

## Comparison of two different methods to build micropotentiometers for low-voltage AC-DC transfer

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**Abstract:** This paper shows a comparison between two different approaches to build micropotentiometers ( $\mu$ pots) for AC-DC transfer measurements at low voltages. An overview of  $\mu$ pots is presented, and two different approaches to build them are introduced. Two  $\mu$ pots built using the different approaches are compared using a calibrated thermal transfer standard, and the results are presented and discussed.

**Keywords:** ac-dc transfer, low-voltage, micropotentiometers.

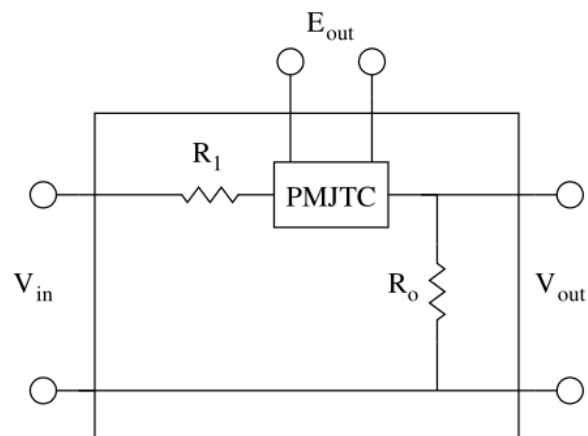
### 1. INTRODUCTION

In the past, AC-DC low voltage calibration (2 mV to 100 mV) was performed at Inmetro using a commercial thermal transfer standard traceable to another NMI [1]. In the last few years we started the implementation of a new system, using micropotentiometers ( $\mu$ pots). Two different approaches were adopted: a  $\mu$ pot using a Planar Multijunction Thermal Converter (PMJTC) [2] and a disk resistor (in-house built) [3-4] and a “discrete  $\mu$ pot” [5], using commercial current shunts as output resistors. In this paper we present an overview of the two technics and compare the obtained results.

### 2. MICROPOTENTIOMETERS

The electrical circuit of a  $\mu$ pot, using a PMJTC as the thermal converter, is presented in figure 1.  $V_{in}$  is the input voltage,  $V_{out}$  is the output voltage,  $R_I$  is the input resistor,  $R_o$  is the output resistor and PMJTC is the thermal converter, with heater resistance  $R_{pmjtc}$ . The output voltage of the PMJTC is  $E_{out}$  and the voltage applied to the PMJTC is  $V_{pmjtc}$ . The device should work up to

1 MHz, so the output resistor should have a nearly flat frequency response up to that value. It is important, also, that its resistance value be small, to reduce the loading when connecting to a device with a finite input impedance [6]. Note that the input voltage ( $V_{in}$ ) must be calculated in function of the  $\mu$ pot parameters to obtain the desired voltage at the output ( $V_{out}$ ).



**Figure 1.** Micropotentiometer circuit.

According to the circuit shown in figure 1, the output voltage of the  $\mu$ pot is given by equation 1 and the voltage applied to the PMJTC is given by equation 2.

$$V_{out} = \frac{V_{in}R_o}{R_1 + R_{pmjtc} + R_o} \quad (1)$$

$$V_{pmjtc} = \frac{V_{in}R_{pmjtc}}{R_1 + R_{pmjtc} + R_o} \quad (2)$$

The PMJTC used has a nominal heater resistance of  $90 \Omega$ , and is rated for a nominal input voltage of  $1 \text{ V}$ . The values of the input resistor ( $R_1$ ) and the output resistor  $R_o$  need to be chosen to satisfy two main conditions: when the output voltage is the nominal voltage of the  $\mu\text{pot}$ ,  $V_{pmjtc}$  should not exceed the maximum rating of the PMJTC; and when  $V_{out}$  is at the minimum working value,  $V_{pmjtc}$  need to be sufficient for a satisfying measurement of  $E_{out}$ .

For this work, a  $\mu\text{pot}$  for the range from  $20 \text{ mV}$  to  $100 \text{ mV}$  will be designed. Two different approaches to implement the output resistor ( $R_o$ ) will be explored: (a) building a disk resistor by soldering SMD resistors on a disk-shaped PCB and (b) using a commercial current shunt.

### 2.1. Micropotentiometer with disk resistor

The  $\mu\text{pot}$  using a disk resistor is shown in figure 2.  $R_1$  is a thin-film resistor of  $500 \Omega$ , and the disk resistor was built using several SMD resistors in parallel. The nominal value of the disk resistor is  $10 \Omega$ . The housing is a brass rectangular box, with female N-type connectors for input and output.

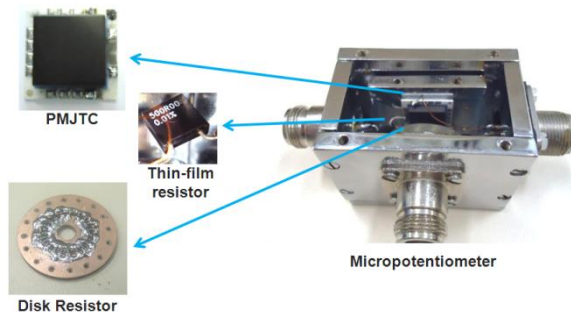


Figure 2. Disk resistor  $\mu\text{pot}$ .

### 2.2. Discrete micropotentiometer

The discrete  $\mu\text{pot}$  uses the same base circuit shown in figure 1, with only one difference: the output resistor,  $R_o$ , is a commercial current shunt. For the range from  $20 \text{ mV}$  to  $100 \text{ mV}$ , the current shunt used has a nominal resistance of  $8 \Omega$ . The housing of the discrete  $\mu\text{pot}$  was built using a brass cylinder, with N-type connectors. A thin-film resistor of  $500 \Omega$  was connected in series with a  $90 \Omega$  PMJTC. The discrete  $\mu\text{pot}$  can be seen on figure 3.



Figure 3. Discrete  $\mu\text{pot}$ .

### 2.3. Micropotentiometers specifications

Table 1 shows the relations calculated by equations 1 and 2 and the output resistance for the built  $\mu\text{pots}$ .

$\mu\text{pot}$	$V_{out} / V_{in}$	$V_{pmjtc} / V_{in}$	$R_o [\Omega]$
disk resistor	0,0166	0,150	10
discrete	0,0134	0,150	8

Table 1. Electrical specifications

Table 2 shows the needed input voltage to obtain the maximum ( $100 \text{ mV}$ ) and minimum ( $20 \text{ mV}$ ) output voltages designed for the  $\mu\text{pots}$ . The voltage applied to the PMJTC ( $V_{pmjtc}$ ) in both cases is shown, also.

$\mu\text{pot}$	$V_{in}$	$V_{out}$	$V_{pmjtc}$
disk resistor	6,02 V	100 mV	0,90 V
	1,20 V	20 mV	0,18 V
discrete	7,46 V	100 mV	1,12 V
	1,49 V	20 mV	0,22 V

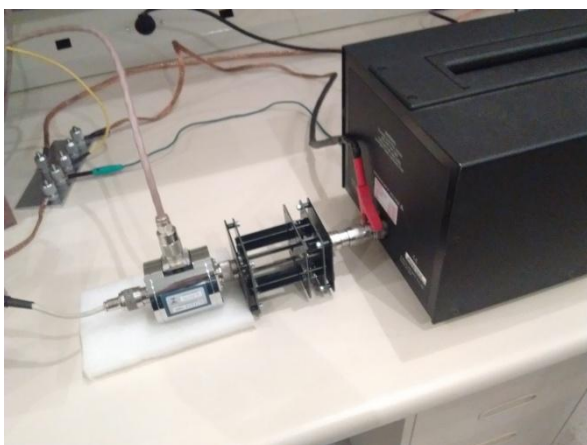
**Table 2.** Input and output voltages.

### 3. RESULTS

The  $\mu\text{pots}$  were measured against a calibrated commercial thermal standard. The measurement setup using the disk resistor  $\mu\text{pot}$  is shown on figure 4, and the measurement system using the discrete  $\mu\text{pot}$  can be seen on figure 5.



**Figure 4.** System with disk resistor  $\mu\text{pot}$ .



**Figure 5.** System with discrete  $\mu\text{pot}$ .

For each frequency, 12 measurements were made. The results for the disk resistor  $\mu\text{pot}$ , corrected with the AC-DC difference of the standard, are presented in table 3.

f [kHz]	0,01	0,065	1	10	100	1000
60 mV	17	18	-3	-1	17	85
20 mV	2	17	-8	-1	14	82

**Table 3.** AC-DC difference in  $\mu\text{A/A}$  for the disk resistor  $\mu\text{pot}$ .

For the discrete  $\mu\text{pot}$ , the results are shown in table 4.

f [kHz]	0,01	0,065	1	10	100	1000
60 mV	20	20	-6	-7	-17	-261
20 mV	3	17	-4	-8	-18	-262

**Table 4.** AC-DC difference in  $\mu\text{A/A}$  for the discrete  $\mu\text{pot}$ .

Table 5 shows the expanded uncertainties.

f [kHz]	0,01	0,065	1	10	100	1000
60 mV	35	23	23	23	28	81
20 mV	51	26	25	26	32	85

**Table 5.** Expanded uncertainties in  $\mu\text{A/A}$ .

### 4. CONCLUSIONS

The stability of the measurements using both  $\mu\text{pots}$  is similar. For 60 mV, the standard deviation of the 12 measurements for each frequency was around 1 ppm. For 20 mV, the standard deviation was around 5 ppm.

The disk resistor  $\mu\text{pot}$  has smaller AC-DC difference for high frequencies than the discrete  $\mu\text{pot}$ , as can be seen on tables 3 and 4. But, on the other hand, the discrete  $\mu\text{pot}$  is easier to be built, and a good connection between the output resistor and the rest of the system is guaranteed by the N-type connector. In the case of the disk resistor  $\mu\text{pot}$ , this connection is more difficult to be made, especially between the outer part of the disk and the housing (figure 2).

The results show that both approaches have similar results, with the advantage of easier construction for the discrete  $\mu$ pots.

## 5. REFERENCES

- [1] XVIII TC4 IMEKO Symposium and IX Semetro, “Proposta de implantação de um sistema de padronização primária de transferência térmica ac-dc de baixa tensão no Inmetro”, September 27-30, 2011.
- [2] Klonz, M., “Accurate thin film multijunction thermal converter on a silicon chip [AC-DC standard]”, *IEEE Transactions on Instrumentation and Measurement*, v. 38, n. 2, pp. 335-337, Abr. 1989.
- [3] X Semetro 10th International Congress of Electrical Metrology, “Inmetro’s Micro-

potentiometer-Based System for Low-Voltage Calibration”, September 25-27, 2013.

- [4] 7º Congresso Brasileiro de Metrologia, “Sistema de padronização primária de transferência térmica ac-dc de baixa tensão do Inmetro”, November 24-27, 2013.
- [5] Geronymo, G.; Ribeiro-Silva, C.I.; Souza, R.M.; Klonz, M., “AC-DC transfer measurements in the mV-range using discrete micro-potentiometers,” *Precision Electromagnetic Measurements (CPEM 2014), 2014 Conference on*, vol., no., pp.514,515, 24-29 Aug. 2014
- [6] M. Klonz and T. Funck, “Micropotentiometers providing low output impedance for millivolt ac-dc transfer”, *IEEE Trans. Instrum. Meas.*, vol. 56, no. 2, pp. 468 – 471, April 2007.