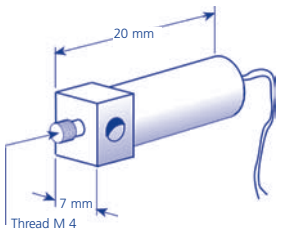
Ruthenium Oxide Temperature Sensors

- Temperature Range 50 mK - 4.2 K

Ruthenium oxide
Temperature: Max 4.2 K



The thick film RuO_2 chip sensor has been mounted in a gold-plated copper holder. The holder is designed to give a good thermal contact between the sensor and the object of interest while also minimising the mechanical strain on the sensor. Such a strain can cause the calibration to change after thermal cycling. The sensor is wired using four 0.2 mm diameter (36 SWG) polyester enamel coated copper wires, a pair each for the excitation current and measured voltage.

The thermometers have a nominal resistance of 2210 Ω at room temperature, and about 25000 Ω at 50 mK. The sensor has a thread which may be screwed into an ISO metric M4 tapped hole. It also has a clearance hole so that it can be fixed with an M3 bolt.

Ruthenium oxide sensors have relatively small magneto-resistance. For information, see "Magnetoresistance of RuO2-based resistance thermometers below 0.3 K", by Watanabe *et al*, Cryogenics, vol 41, p 143 (2001).

Ordering Information	
30-point (Roth1) calibrated sensor	T1-201
Generic (Roth2) Calibration	T1-202

Calibration

Ruthenium oxide sensors are available with two forms of calibration:

Type "Roth1": A full individual calibration. At temperatures below 650 mK the Provisional Low Temperature Scale PLTS-2000 was applied using a ^{3}He melting curve thermometer. At temperatures above 650 mK the ITS-90 was applied using calibrated germanium resistance thermometers traceable to the US-NIST with the atmospheric boiling point of ^{4}He being used as a fixed point. Checks were made using a CMN paramagnetic susceptibility thermometer and a superconducting fixed-point device.

The accuracy of the Type 1 calibration is

50 mK	<	T ≤150 mK	± 5 mK
150 mK	<	T ≤1.5 K	± 10 mK
1.5 K	<	T ≤4.2 K	± 30 mK

Type "Roth2": A 'generic' calibration. These sensors come from the same production batch as the Type 1 sensors and are mounted on the same type of support. They are thermally cycled to create reproducible resistance versus temperature characteristics. They are supplied with calibration based on the average of a representative sample of Type 1 sensors.

The accuracy of the Type 2 calibration is

50 mK	<	T ≤150 mK	± 19 mK
150 mK	<	T ≤1.5 K	± 70 mK
1.5 K	<	T ≤4.2 K	± 200 mK

The International Temperature Scale (ITS-90) and the Provisional Low Temperature Scale (PLTS-2000) have been used.

Both calibrations are accompanied by a document giving advice on sensor mounting and temperature measurement.

Temperature range

The range of calibration (both types) is 50 mK - 4.2 K.

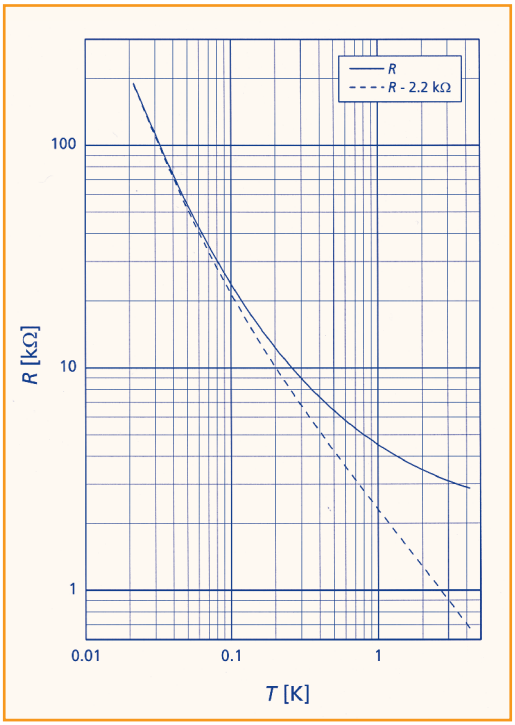
Below 50 mK the sensor does not give accurate results. It can, however, be be used for temperature control purposes in the range 20 – 50 mK in conjunction with another thermometry system (eg nuclear orientation).

Measurement equipment

Above 240 mK, an Oxford Instruments ITC 501, 502, 503 can be used (see Electronics).

Below 240 mK, an AC bridge or IGH with Femtopower card must be used (see Electronics section).

The thermal time constant of the sensor (determined by its heat capacity and thermal resistance to the holder) increases as the temperature drops, and may be several minutes at the lowest temperatures.



Self heating and radio frequency heating

It is important to ensure that the heat dissipated in the sensor is not sufficient to raise its temperature above that of the experimental apparatus. This heat can come from a variety of sources, but in resistance thermometry the most common source of problems is a high excitation current. In general, heat dissipation of the order of one picowatt (10^{-12} W) is acceptable in the milli-kelvin range.

Currents can also be induced by radio frequency (R.F.) interference. These problems can be reduced by screening the cables and using low pass electrical filters on all wires going into the cryostat.

The Oxford Instruments Femtopower system supplied with dilution refrigerators performs a pseudo DC measurement which has been optimised to measure RuO_2 sensors and allows filtering of the measurement lines down to very low frequencies. The Femtopower system can also be fitted to an ITC503.

Typical resistance against temperature curve for a 2210 Ω ruthenium oxide sensor.