DESIGN AND CHARACTERIZATION OF A LOW VOLTAGE DIVIDER

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Abstract

This paper describes the design and characterization of a low voltage divider with 100 : 1, 1000 : 1 and 10000 : 1 ratios in which, if the divider is supplied with 10 V will provide 100 mV, 10 mV and 1 mV outputs of high stability, low noise, low output impedance and stable thermal EMFs whose effects can be further reduced.

Introduction

Low voltage reference values with uncertainties of few nV are required to provide calibration services in areas such as thermocouples, AC-DC thermal transfer standards, electromagnetic power, etc. It is necessary for the calibration of some high accuracy voltmeters and nanovoltmeters to have reference values in the mV level with uncertainties of few nV. By using directly a Josephson Voltage Standards (JVS) this kind of calibrations can be done, but as an alternative, the laboratories that do not have a JVS systems running permanently, could use a reference in the volts level and a high accuracy resistive voltage divider to provide mV reference values. The voltage dividers commercially available do not have the necessary characteristics (high stability and low thermal EMFs) to calibrate the most accurate voltmeters and nanovoltmeters in the mV ranges.

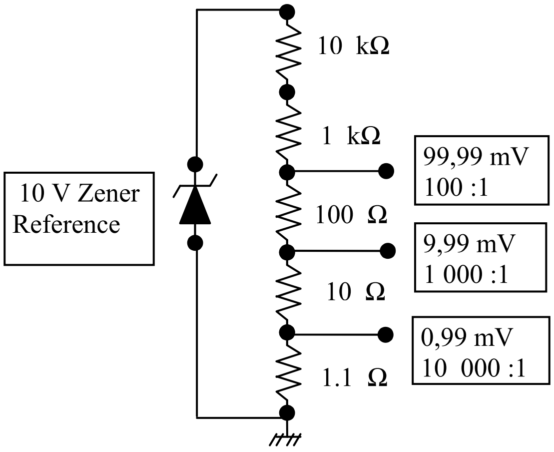

Figure 1. Circuit of the low voltage divider

The low voltage divider

The voltage divider was made by connecting five foil resistors (Vishay type) in series as shown in figure 1.

The resistors used have low temperature coefficient, nevertheless the divider was lodge in a temperature controlled oven in order to reduce the effects due to changes in the environmental temperature and to increase the stability of the divider. The dissipation power of the resistors is very low (8 mW @ 10 kΩ) in order to minimize heating effects.

A stable source, like a Zener Reference or a calibrator, should be used to provide the necessary current for the divider (0.9 mA @ 10 V) and obtain the desirable output voltages.

There are two main sources of noise in the divider: the noise generated by the source and the thermal noise generated by the resistors. If the divider is supplied with a Zener reference at 10 V level, a noise of about 100 nV peak to peak should be considered. For the three divider outputs, the relative value of the peak to peak noise due to the Zener is the same which is about 0.01µV/V. The RMS value of the thermal noise generated by the output resistors can be calculated by the equation:

$$V_{RMS} = \sqrt{4kTRB} \qquad (1)$$

Where: k – Boltzman constant ($1.38 \mathrm{X} 10^{-23}$ JK^{-1})
T – Temperature (K)
R – Resistance (Ω)
B – Bandwidth (Hz)

Considering T = 303 +/- 0.01 K (oven temperature) and B = 10Hz we have V_{RMS} = 4.3 nV for the 100:1 ratio; 1.36 nV for the 1000:1 ratio; and 0.4 nV for the 10 000:1 ratio.

Variations in thermal EMFs during the measurements can produce errors in measurements at this level of voltage; to minimize and stabilize them, some precautions were taken as:

1) Only cooper wire was used.
2) The divider connections and the resistors were thermally anchored to a copper block inside the oven.

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3) The connections to the output wires of the divider were thermally anchored to an external copper block by using nylon screws and beryllium oxide washers.

Temperature control

The resistors of the divider were lodged in a copper block together with the heating element and the sensor of the temperature control as shown the figure 2. The copper block was lodged in a thermal isolated metallic box inside of a second thermal isolated metallic box. A proportional control was used. The temperature control was adjusted around 30°C. The stability observed in a time period of 6 months was 0.01°C.

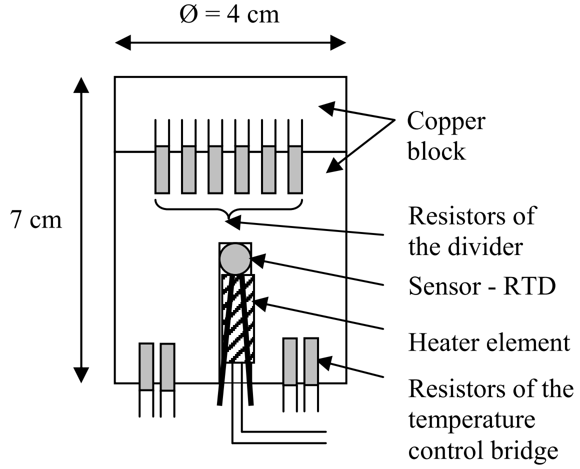

Figure 2. Copper block of the temperature control

Calibration

The divider calibration was done by using a JVS as it is shown in figure 3.

For the calibrations of the divider ratios the input voltage was supplied by an adjustable gain amplifier connected to a Zener Reference, this allows the adjustment of the input voltage. The input voltage level was measured using a DVM which was calibrated against JVS. Each of the output voltage divider was calibrated also against the JVS by the series-opposition technique using a nanovoltmeter as a null detector. In order to have a null, very close to zero, the input voltage of the divider was set up by adjusting the gain of the amplifier.

In order to cancel the thermal EMF generated in the wires coming from the divider's oven to the output terminals a low thermal switch was used to invert the direction of the current circulating into the divider. To cancel the offset of the null detector, the thermal EMFs generated at the external wires and the wires coming from the liquid helium dewar of the JVS another low thermal switch was used.

Results

The divider was supplied by a 10 V Zener reference. The output voltages of the divider were measured during five days using the technique mentioned before; the results are shown in table 1.

Nominal Voltage Ratio	Output Voltage (mV)	Standard Uncertainty of the Output Voltage
100 : 1	99.982 82	+/- 0.3 µV/V
1 000 : 1	9.983 01	+/- 2.0 µV/V
10 000 : 1	0.986 469	+/- 40 µV/V

Table 1. Measurements of the output voltage divider.

A reduction in the output voltage uncertainty is possible by using a less noisy null detector. The stability of the divider is under evaluation. Some results will be shown during the conference.

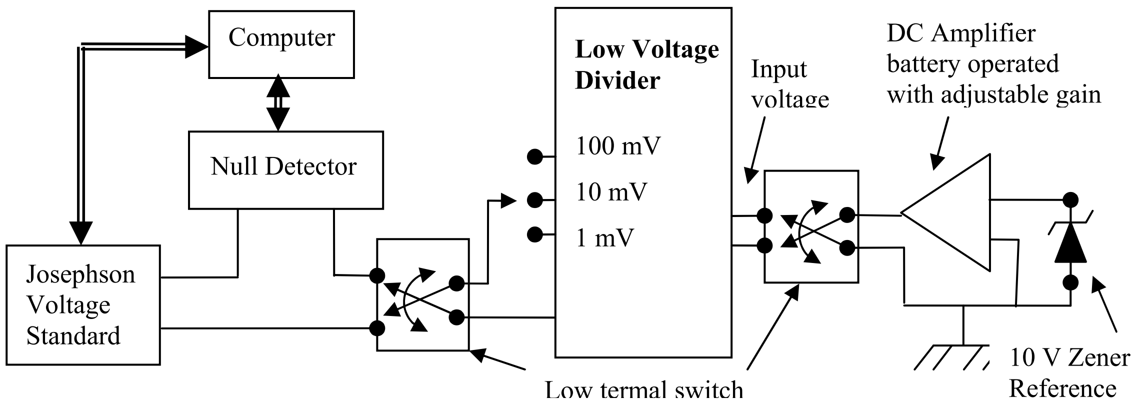

Figure 3. Calibration circuit