SIGNAL CONDITIONING SYSTEM FOR TEMPERATURE MEASUREMENT IN CRYOGENIC APPLICATION

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ABSTRACT: *The continuous monitoring of liquid temperature in cryogenic application is essential requirement from control and safety point of view. Therefore the demand of precision measurement of temperature is addressed using semiconductor diode type sensor. The linearity measurement of semiconductor sensor ensures the cylidricity of cryogenic at its inlets and outlets. 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.*

KEYWORDS: **Silicon diode sensor, Signal conditioning, Cryogenic Temperature.**

1. INTRODUCTION [2]

SST-1 is a long pulse experimental device and has important impact on neutral beam line design.Cryopumps are the integral part of neutral beam system of SST-1 Tokamak. Cryopump has LHe panels surrounded by chevron baffles. LHe panels are cooled down up to 4.2K by LHe and chevron baffles are cooled down at 77K by LN2.In order to monitor and optimize the performance of cryopumps, it is necessary to monitor the temperature at various locations in LN2 and LHe path. This paper describes the design of the signal conditioning for semiconductor diode and show the result of system.

2 SILICON DIODE SENSOR

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 25 K the sensitivity increases and is nonlinear.

Silicon diode sensors are typically excited with a constant 10 µA current. An important feature of silicon diodes is their interchangeability.

3. 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

Step 1 Selection of sensor

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

Configuration

Standard four wire measurement technique is employed for measuring temperature.which is shown in figure 1. Which eliminate the effects of lead resistance in total measure resistance.

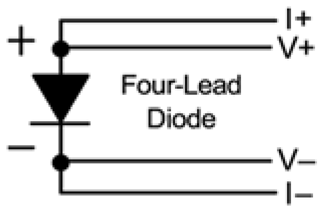


Fig.1Four lead measurement

Step 2 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.

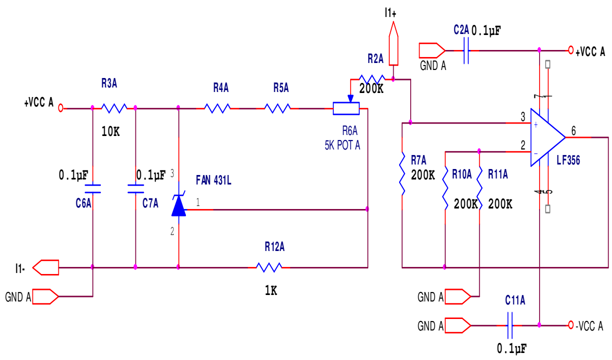
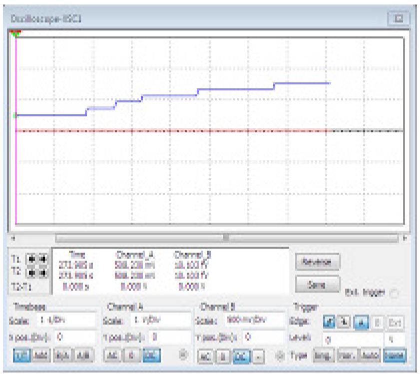


Fig.2 Constant Current Source

The voltage divider made from R7 and R2 provide a reference voltage, Vref, at the non-inverting input to the op amp. The op amp will now do everything in its power to keep the inverting input at the same voltage (Vref) as the non-inverting input. It will do this by varying the current through R6 by changing the voltage of the voltage regulator.

Simulation Result:



The above result is shown that current is remain constant with change in voltage.

Step 3 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.

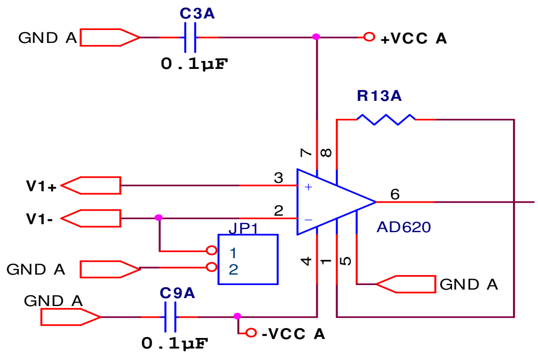
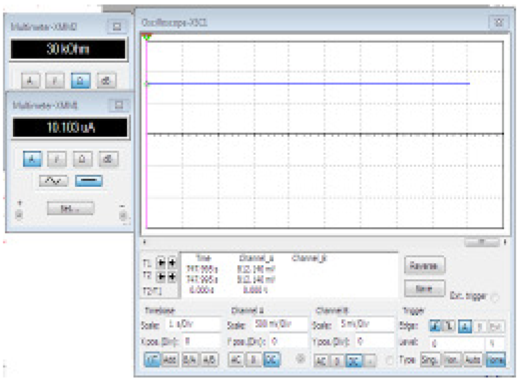


Fig.3 Instrumentation amplifier

Here with help of AD620 this has the industry standard, high performance, low cost in-amp. The user can program any desired gain from 1 to 1000 using a single external resistor. The above figure is shown the design of instrumentation amplifier For the offset voltage correction and input buffering this amplifier is Designed.

Simulation Result:



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

Step 4 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.

Figure shown the design of low pass filter.

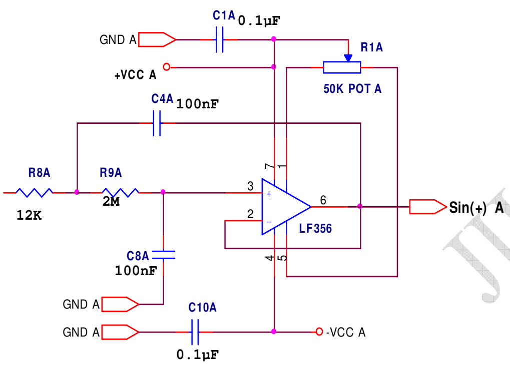


Fig.4 Low pass filter

4. EXPERIMENTAL DATA

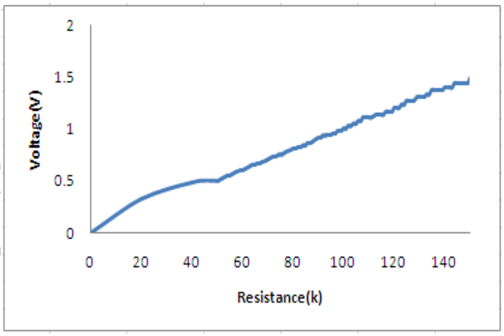
Simulated data with help of multisim is shown below.

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

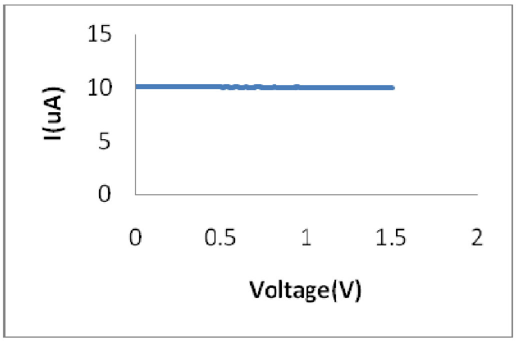
The same design is also implemented on general purpose PCB.which is also tested with some variable load resistor. That experimental data is shown in below table.

Load Resistor (R_L KΩ)	Current (µA)	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

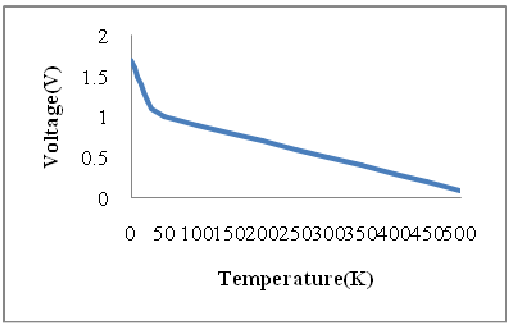
From the above experimental data its shown that with change in variable resistor, current is remain constant and give the filter output.Below graph (a) shown that resistance is incerse and it is compare with standrad curve of sensor diode in graph (b) which indicate that NTC charactristic and graph(c)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



(a)



(b)



(c)

Figure 5(a) Resistance Vs Voltage (b) Voltage Vs Current(c) Temperature Vs Voltage

5. CONCLUSION

From this experiment we are able to conclude that 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.

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