**EE 230 Lab** Lab 4 report

Report: **Non-ideal effects in op-amps**

Lab work done by _____Sean Gordon_____

and _____Tejas Agarwal_____

Lab work date: 3-6-2019

Report submission date: 3-13-2019

Lab Section: E

Graded by _____

Score _____

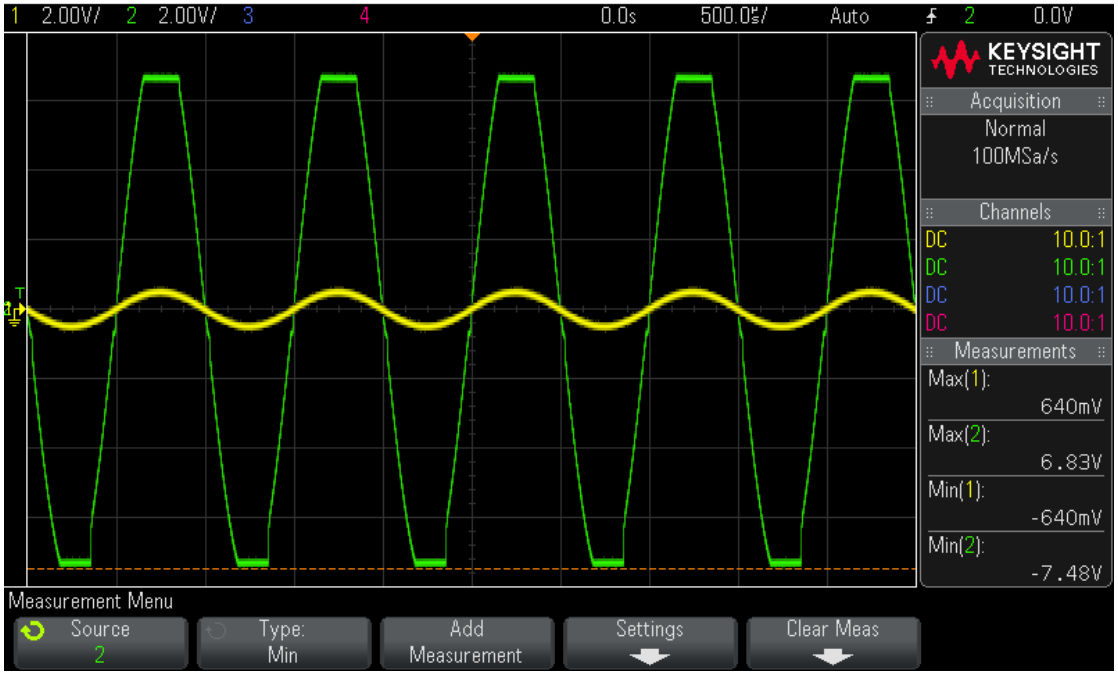
**Introduction**

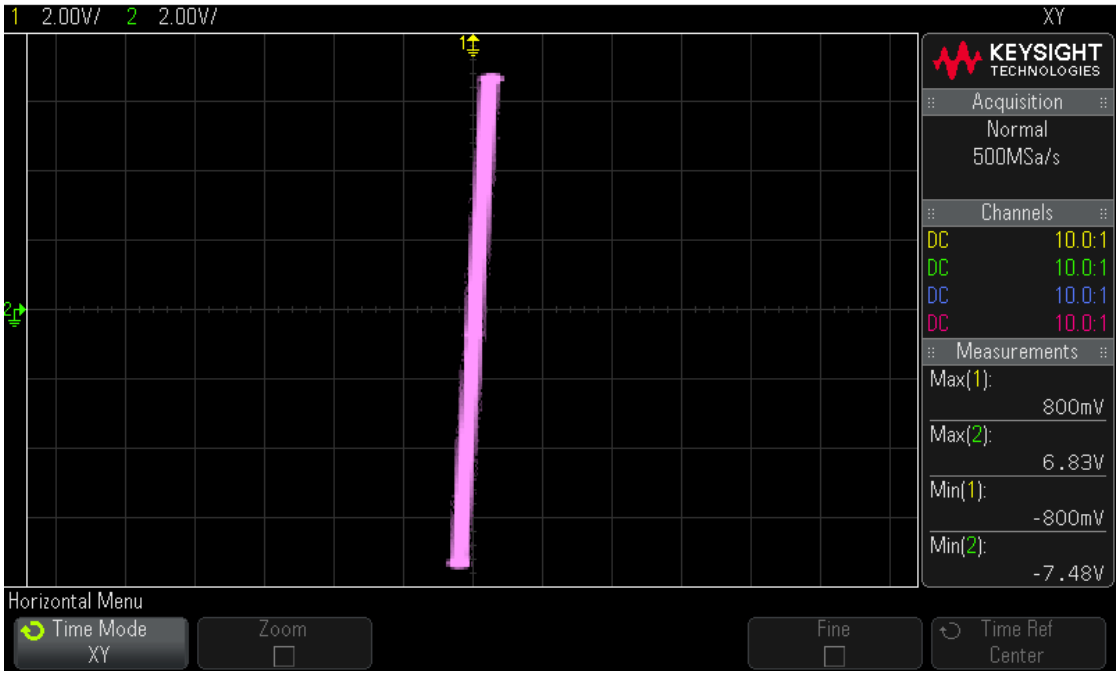
This lab focuses entirely on the limitations of operational amplifiers. The lab contains several scenarios designed to draw attention to specific limitations, going through each in turn.

## A. Power supplies and output voltage limits

### 324 op amp

Figures: Insert images of the oscilloscope trace of the clipped $v_o$ from the 324 non-inverting amp and the x-y transfer function plot.



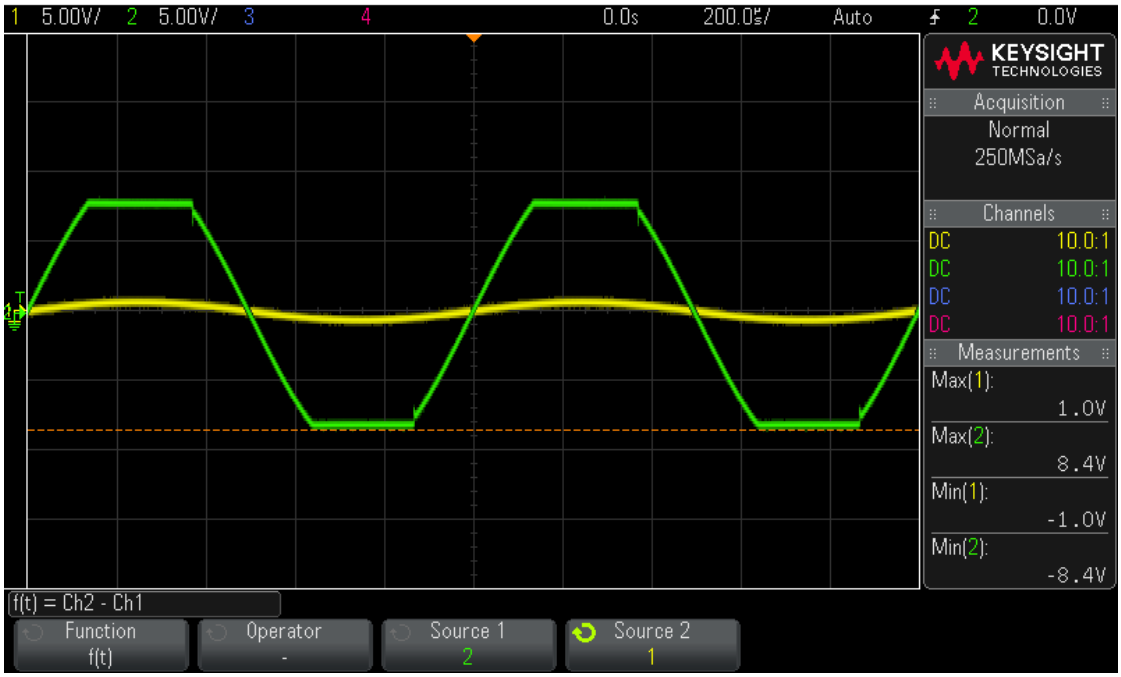



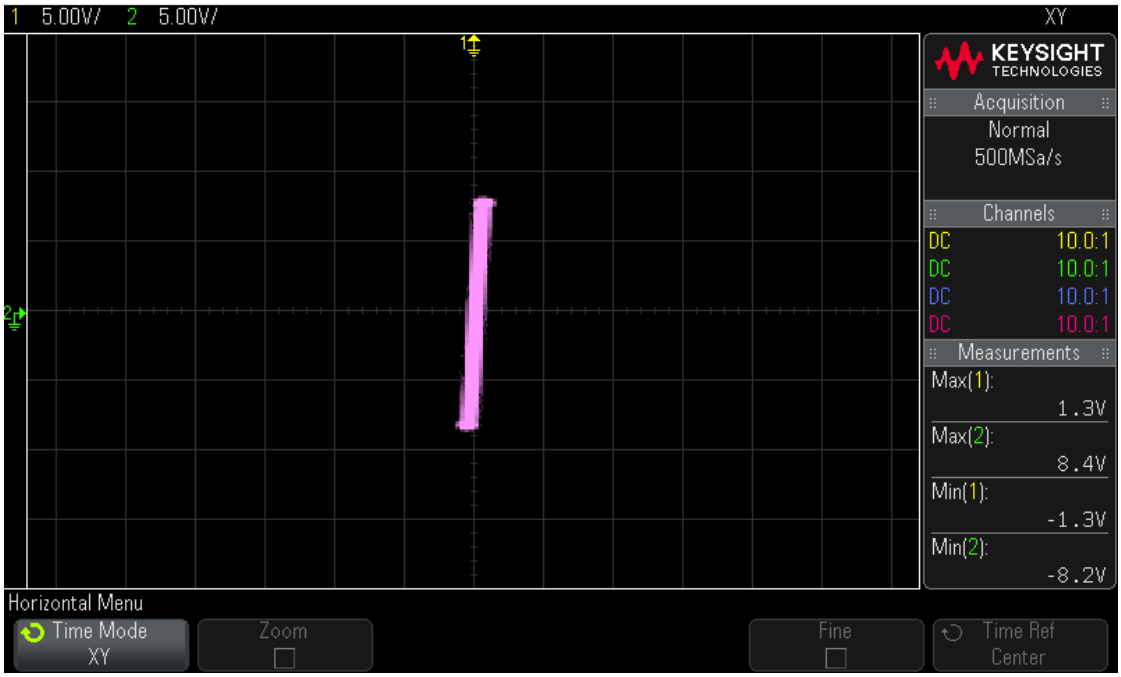

Measured positive output limit: $V_{L+}$_____**6.83v**_____

Measured negative output limit: $V_{L-}$_____**-7.48v**_____

**660 amp**

Figures: Insert images of the oscilloscope trace of the clipped $v_o$ from the 660 non-inverting amp and the x-y transfer function plot.

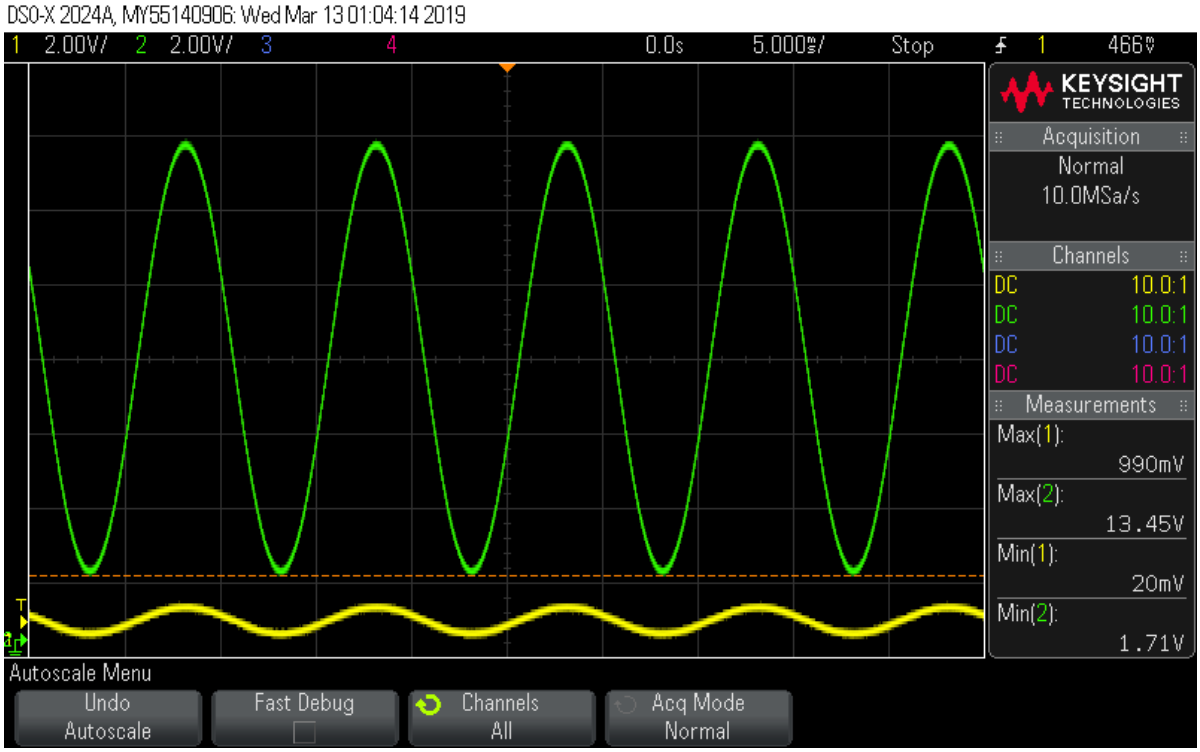



Measured positive output limit: $V_{L+}$_____**8.4v**_____

Measured negative output limit: $V_{L-}$_____**-8.4v**_____

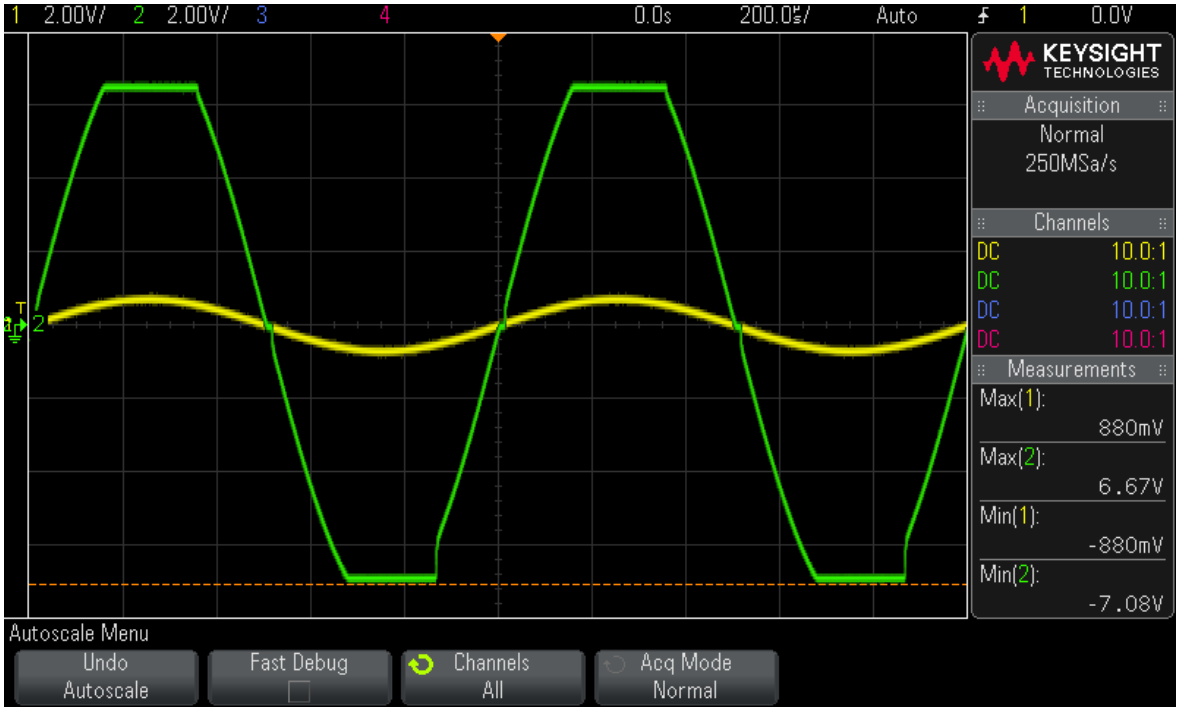
Figures: Insert an image of the oscilloscope trace of the clipped and unclipped $v_o$ from the 660 amp using a single power supply.

## B. Output current limits

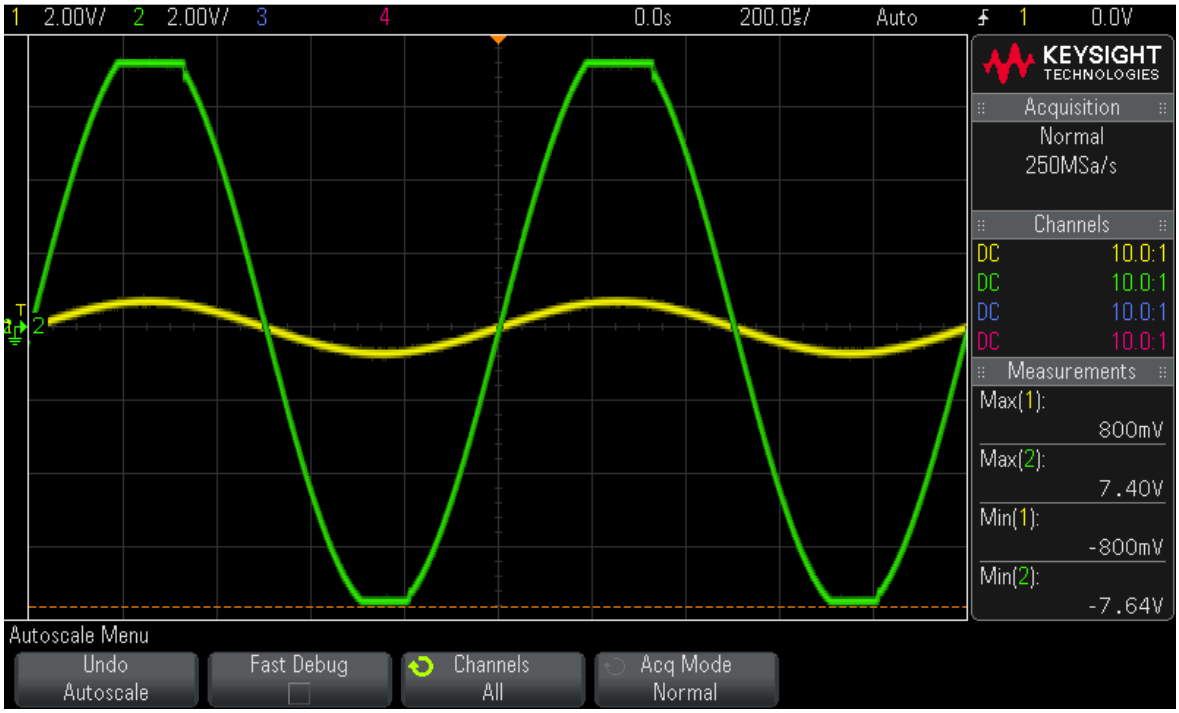
**324:** Measured maximum output current:_____48mA_____

Figure: Insert an image of the output voltage when the output current is at its limit.




**660:** Measured maximum output current:_____37mA_____

Figure: Insert an image of the output voltage when the output current is at its limit.



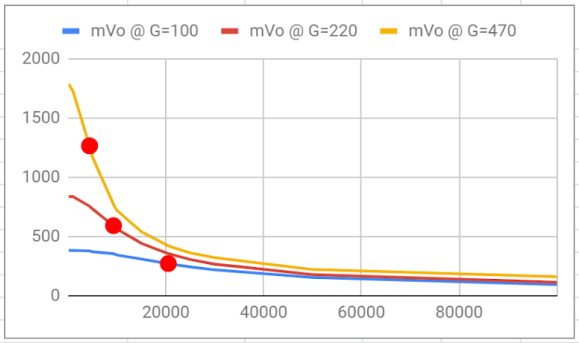
## C. Gain-bandwidth limitations

**660:** Measured gain-bandwidth product:_____2.055mHz_____
*(List the three measured values and also the average of those.)*

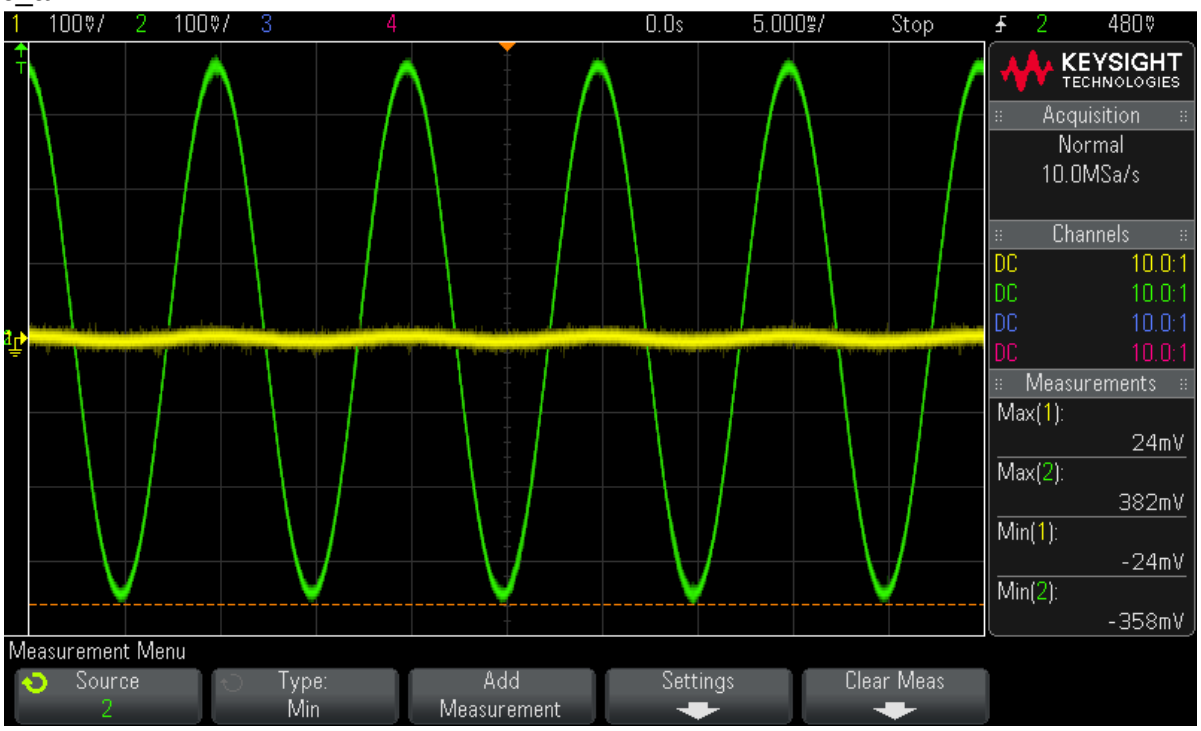
FreqA = 20.5kHz FreqB = 9.3kHz FreqC = 4.4kHz
Freq_Avg = 11.4kHz

Figure: Insert the plot showing the three low-pass responses for the three different gains.

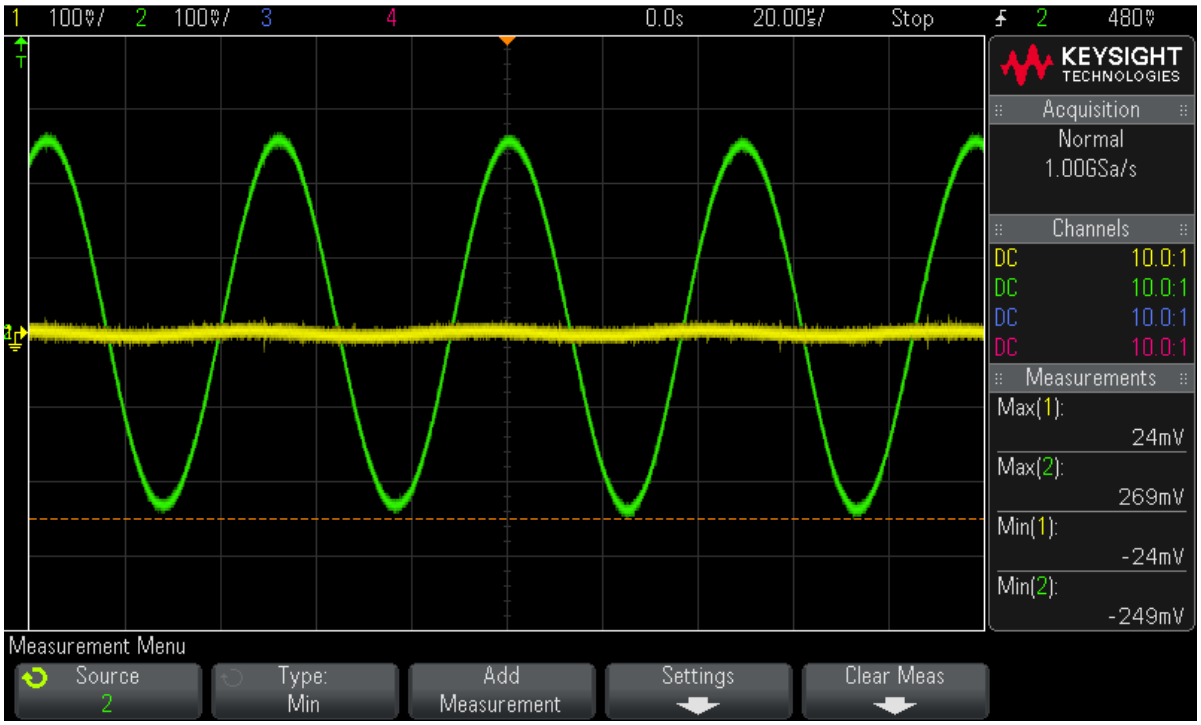
| | A | B | C | D |
|---|---|---|---|---|
| 1 | Freq | mVo @ G=100 | mVo @ G=220 | mVo @ G=470 |
| 2 | 100 | 382 | 836 | 1790 |
| 3 | 1000 | 382 | 836 | 1730 |
| 4 | 4400 | 378 | 756 | 1266 |
| 5 | 5000 | 370 | 732 | 1170 |
| 6 | 9300 | 354 | 591 | 770 |
| 7 | 10000 | 342 | 563 | 720 |
| 8 | 15000 | 309 | 442 | 540 |
| 9 | 20500 | 270 | 354 | 420 |
| 10 | 25000 | 241 | 305 | 360 |
| 11 | 30000 | 217 | 265 | 320 |
| 12 | 50000 | 153 | 177 | 220 |
| 13 | 100000 | 92 | 112 | 160 |
| 14 | | | | |
| 15 | Vmax / √2 | 270 | 591 | 1266 |
| 16 | | | | |



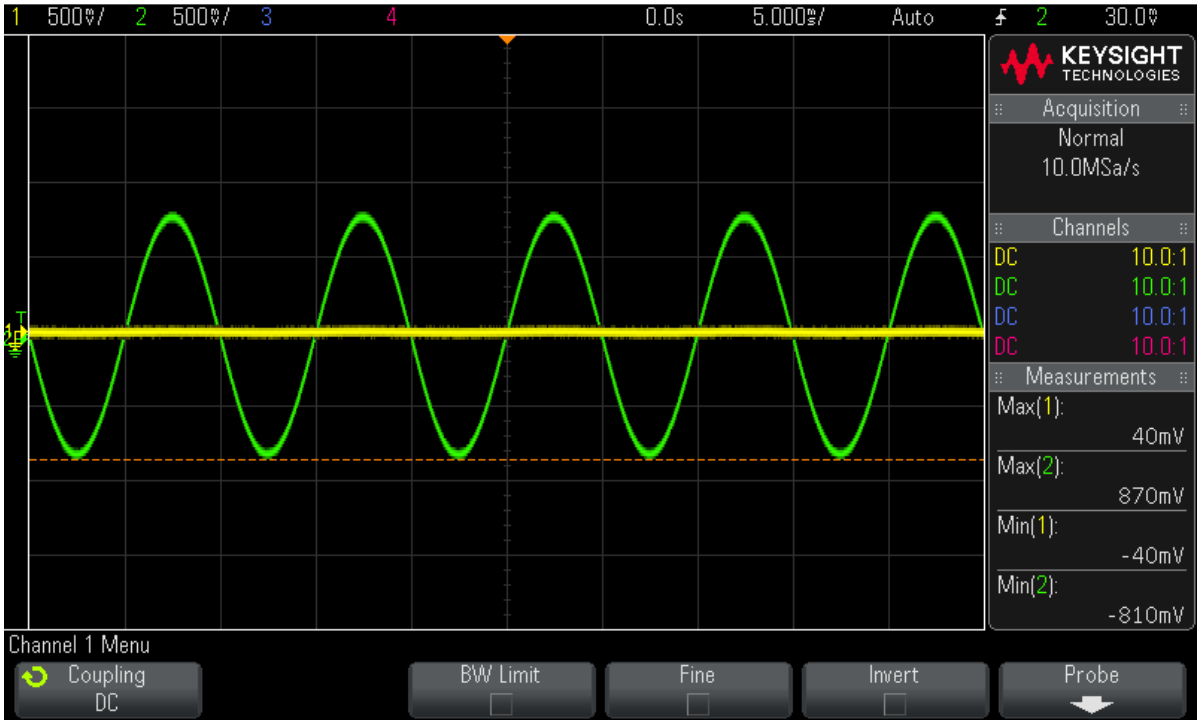
c_a1


1 100mV/ 2 100mV/ 3 4 0.0s 5.000ns/ Stop 2 480mV
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
10.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
DC 10.0:1
DC 10.0:1
Measurements
Max(1):
24mV
Max(2):
382mV
Min(1):
-24mV
Min(2):
-358mV
Measurement Menu
Source 2
Type: Min
Add Measurement
Settings
Clear Meas

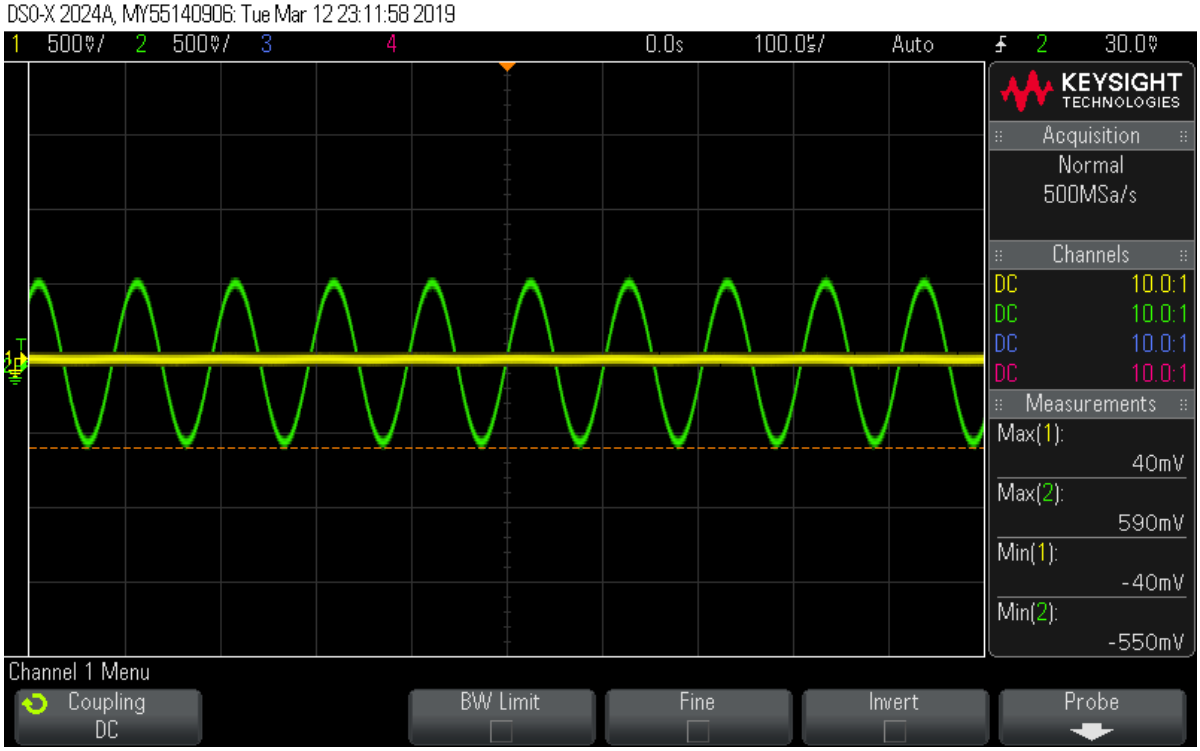
c_a2


1 100mV/ 2 100mV/ 3 4 0.0s 20.00ns/ Stop 2 480mV
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
1.00GSa/s
Channels
DC 10.0:1
DC 10.0:1
DC 10.0:1
DC 10.0:1
Measurements
Max(1):
24mV
Max(2):
269mV
Min(1):
-24mV
Min(2):
-249mV
Measurement Menu
Source 2
Type: Min
Add Measurement
Settings
Clear Meas

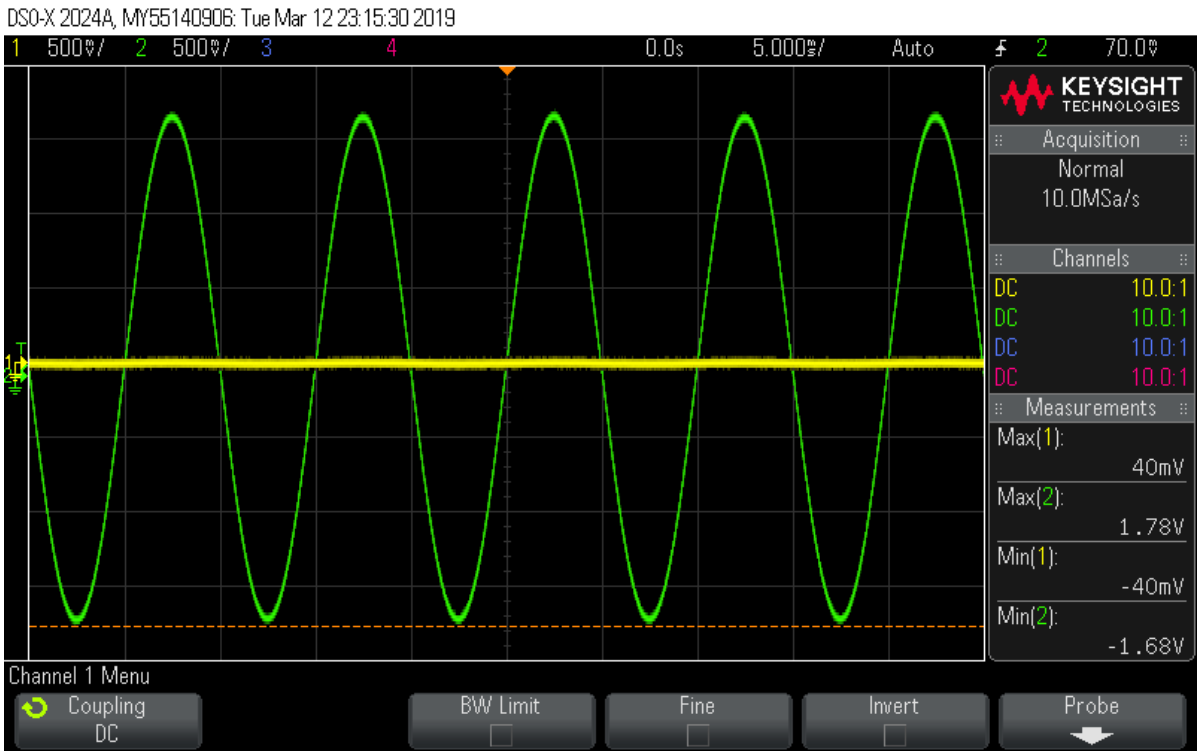
c_b1


1 500mV/ 2 500mV/ 3 4 0.0s 5.000ms/ Auto 2 30.0mV
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
10.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
DC 10.0:1
DC 10.0:1
Measurements
Max(1):
40mV
Max(2):
870mV
Min(1):
-40mV
Min(2):
-810mV
Channel 1 Menu
Coupling
DC
BW Limit
Fine
Invert
Probe

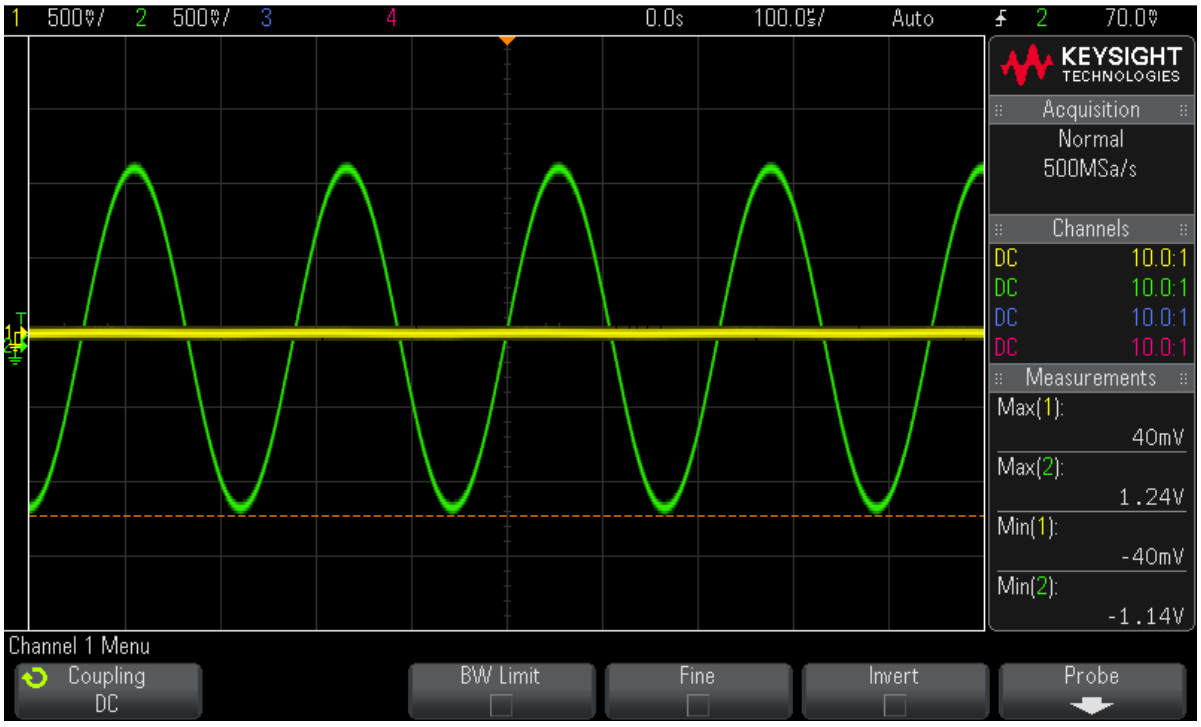
c_b2


DSO-X 2024A, MY55140906: Tue Mar 12 23:11:58 2019
1 500mV/ 2 500mV/ 3 4 0.0s 100.0ns/ Auto 2 30.0mV
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
500MSa/s
Channels
DC 10.0:1
DC 10.0:1
DC 10.0:1
DC 10.0:1
Measurements
Max(1):
40mV
Max(2):
590mV
Min(1):
-40mV
Min(2):
-550mV
Channel 1 Menu
Coupling
DC
BW Limit
Fine
Invert
Probe

c_c1


DSO-X 2024A, MY55140906: Tue Mar 12 23:15:30 2019
1 500mV/ 2 500mV/ 3 4 0.0s 5.000ns/ Auto 2 70.0mV
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
10.0MSa/s
Channels
DC 10.0:1
DC 10.0:1
DC 10.0:1
DC 10.0:1
Measurements
Max(1):
40mV
Max(2):
1.78V
Min(1):
-40mV
Min(2):
-1.68V
Channel 1 Menu
Coupling
DC
BW Limit
Fine
Invert
Probe

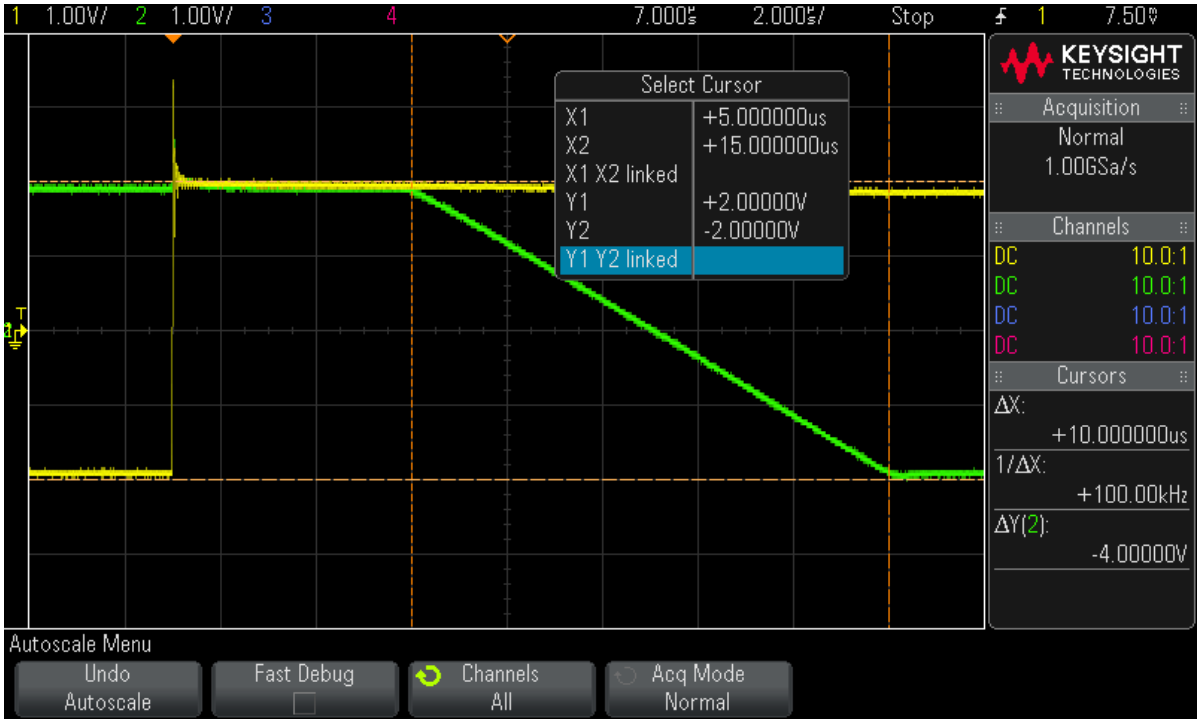
c_c2


DSO-X 2024A, MY55140906: Tue Mar 12 23:17:01 2019
1 500mV/ 2 500mV/ 3 4 0.0s 100.0ns/ Auto 2 70.0mV
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
500MSa/s
Channels
DC 10.0:1
DC 10.0:1
DC 10.0:1
DC 10.0:1
Measurements
Max(1):
40mV
Max(2):
1.24V
Min(1):
-40mV
Min(2):
-1.14V
Channel 1 Menu
Coupling
DC
BW Limit
Fine
Invert
Probe

## D. Slew-rate limitations

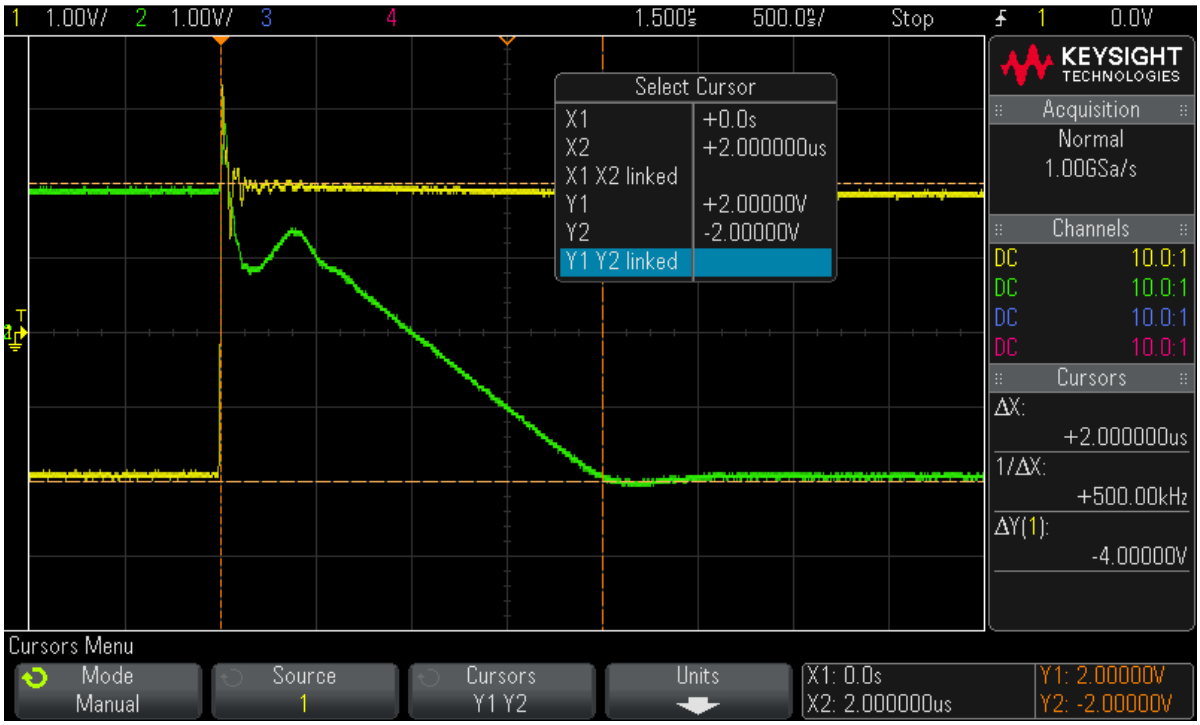
**324:** Measured slew rate:_____.4v/us_____

Figure: Insert an image of slew-rate limited output for the 324 amp.



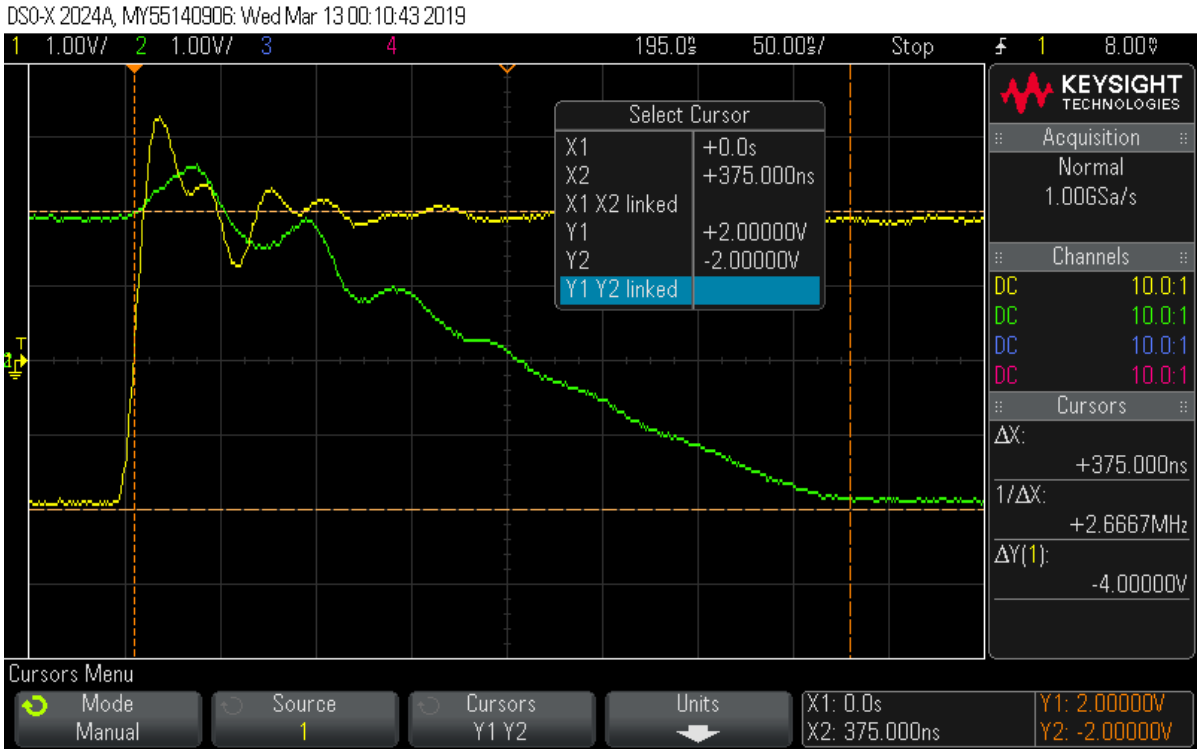

**660:** Measured slew rate:_____2v/us_____

Figure: Insert an image of slew-rate limited output for the 660 amp.

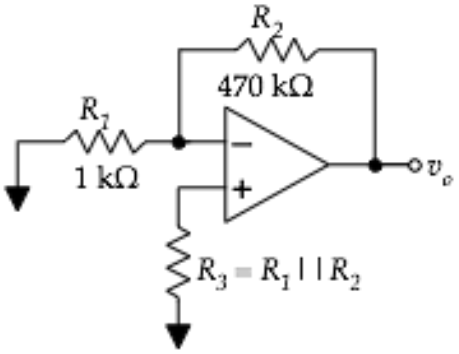


**082:** Measured slew rate:_____10.6v/us_____

Figure: Insert an image of slew-rate limited output for the TL082 amp.



## E. Offset voltage and bias currents




**324:**

Measured $v_o$ with $R_3$ in place = _____-7.9v_____

Offset voltage: $V_{OS}$ = _____.016v_____

Measured $v_o$ with $R_3$ shorted = _____.28v_____

Difference in $v_o$ measurements = _____8.18v_____

Bias current: $I_B$ = _____.0005A_____

**660:**

Measured $v_o$ with $R_3$ in place = _____50mv_____

Offset voltage: $V_{OS}$ = _____.0001v_____

Measured $v_o$ with $R_3$ shorted = _____-20mv_____

Difference in $v_o$ measurements = _____70mv_____

Bias current: $I_B$ = _____.00004A____

**082:**

Measured $v_o$ with $R_3$ in place = _____8v_____

Offset voltage: $V_{OS}$ = _____.017v_____

Measured $v_o$ with $R_3$ shorted = _____8v_____

Difference in $v_o$ measurements = _____0v_____

Bias current: $I_B$ = _____0A_____

## Conclusion

This lab focuses on specific limitations of operational amplifiers, and throughout the course of the lab runs the op-amps in question through a series of tests designed to highlight those limitations. This lab went largely without hitches, however the supplied potentiometers suck and break all the time so part B was very delayed.