

734A and 7001 DC Reference Standards

Technical Data

734A: The simple way to maintain and disseminate your volt

The Fluke 734A DC Reference Standard is a direct voltage reference used to maintain the volt in primary and secondary standards laboratories. It consists of four electrically and mechanically independent 732B DC Standards and a rack-width enclosure. Individual 732Bs provide 10 V and 1.018 V outputs and may be transported easily to remote locations while the reference is maintained in the laboratory. Stability for each output is ± 2 ppm per year (10 V) and ± 0.8 ppm per month (1.018 V). Each 10 V output can drive up to 12 mA of current to simplify use with instrumentation with low input impedance.

The 734A Reference Standard was designed for laboratories that need to maintain traceability to national standards and to distribute the volt to production, service, calibration laboratories or other remote locations. To simplify shipment, each 732B Standard is small and highly portable. And its 72-hour battery life—which can be extended to more than 130 hours with the optional external battery and charger—means it's practical to ship a 732B across town or around the world.



Because each 732B in the 734A Reference Standard is based on the same technology pioneered in the popular 732A—the first standards lab quality 10 V electronic reference—you can rely on it to provide the same high stability and predictable drift rate you’ve come to expect, in a smaller, more portable package.

To simplify support of your 734A, Fluke offers a variety of calibration services to assign values and predicted performance for the 10 V output, traceable to national standards and to the Fluke 10 V Josephson Array.

Why a four-cell reference?

A four-cell reference is desirable any time you need to maintain and disseminate a reference voltage. At a minimum, three cells are intercompared to detect and identify changes in the output of any one cell. A fourth cell may be used as a spare or to transport the volt to or from remote locations. When it returns to the laboratory, it can be compared to the other three to determine if its output has shifted during transport.

However, there is more to a four-cell reference than four outputs. According to NBS Technical Note 1239, published by the U.S. National Bureau of Standards (now NIST) in 1987, four to six references are required to provide measurement integrity and redundancy, and to minimize the number of measurements required. References must be completely independent of one another. Otherwise, common elements, such as a power supply or oven, might affect the correlation of reference outputs. In addition, with frequent intercomparisons of four cells, you can detect when any one of the cells begins to drift beyond specifications or needs to be repaired.



The Fluke Standards Laboratory offers traceability to its own 10 V Josephson Array, an intrinsic standard of voltage, and to national standards.

Each 732B is a stand-alone dc standard with its own power supply, oven, supporting electronics and packaging. Each may be purchased separately, or as a full 734A system, which includes four 732Bs that slide into a rack-width enclosure.

A fractional ppm 10 V reference in your lab

With the 734A, it is remarkably simple to establish and maintain a fractional part per million (ppm) primary voltage standard in your laboratory. Over time, with frequent intercomparisons of your four cells, and regular calibrations of one or more cells, you can reduce the uncertainty of your 734A by a factor of three.

From 1984 until the acquisition of our 10 V Josephson Array, the Fluke Primary Standards Laboratory maintained its corporate volt in this manner, reducing the absolute uncertainty to ± 0.35 ppm traceable to national standards.

Taking your reference to the workload

Standards laboratory operations have changed. In the past, people brought their workload to the standards lab. Today, the functions of the standards lab are being distributed, requiring that many calibrations be performed in the field. The 734A, and its electrically and mechanically independent 732B Standards, was designed to meet that need. The voltage reference remains undisturbed in your laboratory, while at the same time you can distribute the volt to remote locations outside the lab. When the unit is returned to the lab, comparisons can be made to the reference to determine if a shift has occurred during the transfer. To maintain traceability to national standards, one cell may be transported to a national lab or other primary standards lab for calibration, again, without disturbing the reference.

Each 732B Standard is relatively light, weighing just 5.9 kg, and its 72-hour battery life provides ample capacity for long shipments. An optional external battery extends that capacity to 130 hours. A special transit case, designed to hold one 732B and an external battery, simplifies transport even further.

The 732B can stand up to a lot of abuse. The inputs can be shorted indefinitely and are protected up to 1100 V dc, 25 mA, without damaging the cell or affecting its output.

Ideal support for artifact calibration

Combined with 742A-1 and 742A-10k Resistance Standards, a single 732B makes a tough and compact artifact calibration support package for instruments like the 5700A and 5720A Calibrators from Fluke or the 3458A Multimeter from Agilent.

Why should you prefer the 734A?

- **Independence.** The 734A is the only standard of its type offering complete mechanical and electrical independence of each of its four standards.
- **Portability.** Each 732B Standard is designed for portability. Each is small, light, rugged and has a long operating battery life.
- **Confidence.** The 732B is based on the proven technology of the Fluke 732A. The 732A was the first standards lab quality electronic reference to gain wide acceptance as a replacement for saturated standard cells. Originally designed for internal transfers of Fluke’s corporate volt to the production floor, thousands are now in service worldwide in a variety of applications—from maintaining an institutional reference to transferring values from national labs or privately-operated 10 V Josephson Arrays.

The 732B’s reference amplifier and resistors are identical to those used in the 732A. But the package is now half the weight, 75 % smaller, more rugged and offers greatly extended battery life. The rack-width enclosure provides a convenient way to store cells in your lab. And the internal battery is now a common, off-the-shelf model that can be purchased from a wide range of electronic components suppliers, simplifying your support. Or you can use your own battery, connecting it to the 12 V to 15 V dc input on each 732B.



The 734A Reference and 732B Standards are a practical way to maintain and disseminate your volt and to support artifact calibration of instruments like the 5700A and 5720A Calibrators.

The advantages to maintaining your reference at 10 V

The primary benefits of maintaining your voltage reference at 10 V rather than 1.018 V center on efficiency and ease-of-use. At 10 V, you can intercompare standards directly with a digital voltmeter. The effects of noise and thermal EMFs are diminished by a factor of 10 compared to standard cells. And with 10 V Josephson Arrays becoming more common, working at the 10 V level further simplifies the process of establishing traceability. Finally, most modern dc instrumentation today requires a 10 V standard for calibration. When you ratio up to 10 V from 1.018 V, you lose considerable performance.

The 734A supports 1.018 V as well

In applications where saturated standard cells are still used, the 1.018 V output of each 732B Standard in the 734A Reference greatly simplifies intercomparisons of cell banks. And, like the 10 V output, each 1.018 V output is completely electrically and mechanically independent to preserve the integrity of your reference. Unlike standard cells, the 1.018 V output of the 732B may be used immediately after shipment, eliminating the need to let cells stabilize for an extended period.



Supporting your traceability requirements

Fluke provides the products and services you need to manage your traceability requirements. New 732Bs can be ordered with or without calibration certificates. The standard 732B comes without any calibration certificate, with the intention of the owner providing traceability as required locally. When delivery of a new 732B with a calibration certificate is required, then three alternatives are possible:

- **Calibration.** The 732B/H is a 732B where Fluke performs an output voltage calibration on your new standard. Before shipment, your standard is compared to direct voltage standards maintained at Fluke. Your standard, shipped under power, includes a Report of Calibration showing the deviation from nominal and the uncertainty of the calibration. This certificate is traceable to NIST via Fluke's Josephson Array, an intrinsic standard of voltage.
- **Calibration and drift characterization.** The 732B/C is similar to the 732B/H, but it adds drift rate characterization before shipment. The output voltage is compared to a Fluke standard for 90 days. Once the drift rate is known, total uncertainty as a function of time is greatly reduced. The projected output voltage is tabulated for 12 months following calibration. Uncertainty of the projection varies linearly, from + 0.5 ppm at the time of calibration to + 1.5 ppm after 12 months.

732B Standards are small, light and rugged. Their 72-hour battery life, which can be extended to 130 hours with the optional external battery and charger, make them ideal for transfer standards.



The Fluke 732B Standard uses the same specially selected zener reference technology pioneered in the popular 732A.

- **Accredited calibration.** Normally, the 732B calibration certificates are traceable to NIST but are not considered accredited calibrations. For an extra charge, an accredited calibration certificate is available. Contact your Fluke representative for details.

Both the 732B/H and 732B/C require that the standard is shipped to you under power. This continuous power on condition is required during shipment through delivery to your lab for the calibration to remain valid. If continuous power is not maintained, then the validity of the calibration certificate may be compromised. Contact your Fluke representative to determine if the 732B/H or 732B/C alternatives are available in your area.

For existing 732Bs or similar standards that are already in use, the Direct Voltage Maintenance Program is a service where Fluke can provide calibration certificates for these standards. This service consists of two calibration alternatives that can be used depending on your needs.

- Calibrations done by Fluke.** Calibration certificate services can be easily performed on standards returned to Fluke service facilities. Contact your Fluke representative or your local Fluke service center for details regarding these calibration certificate alternatives.
- Calibration in your laboratory.** With the 732B-200 services, a standard owned and calibrated by Fluke, including all necessary connecting cables and clear operating instructions, is sent to your site for comparison with one or more of your own reference standards. You make a series of readings over five days and forward the standard to the next laboratory, then return the measurement results to the Fluke Standards Laboratory. A value for your reference relative to the Fluke standard is assigned. Within one week, a preliminary Report of Calibration is returned to you. Once the standard is returned to Fluke, it is compared to the Fluke Voltage Standard. A final value is assigned to your reference, and a final Report of Calibration is sent to you. The 732B-200 service provides a calibration certificate for one local standard. Each additional standard that requires a certificate can use the 732B-201 service. In this way, comparing multiple standards to a single Fluke standard will provide any required number of standards with individual calibration certificates. *(Note: this service is not available in all areas. Contact your local Fluke representative for details).*

734A specifications

Output voltages

Outputs of 10.0 V and 1.018 V are provided at separate binding-post pairs with the following characteristics:

Stability

Stability for the 732B is specified by the following at a temperature of $T_{cal} \pm 1\text{ }^\circ\text{C}$ ($15\text{ }^\circ\text{C} \leq T_{cal} \pm 35\text{ }^\circ\text{C}$):

Stability (ppm)			
Output Voltage	30 Days	90 Days	1 Year
10 V	0.3	0.8	2.0
1.018 V	0.8	NA	NA

Noise at output terminals

Output noise is specified for both day-to-day observations and for short-term observations. The former is given by the standard deviation about the regression line of a 90-day regression model. The latter is terms of its rms value in a bandwidth as follows:

Output Voltage	Day-to-Day (S1) (ppm)	0.01 Hz 10 Hz (ppm)
10 V	0.065	0.06 rms
1.018 V	0.1	0.3 rms

Output current and impedance

Output Voltage	Output Current	Output Impedance
10 V	12 mA*	$\leq 1\text{ m}\Omega$
1.018 V	NA	$\leq 1\text{ k}\Omega$

* Output current is limited to $\leq 0.1\text{ mA}$ to realize 72-hour operation under battery power

Output adjustment

10 V: 0.15 ppm resolution
 1.018 V: Set at nominal $\pm 1\text{ mV}$
 No adjustment is provided, however the output value changes when the 10 V output is adjusted

Retrace (hysteresis) error (Constant temperature)

$\leq 0.1\text{ ppm}$, 10 minute power off $\leq 0.25\text{ ppm}$, 1 to 24 hours power off

Stabilization time (Constant temperature)

For best results, allow a 14-day stabilization period after power has been off for an extended period of time

No power interruption

No stabilization time is required after moving into another environment

Power off <1 hour

1-hour warm up required

Power off 1 to 24 hours

24-hour warm up required

Temperature coefficient (TC) of output

In the temperature range of $15\text{ }^\circ\text{C}$ to $35\text{ }^\circ\text{C}$, the magnitude of TC is bounded by the following:

10 V TC $\leq 0.04\text{ ppm}/^\circ\text{C}$
 1.018 V TC $\leq 0.1\text{ ppm}/^\circ\text{C}$

Load regulation

10 V output will change less than 1 ppm for a full load change from 0 to 12 mA and less than 0.1 ppm for a load change from 0 to 2 mA

Line regulation

The outputs will change no more than 0.05 ppm for any 10 % line voltage change or for the entire operating range of the battery

Output protection

All outputs can be shorted indefinitely without damage to the instrument. The 10 V output can withstand voltages from other sources as follows:

- For voltages $\leq 220\text{ V dc}$, the unit is protected for up to 50 mA continuous current
- For voltage $\leq 1100\text{ V dc}$, the unit is protected for up to 25 mA continuous current or up to 0.6 joules of energy

Environment

	Temp Relative $^\circ\text{C}$	Range Humidity %	Altitude meters (feet)
Normal Operation	15-35	15-80	0-1,830 (0-6,000)
Safe Operation	0-50	15-90	0-3050 (0-10,000)
Storage (no batt)	-40-50	non-cond	0-12,200 (0-40,000)

Compliance with external standards

ANSI ISA-S2 IEC 348
 CSA C22.2 #231 IEC 1010
 UL 1244

Line power requirements

Voltage	Frequency
90 V to 132 V ac	47 Hz to 63 Hz
180 V to 264 V ac	47 Hz to 63 Hz

Battery operation

When fully charged, the batteries will maintain the 732B for a minimum of 72 hours at 23 °C ±5 °C, with an output current <0.1 mA.

The batteries are rechargeable in less than 24 hours with a self-contained battery charger.

A rear-panel input has been provided to accept an external 12 V battery or equivalent 12 V to 15 V dc power source.

Isolation

The resistance from any 732B output terminal to earth ground or to the ac mains is at least 10,000 MΩ shunted by less than 1000 pF.

Guard and grounding

Chassis ground terminals are provided on both front and rear panels. Access to the internal guard is provided by a front-panel terminal.

Explanation of stability verification

Stability for a given period of time is defined as the output uncertainty minus the calibration uncertainty at the 99 % confidence level. When the output voltage is characterized by a regression model, stability is given by the following equation:

$$\left| b \left(\frac{P}{365} \right) \right| + S_1 t_1 \sqrt{\left[\frac{S_{ra} t_2}{S_1 t_1} \right]^2 + \left(\frac{1}{n} \right) + \left[\frac{(P-\bar{x})^2}{\sum(X_i-\bar{x})^2} \right]}$$

- where
- b = slope of regression in ppm/year
 - S₁ = standard deviation about the regression (SDEV)
 - S_{ra} = SDEV – of data filtered with 7-day moving average filter (MAF)
 - P = period of time under consideration in days
 - \bar{x} = mean time for regression data
 - n = 180 periods (typically 2 measurements per day)
 - X_i = ith period
 - t₁ = student's t statistic for (n-2) degrees of freedom (typically 2.6)
 - t₂ = student's t statistic for $\left[\left(\frac{n}{7} \right) - 2 \right]$ degree of freedom (typically 2.81)

Each data point for the computation of the regression parameters is the average voltage of 50 readings taken in a 50-second measurement period.

Reference standard comparison selection guide

Model	7001	732B	734A ¹
10 V output			
Stability (± ppm), 90 days	0.9	0.7	0.7
Stability (± ppm), 1 year	1.8	1.6	1.2
Predictability			
After 5 points, 3 months apart	± 0.5 ppm/year typ.	± 0.4 ppm/year typ.	± 0.2 ppm/year typ.
Temperature coefficient (15 °C to 35 °C)	< 0.05 ppm	< 0.04 ppm	
Noise			
0.01 Hz to 10 Hz	< 0.10 ppm RMS	< 0.06 ppm RMS	< 0.03 ppm RMS
Std. dev. of 90 days regression	< 0.10 ppm RMS	< 0.065 ppm	< 0.04 ppm RMS
Hysteresis recovery (after battery discharge)	< 0.1 ppm ^[2]	0.2 ppm ^[3]	
Output current	12 mA	12 mA	
Output resistance	< 10 mΩ	< 1 mΩ	
Battery type			
Back-up period	16 hours	72 hours	
Recharge time (typical)	2 hours	24 hours	
Half life	5 years		
Reference conditioning (power loss recovery)	Yes	No	
Temperature			
Operating	+15 °C to 35 °C	+15 °C to 35 °C	
Transit	-18 °C to 45 °C	-40 °C to 50 °C	
Warm-up period	10 min. to ± 0.1 ppm of final output value	1 hour (power off for less than 1 hour)	
Power	< 1 W	< 10 W	< 40 W
Dimensions (H x W x D)	137 x 85 x 290 mm (3.5 x 2.1 x 11.4 in)	135 x 99 x 419 mm (5.3 x 3.9 x 16.5 in)	191 x 432 x 502 mm (7.5 x 17 x 19.75 in)
Weight	2.1 kg (4.5 lb)	5.9 kg (13 lb)	29.6 kg (65 lb)
Safety	UL3111; CE marked; EN61010-1-1; 1993/A2; 1995; CETL	UL1244; CE marked; CSA C22.2 # 231; IEC 348; IEC 1010	

Notes: All specifications, including 732B, are stated with 98 % confidence level.

^[1] 734A specifications are using a mathematical average of four cells.

^[2] After conditioning cycle and maintained within environments down to 10 °C.

^[3] Conditioning not available. Specification assumes reference remains within a temp controlled environment.

^[4] Actual resistance = 500/n, where n = number of references in the Average.



7001: 10 volt solid-state dc voltage reference

The fully isolated, compact 7001 solid state 10 V and 1.018 V direct voltage standard is designed to be robust and portable; its internal batteries support ‘hot shipment and plug-in’. However, should complete power be lost at any time, patented reference conditioning technology over-comes reference device hysteresis and restores the last powered value to the module. The 7001 modules also feature patented dc-dc convertor technology, which achieves unparalleled isolation from the external ac-dc line power adaptor. This makes the 7000 series particularly well suited to Josephson Junction direct comparison

- Self-contained 10 V dc voltage reference
- Reference module interchangeable with nanoscan and transref system
- 10 V and 1.018 V outputs
- Economical entry point into 10 V metrology
- Suitable for unpowered shipment

Self-contained 10 V dc voltage reference

Owning a precision dc voltage reference standard needn't be expensive or inconvenient. The Model 7001 is a complete self-contained solid-state 10 V dc voltage reference in portable unit measuring only 137 x 85 x 290 mm and weighing a mere 2.1 kg (4.6 lb) including batteries. Yet it's capable of delivering 1-year stabilities of better than 1 ppm.

Unique new dc/dc isolation technique

Utilizing a low-temperature oven that minimizes the ageing rate of its zener references diodes, plus thin-film resistor arrays that dramatically reduce the drift and temperature coefficient of its gain defining networks, the Model 7001 gives you a drift predictability after 2-years of better than 0.3 ppm/year and a temperature coefficient better than 0.05 ppm/°C. And because it utilizes a unique new dc/dc isolation technique,

you won't find that the output voltage shifts when you switch between back-up battery and ac line supply power.

Patented zener reference conditioning

The Model 7001 isn't solely reliant on its batteries during transportation. Although it's an advantage to keep the zener diode oven up to temperature during transportation, patented zener reference conditioning guarantees that both the 10 V and 1.018 V outputs return to within ± 0.5 ppm of their previous values if deep discharge of the battery caused oven control to be lost. As a result, unpredicted delays during shipment mean that your 10 V reference won't need complete recalibration.

The optional ruggedized transit case not only protects the unit, it also includes a temperature monitor that tracks environmental conditions during shipment.

7001 specifications

10 V output	
Stability	90 days (± ppm): 0.9 1 Year (± ppm): 1.8
Predictability	± 0.5 ppm/year typical after 5 verification points, 3 months apart
Temperature coefficient (15 °C to 35 °C)	< 0.03 ppm/°C
Noise (rms)	0.01 Hz to 10 Hz: ± 0.10 ppm RMS Standard deviation of 90 day regression: ± 0.10 ppm RMS
Hysteresis recovery	< 0.1 ppm (after conditioning cycle and battery discharge)
Output current	12 mA
Output resistance	< 5 mΩ
Battery	
Type	NiMH
Backup Period	>24 hours from fully charged
Recharge time (typical)	2.5 hours
Half Life	5 years
Environment	
Temperature	Operating: +15 °C to 35 °C Transit: -18 °C to 45 °C Warm-up period: 10 minutes to ± 0.1 ppm of final output value
General specifications	
Power, battery life	< 1 W
12 V dc connection	Yes
Dimensions (H x W x D)	137 x 85 x 290 mm (3.5 x 2.1 x 11.4 in)
Weight	2.1 kg (4.5 lb)
Safety	UL3111, CE marked, EN61010-1-1:1993/A2:1995 CETL

Ordering information

Models

734A Reference Standard

Includes four 732Bs in a rack-width enclosure.
Calibration of each 732B output optional.

732B DC Standard, without calibration certificate, shipped under a power-off condition.

732B/H DC Standard, with calibration certificate included, shipped under power.

732B/C DC Standard with drift characterization and calibration certificate included, shipped under power.

7001 Stand alone 10 V/1.018 V Reference Module complete with calibration certificate and 12 V dc power supply

Direct Voltage Maintenance Program (U.S. only)

732B-200 10 V Output Voltage Calibration On Site

732B-201 Additional 10 V Output Voltage Calibration at the same site

Accessories

7001-CASE Enclosure and Power Supply for Single 7000 Module

7001-65 Ruggedized Transit Case for 7001 – also fits 7100, 7101, 7000 and 7000S

7004-PWR 12 V DC Power Supply for 7000, 7001, and 7004 instruments

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