A cryogenic front-end preamplifier operating at 120 K for bolometric detector

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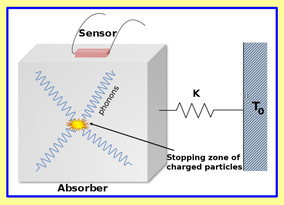
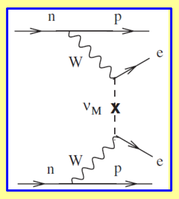
INTRODUCTION

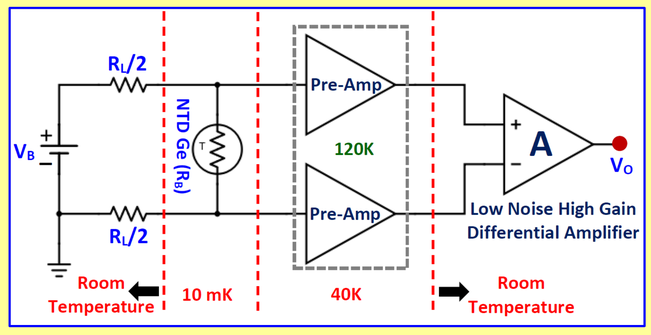


Bolometer principle



Neutrinoless Double Beta Decay

- An experiment to study neutrinoless double beta decay (NDBD) in ^{124}Sn, *TIN.TIN* (The INdia based TIN detector) using NTD Ge sensor, has been initiated in India [1 – 3].
- To enhance the SNR and to minimize the effect of external noise pickups and signal integration due to long cables, it is planned to keep the front-end pre-amplification stage close to the cold sensor.
- One of the key requirement for the front-end preamplifier is the stable voltage gain close to unity under the effect of sensor bias voltage and variation in operating temperature of the sensor.
- Design of a source follower amplifier with active load resistor is presented and their merits/demerits are discussed with respect to a conventional source follower with passive load resistor [4 – 5].



Proposed readout scheme of cryogenic bolometer with preamplifier placed at an intermediate stage (~ 120K)

CIRCUIT DESCRIPTION AND SIMULATION

- The amplifier is implemented with two JFET, where the second FET provides the high dynamic resistance to keep the voltage gain close to unity.
- The effect of DC offset voltage (V_{off}) on the voltage gain is simulated using the SPICE model of a general purpose low noise Si JFET (2SK209).

Source follower amplifier together with sensor biasing circuitry

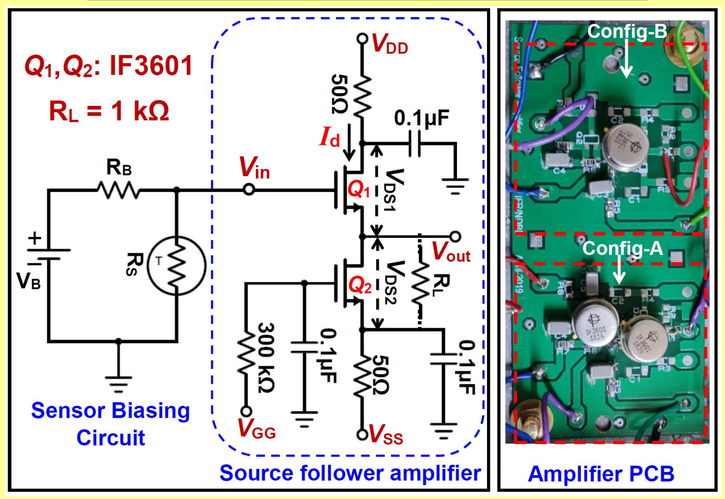
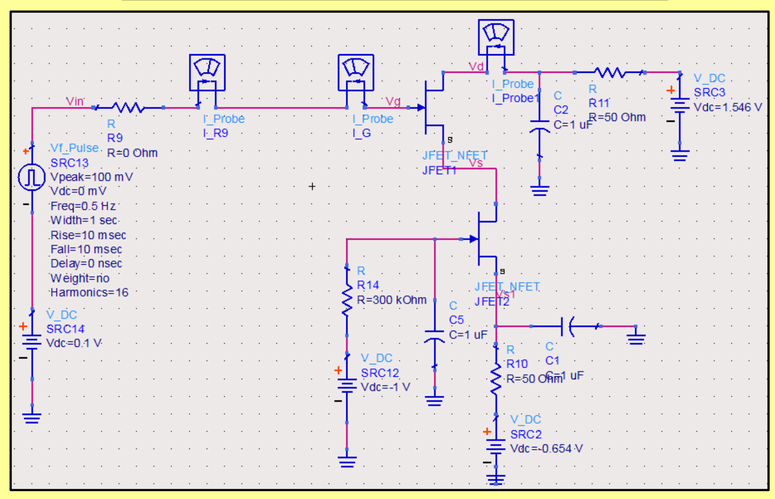


Table 1: Simulated response of a square wave for various DC offset voltages

V_{off} (mV)	I_d (mA)		V_m (mV)	
	Config-A	Config-B	Config-A	Config-B
-100	1.997	1.912	99.844	91.657
-50	1.998	1.956	99.845	91.723
0	1.998	2	99.844	91.788
50	1.998	2.043	99.845	91.850
100	1.999	2.087	99.845	91.911

Simulation model in Advanced Design System from Keysight

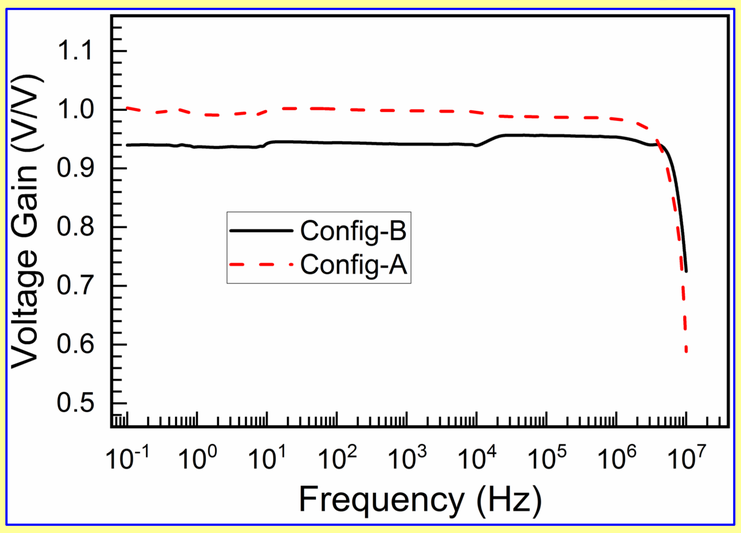


Config-A: Source follower amplifier with active load resistor, Q_2
Config-B: Source follower amplifier with passive load resistor, R_L

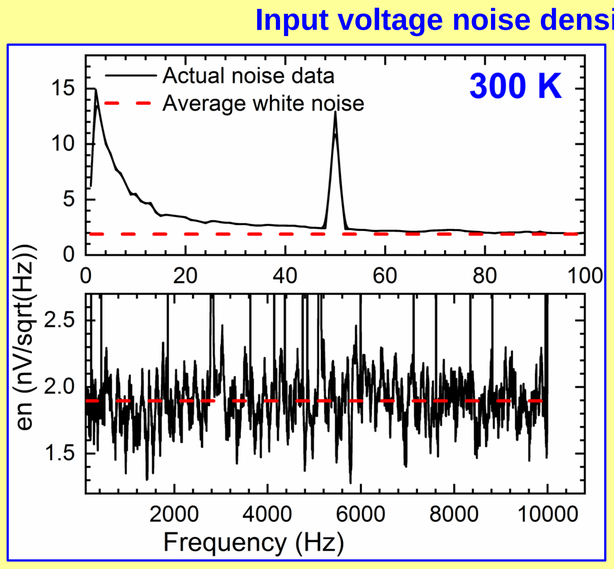
The amplitude of the square wave output varies from 91.657 to 91.911 mV in Config-B, while it is found to be very stable with a small variation from 99.844 to 99.845 mV in Config-A

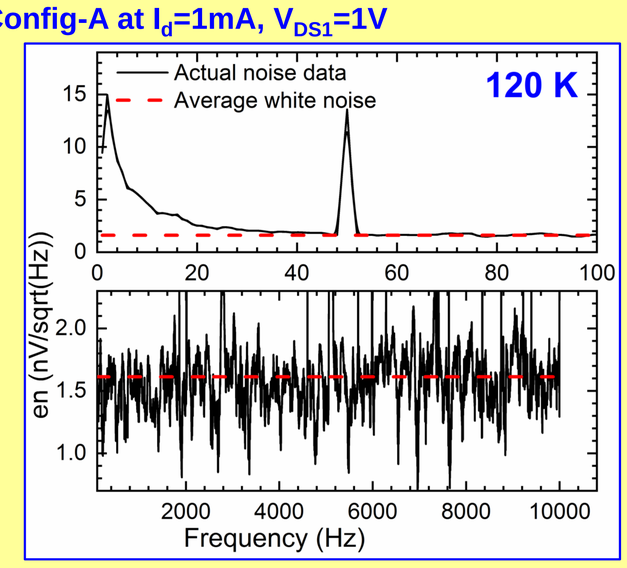
MEASUREMENT AND RESULTS

Frequency response of amplifier at I_d = 1mA, V_{DS1} = 1 V



Input voltage noise density for Config-A at I_d=1mA, V_{DS1}=1V





- Amplifier PCB is enclosed in a small vacuum chamber and is mounted on the cold finger in the cryostat.
- The setup is pumped using rotary and turbo molecular pump.
- The cryostat is filled with LN2 and the PCB cools down to ~ 122 K within 2 hours and remains stable thereafter.

Table 2: Measured voltage gain (A_V) at different bias conditions

Bias point		A_V (Config-A)		A_V (Config-B)	
I_d (mA)	V_{DS1} (V)	T=300 K	T=120 K	T=300 K	T=120 K
0.5	1.0	0.994	0.994	0.920	0.933
1.0	1.0	0.999	0.998	0.941	0.951
2.0	1.0	1.001	1.000	0.956	0.963

Table 3: Measured parameters for Config-A and Config-B

	Bias point			Config-A		Config-B	
	I_d (mA)	V_{DS1} (V)	V_{DS2} (V)	e_n (nV/√Hz)	P_d (mW)	e_n (nV/√Hz)	P_d (mW)
300 K	0.5	1.0	0.975	2.10	1.012	3.03	0.775
	1.0	0.5	0.918	1.89	1.518	2.28	1.6
	1.0	1.0	0.922	1.88	2.022	2.20	2.1
	1.0	2.0	0.926	1.88	3.026	2.18	3.1
	2.0	1.0	0.838	1.81	4.076	1.76	6.4
120 K	0.5	1.0	0.708	1.82	0.879	2.22	0.775
	1.0	0.5	0.658	1.63	1.258	1.53	1.6
	1.0	1.0	0.662	1.64	1.762	1.58	2.1
	1.0	2.0	0.666	1.61	2.766	1.54	3.1
	2.0	1.0	0.589	1.54	3.578	1.25	6.4

CONCLUSION

- Voltage gain of the present design with active load is stable within 0.6 % over a wide range of operating drain current of 0.5-2.0 mA as compared to 3% variation observed with the conventional source follower.
- An input voltage noise density of 1.54 nV/√Hz is obtained at 120 K, with a very low flicker corner frequency of 40 Hz.
- This design would be particularly useful for the bolometer readout circuitry, where the stability over a wide range of operating condition of the front-end amplifier is essential to measure the R_S ~MΩ to GΩ over a temperature range of 10-100 mK.

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