INTEGRATED THIN-FILM MICROPOTENTIOMETERS

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Abstract

Integrated micropotentiometers, new devices fabricated with thin-film technology and the micromachining of silicon, have been developed for the accurate determination of ac voltage from 1 to 200 mV up to 100 kHz and with the potential for higher frequencies.

Introduction

Micropotentiometers (μpots) are used as millivolt and microvolt standards from 10 Hz up to 1 GHz. Conventional μpots [1,2] contain UHF pattern thermoelements and annular, film output resistors with very small inductance in series with the thermoelement heater (see Fig. 1). Thermal voltage converters have been used to calibrate μpot's at about 200 mV from 10 Hz up to 30 MHz [3,4], while lower voltage ranges are characterized by step-down methods. Recently, uncertainties for 100 mV have been reduced at NIST from about 1000 ppm to 50 ppm at 100 kHz and 250 ppm at 1 MHz, and to 200 ppm at 100 kHz for 10 mV.

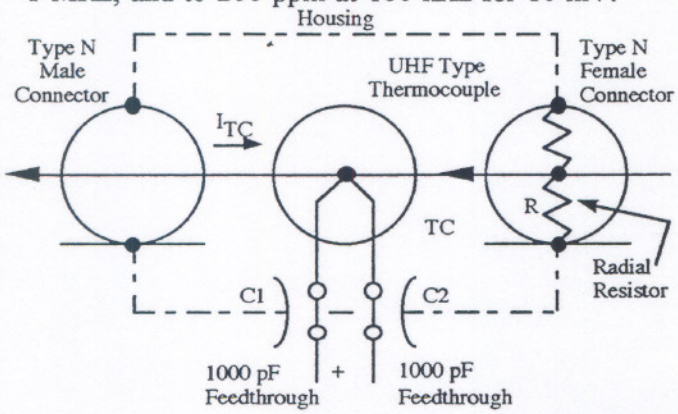

Fig 1. Conventional micropot.

Multijunction thermal converters (MJTCs), using thin-film photolithography, thick-film mounting substrates, and micromachining of silicon [5,6,7], have been developed to measure ac voltage and current. For this project, thin-film thermal converters and output resistors have been fabricated as an integrated structure on the same silicon substrate.

Geometric Design

The new integrated, thin-film micropotentiometers contain all the essential electrical measuring elements of the conventional μpots on the same chip. Planar, thin-film MJTCs [7] and thin-film output resistors have been fabricated using a multilayer, thin-film membrane to achieve high thermal efficiency and optimum electrical performance (see Fig. 2).

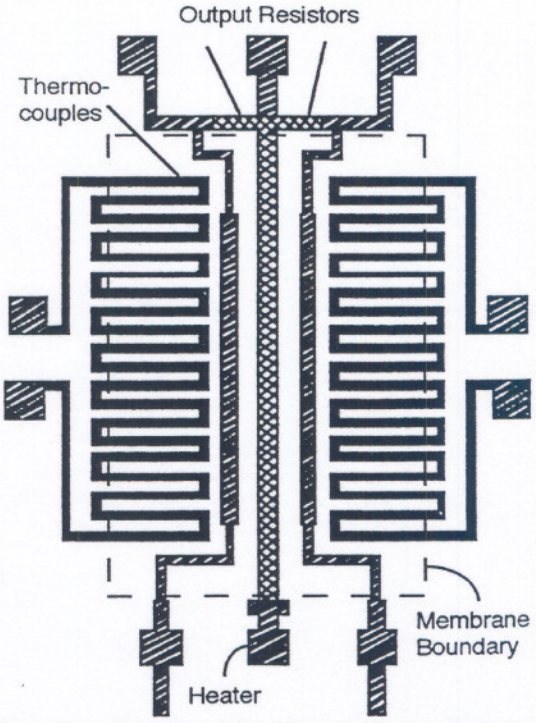

Fig. 2. Integrated, thin-film micropotentiometer with a membrane of about 1.6 x 2 mm.

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In these new structures, the distance between the output resistor and the thermoelement, or MJTC, is reduced more than an order of magnitude compared to conventional µpots. This reduces the standing wave error in the current measurement. The skin effect cannot be neglected in the traditional µpot; however, the MJTC heater and thin-film resistor are so thin in the new structures that the skin effect contribution from them can be neglected. Skin effect remains a factor in the connections and mountings. Several different types of integrated, thin-film µpots have been made. Most of the new µpots were single-range versions with a 5 mA MJTC combined with either a 20-Ω, 2-Ω, or 0.2-Ω resistor. Others were multi-range with as many as five voltage ranges from 1 mV to 200 mV. Several other variations in the structural details have been investigated including different positions for the output resistor, different types of MJTCs, and novel current return paths. Geometries of the MJTC and output resistor have been designed to minimize Thomson and Peltier effects, dielectric losses, and distributed inductances and capacitances, where practical.

Conclusions

Integrated µpots are suitable as millivolt and microvolt standards of ac-dc difference and ac voltage for the calibration of ac calibrators, signal sources, and voltmeters up to 1 MHz with the potential for higher frequencies. These new devices are also suitable as thermal current converters (TCCs) in the 5 -10 mA range and as thermal voltage converters (TVCs) at about 1 V. Results of ac-dc difference measurements are given in Tables I & II.

Frequencies (kHz)	As µpot at 82 mV	As TVC at 1 V	As TCC at 5 mA
0.1	-13	+94	+4
0.4	--	+15	--
1	-21	+1	-4
20	-30	+5	+4
50	-49	+10	+7
100	-60	+21	+10
200	-76	+42	+8
500	-9	+132	-15
1000	+44	+323	-91

Table I. AC-DC differences (ppm) of 20-Ω, integrated µpot.

Frequencies (kHz)	As µpot at 10 mV	As TVC at 1 V	As TCC at 5 mA
0.1	-1	+107	+5
1	+2	0	-2
20	+18	+1	0
50	+34	+2	+8
100	+42	+7	+26

Table II. AC-DC differences (ppm) of 2-Ω, integrated µpot.

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