SUPUESTO PRÁCTICO 1

Un laboratorio de calibración, acreditado por ENAC conforme a la norma UNE ISO/IEC 17025:2017, tiene establecido en su plan de calibración un control entre calibraciones de su multímetro patrón de referencia de 8,5 dígitos, marca FLUKE, modelo 8558A[1], usando resistencias patrón de calibración externa. Se realiza por comparación directa con la medida de resistencia a 4 hilos en el campo de 10 kΩ. La temperatura del laboratorio durante el proceso se mantiene a una temperatura de (23,0 ± 1,0) °C.

La resistencia patrón de referencia es de la marca IET, modelo SR104, de valor nominal 10 kΩ. Las especificaciones principales de este patrón son las indicadas en la tabla 2[2]. La resistencia ha sido calibrada por el CEM con una incertidumbre expandida de 2,0 x $10^{-7}\cdot$ R y ha mostrado una estabilidad a largo plazo de -0,3 ppm/año, en las últimas cinco calibraciones externas, siendo su último valor certificado hace seis meses, de 9,999 984 kΩ a una temperatura de (20,00 °C ± 0,10 °C.

El laboratorio tiene asignado un criterio de aceptación y rechazo de tolerancia de ± (19 ppm de la lectura + 2,0 ppm del fondo de escala) en el campo de 10 kΩ .

Tabla 1: Lecturas del multímetro obtenidas durante el control

n	Lectura, kΩ	n	Lectura, kΩ
1	9,999 983 6	11	9,999 983 6
2	9,999 983 9	12	9,999 982 8
3	9,999 982 5	13	9,999 983 8
4	9,999 982 5	14	9,999 982 8
5	9,999 983 2	15	9,999 982 2
6	9,999 982 8	16	9,999 983 0
7	9,999 983 9	17	9,999 983 0
8	9,999 983 7	18	9,999 983 2
9	9,999 982 6	19	9,999 982 7
10	9,999 982 6	20	9,999 984 0

[1] Véase extracto de las especificaciones del fabricante
[2] Véase también la hoja de datos de especificaciones del fabricante.

Tabla 2: Especificaciones principales de la resistencia patrón ESI SR104

Estabilidad: ± 0,5 ppm/año, a partir del primer año	Ajuste a valor nominal ± 1 ppm
Cociente de temperatura (TC): Alfa: <0,1 ppm/°C a 23 °C; Beta: <0,03 ppm/°C de 18 °C a 28 °C	Cociente de potencia <1 ppm/W
La resistencia cambia <± 0,1 ppm con cambios normales de presión atmosférica y humedad	La fuerza electromotriz térmica en los terminales no supera ± 0,1 µV en condiciones normales.
Resistencia de aislamiento: Todos los terminales mantienen un mínimo de 10^{12} Ω a tierra	Sensor de temperatura interno: resistencia de 10 kΩ con un coeficiente de temperatura de 1000 ppm / °C. Dispone de pozo termométrico para la medida de temperatura con sensor externo
Potencia máxima aplicable: 1 W	Formato sobremesa. No se requieren hornos ni energía externa.

En el contexto de este supuesto práctico, desarrolle los siguientes apartados:

1) Utilizando la información facilitada, desarrolle una estimación de la incertidumbre expandida asociada al error encontrado en la lectura del multímetro, para un valor de referencia nominal de 10 kΩ, aplicando el método GUM. Se incluirá la función modelo, evaluaciones tipo A y tipo B de la incertidumbre típica, determinación de la incertidumbre típica combinada y la incertidumbre expandida. Se justificará la elección del factor de cobertura empleado.

2) Defina el contenido del certificado de calibración emitido, incluyendo la regla de decisión aplicada para el cumplimiento de los criterios metrológicos indicados y el resultado del mismo.

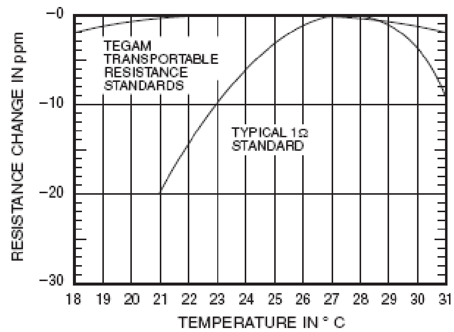
SR102, SR103, SR104

These Transportable Resistance Standards are designed for precision applications. Their accuracy, stability, and low temperature coefficient make them ideal for precise laboratory comparisons without critical environmental controls. For maximum accuracy, these standards offer users a temperature-correction chart and a built-in RTD temperature sensor to measure internal temperature.

Features

- Resistance values of 100 Ω, 1000 Ω, or 10000 Ω
- High accuracy
- High stability - <0.5 ppm/year
- Low temperature coefficient -- <0.1 ppm/°C
- Built-in temperature sensor and temperature-correction chart
- Oil-filled, hermetically sealed, custom resistors
- Increased-stability option (DC) is available to be used in an oil-bath

Transportable Resistance Standard



Temperature coefficient comparison between a typical SR-102 unit and a typical 100 Ω resistance standard

SPECIFICATIONS

Stability

First 2 years: ±1 ppm/year
Thereafter: ±0.5 ppm/year

Temperature coefficient

Temperature coefficient (α):
<0.1 ppm/°C at 23°C
1/2 rate of TC change (β):
<0.03 ppm/°C from 18°C to 28°C
α and β are determined by the following expression:

$$R_S=R_{23}[1+\alpha_{23}(t-23)+\beta(t-23)^2]$$

where R_S = Standard Resistance at temperature t
No ovens or external power required

Power coefficient

<1 ppm/W

Adjustment to nominal

SR102, SR103, SR104: ±1 ppm

Max voltage

500 V peak to case

Power rating

1 W (Momentary 100 W overloads will not cause failure)

Insulation resistance

All terminals maintain a minimum 10^{12} Ω to ground

Internal temperature sensor

100 Ω, 1 k Ω, or 10 kΩ resistor with 1,000 ppm/°C temperature coefficient.
Integral thermometer well is provided for calibration

Hermetic sealing

The hermetically sealed resistors are additionally hermetically sealed in an oil filled can with metal-to-glass seals to improve stability. The resistance changes <±0.1 ppm with normal atmospheric pressure and humidity changes.

Pressure effects

No pressure effects under normal atmospheric changes.

Connection terminals

Five-terminal construction, four-terminal resistor with ground intercept for the standard and temperature resistor.

Thermal emf

Thermal emf at the terminals does not exceed ±0.1 μV under normal conditions.

Thermal lagging

Thermal lagging time constant is 1 hour minimum (1-1/e of total change in one hour).

Dielectric soakage effect

The resistance stabilizes to within 0.1 ppm of final value within 5 seconds with 1 V applied to the resistor.

Current reversal

With the reversal of the current through the resistor, the resistance value changes less than ±0.1 ppm.

Shock effects

The resistance changes is <0.2 ppm when subjected to 2 drops three-foot drops to a concrete floor on each of the 3 mutually perpendicular faces (6 drops total).

SAMPLE TEMPERATURE CORRECTION CHART

IET Labs, Inc. A2LA Certificate Number 2073.01 ACCREDITED

SR-104 RESISTANCE STANDARD

CONSULT INSTRUCTION MANUAL FOR PROPER INSTRUMENT OPERATION

Nominal Value: 10 kΩ
Power Rating: 1 W; momentary 100 W overloads will not cause failure.
Stability: ±1 ppm/ year, first 2 years. ± 0.5 ppm/year thereafter.
Breakdown Voltage: 500 V peak to case.
Power Coefficient: <1 ppm/W

R_{23} (resistance at 23.0 °C)= 10.000 002 96 **kΩ**
Dev. from nominal value= 0.296 **ppm at 23.0 °C**
For corrected resistance at other temperatures, see chart or graph or calculate as follows:

$$R_S = R_{23}\,[\,1 + \alpha_{23}(t-23) + \beta(t-23)^2]$$

Where R_s = Standard Resistance at temperature t
t = Actual temperature as determined by well thermometer or from Temperature Sensor Resistor (R_T) as below

α_{23} = 0.138 ppm/°C

β = -0.023 ppm/°C²

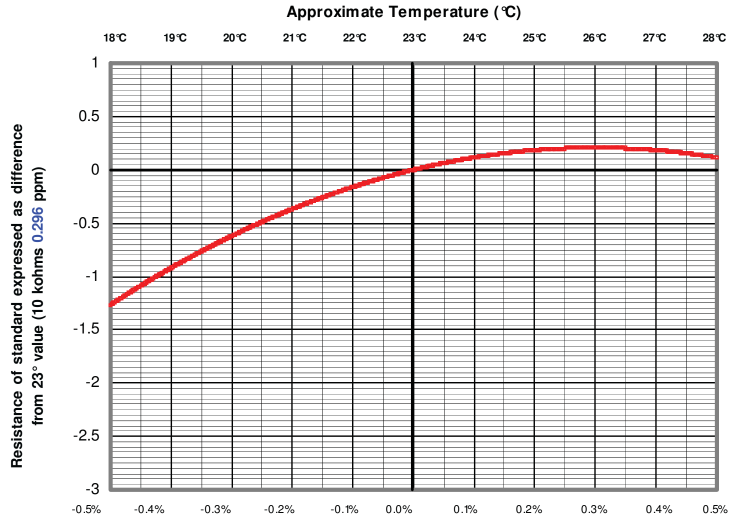
Temperature Sensor Resistance (R_T)
R_{T23} (sensor resistance at 23.0 °C)= 9.999 589 kΩ
Deviation from nominal value = -0.004 1% **at 23.0 °C**

$$T = \left(\frac{R_T - R_{T23}}{R_{T23}} \times 10^3 + 23\right)°C$$

Model: SR-104 **SN:** J1-1041623
By: JOS **Date:** 15-Nov-2010

Temp. (ºC)	Res. (kΩ)	Dev. from Nominal (ppm)
18.0	9.999 990 31	-0.97
18.5	9.999 992 09	-0.79
19.0	9.999 993 76	-0.62
19.5	9.999 995 31	-0.47
20.0	9.999 996 75	-0.33
20.5	9.999 998 07	-0.19
21.0	9.999 999 28	-0.07
21.5	10.000 000 37	0.04
22.0	10.000 001 35	0.13
22.5	10.000 002 21	0.22
23.0	10.000 002 96	0.30
23.5	10.000 003 59	0.36
24.0	10.000 004 11	0.41
24.5	10.000 004 51	0.45
25.0	10.000 004 80	0.48
25.5	10.000 004 97	0.50
26.0	10.000 005 03	0.50
26.5	10.000 004 97	0.50
27.0	10.000 004 80	0.48
27.5	10.000 004 51	0.45
28.0	10.000 004 11	0.41

History of Standard Deviation (ppm)



Temperature of standard resistor expressed as percentage change of Temperature Sensor Resistance (R_T) at temperature T from (R_{T23}) 9.999 589 kΩ.
e.g. if R_T =10.009 588 is 0.1% above R_{T23}, the resistance of the standard =10.000 004 11 kΩ.
(may also be obtained from the formula or the temperature chart)

WARNING

Observe all safety rules when working with high voltages or line voltages. Connect the (G) terminal to earth ground in order to maintain the case at a safe voltage. Whenever hazardous voltages (>45 V) are used, take all measures to avoid accidental contact with any live components: a) Use maximum insulation and minimize the use of bare conductors. b) Remove power when adjusting switches. c) Post warning signs and keep personnel safely away.

formerly manufactured by esi — IET LABS, INC. CAGE CODE: 62015
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SR104Label/100%;/08-07-08

MECHANICAL INFORMATION

Dimensions

Regular
25.4 cm x 20.6 cm x 31.1 cm (10” x 8.1” x 12.25”)
Deleted case (DC) version
12.7 cm x 8.9 cm x 17.8 cm (5.0” x 3.5” x 7.0”)

Weight

Regular
4.8 kg (10.5 lb)
Deleted case (DC) version
1.8 kg (4.0 lb)

OPTIONAL EXTERNAL OIL BATH

This optional version can further enhance the short-term stability of the resistance standard. It comes without the insulated case, so that it may be used in an external oil bath that provides additional temperature stability. This version is called Deleted Case (DC).

When the standards are used in an oil bath, the resistance elements maintain a constant temperature, providing outstanding short-term stability, which is especially important when making Quantum-Hall-Effect measurements.

ORDERING INFORMATION

100 Ω Transportable Resistance Standard:	**SR-102**
1,000 Ω Transportable Resistance Standard:	**SR-103**
10,000 Ω Transportable Resistance Standard:	**SR-104**

Optional:
For deleted case version add -DC at the end of the part number.

Each unit includes:

- Built-in temperature sensor
- Temperature correction chart
- Instruction manual
- ISO/IEC 17025 calibration certificate

Resistance [1][2][3][4][10]

Resistance 4 Wire

Resistance maximum resolution is 8 digits

95 % Confidence				Relative Accuracy ± (μΩ/Ω of reading + μΩ/Ω of range)				Absolute Accuracy ± (μΩ/Ω of reading + μΩ/Ω of range)		
Range	**Full Scale**	**"Mode"**	**Transfer, 20 min [15]**	**24 Hour Tcal ± 1 °C**	**90 day Tcal ± 1 °C**	**365 day Tcal ± 1 °C**	**2 year Tcal ± 1 °C**	**365 day Tcal ± 1 °C**	**365 day Tcal ± 5 °C**	**2 year Tcal ± 5 °C**
1 Ω	2.02 Ω	Normal	2.0 + 4.5	6.0 + 4.5	11 + 4.5	15 + 4.5	30 + 4.5	15 + 4.5	21 + 4.5	32 + 4.5
10 Ω	20.2 Ω	Normal	0.8 + 2.0	4.0 + 2.0	8.0 + 2.0	12 + 2.0	24 + 2.0	12 + 2.0	15 + 2.0	22 + 2.0
100 Ω	202 Ω	Normal	0.2 + 0.6	3.0 + 0.6	6.5 + 0.6	10 + 0.6	20 + 0.5	10 + 0.5	12 + 0.5	18 + 0.5
1 kΩ	2.02 kΩ	Normal	0.2 + 0.6	2.0 + 0.6	6.0 + 0.6	10 + 0.6	20 + 0.5	10 + 0.5	12 + 0.5	18 + 0.5
10 kΩ	20.2 kΩ	Normal	0.2 + 0.6	2.0 + 0.6	6.0 + 0.6	10 + 0.6	20 + 0.5	10 + 0.5	12 + 0.5	18 + 0.5
100 kΩ	202 kΩ	Normal	0.2 + 0.6	2.0 + 0.6	6.0 + 0.6	10 + 0.6	20 + 0.5	10 + 0.5	12 + 0.5	18 + 0.5
1 MΩ	2.02 MΩ	Normal	0.5 + 1.5	1.0 + 1.5	5.5 + 1.5	10 + 1.5	20 + 1.0	11 + 1.0	13 + 1.0	20 + 1.0
10 MΩ	20.2 MΩ	Normal	2.5 + 15	4.0 + 15	12 + 15	20 + 15	40 + 10	21 + 10	29 + 10	43 + 10
100 MΩ	202 MΩ	Normal	15 + 150	40 + 150	43 + 150	45 + 150	90 + 100	51 + 100	131 + 100	197 + 100
1 GΩ	2.02 GΩ	Normal	200 + 1500	300 + 1500	450 + 1500	600 + 1500	1200 + 1500	600 + 1500	1410 + 1500	2110 + 1500
1 Ω	2.02 Ω	Lo Current	2.0 + 4.0	6.0 + 4.5	11 + 4.5	15 + 4.5	30 + 4.5	15 + 4.5	21 + 4.5	32 + 4.5
10 Ω	20.2 Ω	Lo Current	0.8 + 1.4	40 + 2.0	8 + 2.0	12 + 2.0	24 + 2.0	12 + 2.0	15 + 2.0	22 + 2.0
100 Ω	202 Ω	Lo Current	2.5 + 2.0	8.7 + 2.0	11.2 + 2.0	14 + 2.0	21 + 2.0	14.4 + 2.0	17 + 2.0	25 + 2.0
1 kΩ	2.02 kΩ	Lo Current	2.5 + 2.0	9.3 + 2.0	11.8 + 2.0	15 + 2.0	22 + 2.0	16 + 2.0	18 + 2.0	27 + 2.0
10 kΩ	20.2 kΩ	Lo Current	2.5 + 2.0	12.9 + 2.0	15.4 + 2.0	19 + 2.0	26 + 2.0	19 + 2.0	21 + 2.0	32 + 2.0
100 kΩ	202 kΩ	Lo Current	5.0 + 0.6	12.9 + 0.6	15.4 + 0.6	19 + 0.6	26 + 0.6	19 + 0.6	21 + 0.6	32 + 0.6
1 MΩ	2.02 MΩ	Lo Current	7.0 + 1.0	11.6 + 1.0	13.6 + 1.0	17 + 1.0	24 + 1.0	17 + 1.0	25 + 1.0	38 + 1.0
10 MΩ	20.2 MΩ	Lo Current	20 + 10	40 + 10	43 + 10	46 + 10	55 + 10	46 + 10	126 + 10	190 + 10
100 MΩ	202 MΩ	Lo Current	250 + 100	250 + 100	350 + 100	500 + 100	1000 + 100	515 + 100	1320 + 100	1970 + 100
1 GΩ	2.02 GΩ	Lo Current	250 + 1500	300 + 1	450 + 1500	600 + 1500	1200 + 1500	600 + 1500	1410 + 1500	2110 + 1500
10 MΩ	20.2 MΩ	HV	2.0 + 1	5.8 + 1	6.5 + 1	7.0 + 1	14 + 1	15 + 1	17 + 1	26 + 1
100 MΩ	202 MΩ	HV	3.5 + 10	7.4 + 10	8.0 + 10	9.0 + 10	18.0 + 10	60 + 10	68 + 10	102 + 10
1 GΩ	2.02 GΩ	HV	20 + 100	27 + 100	28 + 100	30 + 100	60.0 + 100	150 + 100	230 + 100	345 + 100
10 GΩ [14]	20.2 GΩ	HV	250 + 1000	250 + 1000	350 + 1000	500 + 1000	1000 + 1000	525 + 1000	1330 + 1000	1990 + 1000

Temperature Coefficient (not applicable if within Tcal ± 1 °C)

Range	"Mode"	± µΩ/Ω of reading/°C 15 °C to 30 °C		± (µΩ/Ω of reading/°C + Ω/°C) 5 °C to 40 °C [13]
1 Ω	Normal	1.5	or	2.5 + 1.5 µ
10 Ω	Normal	0.6	or	1.0 + 15 µ
100 Ω	Normal	0.5	or	0.8 + 20 µ
1 kΩ	Normal	0.5	or	0.8 + 200 µ
10 kΩ	Normal	0.5	or	0.8 + 2 m
100 kΩ	Normal	0.5	or	0.8 + 20 m
1 MΩ	Normal	0.6	or	1.0 + 200 m
10 MΩ	Normal	2	or	3.0 + 2
100 MΩ	Normal	20	or	30 + 20
1 GΩ	Normal	200	or	300 + 200
1 Ω	Lo Current	1.5	or	2.5 + 1.5 µ
10 Ω	Lo Current	0.6	or	1.0 + 15 µ
100 Ω	Lo Current	0.6	or	1.0 + 150 µ
1 kΩ	Lo Current	0.6	or	1.0 + 1.5 m
10 kΩ	Lo Current	0.6	or	1.0 + 15 m
100 kΩ	Lo Current	0.6	or	1.0 + 20 m
1 MΩ	Lo Current	2	or	3.0 + 200 m
10 MΩ	Lo Current	20	or	30 + 2
100 MΩ	Lo Current	200	or	300 + 20
1 GΩ	Lo Current	200	or	300 + 100
10 MΩ	HV	0.6	or	1.0 + 2.5
100 MΩ	HV	2	or	3.0 + 25
1 GΩ	HV	20	or	30 + 250
10 GΩ [14]	HV	200	or	300 + 2.5 k

Voltage and Current Parameters

Range	"Mode"	Measurement Current	Measurement Voltage at Full Scale
1 Ω	Normal	100 mA	200 mV
10 Ω	Normal	10 mA	200 mV
100 Ω	Normal	10 mA	2 V
1 kΩ	Normal	1 mA	2 V
10 kΩ	Normal	100 µA	2 V
100 kΩ	Normal	100 µA	20 V
1 MΩ	Normal	10 µA	20 V
10 MΩ	Normal	1 µA	20 V
100 MΩ	Normal	100 nA	20 V
1 GΩ	Normal	10 nA	20 V
1 Ω	Lo Current	100 mA	200 mV
10 Ω	Lo Current	10 mA	200 mV
100 Ω	Lo Current	1 mA	200 mV
1 kΩ	Lo Current	100 µA	200 mV
10 kΩ	Lo Current	10 µA	200 mV
100 kΩ	Lo Current	10 µA	2 V
1 MΩ	Lo Current	1 µA	2 V
10 MΩ	Lo Current	100 nA	2 V
100 MΩ	Lo Current	10 nA	2 V
1 GΩ	Lo Current	10 nA	20 V
10 MΩ	HV	10 µA	200 V
100 MΩ	HV	1 µA	200 V
1 GΩ	HV	100 nA	200 V
10 GΩ [14]	HV	10 nA	200 V

Notes to Performance Specifications

1. Specifications apply for default configuration for aperture and resolution.
2. Assumes 3 hour warm-up period.
3. Input zero or offset null required whenever the temperature moves more than ±1 °C from the temperature at which the previous Zero operation was performed. Or NULL using Math.
4. For all specification tables, TCal = Ambient calibration temperature.
5. Integration time >1 Power Line cycle.
6. Valid for signals >1 % Full Scale. Signals must be DC coupled <40 Hz.
7. Maximum Volt.Hertz 3 x 10^7.
8. Maximum input to front and rear terminals is 2 A.
9. DCV Digitizing and DCV aperture <100 µs : for inputs > 160 % of range add 20 µV/V of range.
10. Tru Ohms mode available on 2 Ω to 20 kΩ ranges. Read Rate reduced in Tru Ohms Mode. Specification for Tru Ohms same as corresponding Normal or Lo Current range.
11. Valid for 4-wire sensor.
12. Not including sensor uncertainty.
13. The zero TC specification only needs to be applied if an input zero has not been performed within ±1 °C of the current operating temperature.
14. >2 GΩ Relative Humidity Operating <80 % to 30 °C <70 % to 40 °C.
15. Transfer specification for DCV, DCI, and Ohms applies to measurement made between 10 % and 120 % of range for deviations of up to 10 % of the initial measurement made using the same configuration for range, filter, aperture, delay etc. Specification accounts for linearity and noise but excludes temperature coefficient which should be calculated from the data provided according to the environment in which the instrument is used.
16. Transfer specification for ACV and ACI applies to measurements made between 10 % of range and full scale and accounts for deviations of up to 1 % of frequency and 10 % of amplitude of the initial measurement. Measurement must be made using the same configuration for range, filter, aperture, delay etc. The quoted transfer specification accounts for linearity, flatness and noise but excludes temperature coefficient which should be calculated from the data provided according to the environment in which the instrument is used.
17. Extended HF mode must be selected.
18. Differential non-linearity is included in the specification.
19. For AC signals refer to the ACV/ACI specification.