Application Note

Changing to the 1990 Volt and Ohm

Introduction

On January 1st, 1990, the U.S. National Institute of Standards and Technology (NIST), and other national standards organizations worldwide, will establish new values for the volt and ohm. These values are based on the Josephson effect for the volt and the Quantum Hall effect for the ohm and are consistent with the International System of Units (abbreviated SI) established throughout the industrial world. This change will benefit trading nations by establishing a common standard and international consistency of electrical measurements.

National labs have made similar adjustments in the past. For example, the last adjustment of the U.S. volt occurred in 1969 and was of about the same magnitude as the upcoming change. At that time, only a very small percentage of the instrument population was affected and those instruments were generally found in standards laboratories. Today however, a much larger proportion of the instrument base is impacted by these changes. Such high-accuracy instruments are now found not just in the standards lab, but also in the calibration lab, the manufacturing environment, rental services, equipment pools, service and repair facilities, etc.

This Application Note briefly describes the changes that are being made, what the changes mean, and how to implement them.

The Changes Being Made

The amount of change required to bring the volt and ohm in line with the new representations will vary from country to country. For the U.S., the adjustment to be made for the volt is +9.264 parts per million (ppm) and for the ohm is +1.69 ppm, as indicated in Figure 1 and Table 3. Since the units of both the volt and the ohm will increase for most countries, the value assigned to fixed standards will decrease. To avoid confusion as to the size and sign of the correction, it is best to make the change (of fixed standards) by multiplying the current value (the "old" value) by a correction factor.

For example, in the U.S., a Fluke Model 732A Reference Standard which produces 10.0000234 "old" volts will produce 9.9999308 SI volts ("1990" volts). The 9.9999308 SI volts is derived by multiplying 10.0000234 times 0.99999074 (the correction factor for the U.S. volt). A Fluke Model 742A-10K Resistance Standard which has a current value of 9.9999892 kΩ will have a value of 9.9999723 SI kΩ ("1990" ohms), and is obtained by multiplying 9.9999892 by 0.99999831.

Values for fixed standards in other countries may be adjusted similarly using the information in Figure 1 and Tables 3 and 4. Using France (LCIE) as an example, the voltage correction is 0.99999326 (1-6.74X10E-6) and the resistance correction is 0.99999943 (1-0.66X10E-6).

Also, the value for current will change as a function of the changes to the volt and ohm. In France, the change in the Unit of Current will be +6.08 ppm. The correction multiplier for current will be 0.99999392 (i.e, 0.999990326/0.99999934).

The watt also changes. In France the correction multiplier for power is 0.99998718 [$(0.99999326)^2$/ 0.99999934] since $P=V^2/R$.

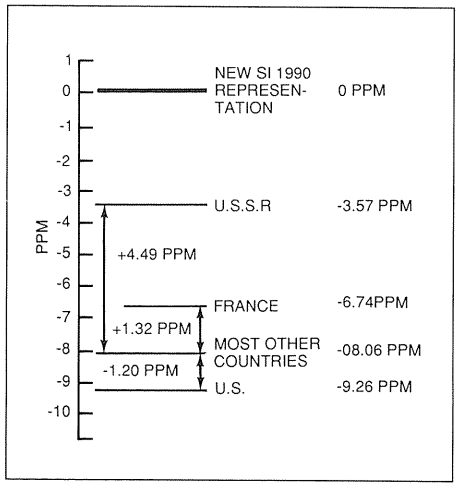

Figure 1. A graphical comparison of the value of the present representation of the volt of various countries.

FLUKE

NIST Recommendations for Implementing the 1990 Volt and Ohm Change

In June, 1989, the U.S. National Institute of Standards and Technology (NIST) issued Technical Note Number 1263, titled "Guidelines for Implementing the New Representation of the Volt and Ohm Effective January 1st, 1990."* In this technical note, NIST recommended the following:

- If the required accuracy of an instrument is less than five times greater than the change, the instrument should be adjusted as soon as practical after January 1st, 1990.
- If the required accuracy of an instrument is between five and ten times the magnitude of the change, the situation should be assessed on a case by case basis. Some of these instruments may require adjustment
- If the required accuracy of an instrument is greater than ten times the magnitude of the change, no adjustment need be made.

The actions recommended for instruments of these accuracies are summarized in Table 1.

Action	Volt	Ohm
Must Adjust	MSA≤50	MSA≤10
"Gray" Area	50<MSA<100	10<MSA<20
Forget It	MSA≤100	MSA≤20

Table 1. Manufacturers' Specified Accuracies (MSA) in PPM

Impedance, inductance and capacitance are also affected by these changes, but in almost all cases the effect will be insignificant. The U.S. farad is being adjusted at the same time by -0.14 ppm; again, an insignificant amount in most cases.

Because the change in the volt and ohm does not necessitate changing the calibration interval for an instrument, the present interval should be maintained. Any adjustments made should be fully documented and the instrument properly labeled. This is especially important to avoid the danger of reassigning new values a second time, or to allow errors to be corrected if the adjustment is made in the wrong direction.

Since standards play such an important role in the calibration chain, the recommendation regarding their reassignment is conservative. The values of all standards of voltage with accuracies of 100 ppm or better, and standard resistors with accuracies better than 20 ppm, should be reassigned to bring them into compliance with the changes. Typically, there will be no physical change to voltage or resistance standards, only a numerical change in their assigned values is required. In fact, NIST advises against making physical adjustments to standards, even if it is easily done.

Consult section 2.0 of NIST Technical Note 1263 for the detailed NIST recommendations. The technical note contains much useful information, including examples of some commonly encountered problems. We strongly recommend that you secure a copy and use it in planning your change to the new units.

Fluke Recommendations

Table 2 lists the Fluke manufactured equipment affected by the changes. Each piece of equipment on this list, except for reference standards, should be adjusted according to manufacturer's recommendations to bring it into compliance with the new representation.

Because many customers use some models of Fluke reference standards as calibrators or working standards, they should not hesitate to adjust these instruments. It is the application of the instrument that counts, not necessarily the name and model number. Fluke can provide adjustment procedures for all its reference standards except the 742A resistor, which must be returned to the factory for selection of a new trim resistor. Primary standards should be revalued, not adjusted.

Type of Equipment	Adjustment Required Vdc < 50 ppm Ohms < 10 ppm Fluke Model Number	Adjustment Recommended Vdc 50 to 100 ppm Ohms 10 to 20 ppm Fluke Model Number
Differential Voltmeters	883A, 885A, 887AB, 895A	881A, 891A, 893A, 896A
Digital Voltmeters	8375A, 8400A, 8500A, 8502A, 8505A, 8506A, 8520A, 8522A, 8840A, 8840A/AF, 8842A	PM 2534, PM 2535, 8125A, 8200A, 8300A, 8350A, 8425A, 8800A, 8810A
Calibrators	332A, 332B, 332D, 335A, 335D, 341A, 343A, 515A, 3330A, 3330B, 5100B, 5101B, 5102B, 5440A, 5440B, 5442A, 5450A, 5700A	382A, 5100A, 5101A
Reference Standards	731A, 731B, 732A, 742A	
Programmable Power Sources		4210A, 4216A, 4250A, 4265A,

Table 2. Fluke Equipment Affected by the Changes in the Volt and Ohm Representations

**Copies of the NIST Technical Note 1263 titled "Guidelines for Implementing the New Representation of the Volt and Ohm Effective January 1, 1990" can be ordered by writing to:*

Norman B. Belecki
National Institute of Standards and Technology
Bldg. 220, Room B146
Gaithersburg, MD 20899

Country	Lab	Change in Volt[1] (PPM)	Change in Ohm[1,2] (PPM)	Ohm Drift Rate (annual before January 1, 1990)	Change in Ampere[1] (PPM)	Change in Watt[1] (PPM)
—	BIPM	8.06	1.90	-0.062	6.16	14.22
Australia	CSIRO	8.06	0.09	0.00	7.97	16.03
Belgium	IGM	8.06	1.90	NA	6.16	14.22
Canada	NRC	8.06	3.40	-0.010	4.66	12.72
China (PRC)	NIM	8.97	1.50	-0.031	7.47	16.44
Denmark	IFM	8.06	NC	NA	8.06	16.12
Finland	TRC	8.06	0.00	NA	8.06	16.12
France	LCIE	6.74	0.66	0.010	6.08	12.82
E.Germany(DDR)	ASMN	8.06	1.80	-0.047	6.26	14.32
W.Germany(FRG)	PTB	8.06	0.56	0.008	7.50	15.56
Italy	IENI	8.06	-0.30	0.005	8.36	16.42
Japan	ETL	8.06	NC	0.000	8.06	16.12
Korea (ROK)	KSRI	9.80	0.70	NA	9.10	18.90
The Netherlands	VSL	8.06	1.20	-0.026	6.86	14.92
Norway	NMS	8.06	1.60	NA	6.46	14.52
South Africa	CSIR	8.40	1.40	NA	7.00	15.40
Sweden	SP	7.30	1.70	NA	5.60	12.90
Switzerland	FOM	8.06	1.54	NA	6.52	14.58
USSR	IMM	3.57	0.02	0.057	3.55	7.11
UK	NPL	8.06	1.61	-0.060	6.45	14.51
USA	NIST	9.26	1.69	-0.053	7.57	16.84

NA = Not Available *NC = No Change*

1: From BIPM Report 89/7. These are estimates as of June, 1989. BIPM will publish final official changes in April, 1990.
2: Drift rates obtained from Report of the 17th Session of the Comite Consultatif d'Electricite (1986) and from a report from NIST to the NCSL ad hoc committee for the Change in the Volt and Ohm. Values reported are probably not accurate beyond the second decimal place. Contact the appropriate National Laboratory for the official value to be used. Drift rates of standard resistors that are based on calibrations against standards which have NEGATIVE drift rates should be REDUCED by the listed drift rate after 1/1/90. For example, in the USA, drift rates will be decreased by 0.053 ppm/year.

Table 3. Changes in Units (ppm) by Country

Country	Lab	Volt	Ohm	Ampere	Watt
—	BIPM	0.99999194	0.99999810	0.99999384	0.99998578
Australia	CSIRO	0.99999194	0.99999991	0.99999203	0.99998397
Belgium	IGM	0.99999194	0.99999810	0.99999384	0.99998578
Canada	NRC	0.99999194	0.99999660	0.99999534	0.99998728
China (PRC)	NIM	0.99999103	0.99999850	0.99999253	0.99998356
Denmark	IFM	0.99999194	1.00000000	0.99999194	0.99998388
Finland	TRC	0.99999194	1.00000000	0.99999194	0.99998388
France	LCIE	0.99999326	0.99999934	0.99999392	0.99998718
E.Germany(DDR)	ASMN	0.99999194	0.99999820	0.99999374	0.99998568
W.Germany(FRG)	PTB	0.99999194	0.99999944	0.99999250	0.99998444
Italy	IENI	0.99999194	1.00000030	0.99999164	0.99998358
Japan	ETL	0.99999194	1.00000000	0.99999194	0.99998388
Korea (ROK)	KSRI	0.99999020	0.99999930	0.99999090	0.99998110
The Netherlands	VSL	0.99999194	0.99999880	0.99999314	0.99998508
Norway	NMS	0.99999194	0.99999840	0.99999354	0.99998548
South Africa	CSIR	0.99999160	0.99999860	0.99999300	0.99998460
Sweden	SP	0.99999270	0.99999830	0.99999440	0.99998710
Switzerland	FOM	0.99999194	0.99999846	0.99999348	0.99998542
USSR	IMM	0.99999643	0.99999998	0.99999645	0.99999289
UK	NPL	0.99999194	0.99999839	0.99999355	0.99998549
USA	NIST	0.99999074	0.99999831	0.99999243	0.99998316

Table 4. Correction Factors by Country

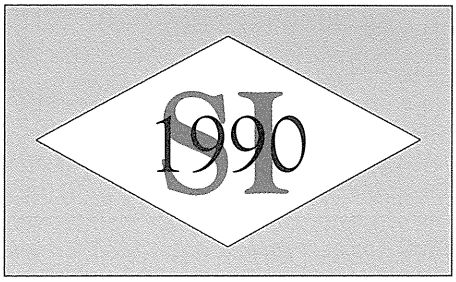

Figure 2. The U.S. National Conference of Standards Laboratories (NCSL) sticker for indicating equipment that is calibrated or adjusted to the new unit representations.

Whenever an instrument or piece of test equipment is adjusted or calibrated to the new units, the change must be documented and the equipment appropriately labeled. Documentation should include the date, "before" and "after" readings, the standard used and its value, the name of the person making the adjustment, and the procedure used. A special "SI-1990" sticker, or one similar to the example shown in Figure 2, should be placed on instruments that have been adjusted to the new volt and ohm**. The purpose of the sticker is to notify calibration personnel and users that the instrument has been adjusted to the new values. It is not intended to replace the customary calibration sticker. These stickers should be used on affected instruments through 1990, after which it should be safe to assume most equipment has been calibrated to the new values.

Making the Change in Your Facility

It is absolutely necessary that the change to the new volt and ohm be carried out in a well planned and orderly fashion. Planning is essential, and so is a proper and orderly execution of the plan. While it is not possible to provide a plan that will fit every situation, Fluke has developed an approach which may be adapted to your unique situation. At the very least, what follows can serve to remind you of areas which should be considered in your plan.

1. Form a committee or working group that includes the proper people for getting the job done. At Fluke, the "Volt-Change Committee" included people from Quality (chairman), Metrology, Production, Marketing, and Service.

2. Become informed. Studying this application note is a first step. Obtain and read NIST Technical Note 1263; you will find it informative and helpful. Contact manufacturers for specific information on which of their instruments are affected, and for specific instructions for adjusting the instruments you have.

3. Determine what you don't want to happen. For Fluke, this list included:

- Instruments rejected by customers after January 1st, 1990
- Unnecessary in-warranty repairs
- A flood of equipment into the calibration lab, standards lab, and technical centers on January 2nd, 1990
- A mix of old and new volt/ohm in the factory
- Technicians making corrections to readings
- Modified procedures for use between January 1st, 1990 and the next routine calibration
- Audit problems with inspectors and government administrators.

4. Determine what you do want to happen. For Fluke, this included two major items:

- Help customers make the change with a minimum of effort, cost, and disruption
- Minimize cost and disruption in production and service facilities

5. Identify affected equipment by manufacturer and model number (see Table 3).

6. Develop a detailed plan for implementing the change in your facility. Fluke's plan for the factory includes the following:

- Identify affected equipment by model, control number, and user
- Determine which are used in critical applications
  - Final test stations
  - QA audit stations
  - Some subassembly test stations
  - Standards lab, cal lab, and tech centers
- Recalibrate critical instruments without disrupting production and service
- Update entire production line at one time using special teams over one or two weekends
  - perform most calibration in place
  - identify updated equipment with "SI-1990" sticker
  - adjust non-critical equipment when recalled on normal calibration schedule
- Hold information meetings to inform production and QA people of what is happening, when, and why; explain the meaning of the "SI-1990" sticker

***SI-1990 stickers, in sheets of 187, can be ordered from the NCSL business office for a nominal fee. For more information contact:*

National Conference of Standard Laboratories
1800 30th Street, Suite 305B
Boulder, CO 80301
(303) 440-3339

- Additional considerations:
  - Calibration due dates normally will not change — if they did, you could expect quarterly, semi-annual, and annual peaks in calibration workload far into the future
  - Do not adjust instruments with out the use of a standard — thus you will avoid the problem of multiple adjustments and improper adjustments
- Equipment from updated production lines and service facilities will ship with "SI-1990" sticker in place and with a printed sheet that explains its meaning
- The changeover will commence in mid-November (earlier for some long-lead stations) and will be completed by December 1st, 1989
- Do not plan to send all your voltage and resistance standards to Fluke or your national lab on January 1, 1990

7. The standards and calibration labs might require special instructions. At Fluke, these labs and the Fluke Technical Centers added the following to the plan for production facilities:

- Make adjustments in the following order
  - Make arithmetic corrections to reference standards — DO NOT ADJUST.
  - Recalibrate calibrators such as the 5100B, 5440A/B, and 5700A/5725A
  - Recalibrate meters and miscellaneous equipment
  - Recalibrate customer instruments

Note: Some facilities will maintain duplicate test stations, running both the new and old values during the transition period.

- Be sure to identify and correct standard values imbedded in software.
- Each facility will develop its own plan and timetable for making the transition and handling the surge in workload.

8. Develop a plan for supporting your customers. Fluke has been following its plan for over a year — this application note is one part of that plan. Your customers differ from ours, and so you will need a different plan to meet their specific needs.

9. Make the plan work. Everyone involved must be alert and ready to spot problems; guidelines and resources must be in place for correcting them.

If you use control charts, they should be carefully annotated to indicate the date and the amount of the change. NIST Technical Note 1263 contains a thorough discussion of the means for dealing with control charts.

Failure to record and maintain records of changes can lead to disaster. All changes should be recorded as they are made, in the laboratory log book as well as on the calibration record for the instrument itself. If an error is made, the log book will quickly reveal the affected instrument population. After the adjustments to equipment in the laboratory, and before adjustments to clients' equipment are made, the last adjusted item should be checked directly against the primary standards, if possible, to ensure that the adjustments were made consistently, the correct sign was observed, etc.

Customer Assistance

Early Changeover to New Volt and Ohm

While the change in international values of the volt and ohm will occur on January 1st, 1990, Fluke will make the changeover on December 1st, 1989. This means that standards, calibrators and instruments shipped from production or service after that date will be calibrated to the new values. This timetable was chosen as the optimum for avoiding inconvenience and cost to our customers due to normal shipping and handling delays. Most instruments shipped after December 1st will arrive in the customer's facility to be placed in service early in January 1990.

Support from our Technical Centers

Our technical centers, strategically located throughout the U.S., Europe and the rest of the world, have been staffed and equipped to handle the expected large workload brought about by the change in the volt and ohm. They offer complete calibration and repair services for all affected test equipment. To accommodate customers who want early adjustment of their instruments, and to reduce the workload around January 1st, 1990, our technical centers will offer optional calibrations to the new values. After October 1st, 1989, calibration to the new volt and ohm will be offered as an option. After December 1st, 1989, all instruments we ship will be calibrated to the new values.

In many areas, we can provide on-site calibration service for customers who desire it. Whatever the case, we will provide full documentation for record keeping purposes and to support traceability requirements, and can provide proper scheduling for future calibration and maintenance.