# 10 V measurements with 1V-JVS using a resistive voltage divider

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## Abstract

This paper describes the design, built and characterization of a resistive voltage divider to compare the 10 V solid state voltage standards output directly with a 1V-Josephson voltage standard. A recent comparison with BIPM [1] exhibits an agreement of 0.024 µV/V with a combined uncertainty uc = 0.04 µV/V.

## Introduction

For more than 17 years INTI has a 1V Josephson voltage standard (1V-JVS) as a reference in voltage. The 1.018 V solid state voltage standard (zener) output is measured in opposition with a 1.018 V reference Josephson voltage. A high stability HP 3458 multimeter (DVM) was then used for measuring the 10 V zener output, with the 10 V multimeter range previously corrected with the 1.018 V zener output. The DVM 10 V range linearity was previously checked with Hamon boxes. With this method an expanded uncertainty of 0.5 µV/V was obtained. This method has some drawbacks, as the poor accuracy of measurements, the dependence of 10 V zener output measurements with 1.018 V zener output, which is more unstable than the 10 V output, and the inaccurate method, using scaling resistors, to measure the linearity of the 10 V range of the HP3458 multimeter. To improve 10 V measurements a resistive voltage divider was designed, built and characterized. It is based on tetrahedral junctions and sealed oil-filled commercial resistors The Hamon series-parallel method is used to obtain the divider ratio [2].

## Resistive voltage divider

The divider has 1:10 ratio. It has 100 kΩ as input resistance, to minimize loading errors of the 10 V zener output. A 10 kΩ output resistance was selected to reduce the contact resistance effects. To build it a set of oil-filled and sealed Vishay resistors were selected. Their nominal values were 30 kΩ for three of them and one of 10 kΩ. All resistors have a temperature coefficient ≤ 0.05 ppm/ºC and a tolerance ≤ 0.005 %. Low thermal emf Cu-Te golden plated binding post connectors isolated with PTFE were used to make external connections, see figure 1.
To increase specific heat and thermal stability of the surrounding medium the resistors were allocated into a cooper block and each resistor case was greased with thermal conducting grease before mounting.

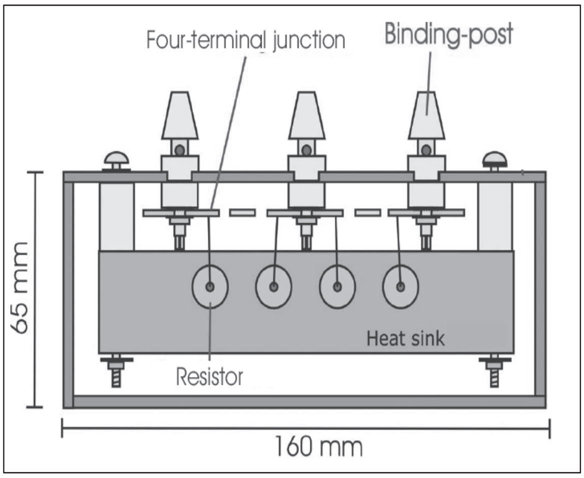


Figure 1. Lateral view of the divider

The resistors are permanently connected in series by tetrahedral cooper junctions [3]. Thus, each element is a four-terminal resistor.

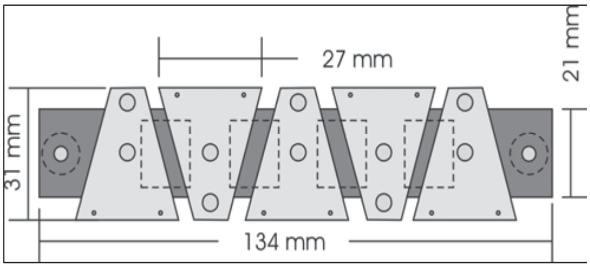


Figure 2. Tetrahedral cooper junctions

## Divider ratio measurement

To characterize the divider the 30 kΩ resistors are connected in parallel and compared with the 10 kΩ resistor. Hence, it is possible to measure a 1:1 voltage ratio with a high accuracy potentiometric system, which was specially designed and built at INTI to

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calibrate high accuracy 10 kΩ standard resistors. $\alpha_{i-j} = R_i / R_j$ is the ratio of resistances $i$ and $j$. $R_P$ and $R_S$ are the equivalent resistance values in parallel and series connections of the 30 kΩ resistors of the divider. To obtain $R_P$ terminals A-B and C-D are short-circuited by connecting cooper bars (dotted lines in Figure 3). Two extra cooper bars are used to perform four-terminal resistor ratio measurement. With $R_4$ the resistance of the 10 kΩ resistor, the divider ratio $\alpha_{p-4}$ is determined. Junction resistances have been measured being less than 1 μΩ.

## Measurement setup

The 10 V zener output was connected to the resistive voltage divider input and its output was measured in opposition with the JVS (see Figure 3). An Agilent 34420A nanovoltmeter was used as detector.

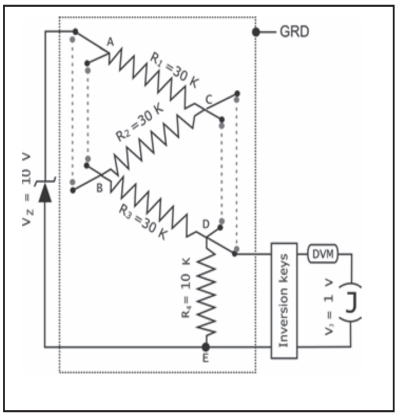


Figure 3. Diagram of connections to measure 10 V zener output with JVS using the divider. Dotted lines A,B and C,D terminals correspond to short circuits used to perform divider ratio calibration.

The 10 V zener output $V_Z$ is

$$V_Z = V_J\left(\frac{R_S + R_4}{R_4}\right) = V_J(1 + \alpha_{S-4})$$

where current through the DVM and leakage currents have been neglected. At first order $R_s$ is related to $R_p$ as $\alpha_S = 9\alpha_{P-4}$, then the 10 V zener output can be determined. For each measurement the divider ratio was measured before and after the JVS zener measurements.

## Results

A series of 10 V zener output measurements is shown in Figure 4 where the resistive divider method and the multimeter method are compared. The values of both methods are very close, but the expanded uncertainty of measurement was reduced to less than one half with the divider method.

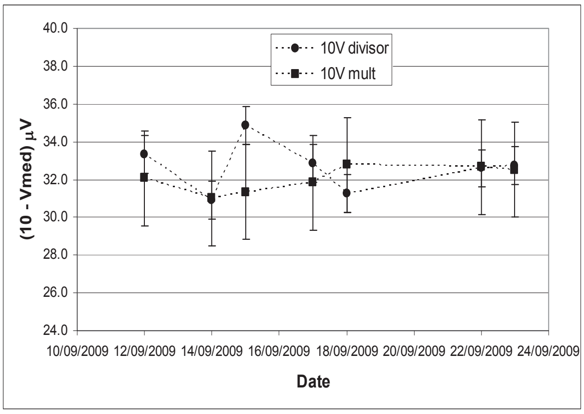


Figure 4. Comparison of 10 V measurements using both methods.

The type B estimated combined standard uncertainty for the divider is shown in Table 1.

**Table 1.** Type B $u_C$ estimated uncertainty

| Source of uncertainty | Type | $u_i$ [μV/V] | $c_i$ | $(c_iu_i)^2$ | % |
|---|---|---|---|---|---|
| Ratio calibration (α) | Rect | 9.2E-02 | 0.9 | 6.9E-03 | 52.5 |
| Loading | Rect | 7.9E-02 | 1.0 | 6.9E-03 | 47.5 |
| Leackage | Rect | 2.0E-04 | 1.0 | 4.0E-08 | 0.00 |
| **$u_C$ [μV/V]** | | **0.115** | | | **100** |

## Conclusions

The use of the resistive voltage divider allowed to improve the 10 V zener output measurements using a 1V-JVS. It was possible to decrease the expanded uncertainty to 0.1 μV/V by measuring the more stable 10 V output in a direct way against JVS, avoiding the linearity deviation of the DVM 10 V range. The results of the bilateral comparison with BIPM were very satisfactory with an agreement of 0.024 μV/V.


## Acknowledgments

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## References


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