AV241 - Instrumentation and Control Lab

Instrumentation Lab-3

Experiment-1

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SC22B146

Aim:

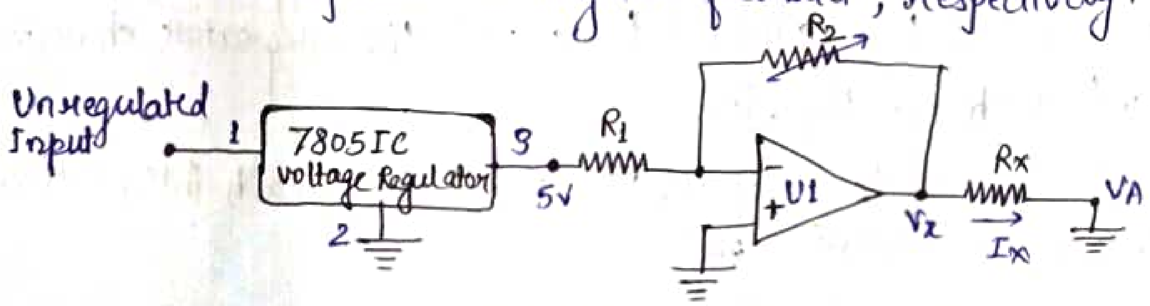
① Reference current generation unit.
② Current measurement technique 1 — Transimpedance Amplifier.
③ Current measurement technique 2 — Current Integrator.

Component and Equipments Required:

① Voltage regulator IC - 7805
② Opamp IC - 0707
③ Switch IC - CD4053
④ Resistors
⑤ Capacitors
⑥ DC power supply
⑦ Digital storage oscilloscope
⑧ Multimeter
⑨ Function generator.

Theory:

Measurement of currents in sub-micro ampere ranges are usually done using Opamp current-to-voltage converter circuits. Opamps are ~~generated~~ operated in voltage amplifier configuration with a passive component (either resistor, capacitor or semiconductor) as the feedback element. Conventional opamp current-to-voltage converter circuits are the transimpedance amplifiers and current generator amplifier having a resistor and capacitor in negative feedback, respectively.

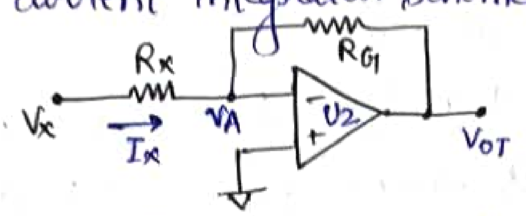


Circuit for current generation

Generated current, I_x, is given by

$$I_x = -\frac{5R_2}{R_1 R_x} \quad [R_2 \text{ is varied to change } I_x]$$

This generated current must be sensed using the transimpedance amplifier and current integrator schemes.



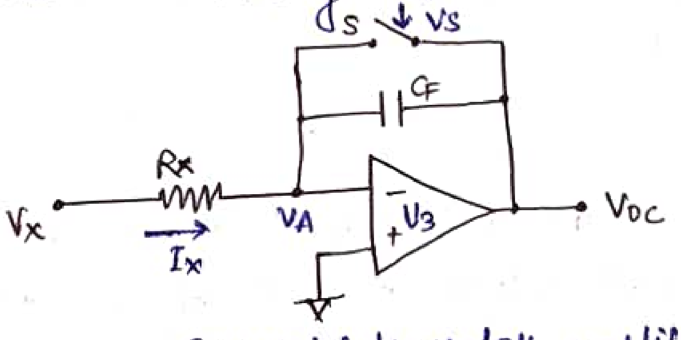
Transimpedance Amplifier

The point V_A of the generation circuit is connected to the inverting terminal of opamp U2 of the transimpedance amplifier. The zero potential required at point for the flow of I_x is achieved using the virtual short condition of the inverting amplifier.

The output of the circuit, V_{OT}, is given by

$$V_{OT} = -I_x R_G$$

The output of the TIA, being DC, can be measured using a multimeter.



Current integrator amplifier

Integrator is periodically discharged by using switch S. Switch S is implemented using the CD4053 multiplexer IC. The generation of switch control signal Vs is generated using the function generator. The duty cycle of Vs needs to be adjusted to adjust the integrator charging time, T_C, and discharge time, T_D.

The peak value of the output, V_{oc} at the end of each integration cycle is given by the relation:

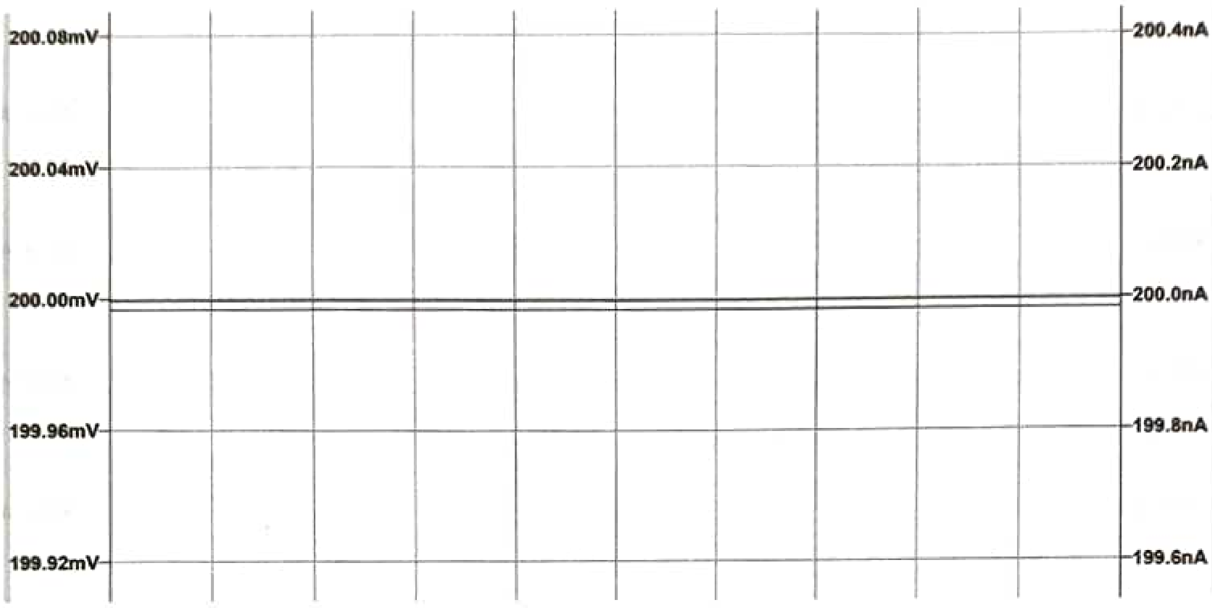
$$V_{oc} = \frac{-I_x T_c}{C_F}$$

Required Details:

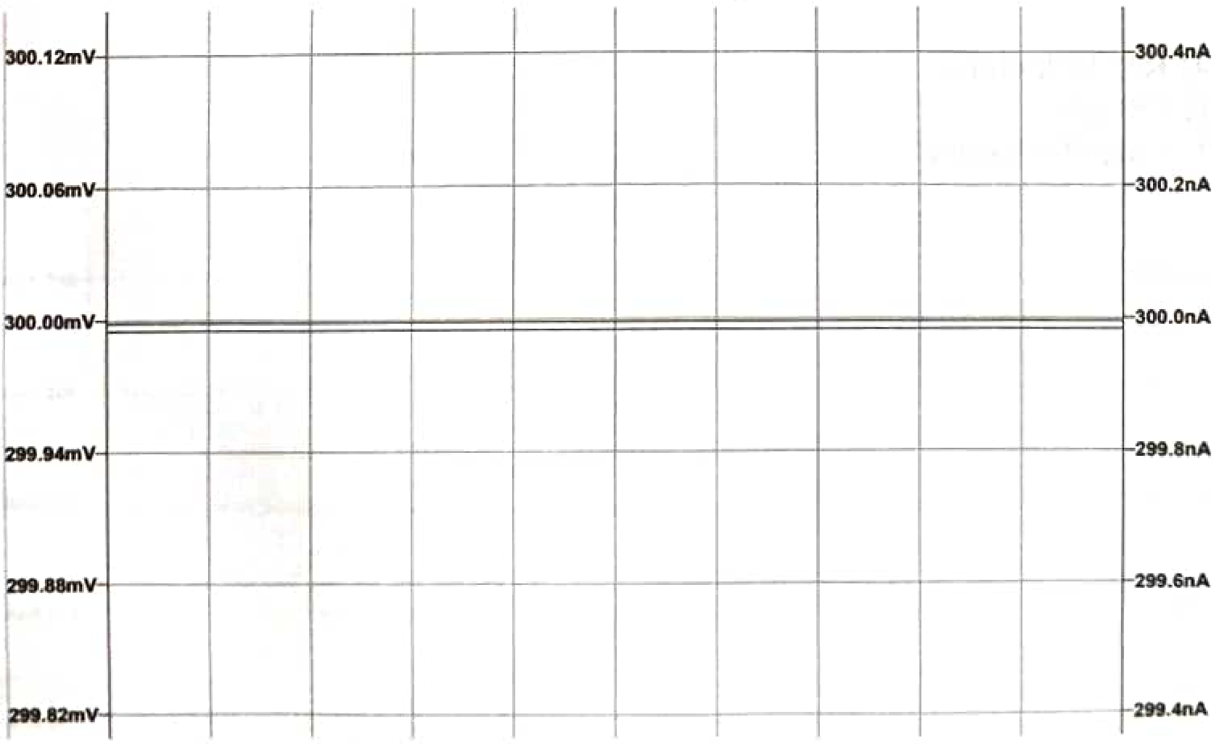
1. Details of the ICs used with their corresponding pin details.
2. Procedure of experiment.
3. Tabular column of experimental results, V_{OT} and V_{OC}, for current range (100nA, 1 μA), each reading separated by 50 nA with error and non-linearity.
4. Waveforms of V_S and V_{OC}.
5. Plotted output characteristics of TIA and current integrator.
6. Inferences.

Experiment Simulation Result:

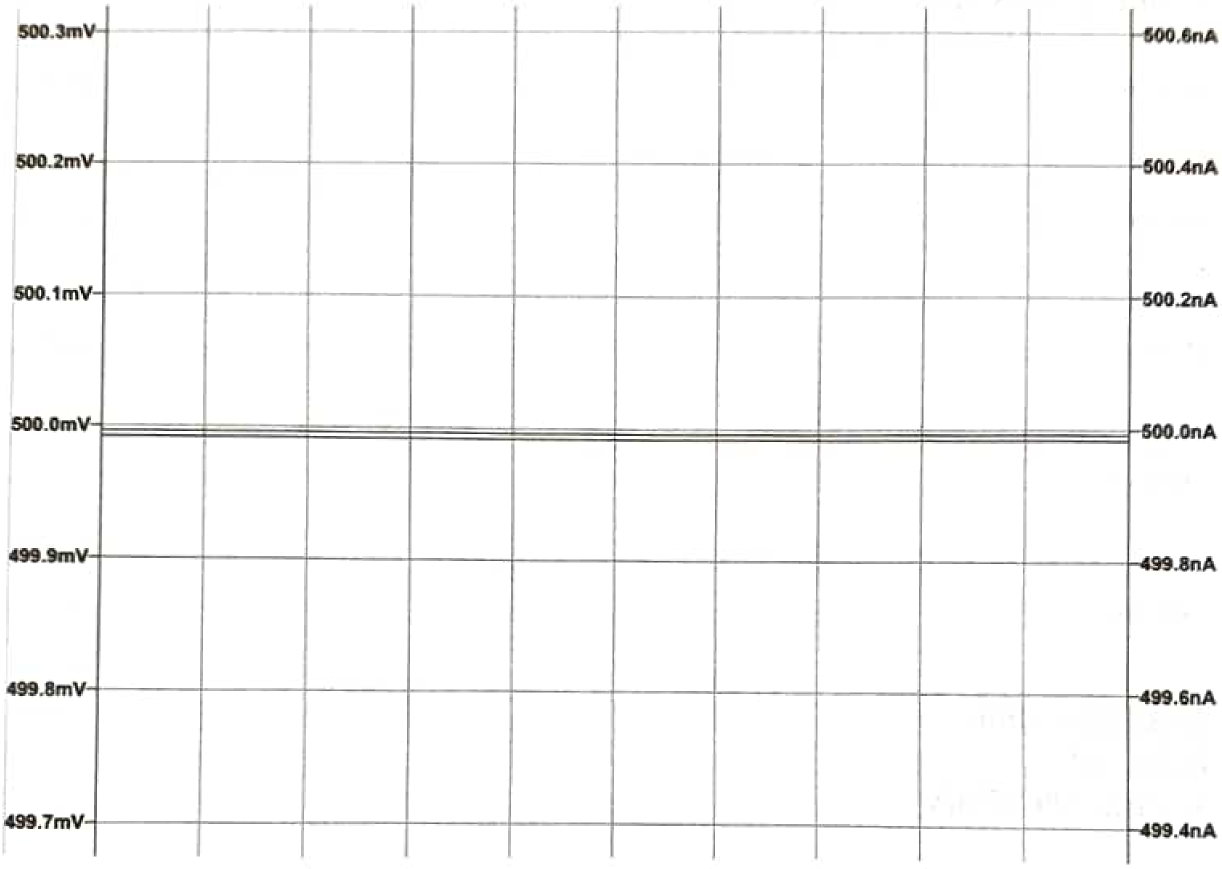
1) R3: 4 k ohms
I: 200 nA
V_out: 199.98 mV



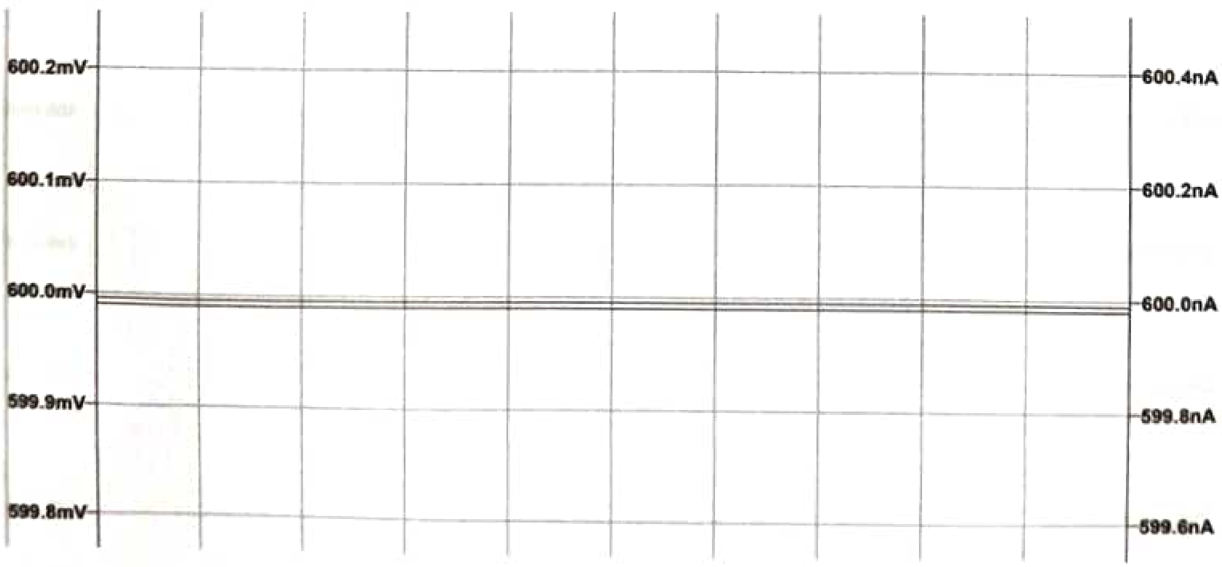
2) R3: 6 k ohms
I: 300 nA
V_out: 299.97 mV



3) R3: 10 k ohms
I: 500 nA
V_out: 499.97 mV

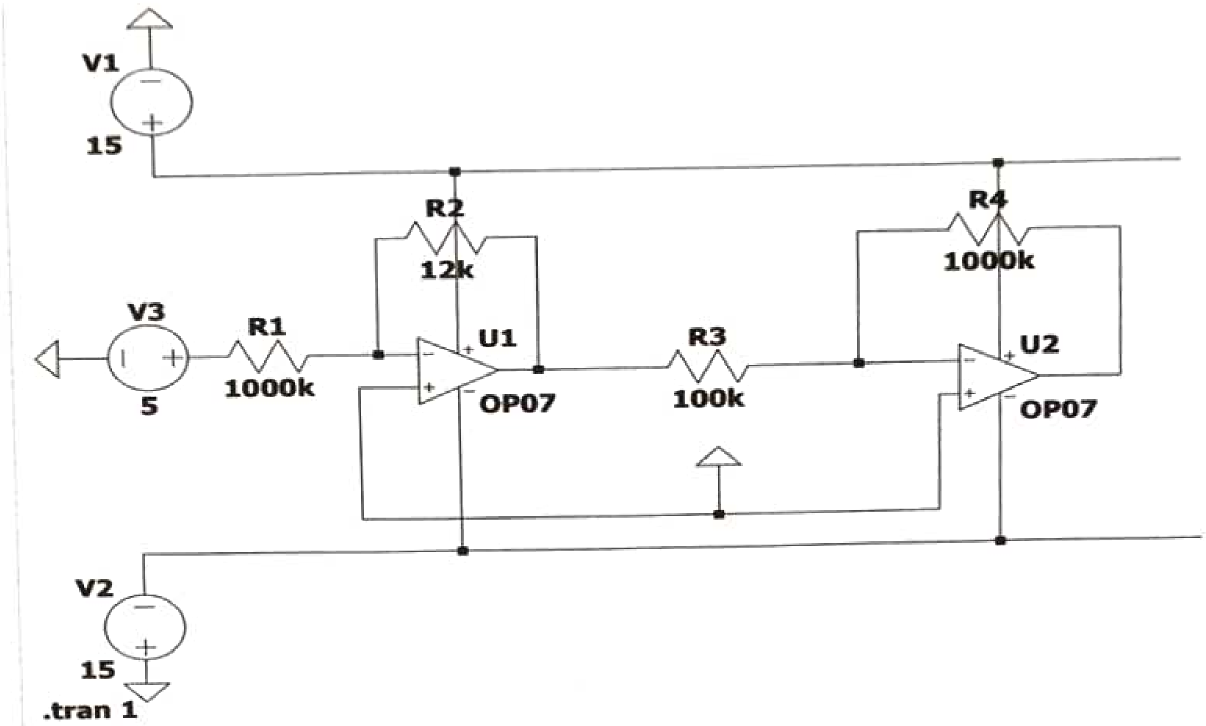


4) R3: 12 k ohms
I: 600 nA
V_out: 599.98 mV

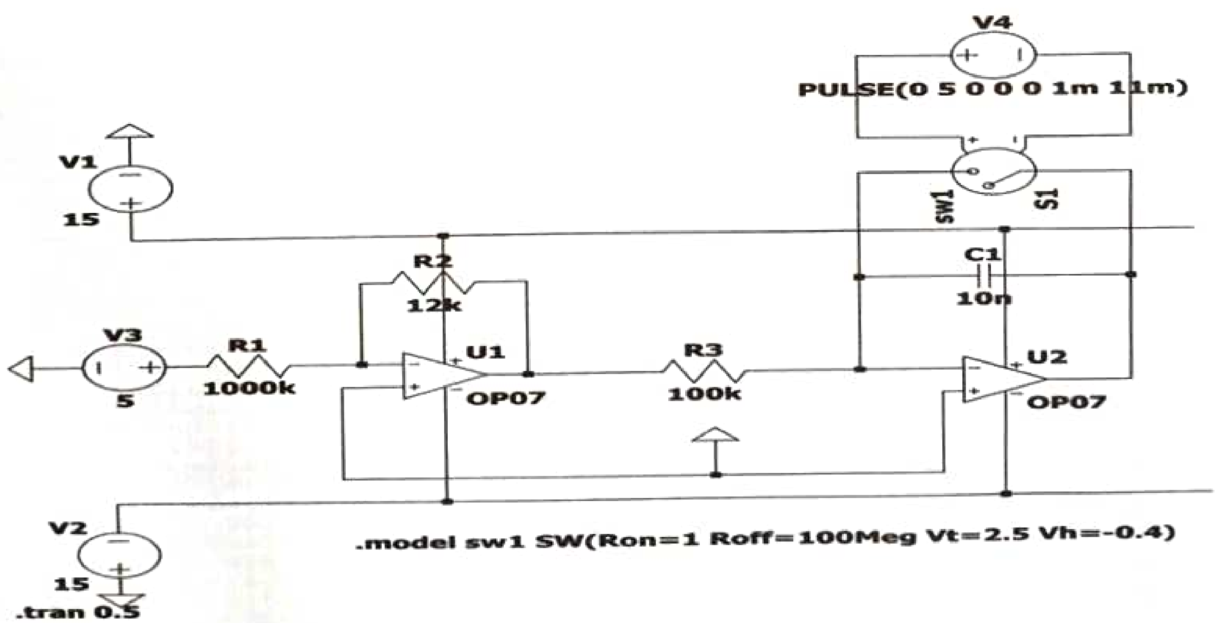


Experiment Simulation:

Transimpedance Amplifier (TIA) Circuit:



Integrator Circuit:



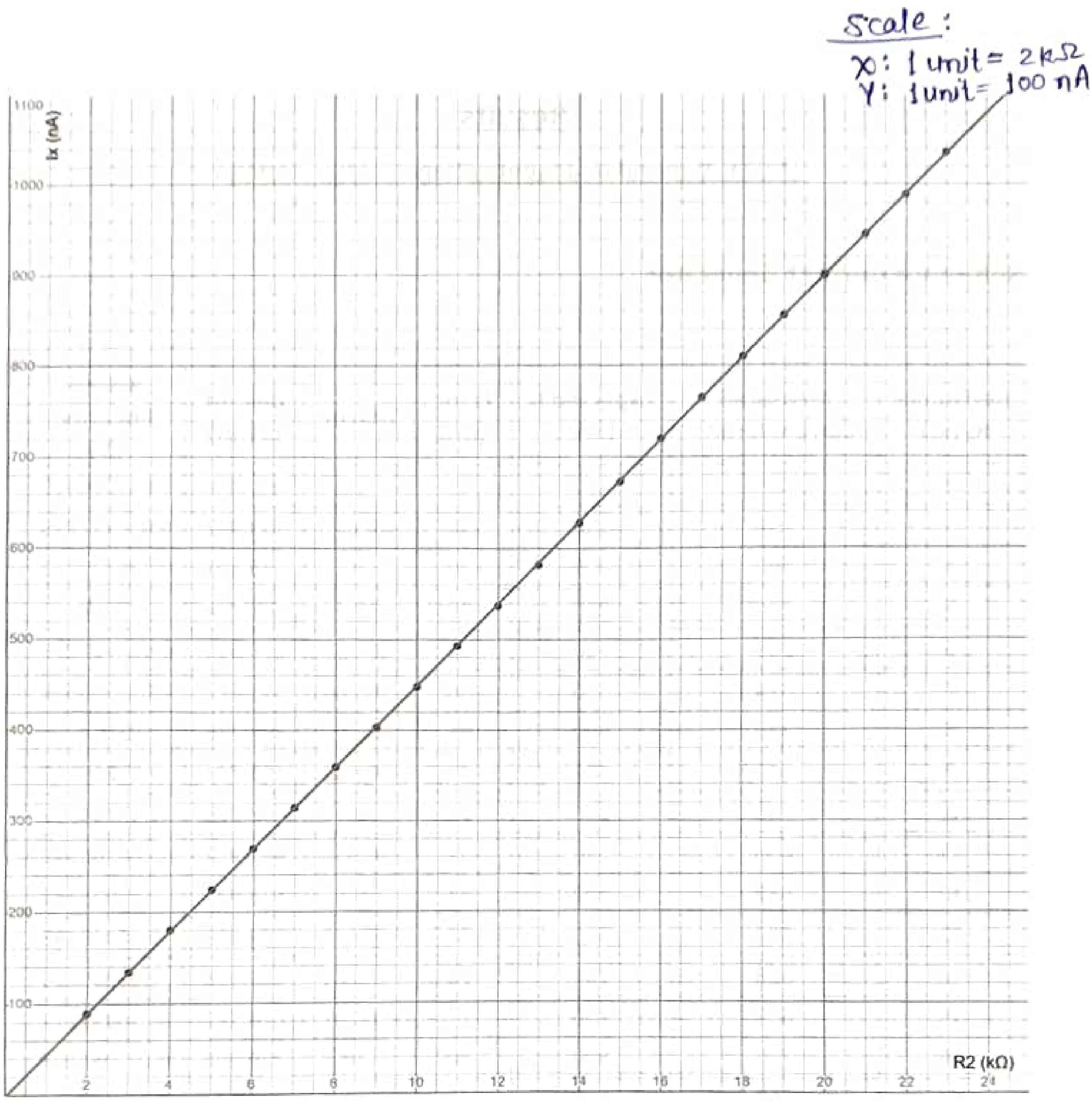
Results

[NOTE: Unregulated input voltage = $+V_{cc}$ = 10 V]

Reference Current Generator

Resistance R_2 (kΩ)	Measured Current I_x (nA)	Expected I_x (nA)	Error (nA)	%Error	Best-fit Ix (nA)	%Non-linearity (%)
2	89	100	-11	-11	88.383	0.056090909
3	134	150	-16	-10.667	133.442	0.050727273
4	180	200	-20	-10	178.501	0.136272727
5	224	250	-26	-10.4	223.56	0.04
6	269	300	-31	-10.333	268.618	0.034727273
7	314	350	-36	-10.286	313.677	0.029363636
8	359	400	-41	-10.25	358.736	0.024
9	403	450	-47	-10.444	403.794	-0.07218182
10	448	500	-52	-10.4	448.853	-0.07754545
11	493	550	-57	-10.364	493.912	-0.08290909
12	537	600	-63	-10.5	538.971	-0.17918182
13	582	650	-68	-10.462	584.029	-0.18445455
14	628	700	-72	-10.286	629.088	-0.09890909
15	673	750	-77	-10.267	674.147	-0.10427273
16	720	800	-80	-10	719.206	0.072181818
17	765	850	-85	-10	764.264	0.066909091
18	810	900	-90	-10	809.323	0.061545455
19	855	950	-95	-10	854.382	0.056181818
20	900	1000	-100	-10	899.44	0.050909091
21	945	1050	-105	-10	944.499	0.045545455
22	989	1100	-111	-10.091	989.558	-0.05072727
23	1036	1150	-114	-9.913	1034.617	0.125727273

Line of best fit: $y = mx + b; m = 45.0587, b = -1.73405$



Plot: I_x vs R_2 for Reference Current Generator with Line of Best Fit

Current Measurement through Transimpedance Amplifier

Resistance R_2 (kΩ)	Output Voltage V_{OT} (mV)	Measured Current $\lvert I_x \rvert$ (nA)	Expected $\lvert I_x \rvert$ (nA)	Error (nA)	%Error (%)	Best-fit I_x (nA)	%Non-linearity (%)
2	95	95	100	-5	-5	94.569	0.035916667
3	145	145	150	-5	-3.3333	144.164	0.069666667
4	194	194	200	-6	-3	193.759	0.020083333
5	244	244	250	-6	-2.4	243.355	0.05375
6	293	293	300	-7	-2.3333	292.95	0.004166667
7	343	343	350	-7	-2	342.545	0.037916667
8	392	392	400	-8	-2	392.14	-0.01166667
9	442	442	450	-8	-1.7778	441.735	0.022083333
10	492	492	500	-8	-1.6	491.33	0.055833333
11	540	540	550	-10	-1.8182	540.925	-0.07708333
12	590	590	600	-10	-1.6667	590.521	-0.04341667
13	639	639	650	-11	-1.6923	640.116	-0.093
14	689	689	700	-11	-1.5714	689.711	-0.05925
15	738	738	750	-12	-1.6	739.306	-0.10883333
16	788	788	800	-12	-1.5	788.901	-0.07508333
17	838	838	850	-12	-1.4118	838.496	-0.04133333
18	887	887	900	-13	-1.4444	888.091	-0.09091667
19	937	937	950	-13	-1.3684	937.687	-0.05725
20	986	986	1000	-14	-1.4	987.282	-0.10683333
21	1039	1039	1050	-11	-1.0476	1036.88	0.176916667
22	1088	1088	1100	-12	-1.0909	1086.47	0.127333333
23	1138	1138	1150	-12	-1.0435	1136.07	0.161083333

Line of best fit: $y = mx + b; m = 49.5951, b = -4.62112$

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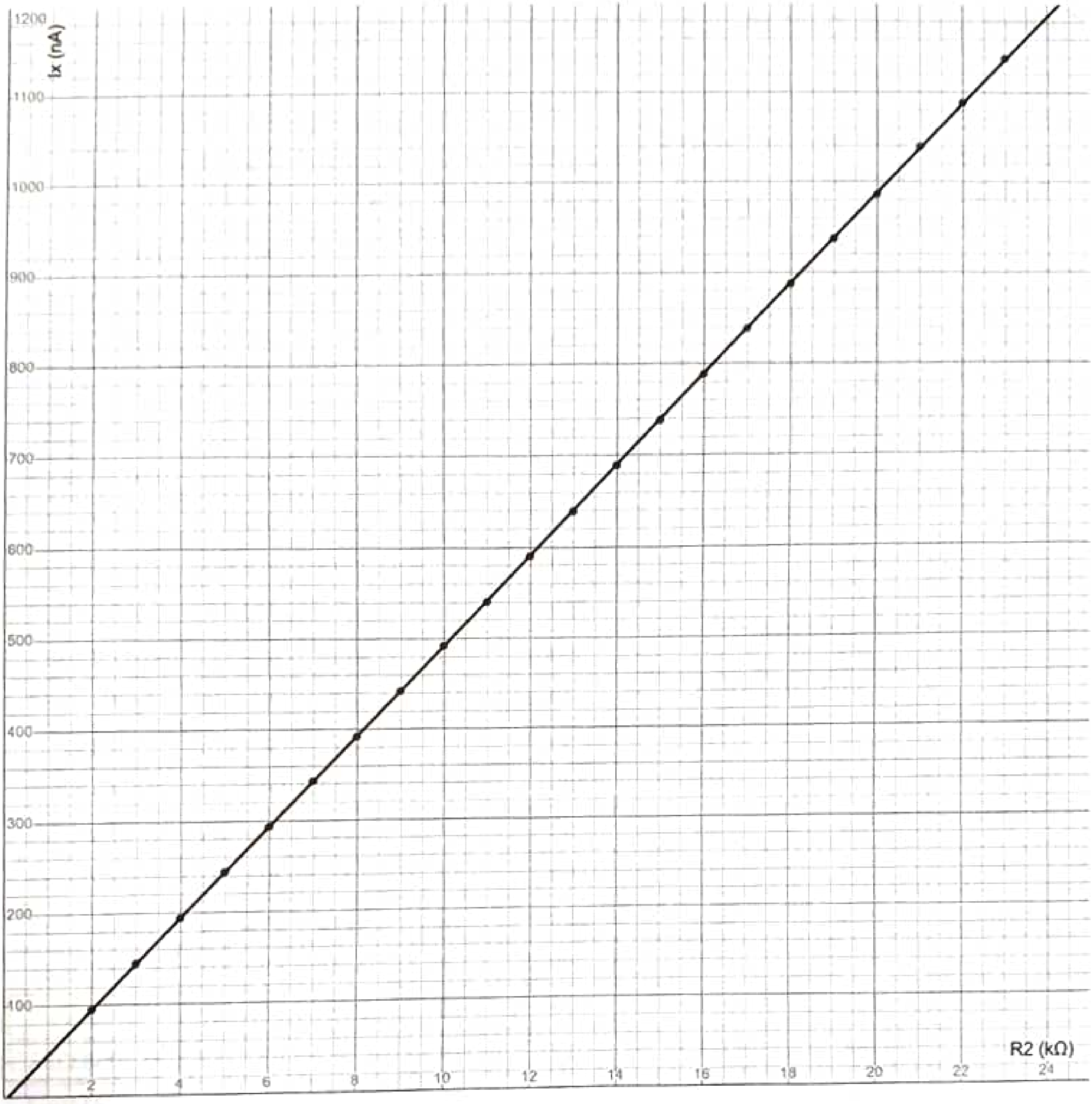
Scale:
X: 1 unit = 2 kΩ
Y: 1 unit = 100 nA



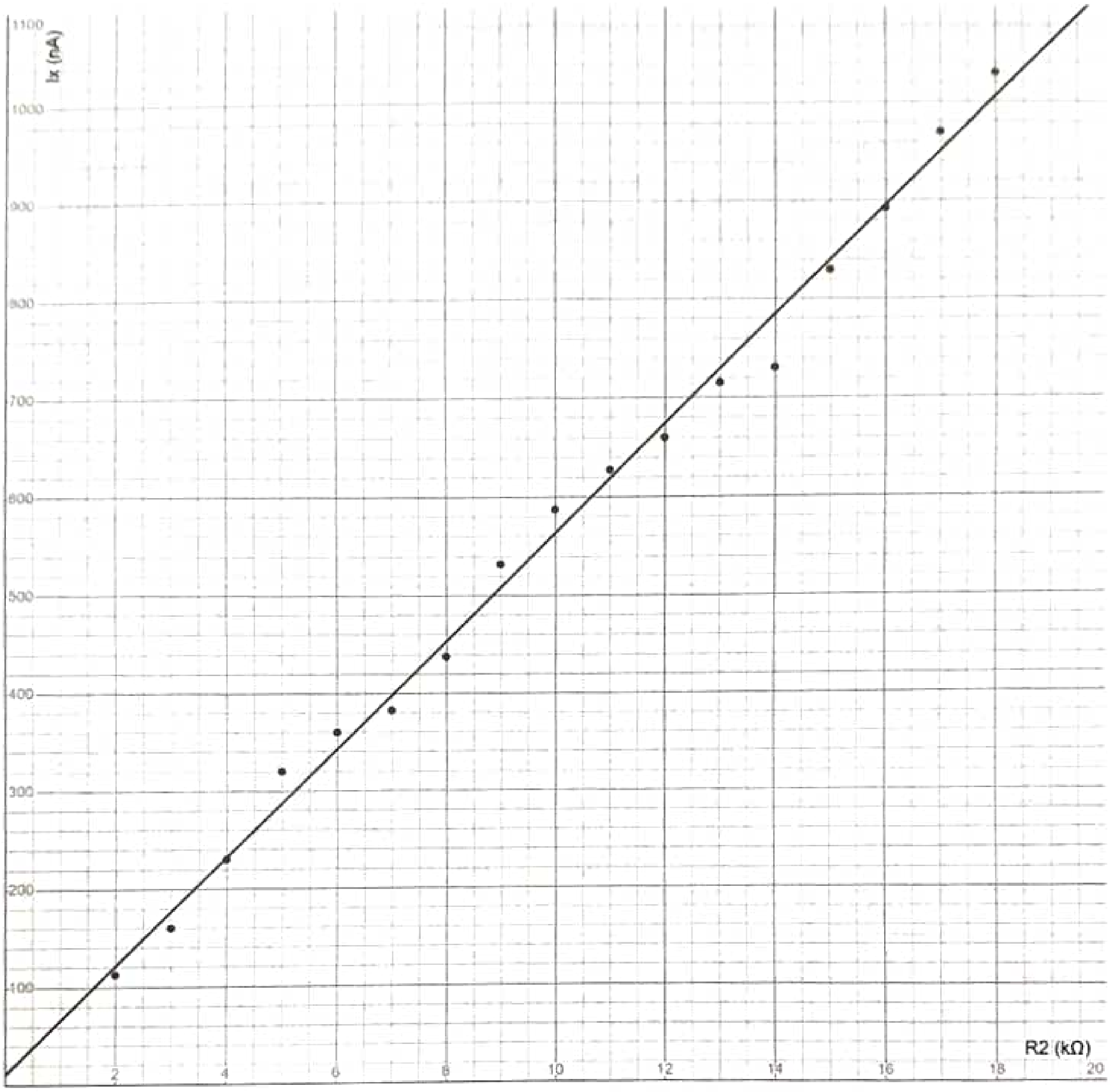
Plot: I_x vs R_2 for TIA with Line of Best Fit

Current Measurement through Current Integrator

Resistance R_2 (kΩ)	Output Voltage V_OC (mVpp)	Measured Current $\lvert I_x \rvert$(nA)	Expected $\lvert I_x \rvert$(nA)	Error (nA)	%Error (%)	Best-fit Ix (nA)	%Non-linearity (%)
2	112.5	112.5	100	12.5	12.5	121.137	-0.71975
3	160	160	150	10	6.6667	176.414	-1.36783333
4	230	230	200	30	15	231.691	-0.14091667
5	320	320	250	70	28	286.968	2.752666667
6	360	360	300	60	20	342.245	1.479583333
7	382.5	382.5	350	32.5	9.2857	397.522	-1.25183333
8	437.5	437.5	400	37.5	9.375	452.799	-1.27491667
9	532	532	450	82	18.222	508.076	1.993666667
10	587.5	587.5	500	87.5	17.5	563.353	2.01225
11	627.5	627.5	550	77.5	14.091	618.63	0.739166667
12	660	660	600	60	10	673.907	-1.15891667
13	715	715	650	65	10	729.184	-1.182
14	730	730	700	30	4.2857	784.461	-4.53841667
15	830	830	750	80	10.667	839.738	-0.8115
16	892.5	892.5	800	92.5	11.563	895.015	-0.20958333
17	970	970	850	120	14.118	950.292	1.642333333
18	1030	1030	900	130	14.444	1005.569	2.035916667

Line of best fit: $y = mx + b; m = 55.277, b = 10.5833$

Scale :
X : 1 unit = 2 k Ω
Y : 1 unit = 100 nA



Plot: I_x vs R_2 for Current Integrator with Line of Best Fit