EE230: Lab 5.
Simple Application Circuits

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1 Overview of the experiment

1.1 Aim of the experiment

To simulate Photodiode Application Circuit and 3 Opamp Based Instrumentation Amplifiers using NGSPICE.

1.2 Methods

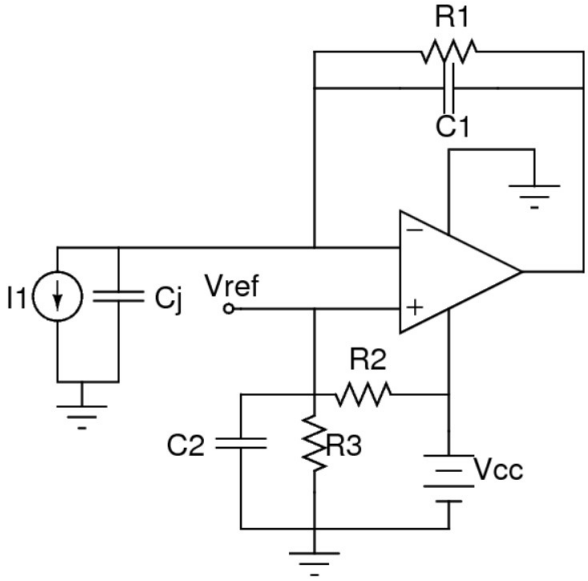
The netlists for Photodiode Application Circuit and 3 Opamp Based Instrumentation Amplifiers were made in NGSPICE.

Subcircuit for LM324 operational amplifier was directly used in the netlists.

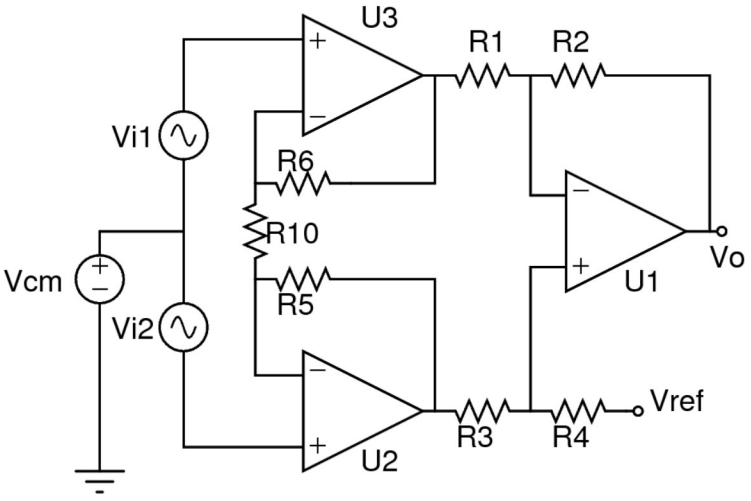
Plots for various waveforms were made as per the handout. The parameters that were supposed to be found as per the handout, were graphically evaluated.

2 Design

2.1 Circuit Diagrams



Photodiode Application Circuit



Instrumentation Amplifier

3 Simulation results

3.1 Code snippets

3.1.1 Photodiode Application Circuit - DC analysis

```
Photo Diode
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.include lm324.txt
v1 3 0 ac 0 dc 5
r2 2 5 13.7k
r3 2 0 280
x1 2 1 3 0 5 lm324
c2 2 0 1u
r1 1 5 1.4Meg
c1 1 5 3.3p
vref 2 0 dc 0.1 ac 0
i1 1 0 ac 0 dc
cj 1 0 11p

.dc i1 0 2.4u 0.1u
.control
run
plot v(5)
.endc
.end
```

3.1.2 Photodiode Application Circuit - AC analysis

```
Photo Diode Bode Plot
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.include lm324.txt
v1 3 0 dc 5
r2 2 5 13.7k
r3 2 0 280
x1 2 1 3 0 5 lm324
c2 2 0 1u
r1 1 5 1.4Meg
c1 1 5 3.3p
vref 2 0 0.1
i1 1 6 dc 0 ac 1.5u
vd 6 0 0
cj 1 0 11p

.ac dec 10 10 100Meg
.control
run
plot {20*log10(abs(v(5)/i(vd)))} xlog
.endc
.end
```

3.1.3 3 Opamp Based Instrumentation Amplifier - Common Mode Input

```
Instrumentation Amplifier
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.include ua741.txt

vp 3 0 dc 15
vn 4 0 dc -15
vi1 1 8 0
vi2 6 8 0
vcm 8 0 0
vref 9 0 0
r6 2 5 10k
r5 7 10 10k
r10 2 7 2.21k
r1 5 12 10k
r2 12 15 10k
r3 10 11 10k
r4 11 9 10k
x1 1 2 3 4 5 ua741
x2 6 7 3 4 10 ua741
x3 11 12 3 4 15 ua741

.dc vcm -2 2 0.1
.control
run
plot v(15)
.endc
.end
```

3.1.4 3 Opamp Based Instrumentation Amplifier - Differential Input

```
Instrumentation Amplifier
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.include ua741.txt

vp 3 0 dc 15
vn 4 0 dc -15
vi1 1 8 sin(0 250m 1k 0 0)
vi2 6 8 sin(0 -250m 1k 0 0)
vcm 8 0 0
vref 9 0 0
r6 2 5 10k
r5 7 10 10k
r10 2 7 2.21k
r1 5 12 10k
r2 12 15 10k
r3 10 11 10k
r4 11 9 10k
x1 1 2 3 4 5 ua741
x2 6 7 3 4 10 ua741
x3 11 12 3 4 15 ua741

.tran 0.01ms 10ms
.control
run
plot v(1) - v(6)
plot v(15)
.endc
.end
```

3.2 Simulation Results

3.2.1 Photodiode Circuit

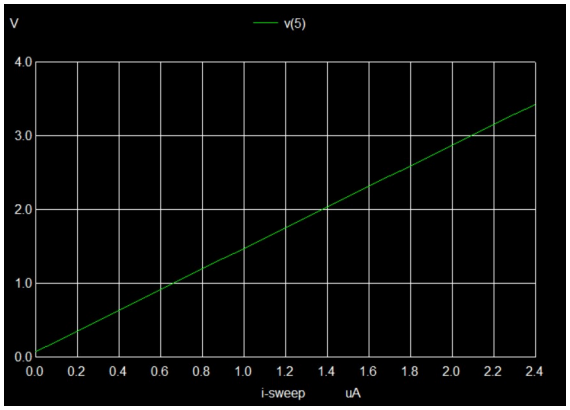

Fig 1.1
Output Voltage vs Input Current
v(5): Output Voltage (V_o), I_{sweep}: Input Current (I_{in})

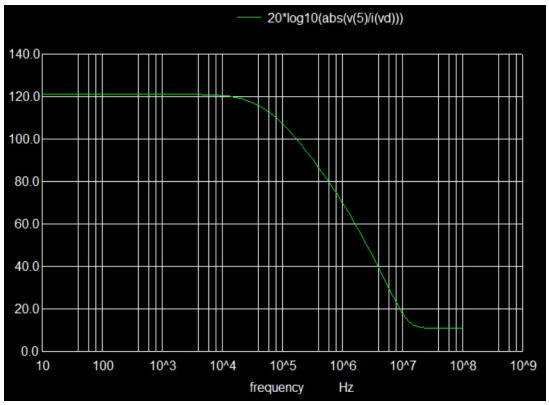

Fig 1.2
$20log_{10}(|\frac{V_{out}}{I_{in}}|)$ *vs Frequency Bode Plot*

3.2.2 Instrumentation Amplifier

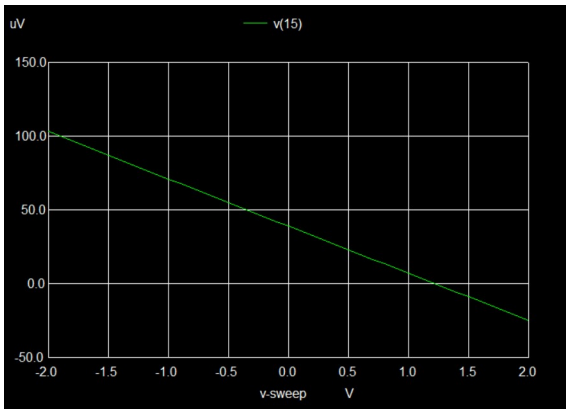

Fig 1.3
Output Voltage vs Common Mode Input Voltage (V_{cm})
v(15): Output Voltage V_o, v-sweep: Input Voltage V_{cm}

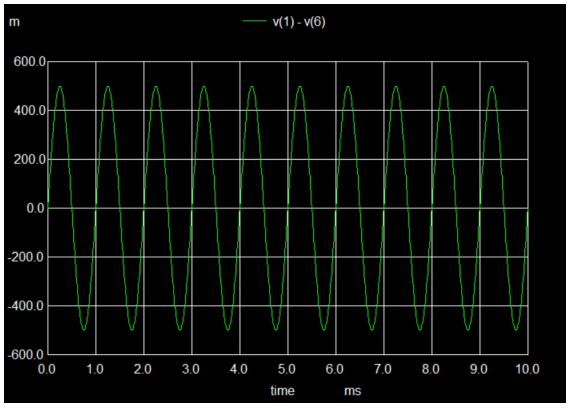

Fig 1.4
Difference between Input Signals
v(1)-v(6): Difference Input Signals ($V_{i1} - V_{i2}$)

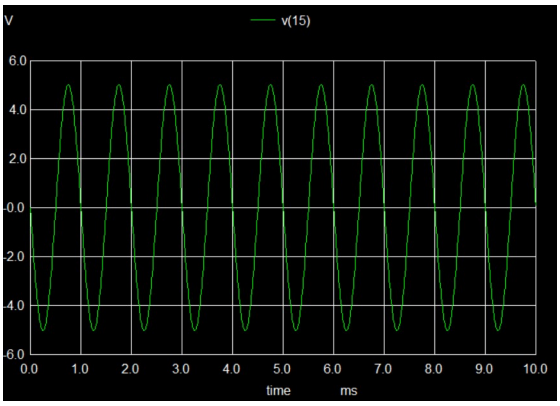

Fig 1.5
Output Waveform for Instrumentation Amplifier
v(15): Output Voltage V_o

4 Experimental results

4.1 Answers to Questions in Handout

4.1.1 1(b)

The 3-dB down cutoff frequency was obtained from the plot as ≈ 31700Hz

4.1.2 2(a)

The theoretical differential gain of the instrumentation amplifier system is $\frac{V_{out}}{V_{i1}-V_{i2}}$ $= 1+\frac{2R_6}{R_{10}} \approx 10.05$. Which matches with the experimental results we obtained in Fig 1.5 where the output waveform is ≈ 10 times amplified than the differential input.