EE230:experiment No.5
Opamp circuits-3

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1 Overview of the experiment

1.1 Aim of the experiment

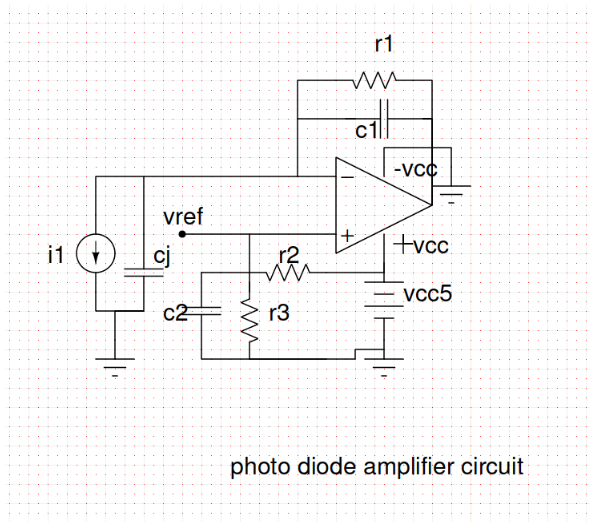
To simulate the following circuits using NGSPICE and compare the results with experimental observations:
1. Photodiode application circuit using op-amp LM324
2. 3 op-amp based Instrumentation Amplifier

1.2 Methods

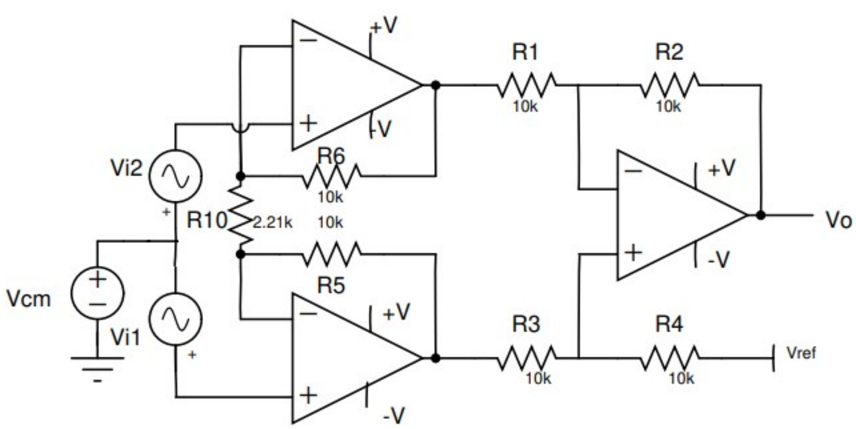
The simulating software used is Ngspice. We used the provided model files for diode and op-amp.

2 Circuit Design

2.1 Photodiode Application Circuit



2.2 3 op-amp based Instrumentation Amplifier



3 simulation results

3.1 Code Snippet

All the files which are included in the code using .include command are already uploaded on moodle in lab submission.

photo diode-current dc analysis

```
photo diode
.SUBCKT LM324 1 2 3 4 5
C1 11 12 5.544E-12
C2 6 7 20.00E-12
DC 5 53 DX
DE 54 5 DX
DLP 90 91 DX
DLN 92 90 DX
DP 4 3 DX
EGND 99 0 POLY(2) (3,0) (4,0) 0 .5 .5
FB 7 99 POLY(5) VB VC VE VLP VLN 0 15.91E6 -20E6 20E6 20E6 -20E6
GA 6 0 11 12 125.7E-6
GCM 0 6 10 99 7.067E-9
IEE 3 10 DC 10.04E-6
HLIM 90 0 VLIM 1K
Q1 11 2 13 QX
Q2 12 1 14 QX
R2 6 9 100.0E3
RC1 4 11 7.957E3
RC2 4 12 7.957E3
RE1 13 10 2.773E3
RE2 14 10 2.773E3
REE 10 99 19.92E6
RO1 8 5 50
RO2 7 99 50
RP 3 4 30.31E3
VB 9 0 DC 0
VC 3 53 DC 2.100
VE 54 4 DC .6
VLIM 7 8 DC 0
VLP 91 0 DC 40
```

```
VLN 0 92 DC 40
.MODEL DX D(IS=800.0E-18)
.MODEL QX PNP(IS=800.0E-18 BF=250)
.ENDS
i 0 1 dc
cj 1 0 11p
c1 1 2 3.3p
r1 1 2 1.4Meg
vref 3 0 0.1
vcc1 4 0 15v
vcc2 5 0 -15v
r2 3 4 13.7k
r3 3 0 280
c2 3 0 1u
x1 3 1 4 5 2 LM324
.dc i 0 2.4u 0.1u
.control
run
plot v(2)
.endc
.end
```

photo didoe-current ac analysis

```
photo diode
.SUBCKT LM324 1 2 3 4 5
C1 11 12 5.544E-12
C2 6 7 20.00E-12
DC 5 53 DX
DE 54 5 DX
DLP 90 91 DX
DLN 92 90 DX
DP 4 3 DX
EGND 99 0 POLY(2) (3,0) (4,0) 0 .5 .5
FB 7 99 POLY(5) VB VC VE VLP VLN 0 15.91E6 -20E6 20E6 20E6 -20E6
GA 6 0 11 12 125.7E-6
GCM 0 6 10 99 7.067E-9
IEE 3 10 DC 10.04E-6
HLIM 90 0 VLIM 1K
Q1 11 2 13 QX
Q2 12 1 14 QX
R2 6 9 100.0E3
RC1 4 11 7.957E3
RC2 4 12 7.957E3
RE1 13 10 2.773E3
RE2 14 10 2.773E3
REE 10 99 19.92E6
RO1 8 5 50
RO2 7 99 50
RP 3 4 30.31E3
VB 9 0 DC 0
VC 3 53 DC 2.100
VE 54 4 DC .6
VLIM 7 8 DC 0
VLP 91 0 DC 40
VLN 0 92 DC 40
.MODEL DX D(IS=800.0E-18)
.MODEL QX PNP(IS=800.0E-18 BF=250)
.ENDS
```

```
    i 0 1 dc 1.5u ac 1
cj 1 0 11p
c1 1 2 3.3p
r1 1 2 1.4Meg
vref 3 0 0.1
vcc1 4 0 15v
vcc2 5 0 -15v
r2 3 4 13.7k
r3 3 0 280
c2 3 0 1u
x1 3 1 4 5 2 LM324
.ac dec 10 10 100Meg
.control
run
plot vdb(2)
.endc
.end
```

instrumentation amplifier-part a instrumentation amplifier

```
.subckt ua741 1 2 3 4 5
c1 11 12 8.661E-12
c2 6 7 30.00E-12
dc 5 53 dx
de 54 5 dx
dlp 90 91 dx
dln 92 90 dx
dp 4 3 dx
egnd 99 0 poly(2) (3,0) (4,0) 0 .5 .5
fb 7 99 poly(5) vb vc ve vlp vln 0 10.61E6 -10E6 10E6 10E6 -10E6
ga 6 0 11 12 188.5E-6
gcm 0 6 10 99 5.961E-9
iee 10 4 dc 15.16E-6
hlim 90 0 vlim 1K
q1 11 2 13 qx
q2 12 1 14 qx
r2 6 9 100.0E3
rc1 3 11 5.305E3
rc2 3 12 5.305E3
re1 13 10 1.836E3
re2 14 10 1.836E3
ree 10 99 13.19E6
ro1 8 5 50
ro2 7 99 100
rp 3 4 18.16E3
vb 9 0 dc 0
vc 3 53 dc 1
ve 54 4 dc 1
vlim 7 8 dc 0
vlp 91 0 dc 40
vln 0 92 dc 40
.model dx D(Is=800.0E-18 Rs=1)
.model qx NPN(Is=800.0E-18 Bf=93.75)
.ends
```

```
vcm 1 0 dc
vi1 1 2 0
vi2 1 4 0
x3 2 3 6 7 8 ua741
x2 4 5 9 10 11 ua741
r10 3 5 2.21k
r5 5 11 10k
vcc31 6 0 15v
vcc32 7 0 -15v
vcc21 9 0 15v
vcc22 10 0 -15v
r6 3 8 10k
r1 8 12 10k
r2 12 13 10k
r3 11 14 10k
r4 14 15 10k
vref 15 0 0
x1 14 12 16 17 13 ua741
vcc11 16 0 15v
vcc12 17 0 -15v
.dc vcm -2 2 1m
.control
run
plot v(13)
.endc
.end
```

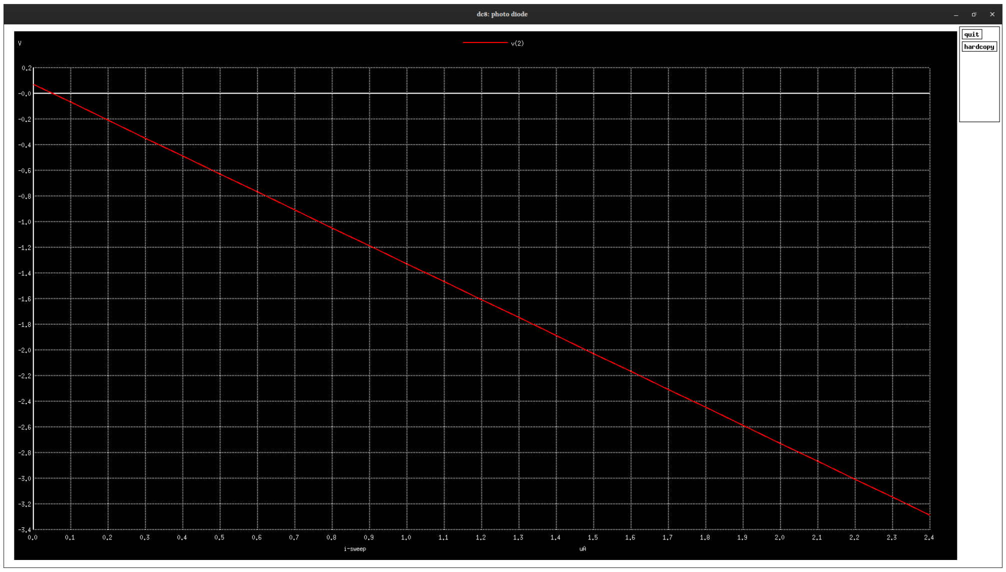
instrumentation amplifier-part c instrumentation amplifier

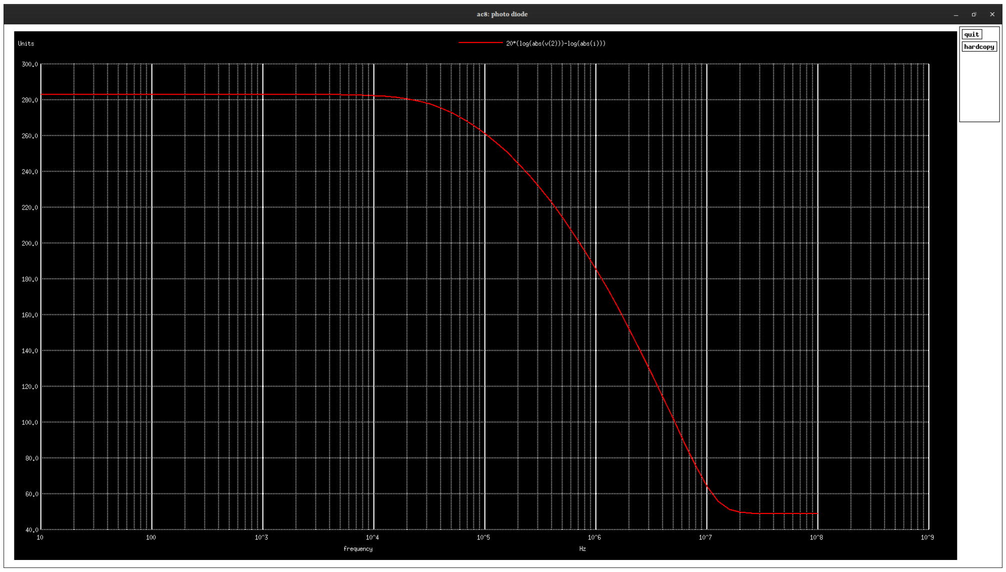
```
.subckt ua741 1 2 3 4 5
c1 11 12 8.661E-12
c2 6 7 30.00E-12
dc 5 53 dx
de 54 5 dx
dlp 90 91 dx
dln 92 90 dx
dp 4 3 dx
egnd 99 0 poly(2) (3,0) (4,0) 0 .5 .5
fb 7 99 poly(5) vb vc ve vlp vln 0 10.61E6 -10E6 10E6 10E6 -10E6
ga 6 0 11 12 188.5E-6
gcm 0 6 10 99 5.961E-9
iee 10 4 dc 15.16E-6
hlim 90 0 vlim 1K
q1 11 2 13 qx
q2 12 1 14 qx
r2 6 9 100.0E3
rc1 3 11 5.305E3
rc2 3 12 5.305E3
re1 13 10 1.836E3
re2 14 10 1.836E3
ree 10 99 13.19E6
ro1 8 5 50
ro2 7 99 100
rp 3 4 18.16E3
vb 9 0 dc 0
vc 3 53 dc 1
ve 54 4 dc 1
vlim 7 8 dc 0
vlp 91 0 dc 40
vln 0 92 dc 40
.model dx D(Is=800.0E-18 Rs=1)
.model qx NPN(Is=800.0E-18 Bf=93.75)
.ends
```

```
vcm 1 0 0
vi1 2 1 sin(0 250m 2k 0 0)
vi2 1 4 sin(0 250m 2k 0 0)
x3 2 3 6 7 8 ua741
x2 4 5 9 10 11 ua741
r10 3 5 2.21k
r5 5 11 10k
vcc31 6 0 +15v
vcc32 7 0 -15v
vcc21 9 0 +15v
vcc22 10 0 -15v
r6 3 8 10k
r1 8 12 10k
r2 12 13 10k
r3 11 14 10k
r4 14 15 10k
vref 15 0 0
x1 14 12 16 17 13 ua741
vcc11 16 0 15v
vcc12 17 0 -15v
.tran 0.1u 10m
.control
run
plot v(2)-v(4)
plot v(13)
.endc
.end
```

3.2 Simulation Results

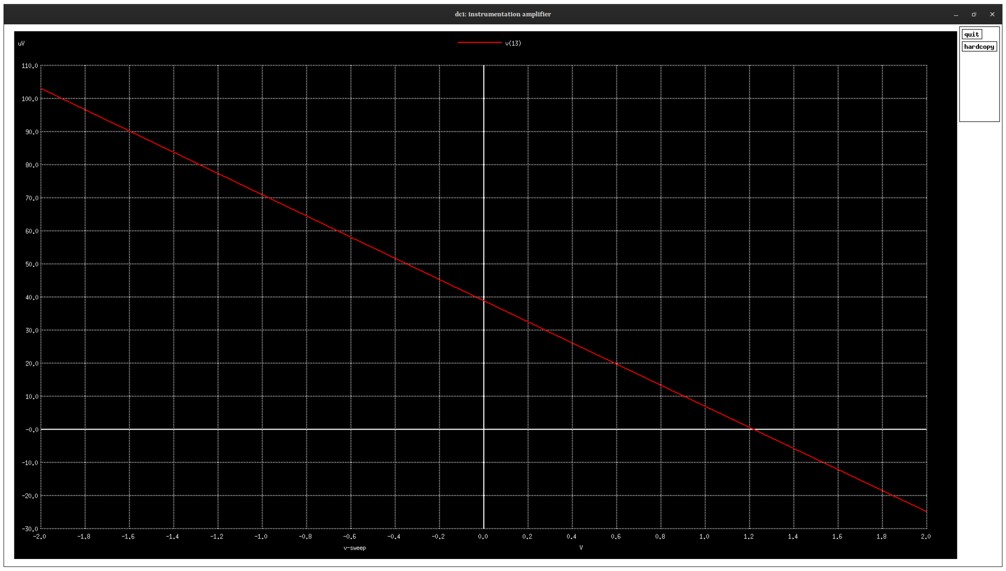
photodiode-amplifier

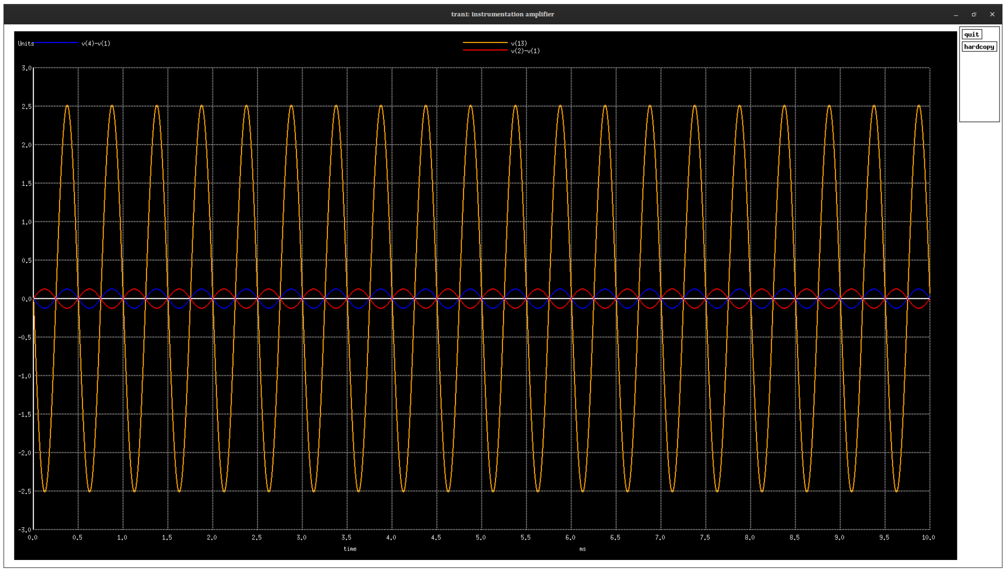




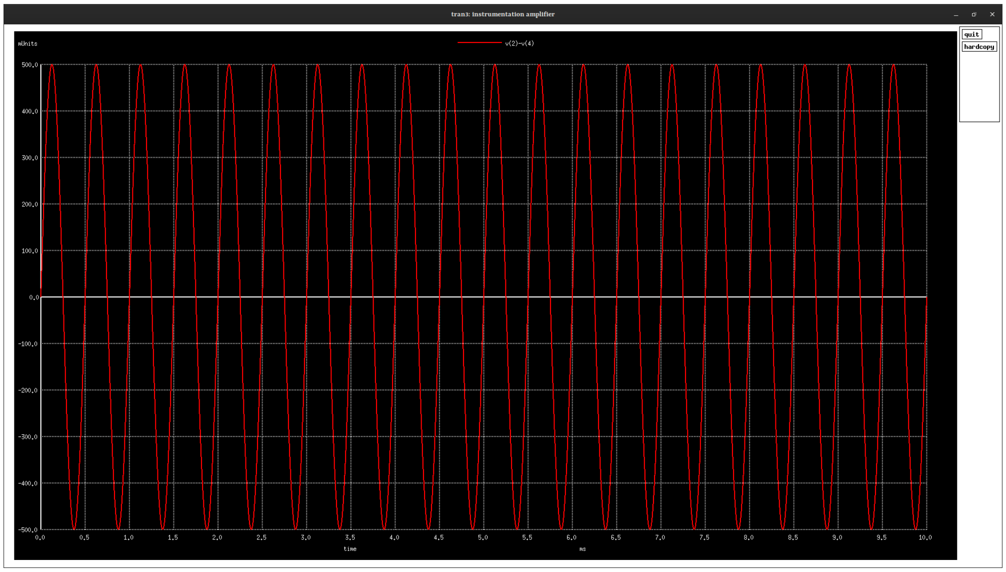
The cutoff frequency for the amplifier has been calculated using the 3dB frequency. Experimentally it came out to 580Hz

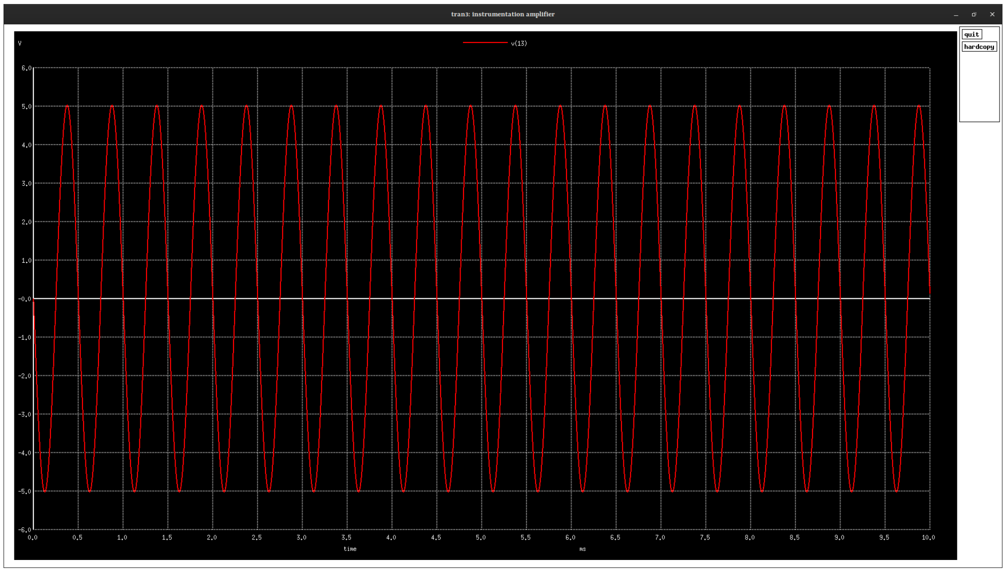
3 op-amp based Instrumentation Amplifier





tran1: instrumentation amplifier
Units
v(4)-v(1)
v(13)
v(2)-v(1)
quit
hardcopy
3,0
2,5
2,0
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2,0
-2,5
-3,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0
5,5
6,0
6,5
7,0
7,5
8,0
8,5
9,0
9,5
10,0
time
ms


tran3: instrumentation amplifier
quit
hardcopy
mUnits
v(2)-v(4)
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
-500.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
time
ms


tran3: instrumentation amplifier
quit
hardcopy
v(13)
V
6.0
5.0
4.0
3.0
2.0
1.0
-0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
time
ms

3.3 Explanation

$$gain = \frac{R4}{R3} * (1 + \frac{2R5}{R10}) \tag{1}$$

differential gain came out to be 10.