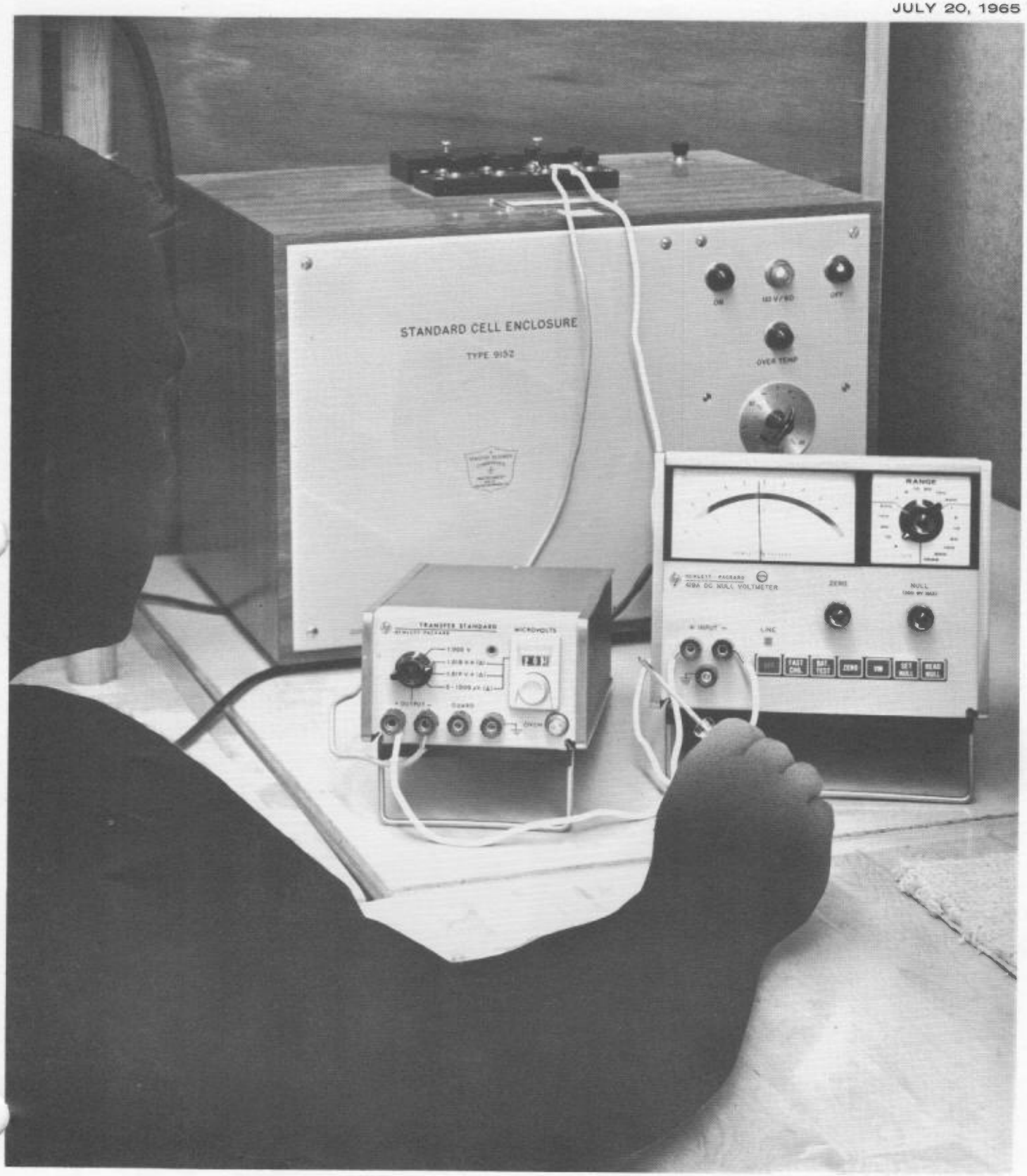
HEWLETT hp PACKARD

PRECISION DC VOLTAGE MEASUREMENTS

Application Note 70

JULY 20, 1965



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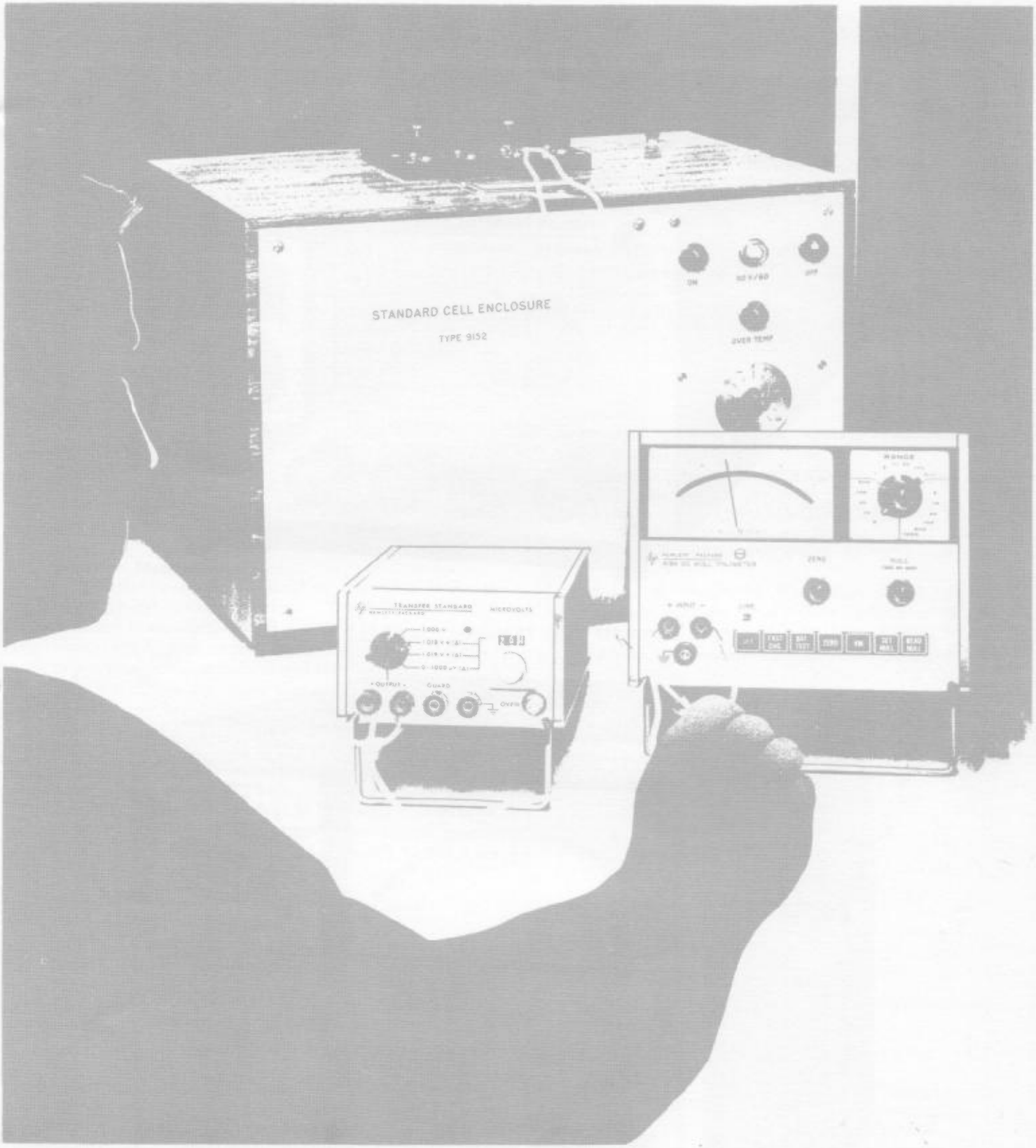


PRECISION DC VOLTAGE MEASUREMENTS

HP 735A TRANSFER STANDARD

HP 419A DC NULLMETER

PRECISION DC VOLTAGE MEASUREMENTS

Introduction

Instruments recently developed by Hewlett-Packard simplify precision DC calibration measurements that were previously considered feasible only by highly specialized personnel and under exacting environmental conditions. Although the standards laboratory environment is still the ideal for precision DC measurements, these new instruments have been designed to provide much of standard lab's precision in a wide range of other situations. Instruments such as the –hp– Models 735A TRANSFER STANDARD, 740A DC STANDARD/DIFFERENTIAL VOLTMETER, and 419A DC NULL VOLTMETER are tested to better than their published specifications during production, and once again prior to shipment. Instrumentation used during their production and in quality control is calibrated once a month from precise standards *traceable to the National Bureau of Standards.*

Transfer Measurements

Transfer standards are useful to compare field instruments against working standards. The ϕ 735A Transfer Standard in conjunction with the ϕ 419A DC Null Voltmeter provide a convenient method of direct comparison between saturated or unsaturated standard cells to 1 or 2 parts per million over short time intervals in a standards laboratory environment. The transfer accuracy between a saturated and an unsaturated standard cell or between either of these and 1 volt is better than 10 ppm. Figure 5 describes by simple techniques how the 735A Transfer Standard can be set at 1 volt to an accuracy of 2 ppm during a working day in a normal laboratory environment.

Block diagrams and step-by-step procedures illustrating typical techniques using the ϕ 735A Transfer Standard are described in Figures 1, 2, 3 and 4.

Calibration Measurements

The basic technique shown in Figure 3 can be applied to calibration and measurement problems in several ways. Precision differential voltmeters can be certified on all ranges to the system accuracy of 2 ppm ± divider accuracy which is typically 10 to 12 ppm. This indicates that voltage sources and measurements can be established with this precision. Calibration of a dc source such as the 740A DC STANDARD is shown in Figure 4. A solid copper contact DPDT knife switch is used to substitute a short circuit for the –hp– 735A, allowing thermal emf's to be nulled out using the 3 μv range of the 419A. For optimum precision, step (4) of Figure 4 should be repeated every time connections are changed on the voltage divider. Figure 4 is a modified version of Figure 3 providing additional instructions for nulling thermal emfs. The difference in the VOLTAGE SET indicated on the 740A and the indication of the 419A ± the accuracy of the 735A and the precision divider provides an absolute calibration of the dc standard under test. (See Figure 4 (6)).

Differential voltmeters, digital voltmeters, and other high impedance devices can be calibrated directly using the procedure outlined in Figure No. 3 to provide a precision voltage source. Loading effects of the meter being calibrated can be compensated at all 100:1 and 10:1 ratio combinations by adjusting the 740A so that the 419A reads zero on the 3 μv range while the load is connected to the precision voltage divider.

— APPENDIX —

References:

HP 419A DC NULL DETECTOR, Operating and Service Manual

HP 735A TRANSFER STANDARD, Operating and Service Manual

HP 740A DC STANDARD/DIFFERENTIAL VOLTMETER, Operating and Service Manual

HP APPLICATION NOTE NO. 69 "Which dc Voltmeter"

HP Journal, Volume 16, No. 9, May 1965.

Electronic Precision Measurement Techniques and Experiments, Prentice Hall, Englewood Cliffs, N. J.

Precision Measurement and Calibration, Electricity and Electronics Handbook 77, Volume I, U.S. Dept. of Commerce, National Bureau of Standards.

Figure No. 1

STANDARD CELL COMPARISONS

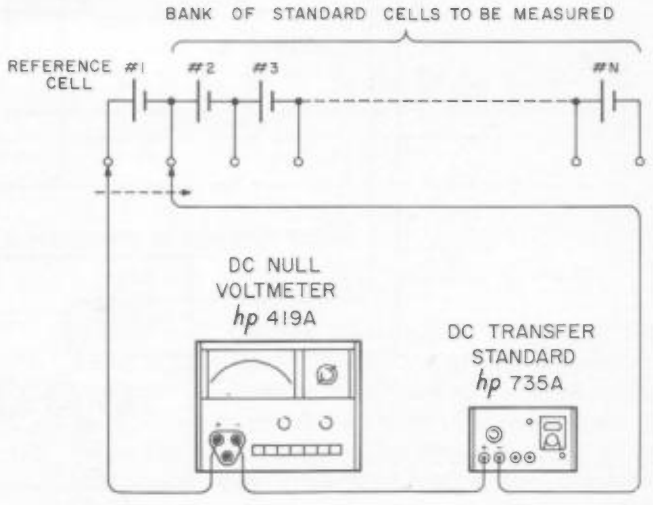


FIGURE 1. BLOCK DIAGRAM FOR STANDARD CELL COMPARISONS.

1) Allow ϕ 735A to warm up 30 minutes prior to making measurements.
2) Make connections with insulated, solid copper wire as

indicated by solid lines except omit connection to standard cell.

3) Set the hp 419 range switch to 300 microvolts, push Zero button. Adjust zero of the 419A until it reads zero on the 3 μv range. Return the range switch to 300 μv and press the VM button.
4) Set hp 735A switch to 1.018 + (Δ) for saturated or 1.019 + (Δ) unsaturated cell comparison. Adjust MICROVOLTS so that the switch position plus microvolts is exactly equal to voltage shown on cell #1 certification. Lock MICROVOLTS knob.
5) Connect leads to cell #1.
6) Using a small screwdriver, adjust the CAL control on the hp 735A so that the hp 419A reads zero as the range switch is changed to the 3 μv range. The hp 735A output is now exactly equal to cell #1 voltage to better than 0.1 ppm.
7) Depress hp 419A ZERO pushbutton. Move test leads to cell #2.
8) Depress VM button and adjust the hp 735A MICROVOLTS control until the hp 419A again indicates zero on the 3 μv range. Record the hp 735A switch position plus the MICROVOLTS dial reading. This is the absolute voltage of the cell referred to cell #1.
9) Repeat steps (8) and (9) for all cells.
10) The deviation between each cell and cell #1 is obtained by finding the algebraic difference between each reading recorded in step (9) and the certified value of cell #1. The deviation from cell to cell can be obtained by finding the algebraic difference between each of the readings obtained in step (9).

Figure No. 2

A PRECISION 0 TO 1 VOLT SOURCE

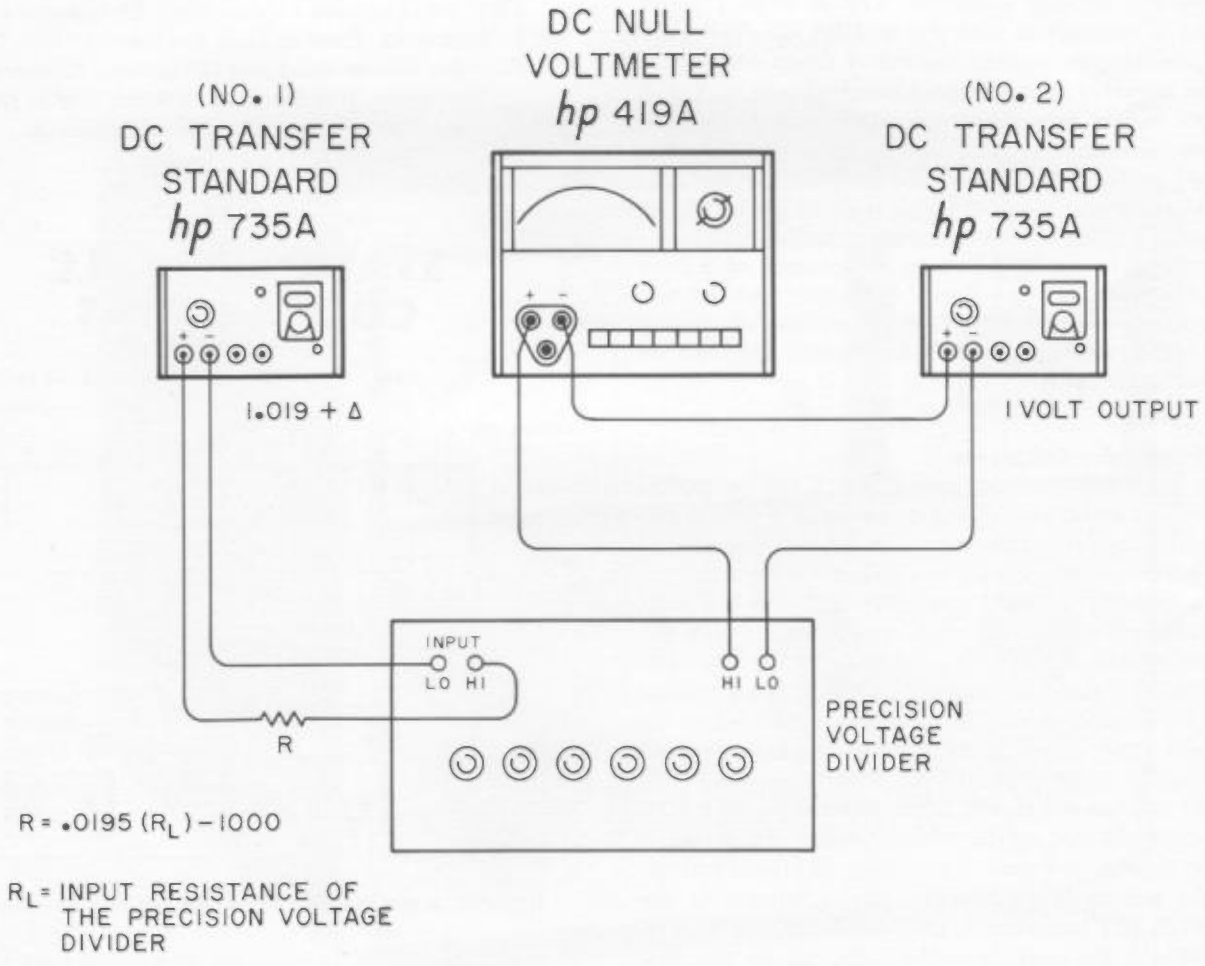


FIGURE 2. BLOCK DIAGRAM FOR ESTABLISHING A PRECISION 0.1 TO 1 VOLT SOURCE.

1) Connect equipment as shown using insulated, solid copper wire. Allow a 30 minute stabilization period after the hp 735A's are turned on before final adjustments are made.
2) The hp 735A (No. 1) connected to the input of the precision voltage divider is used as a finely adjustable, stable voltage source. The hp 735A (No. 2) used with the hp 419A on the output is the transfer standard and has been calibrated at the 1 volt output to 2 ppm using procedure shown in Figure 5.
3) Set 735A (No. 1) connected to the voltage divider input to supply 1.019 V + (Δ).
4) Depress ZERO button on 419A and adjust to zero on the 3 μv range. Then return range switch to 300 μv.
5) With the 735A (No. 2) on the output side of the voltage divider set at 1.000 volt, and the precision voltage divider dials set at 9-9-9-9-9-10; depress VM button on the 419A.
6) Adjust the 735A (No. 1) MICROVOLTS control on the input of the voltage divider until the 419A indicates zero on the 3 μv range. Disconnect the 419A and 735A (No. 2).
7) The voltage now available at the output of the voltage divider is 0 to 1.00000V; accurate and stable to 2 ppm ± accuracy of the divider for short periods in a standards laboratory environment.

Figure No. 3

A PRECISION 1 TO 1000 VOLT SOURCE

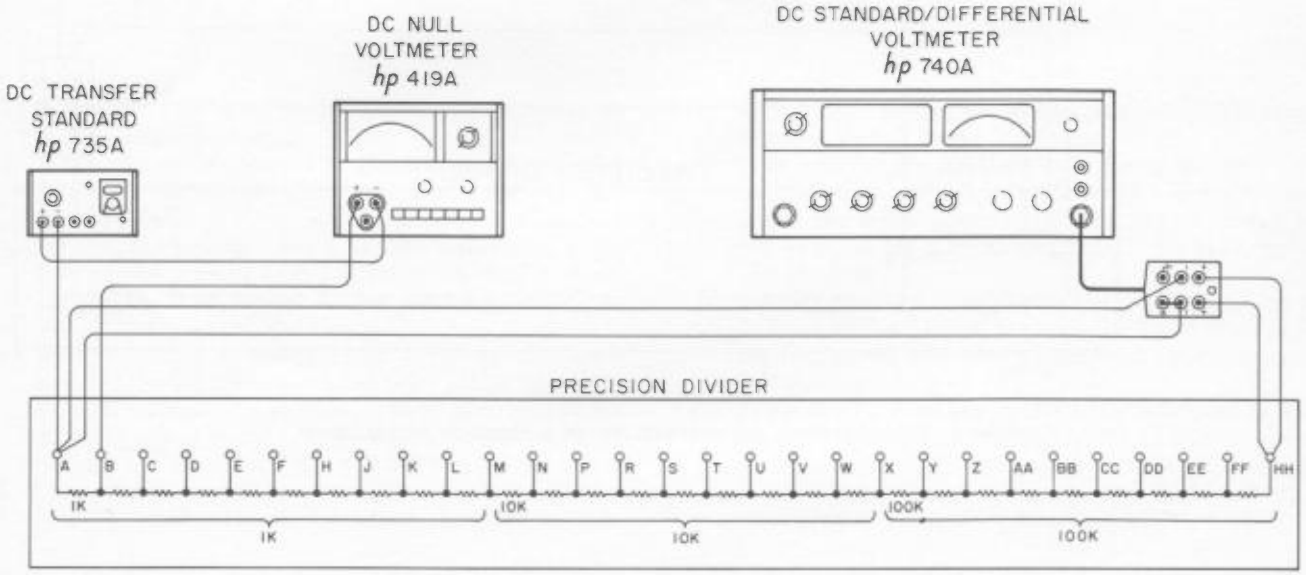


FIGURE 3. BLOCK DIAGRAM FOR ESTABLISHING A PRECISION 1 TO 1000 VOLT SOURCE.

1) Connect equipment as shown using insulated, solid copper wire. Allow a 30 minute stabilization period for the 735A and 740A before final adjustments are made. Be sure the 740A OUTPUT is off.
2) The 735A is the transfer standard that has been calibrated at the 1 volt output to 2 ppm using the procedure shown in Figure 5.
3) Depress the ZERO button on the 419A and adjust to ZERO on the 3 μv range. Return the range switch to 300 μv.
4) Set the output of the 740A in DC STANDARD mode to 1000 volts and turn on the OUTPUT. Adjust the VERNIER on the 740A until the 419A reads zero.
5) Continue to adjust the VERNIER of the 740A while the 419A range switch is reduced to 3 μv full scale.
6) When the 419A reads zero on the 3 μv range, 1000 volts have been established across the Precision Divider to an accuracy of 2 ppm ± accuracy of the divider.
7) Other precision voltages can be established at other points on the Precision Voltage Divider by this same technique. All will have the basic accuracy of 2 ppm ± accuracy of the divider.

Figure No. 4

CERTIFYING A PRECISION DC STANDARD

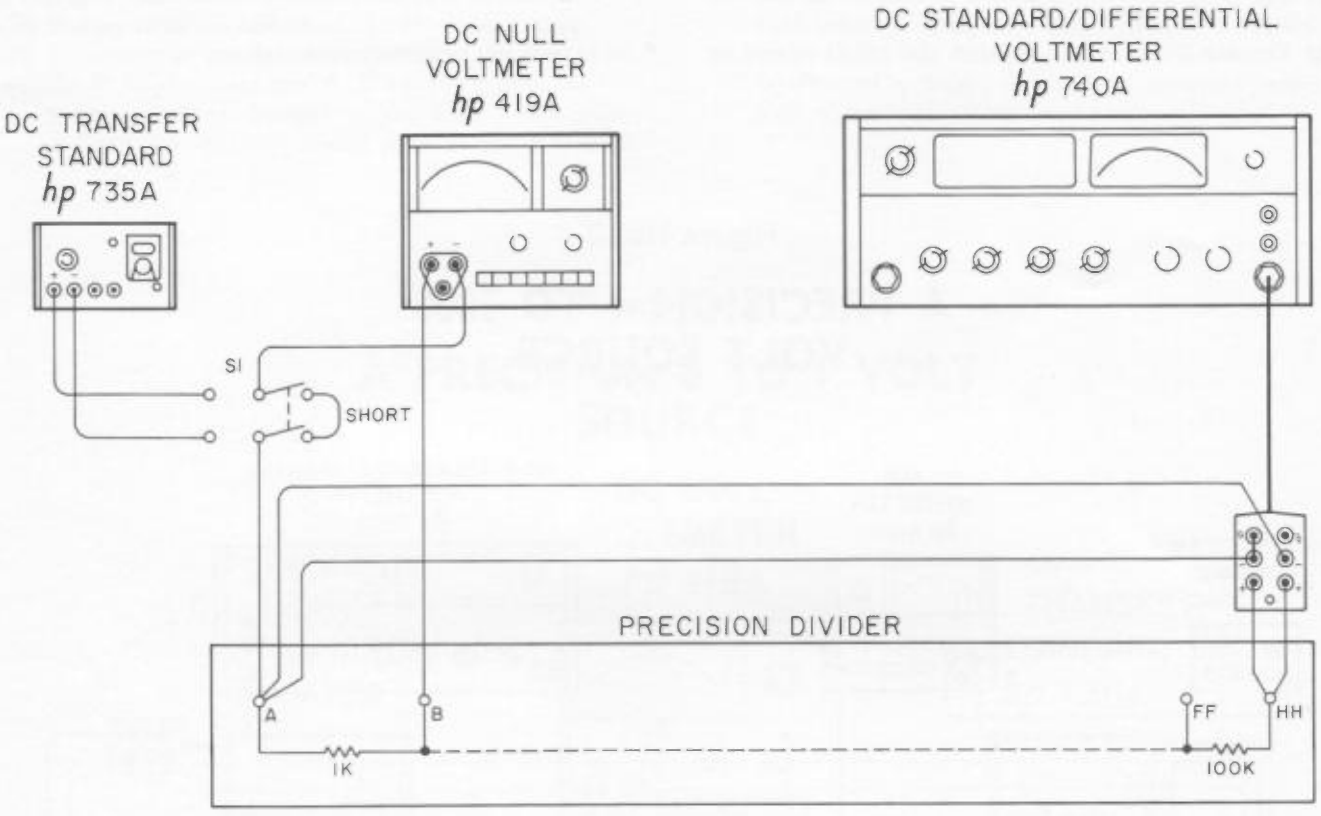
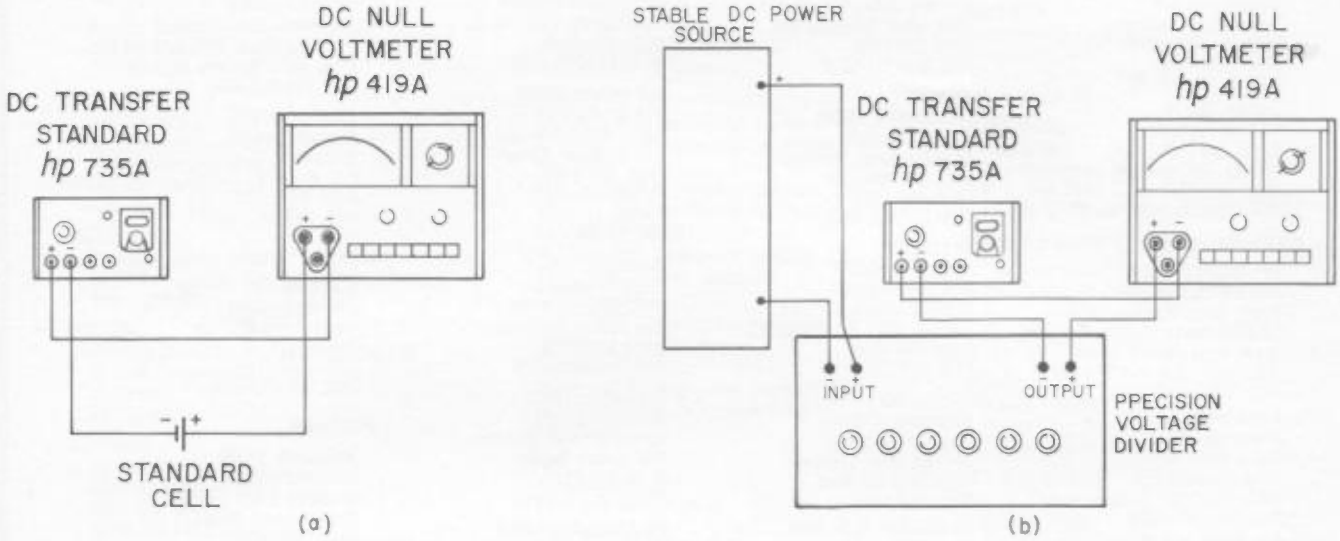


FIGURE 4. BLOCK DIAGRAM FOR CERTIFICAION OF A PRECISION DC STANDARD.

1) Connect equipment as shown using insulated, solid copper wire. Switch S_1 should be a solid copper contact knife switch. Allow a 30 minute stabilization period for the 735A and 740A before final adjustments are made. Be sure the 740A OUTPUT is off.
2) The 735A is the transfer standard that has been calibrated at the 1 volt output to 2 ppm using the procedure shown in Figure 5.
3) Depress the ZERO button on the 419A and adjust to ZERO on the 3 μv range. Return the range switch to 300 μv.
4) Place S_1 in SHORT position. Set the 740A to DC STANDARD mode and to the 1 volt range. Connect the + output of the 740A to point B on the divider. With all VOLTAGE SET controls and the VERNIER on the 740A set fully counterclockwise, press the OUTPUT button and adjust ZERO SET until the 419A reads zero on the 3 μv range. Return the 419A to the 300 μv range and move S_1 to the 735A position.
5) Set the output of the 740A to exactly 1 volt as indicated by its VOLTAGE SET controls and VERNIER.
6) Adjust the 419A range switch to obtain as near full scale reading as possible. The reading of the 419A in microvolts ± the combined uncertainty of the 735A and the precision voltage divider in parts per million provides the deviation in ppm of the 740A, 1 volt range, referenced directly to the primary standard cell.
7) Other calibrations can be established at various voltage levels using the divider ratios available. In each case the deviation can be read directly as indicated in (6).

Figure 5

CALIBRATING THE -hp- 735A TO ONE VOLT ±2 PPM



1) Allow the 735 A to warm up 30 minutes prior to making any adjustments.
2) Make connections shown in (a) with insulated solid copper wire except omit one connection to the standard cell.
3) Set the 419A range switch to 300 microvolts, push Zero button. Adjust ZERO of the 419A until it reads zero on the 3 uv range. Return the range switch to 300 μv and press the VM button.
4) Set –hp– 735A switch to 1.018 + (Δ) for saturated or 1.019 + (Δ) for unsaturated cell. Adjust MICROVOLTS so that the switch position plus microvolts is exactly equal to the voltage shown on the standard cell certification. Lock the MICROVOLTS knob.
5) Connect the remaining lead to the standard cell.
6) Using a small screwdriver, adjust the CAL control on the 735A so that the 419A reads zero as the range switch is rotated to the 3 μv range.
7) Now connect the equipment as shown in (b).
8) Set the precision voltage divider for a 1:1 ratio and adjust the stable power source for a null (zero) on the 419A on the 3 uv range. Return the 419A to the 300 μv range.
9) Set the precision voltage divider to a ratio equal to 1/735A setting [1/1.018 + (Δ), or 1/1.019 + (Δ)], depending on whether a saturated or unsaturated cell was used in step (4).
10) Move the 735A switch to the 1.000 volt position and carefully adjust A2R8 in the 735A to obtain a zero reading on the 419A 3 uv range. The 1.000 volt output of the 735A is now adjusted within 2 ppm referenced to the primary standard cell.

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