Selection of sensor for Cryogenic Temperature Measurement

[1]Ms.Dimple P. Khant [2]Prof. S. T. Shah
[1]M.E.[Electronics and Communication]Student [2]Asst. Professor
[1, 2]Department of E & C Engineering
[1, 2]L.J. Institute of Engineering and Technology, Ahmedabad, Gujarat

Abstract— The continuous monitoring of liquid temperature in cryogenic application is essential requirement from control and safety point of view. . Several factors must be considered when selecting the type of sensor to be used in a specific application Any temperature dependent parameter can be used as a sensor if it fits the requirements of the given application. These parameters include resistance, forward voltage (diodes), thermal EMFs, capacitance, expansion/contraction of various materials, magnetic properties, noise properties, nuclear orientation properties, etc. The two most commonly used parameters in cryogenic are voltage (diodes) and resistance. There are several reasons for choosing diode thermometry or resistance thermometry. Therefore this paper present the demand of precision measurement of temperature is addressed using semiconductor diode type sensor and resistor type sensor by sensor characteristic.

I. INTRODUCTION [1] [2]

Temperature monitoring is central to the majority of data acquisition systems. Some factors should be considered during the selection of sensor in specific application: like temperature range, accuracy, response time, stability, linearity, and sensitivity. Another important is price, which varies with the accuracy rate and the mounting style of the device. This paper also presents the temperature signal conditioners that are developed to maintain the integrity of the sensor's output. Regardless of the types of sensors or transducers you are using, the proper signal conditioning equipment can improve the quality and performance of your system measurement[1].For improving the measuring accuracy and stability of sensor output, based on principles of the sensor diode signal conditioning circuit using analog circuit's technology is designed. The feasibility of conditioning circuit is analyzed for the measure data. The main goal is to measure temperature in cryogenic. The quality and performance of the signal conditioning section is very important. Instrumentation amplifier, filtering methods, and operational amplifiers used in order to obtain clear measurement at desired voltage level. Signal conditioning circuit is tested and evaluated using the diode sensor input signal. This satisfied diode characteristic properly.

II. DIODES

A diode temperature sensor is the general name for a class of semiconductor temperature sensors. They are based on the temperature dependence of the forward voltage drop across a p-n junction. The voltage change with temperature depends on the material. The most common is silicon, but gallium arsenide and gallium aluminum arsenide are also used. Silicon diodes can be used from 1.4 K to 500 K. From 25 K to 500 K, a silicon diode has a nearly constant sensitivity of 2.3 mV/K. below 25K the sensitivity increases and is nonlinear. The temperature response curve is shown in Figure 1. [3]

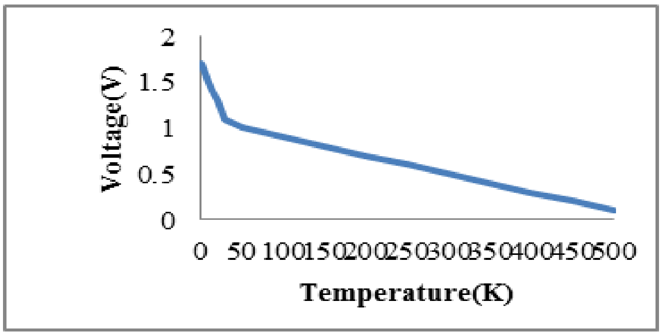


Fig.1 – Curve DT-670 and DT-470

The semiconductor packaging is robust and allows for solder mounting for probes and circuits and easy installation and handling. Silicon diode sensors are typically excited with a constant 10 µA current. The output signal is fairly large: 0.5 V at room temperature and 1 V at 77 K. This can be compared to platinum where a 100 Ω PRT with a 1 mA excitation has only a 100 mV signal at 273 K. The straightforward diode thermometry instrumentation is shown in *Figure 2*.[3]

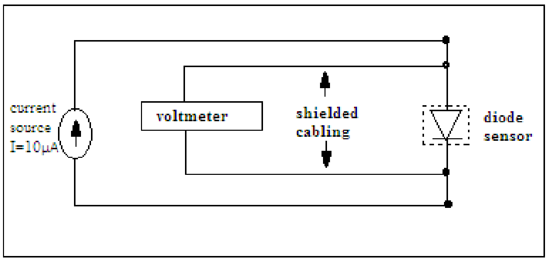


Fig. 2 – Typical diode sensor instrumentation schematic

An important feature of silicon diodes is their interchangeability. Silicon diodes from a particular manufacturer are interchangeable or curve-matched over their whole range. This is typically defined in terms of tolerance bands about a standard voltage-temperature response curve. The large temperature range, nearly linear sensitivity, large signal and simple instrumentation make the diode useful for applications that require a better accuracy than thermocouples. [3]

III. RESISTORS

Temperature sensors based on the changing resistance with temperature can be classified as positive temperature coefficient (PTC) or negative temperature coefficient (NTC). Platinum RTDs are the best example of

PTC resistance sensors. Other PTC RTDs include rhodium-iron, nickel, and copper RTDs. *Figure 3* shows typical resistance sensor instrumentation schematic. A PTC RTD is typically metallic (platinum) and has a fairly linear temperature-resistance response. NTC RTDs are semiconductors or semi-metals (doped germanium, Cernox™). They have extremely nonlinear response curves, but are much more sensitive to temperature change.[3]

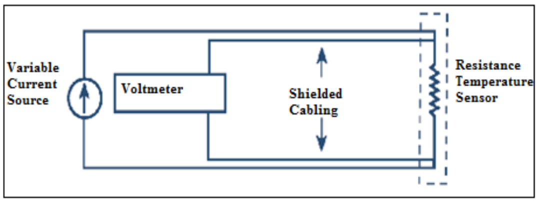


Fig. 3 – Typical resistance sensor instrumentation Schematic

Cernox™ is a Sputter-deposited thin film resistor. Cernox shows good temperature sensitivity over a wider range (0.1 K to 420 K) and is highly resistant to magnetic field-induced errors and ionizing radiation. This makes Cernox more robust than other NTC RTDs.[3]

IV. SIGNAL CONDITIONING

In electronics, signal conditioning means manipulating an analogue signal in such a way that it meets the requirements of the next stage for further processing. Most common use is in analog-to-digital converters.

This signal conditioning consists,

- Input Signal(from sensor)
- 10µA Constant Current Source
- Measure Output Voltage from sensor
- Need low-pass filter

A. *Selection of sensor*

For the signal conditioning we have used diode sensor because, At low temperature it is having very good accuracy compare to other transducer used as such temperature like resistor, cernox, because it has no self-heating problem.

Its characteristic is shown in below table.

Sensor Type	Silicon Diode	Cernox RTD
Temperature Coefficient	Negative	Negative
Sensor Units	Volts(V)	Ohms(Ω)
Input Range	0-2.5V	0-7500(Ω)
Sensor Excitation (Constant Current)	10µA ±0.01%	10µA ±0.01%
Temperature Range	1.4-475K	3.5-400K
Typical Sensor Sensitivity	-30mV/K at 4.2K -1.9mV/K at 77K -2.4mV/K at 300K -2.2mV/K at 475K	-770Ω/K at 4.2K -1.5Ω/K at 77K -0.1Ω/K at 300K
Size	1mm high×1.9mm wide× 3.2mm long	1mm high×1.9mm wide× 3.2mm long
Mass	37mg	40mg
Interchangeability	yes	No

Table 1: characteristic of sensors

Configuration

Standard four wire measurement technique is employed for measuring temperature.which is shown in figure 4. Which eliminate the effects of lead resistance in total measure resistance.

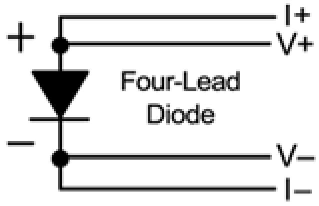


Fig.4 Four lead measurement

B. *Constant Current Source*

Frequently, such as when you want to measure temperature with a silicon diode, it is desirable to have a reproducible constant current source. For silicon diode sensor the required excitation is 10µA is necessary. so by considering this characteristic here constants current source is designed with the help of operational amplifier.

C. *Instrumentation Amplifier*

An instrumentation amplifier is a closed-loop gain block that has a differential input and an output that is single-ended with respect to a reference terminal. Most commonly, the impedances of the two input are balanced and have high values, typically $10^9\Omega$, or greater. The input bias currents should also be low, typically 1 nA to 50 nA. As with op amps, output impedance is very low, nominally only a few milliohms, at low frequencies.

The above result is shown the one of the voltage level where the load resistor value is set at 110kΩ.

D. Low pass filter

Noise reduction is also a common requirement. The unity-gain Sallen-Key has the best gain accuracy because its gain is not dependent on component values. So to reduce the noise sallen-key active filter is used which has unity gain, larger bandwidth, no. magnetic emission.

V. EXPERIMENTAL DATA

Simulated data is shown below.

I(µA)	Resistance(K)	Vout(V)	Vf(V)
10.048	50	0.502	0.502
9.992	60	0.605	0.605
10.103	70	0.704	0.704
10.103	80	0.812	0.812
9.992	90	0.916	0.916
9.992	100	1.003	1.003
9.992	110	1.108	1.108
9.992	120	1.202	1.202
9.992	130	1.313	1.313
9.992	140	1.399	1.399
9.992	150	1.498	1.498

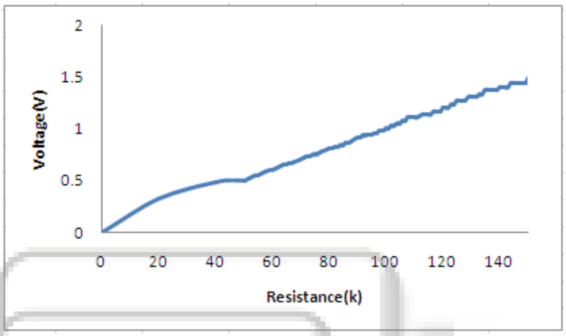
Table 2: Simulated data

The same design is also implemented on general purpose PCB.which is also tested with some variable load resistor. That experimental data is shown in below table.

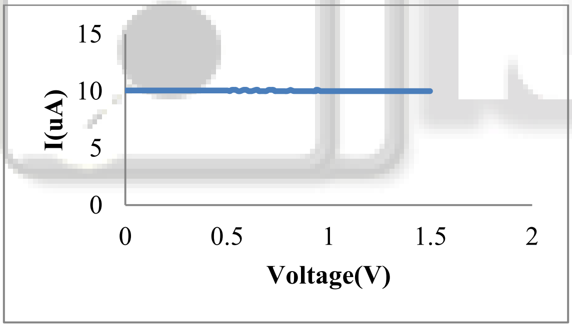
Load Resistor (R_L KΩ)	Current (IμA)	V_{out} (volt)	V_f (volt)
47	10	0.478	0.478
94	10	0.956	0.956
141	10	1.435	1.435
188	10	1.910	1.910

Table 3: Experimental data

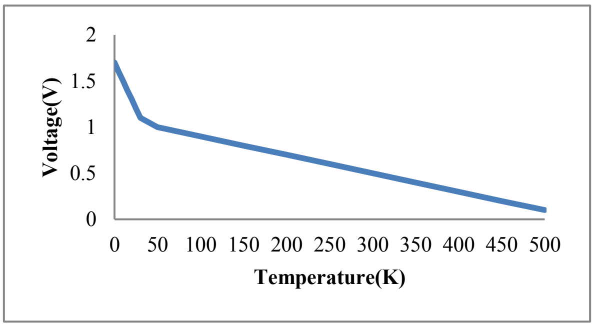
From the above experimental data its shown that with change in variable resistor, current is remain constant and give the filter output.Below graph (a) shown that resistance is incerse and it is compare with standrad curve of sensor diode in graph (b) which indicate that NTC charactristic and graph(c) shown the constant current .



(a)



(b)



(c)

Fig.5 (a) Resistance V/s Voltage (b) Voltage V/s Current(c) Temperature V/s Voltage

VI. CONCLUSION

From this experiment we are able to conclude that from the diode sensor and resistor (Cernox™), the NTC silicon diode(DT 470) transducer is working appropriately and we have seen characteristic of that diode sensor is found correctly by compare it with the standard curve of temperature where resistance is increase and temperature is decreases.

REFERENCES

[1] "Selecting the right sensor for temperature measurement" by Mihai Bogdan Maria Vintan ,University of "Lucian Blaga" Sibiu, Faculty of Engeneering, RomaniaB-dul Victoriei, no.10, Sibiu, phone: 0269-232341

[2] "Signal Conditioning system for temperature measurement in cryogenic application" by [1]Ms.D P Khant, [2] Mr. P.J.Patel, [3]Mr. L.K.Bansal, [4] PROF. S.N. Shah.

[3] " Lake Shore Cryogenic, Inc., *Temperature Measument and Control Product Catalog* (1999). www.lakeshore.com

[4] "Op-Amp and Linear integrated circuits" by Ramakant A. Gayakwad

[5] L.K.Bansal, P.J.Patel, V.Prahlad, K.Qureshi, V.B.Patel,L.N.Gupta,D.P.Thakkar,C.B.Sumod, V.Vadher S.Parmar, N.Contractor, A.K.Sahu, S.K.Sharma and U.K.Baruah "Integration of Cryopump Instrumentation for SST-1 NBI, *Institute of Plasma Research, Bhat, Gandhinagar, India.*

[6] "Eleven point calibration of capacitance type cryo level sensor of LOX and LH_2 systems of cryogenic stage using four wire type discrete array level sensor setup",A.S.Gour[1] ,M.Das[1] ,R.Karunanithi[1,] S.jacob[1,],M.V.N.Prasad[2] ,[1]Center for cryogenic Technology, Indian Institute of science,Bangalore,india.[2]Liquid propulsion system Center,ISRO,Bangalore,India.