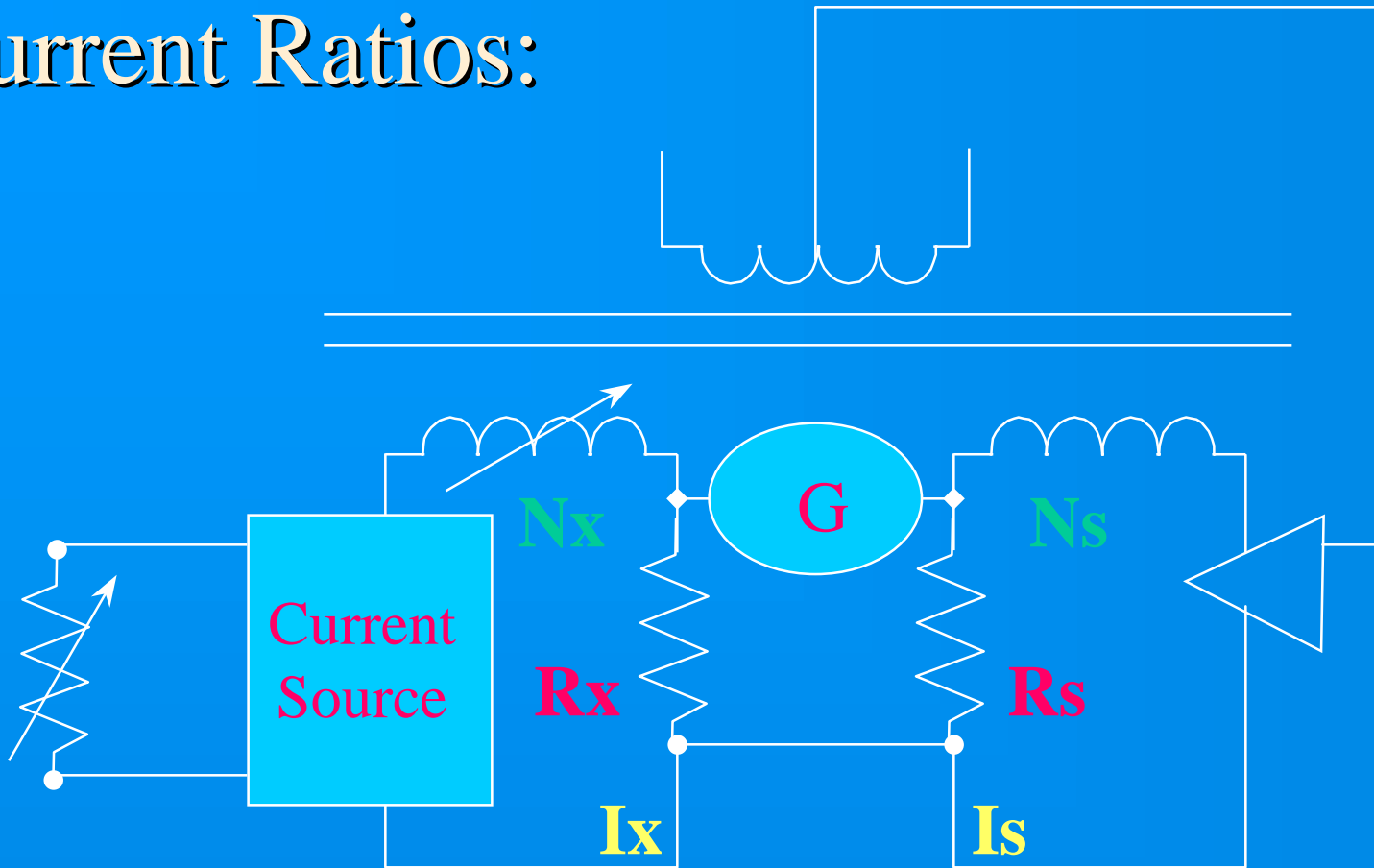
- Primary Std. for 10K to 1G Build Up
- Automatically Assigns Values and Calculates Uncertainties
 - Voltage Coefficients of High Value Air Resistors
 - Automated Potentiometer - *Voltage Maintenance*

Direct Current Comparator:

Binary Wound

- History
- Limitations
- Advantages
- Applications
- Block Diagram

Current Ratios:



$$E_s = E_x$$

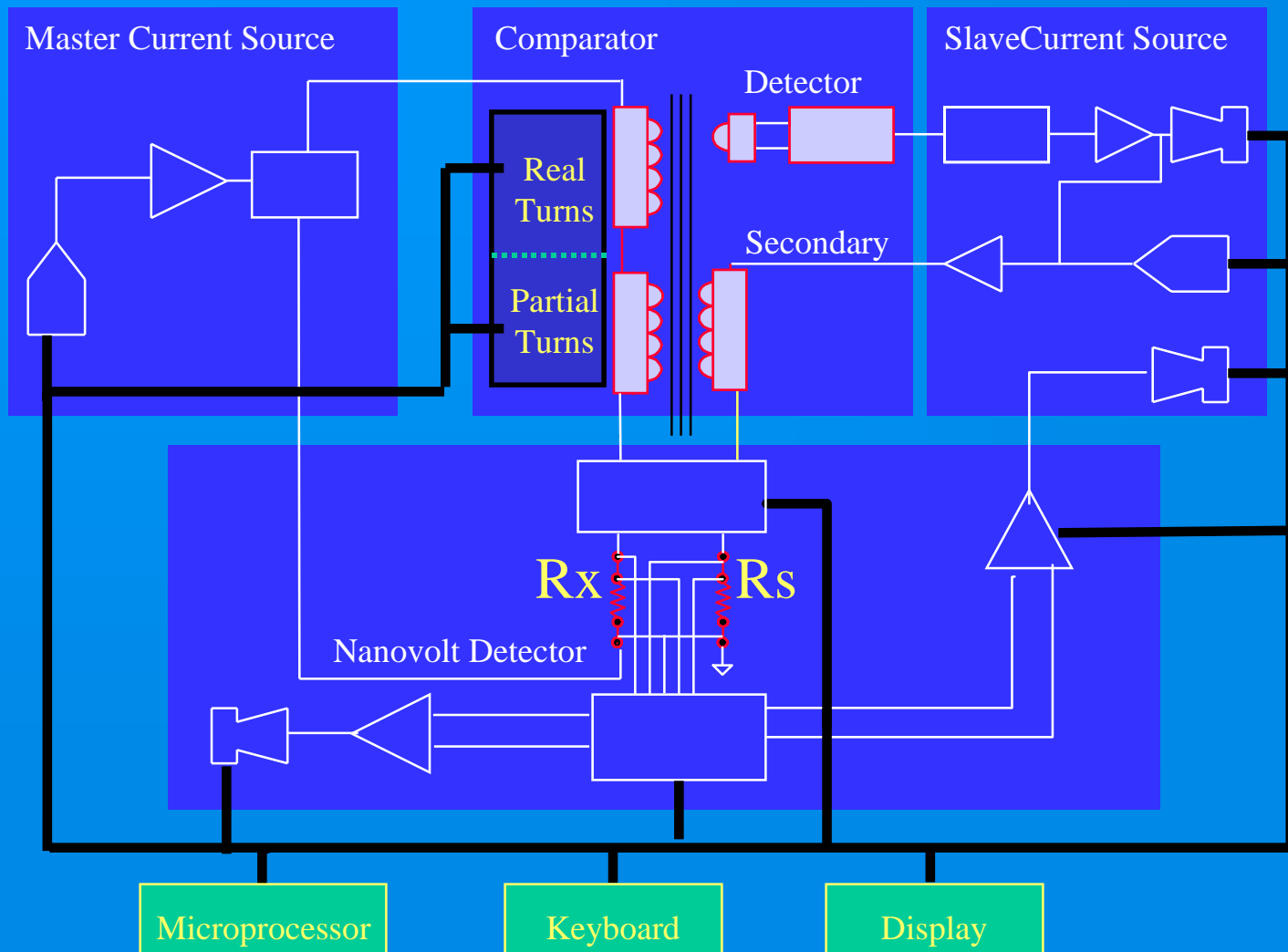
$$I_s R_s = I_x R_x$$

$$I_s N_s = I_x N_x$$

$$R_x = \frac{N_x}{N_s} \times R_s$$

Direct Current Comparator:

Binary Wound



Direct Current Comparator:

Binary Wound

. 1u to 1.0u Ohm:	<10 ppm	100 to 2000 Amps
1.0u to 1.0m Ohm:	<1.0 ppm	100 to 2000 Amps
1.0m to 100m Ohm:	<0.2 ppm	1 to 100 Amps
100m to 10K Ohm:	<0.1 ppm	10mA to 10 Amps
1.0 to 10K Ohm:	<0.1 ppm	10uA to 150mA
10K to 10K:	<0.2 ppm	10uA to 2mA

Range: 0.001 to 10K Ohms Resolution: ± 0.001 ppm of Full Scale

Ratio: 0 to 13

Linearity: Self Calibration to ± 0.01 ppm

Direct Current Comparator:

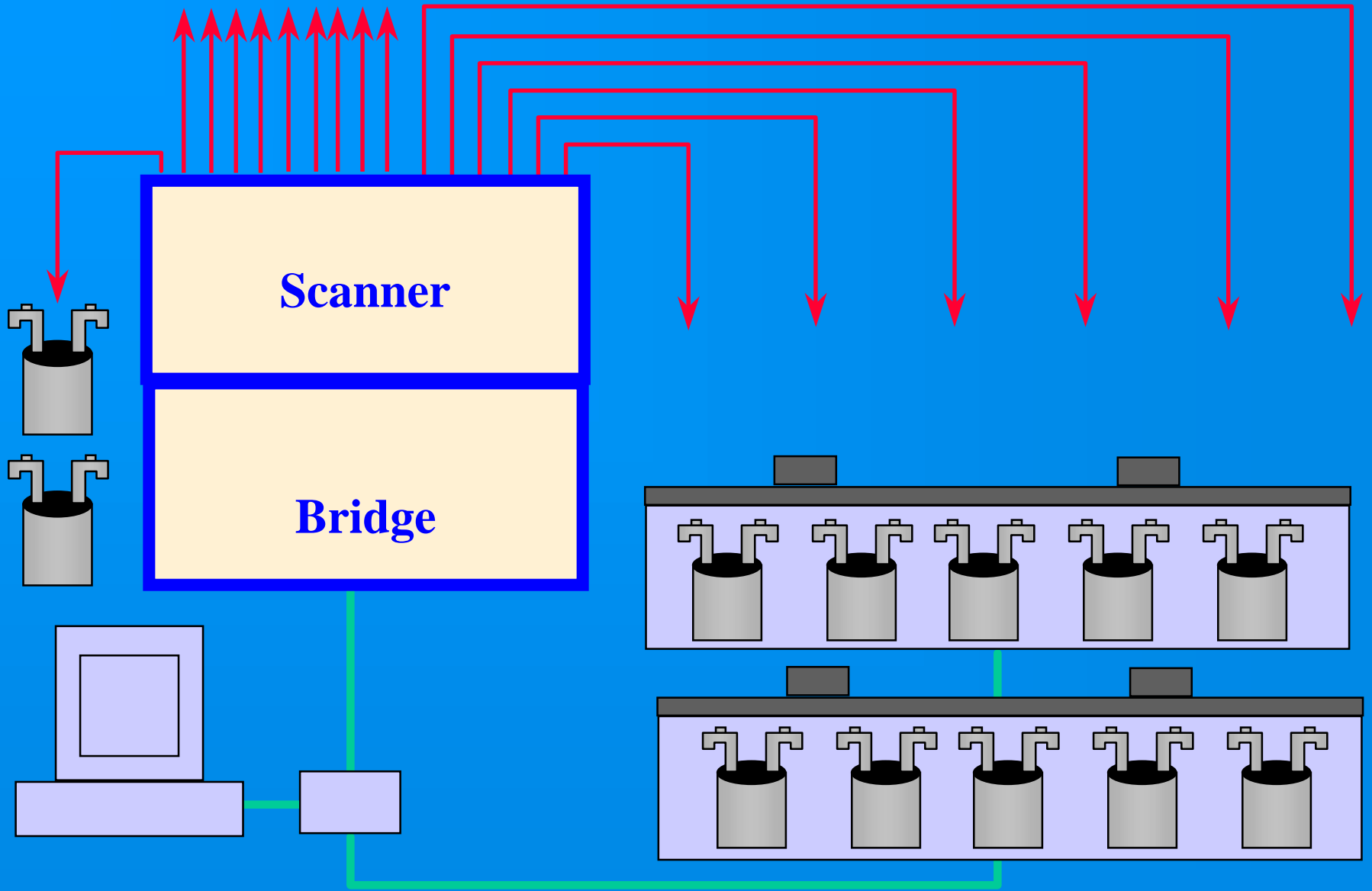
Binary Wound

- Low Current & Voltage Noise
- Range Extenders to 20,000 Amps
 - Measurement Speed
- Verifiable Throughout Range
- Manual or IEEE488 Interface
 - Windows Operating Software
- Self Calibration - *no stored corrections*

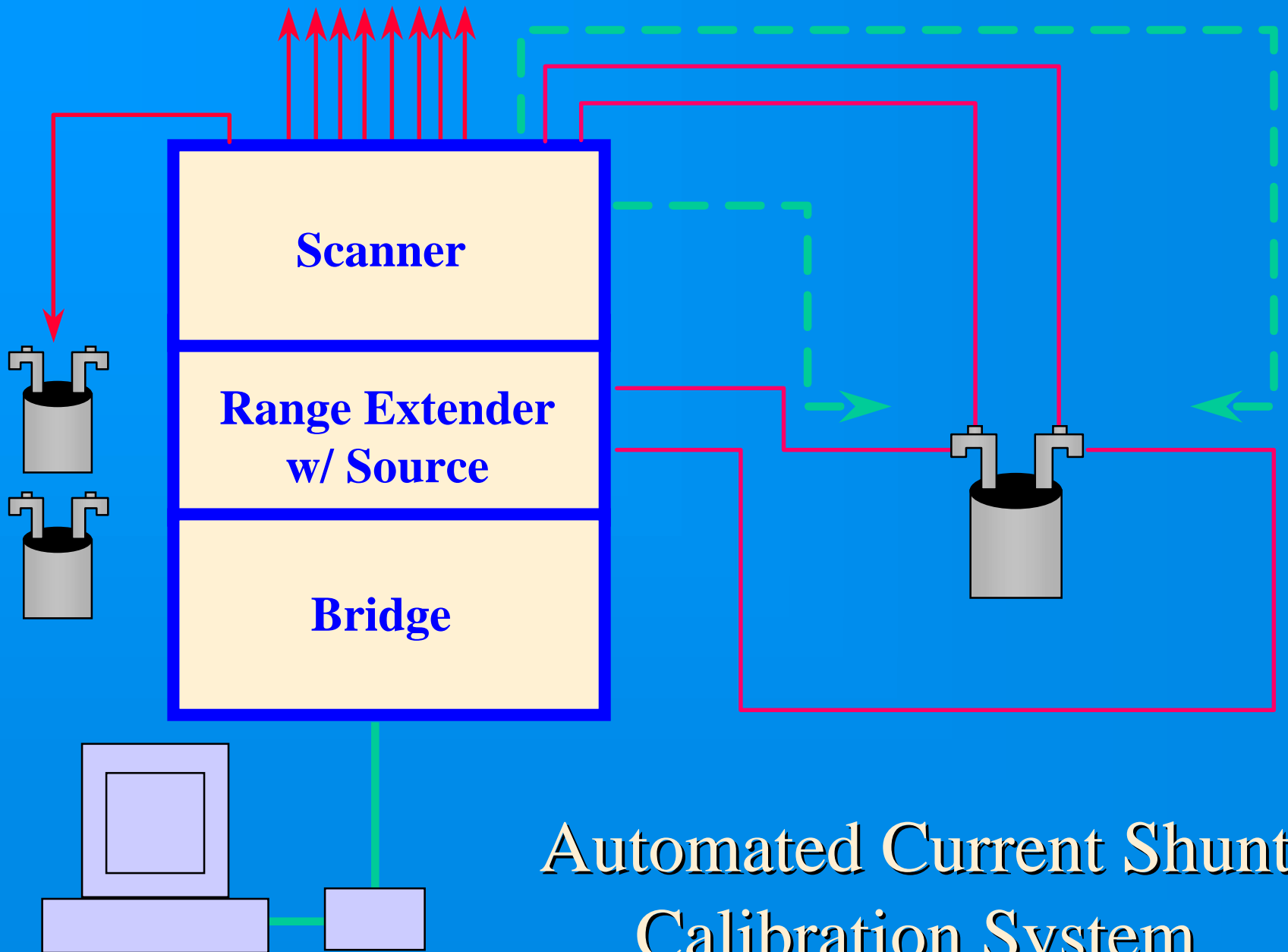
Direct Current Comparator:

Binary Wound

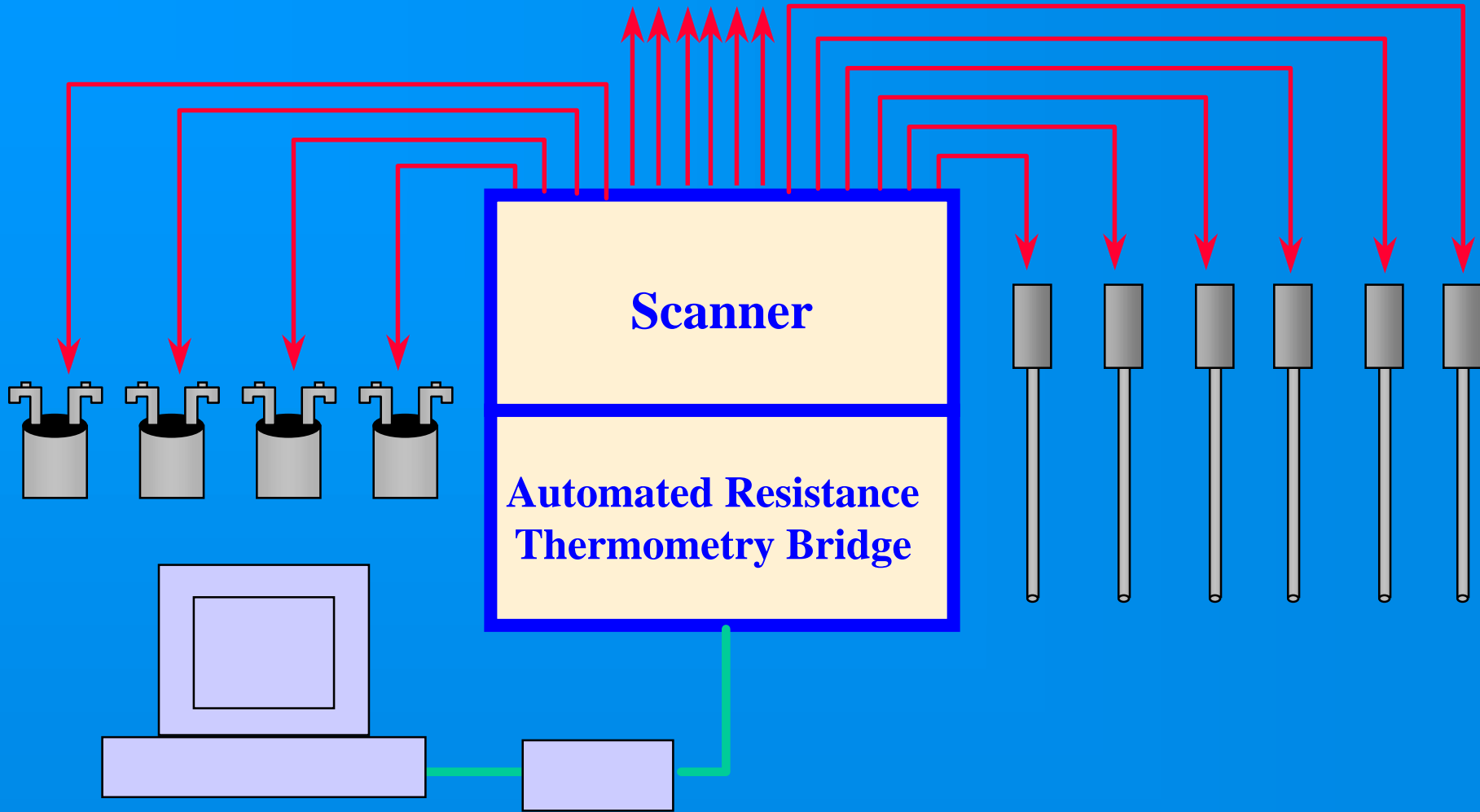
- Primary Resistance Intercomparison < 10K Ohms
 - Automated DC Thermometry Bridge
 - Automated Current Shunt System
 - 13:1 Ratio - QHE Applications



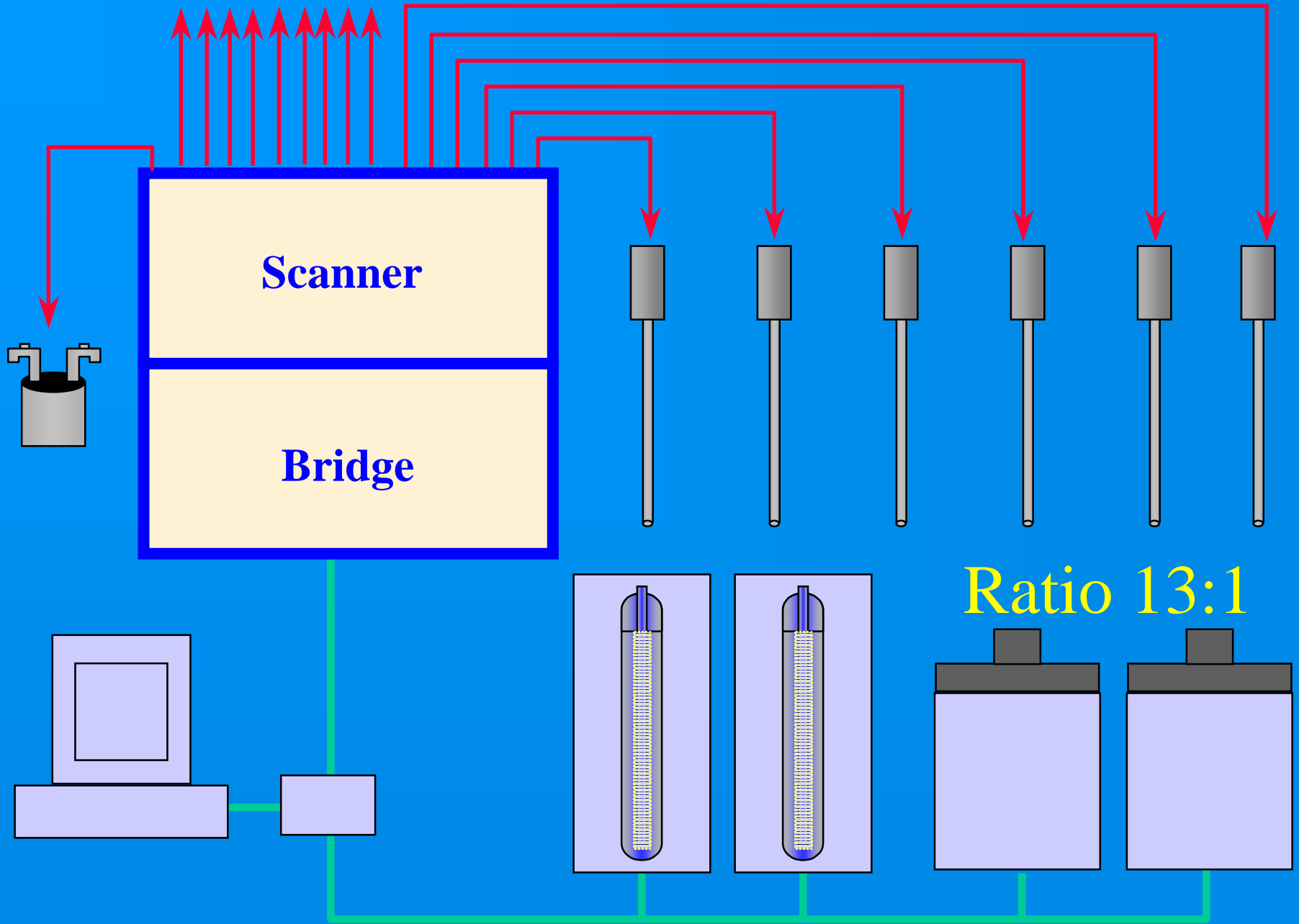
Automated Resistor Calibration



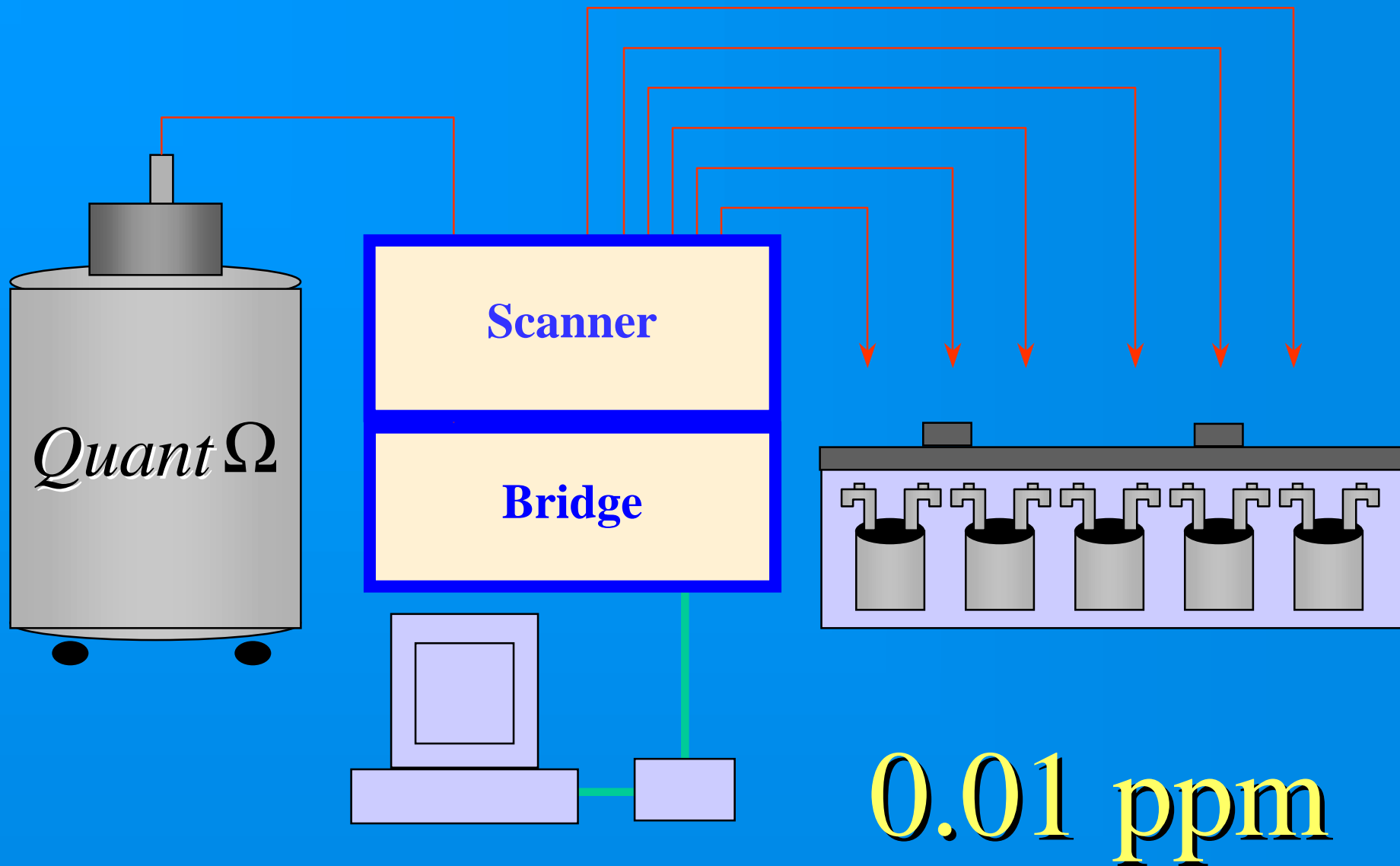
Automated Current Shunt
Calibration System



Multiple Channel Automation



Automated Temperature Calibration



Automated QHE Resistance System



Automation Requirements:

- Multiple Channels
- Windows Interface
- Task Programmable
- Mathematics Capabilities
 - System Verification
 - Document Generation
 - Customization
 - Turn Key System
- No Manual Intervention

Laboratory Issues:

\$ Speed

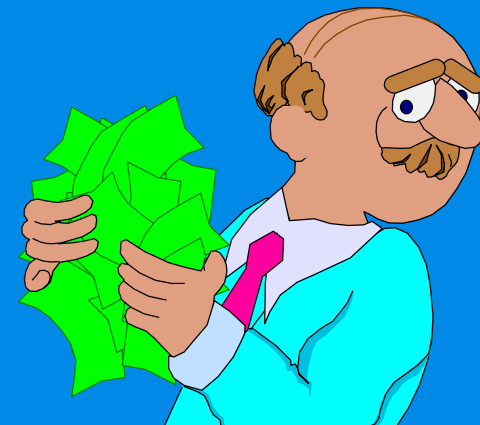
\$ Accuracy

\$ Measurement Range

\$ Reliability

\$ Complete Automation

\$ Verifiable

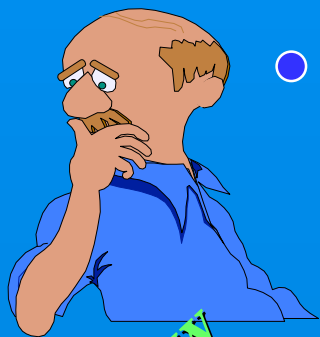


The Facts:

- Multiple System Advantage
 - Speed and Accuracy
 - Turn-Key System
 - Proven Technology

Automation?

DC Metrology Standards
AC Power Standards



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New Web Site: <http://www.mintl.com>