Physics 111A Lab 5

Pre-Lab Questions

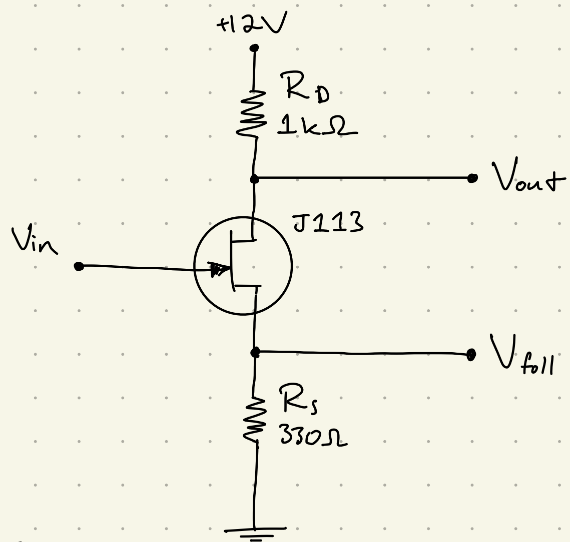
1) To increase gain, either R_S can decrease or R_D can increase. Arbitrarily increasing R_D values would cause the current to decrease, making it harder to read the signal. Decreasing R_S would cause r_s to become dominant and make the gate fall out of the ideal regime.

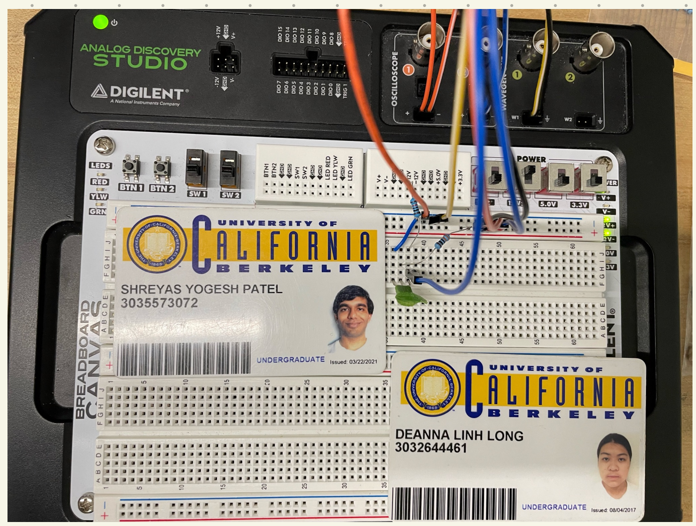
2) A 100 MHz carrier modulated at 5 kHz extends between a band of frequencies from 99.995 - 100.005 MHz.

3) One gate is held at a constant V_{GS} being connected to ground while the other is able to be modified. This means that if by changing the V_{GS} of one gate, you change how much current can pass through its side of the circuit and in turn how much has to the go through the other gate. This then means that a higher current through the grounded gate means a lower V_{out} since the V across R_D will increase.

Lab Exercises:

Problem R5.1:





$V_{GS} = 0.1\ mV$

$V_{foll} = 1.317\ V$

$V_{out} = 7.97\ V$

$I_{DS} = 3.95\ mA$

$V_{DS} = 6.65\ V$

a) $\frac{V_{foll}}{V_{in}} = G = 0.757$

$G = \frac{R_s}{R_s + r_s} \Rightarrow G(R_s + r_s) = R_s \Rightarrow r_s = \left(\frac{1-G}{G}\right) R_s = 106\ \Omega$

b) $V_{out} = 163\ mV$

$G = -2.329$

exact $G = -\frac{R_D}{R_s + r_s} = -\frac{1k\Omega}{330 + 106} = -2.29$

approx $G \approx -\frac{R_D}{R_s} = -3.03$

The approximate gain equation can be seen as close enough.

V_{out} is inverted

$\langle V_{out} \rangle = 7.96\ V$

c) max amp $V_{out} = 4.14\ V$

The amplitude is limited by Vout being unable to exceed 12V, the V_D

Problem R5.2

R_D (kΩ)	G	$\langle V_{out} \rangle$ (V)
1	-2.329	7.96
1.5	-3.44	5.97
2.2	-4.44	3.34
3	-1.02	1.64
5.1	-0.124	0.87
7.5	-0.071	0.58
10	-0.054	0.44

The largest gain was -4.44.

The gain peaks when $\langle V_{out} \rangle \approx$ max V_{out} amplitude and decreases when R_D changes this value to lower or higher values.

Problem R5.3

R_S (Ω)	G	$-\frac{R_D}{R_S}$	r_s (Ω)
100	−4.64	−10	115.5
47	−1.256	−21.27	749.2
22	−0.65	−45.45	1516.5
10	−0.509	−100	1954.6
0	−0.453	∞	2207.5

The gain is smaller and smaller as R_s decreases while the simplified gain formula increases.

$$G = -\frac{R_D}{R_s + r_s} \Rightarrow r_s = -\frac{R_D + G R_s}{G}$$

Problem R5.4

$$G = \frac{R_D}{R_s}, \quad Z_s = \left(\frac{1}{R} + j\omega C\right)^{-1} = \left(\frac{1+j\omega RC}{R}\right)^{-1} = \frac{R}{1+j\omega RC} = \frac{R(1-j\omega RC)}{1+(\omega RC)^2}, \quad R_s = \frac{R}{1+(\omega RC)^2}, \quad G = \frac{G_0}{\sqrt{2}}$$

$$\log G = 3 \Rightarrow \log\left(\frac{R_D(1+(\omega RC)^2)}{R}\right) = 3 \Rightarrow \frac{R_D}{R}\left(1+(\omega RC)^2\right) = 10^3 \Rightarrow 1+(\omega RC)^2 = \frac{10^3 R}{R_D} \Rightarrow \omega RC = \left(\frac{10^3 R}{R_D} - 1\right)^{\frac{1}{2}} \Rightarrow \omega = \frac{1}{R_s C}\left(\frac{10^3 R_s}{R_0} - 1\right)^{\frac{1}{2}}$$

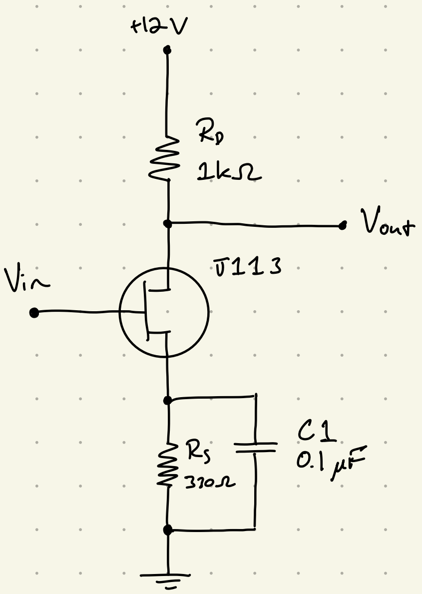
$$G = \frac{1}{\sqrt{2}} G_0 \Rightarrow$$

$R_s = 330\Omega$

JFET	G @ ω = 200 kHz
0	19.5 dB
1	19.6 dB
2	19.5 dB
3	19.3 dB
9	19.4 dB
Ave.	19.45 dB
STD	0.123

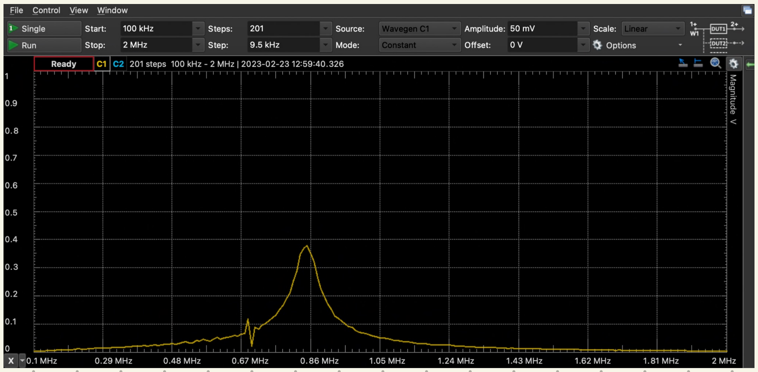
$R_s = 0\Omega$

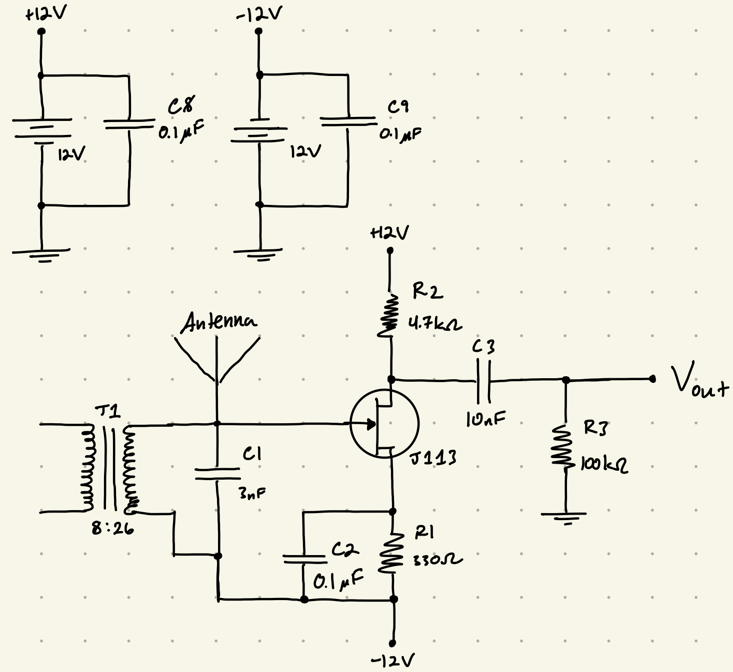
JFET	G @ ω = 200 kHz
0	−7.01 dB
1	−5.34 dB
2	−7.96 dB
3	−5.625 dB
9	−8.4 dB
Ave.	−6.88
STD	1.348



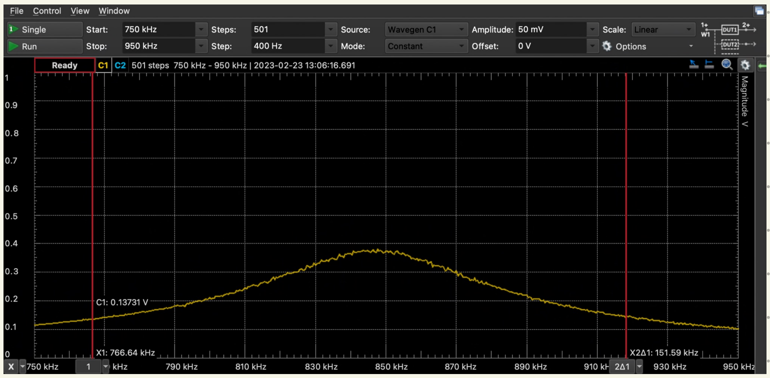
Problem R 5.5

c)





d)



$$f_0 = 847.73 \text{ kHz}$$

$$2\pi f_0 = \frac{1}{\sqrt{LC_1}} \Rightarrow L = \frac{1}{(2\pi f_0)^2 C_1} = \frac{1}{(2\pi(847.73 \text{ kHz}))^2 (3 \text{ nF})} = 11.75 \ \mu H$$

The number of coils and how tightly they were wound as well as the antenna placement and length are all possible sources of error.

$$V_{peak} = 0.37895 \text{ V}$$

$$V_{-3dB} = 816.73 \text{ kHz}, \ 876.2 \text{ kHz}$$

e) $$Q = \frac{847.73 \text{ kHz}}{(876.2 - 816.73) \text{ kHz}} = 14.25$$

i) $$Q = R_{par}\sqrt{\frac{C}{L}} \Rightarrow R_{par} = Q\sqrt{\frac{L}{C}} = 14.25\sqrt{\frac{11.75 \ \mu H}{3 \text{ nF}}} = 891.812 \ \Omega$$

It is not plausible that R_{par} is the cause of the low Q since the only R_{par} is R_g of the JFET which is much higher then the calculated R_{par}.

ii) $$Q = \frac{1}{R_{ser}}\sqrt{\frac{L}{C}} \Rightarrow R_{ser} = \frac{1}{Q}\sqrt{\frac{L}{C}} = \frac{1}{14.25}\sqrt{\frac{11.75 \ \mu H}{3 \text{ nF}}} = 4.392 \ \Omega$$

for 22 gauge, $R/\ell = 52.9392 \ \Omega \text{km}^{-1}$, $\ell \approx 3 \text{m}$, $R_{wire} = 0.1588 \ \Omega$
resistance of the wire is too low to explain the low Q

Our BW is 59.47 kHz, so upto ~6 stations can be received simultaneously.

f) predicted $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(11.75\mu H)(1nF)}} = 1.47 \text{ MHz}$

measured $f_0 = 1.33 \text{ MHz}$

The resonat frequency does change. Measured value has a % diff of 9.5% from predicted.

g) peak $V_{out} = 0.39109V$

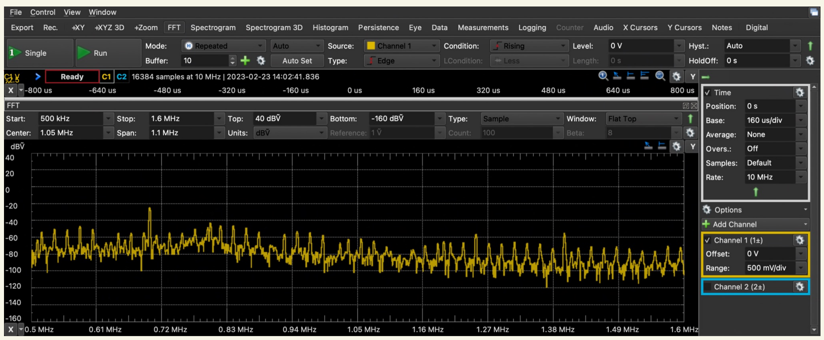
peak $V_{C1} = 0.02783V$

$G = 14.05$

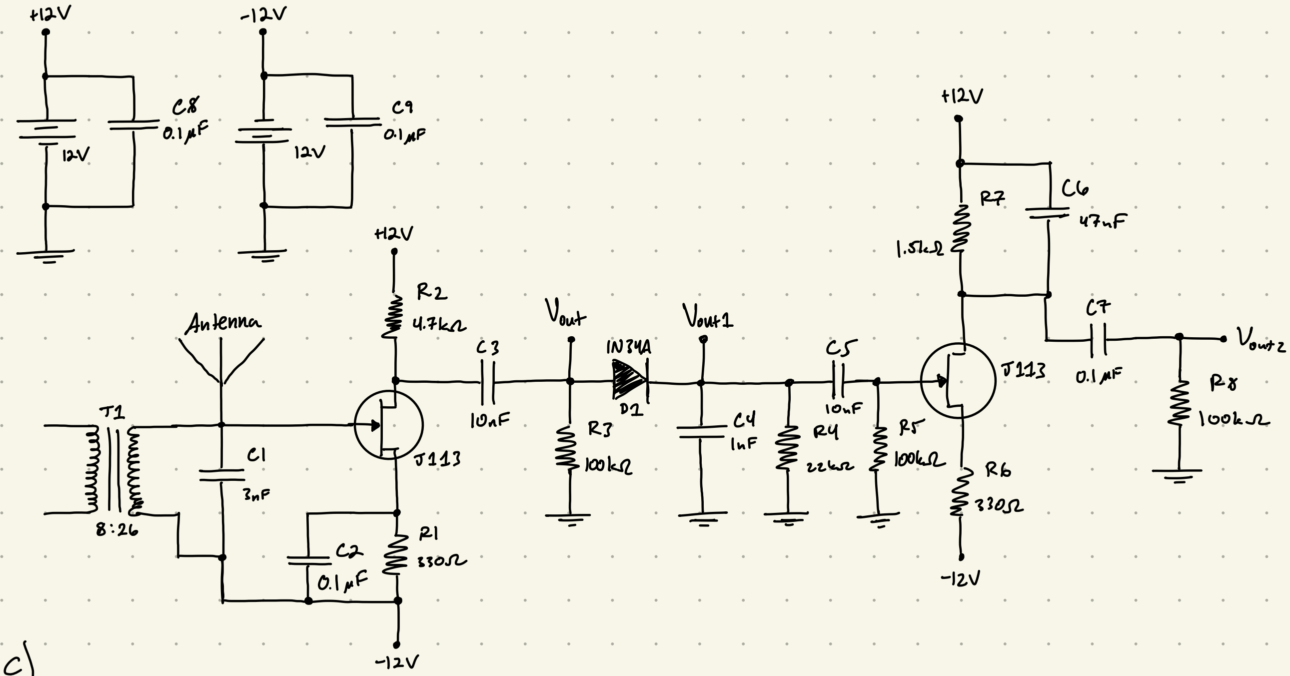
h) $w = \frac{1}{\sqrt{LC}} \Rightarrow C = \frac{1}{w^2 L} = \frac{1}{(2\pi f)^2 L}$

$f = 740 \text{ kHz}, \quad C = \frac{1}{(2\pi(740 \text{ kHz}))^2 (11.75\mu H)} = 3.94 \times 10^{-9} F = 3.94 nF \approx 4nF$

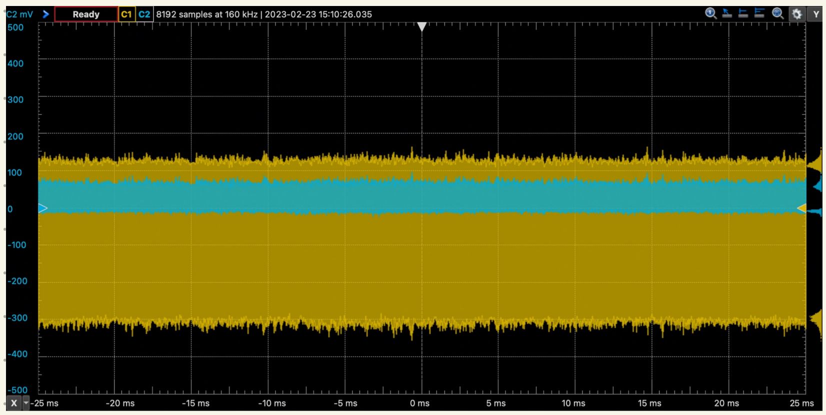
i)



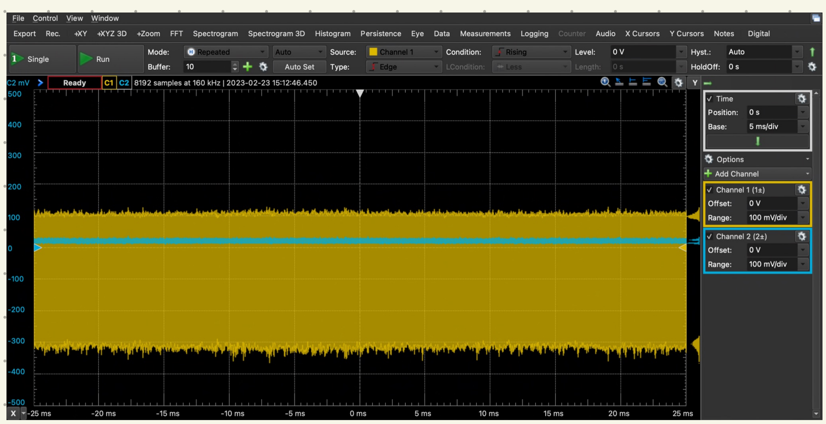
Problem R5.6



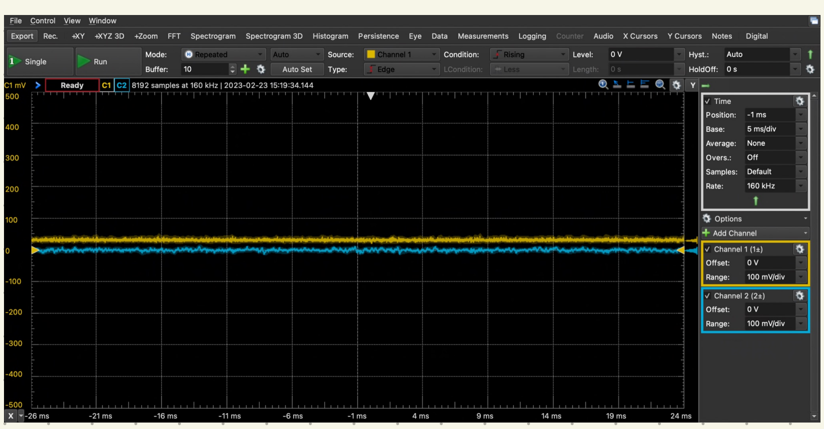
c)



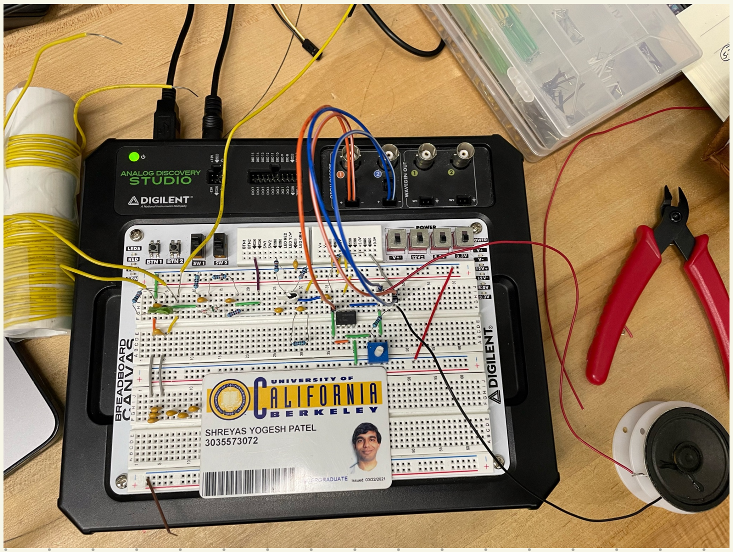
d)



e)



Problem R5.7

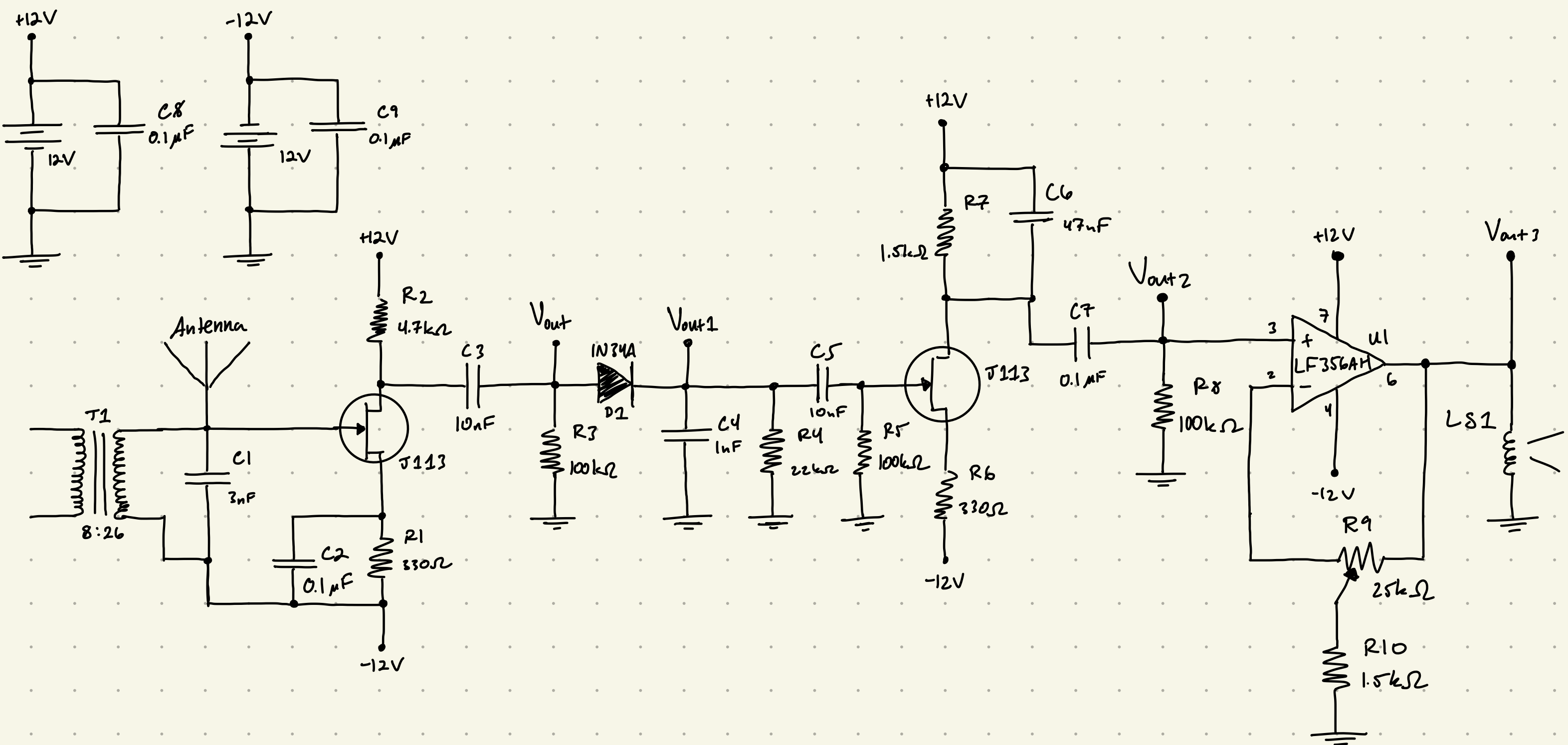


d)

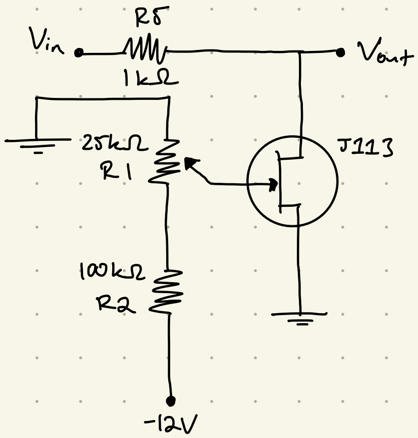
station	frequency (kHz)	C1 (nF)
KCBS	740	3.94
KVTO	1400	1.1
KMKY	1310	1.26

$$C_1 = \frac{1}{(2\pi f)^2 L}$$

We used a fake radio source using Waveforms.

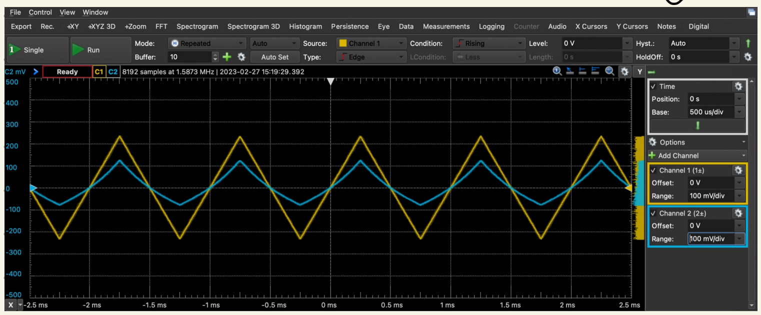


Problem R5.8

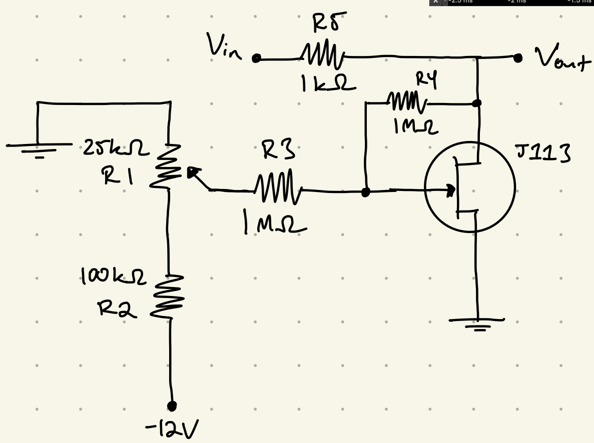


The higher Vout gets, the more distorted Vout becomes, becoming more distorted and non-linear.

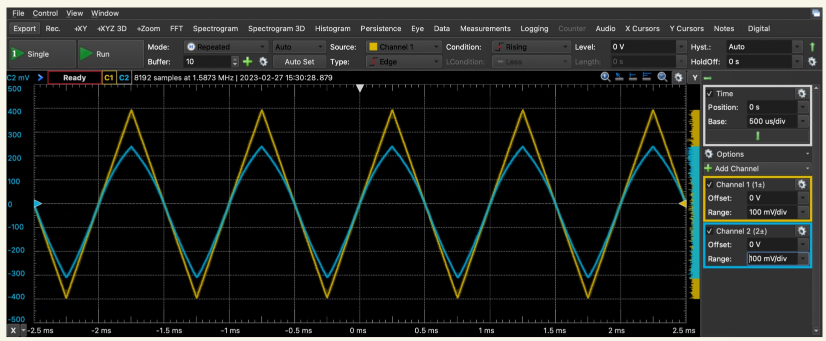
The largest signal to pass relatively undistorted is $V_{in} = 240\,mV$.



Problem R5.9



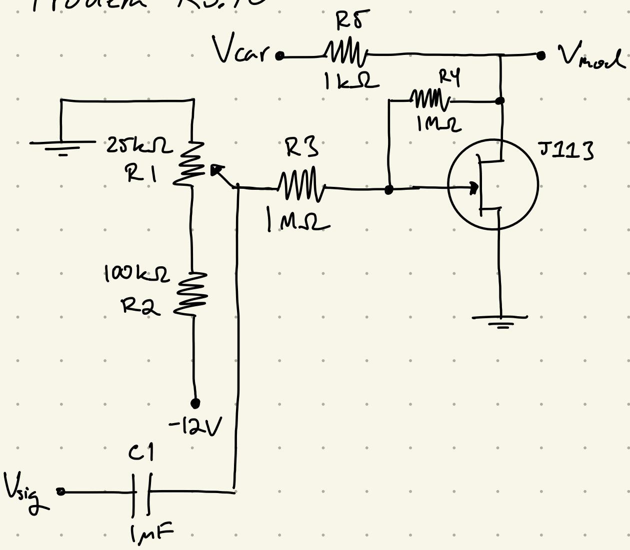
Largest is now $V_{in} = 400\,mV$.

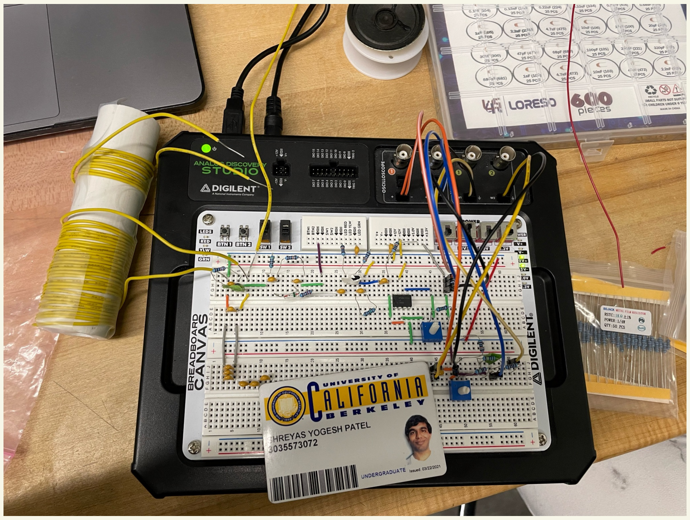


Attenuation: $\frac{V_{out}}{V_{in}} = \frac{391.1\,mV}{238.6\,mV} = 0.61$

$$V_{out} = \frac{R_{DS}}{R_{DS} + R_5} V_{in} \Rightarrow A = \frac{R_{DS}}{R_{DS} + R_5} \Rightarrow A R_{DS} + A R_5 = R_{DS} \Rightarrow R_{DS} = \frac{A}{1-A} R_5 = \frac{0.61}{0.39}(1\,k\Omega) = \underline{1.564\,k\Omega}$$

Problem R5.10



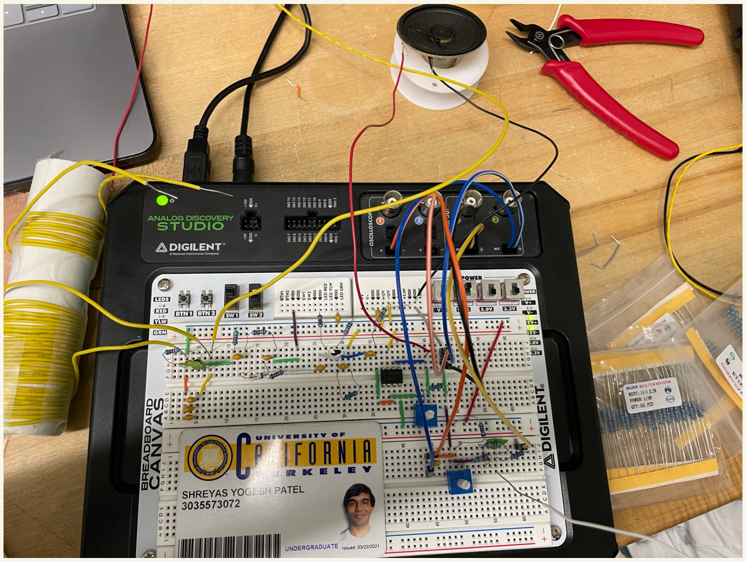


Problem R5.11

$f = 490\,kHz$, $C_1 = \dfrac{1}{(2\pi f)^2 L} = 8.978\ nF \approx 9\ nF$

used $C_1 = 8.7\ nF$, $4\ nF$ capacitors in parallel with $4.7\ nF$ capacitor

$f = 400\,kHz$, $C_1 = 13.47\ nF \approx 13.5\ nF$

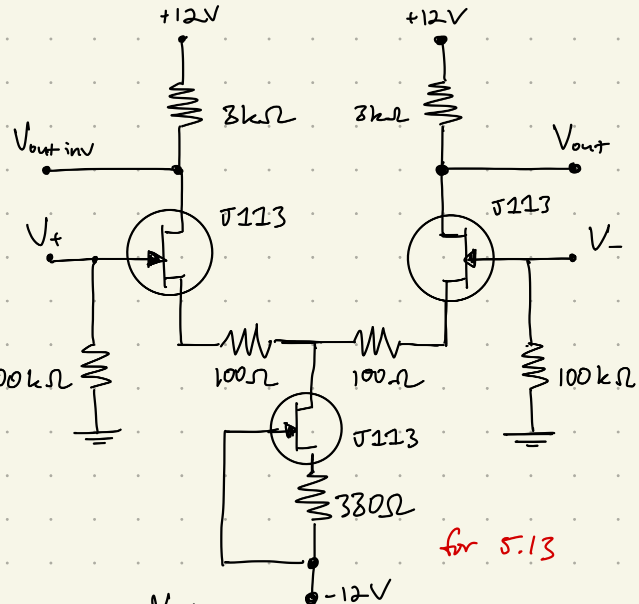


Problem R5.12

a) $V_+ = 95.93\ mV$, $V_- = -101.25\ mV \Rightarrow V_\Delta = \frac{1}{2}(95.93 + 101.25) = 98.59\ mV$

$V_{out} = 0.8\ V$, $V_{\Delta\,ideal} = \frac{1}{2}(100 + 100) = 100\ mV$

$G_\Delta = \frac{0.8V}{98.59\ mV} = 8.11$, ideal $G_\Delta = \frac{0.8\ V}{100\ mV} = 8$



b) V_{out} is in phase with V_+ so its phase is also $0°$.

c) $V_+ = 99.78\ mV$, $V_{out} = 0.35\ V$, $V_- = 0\ V$

$V_\Delta = \frac{1}{2}(99.78 - 0) = 49.89\ mV$

$\frac{V_{out}}{\sqrt{V_\Delta^2 + V_+^2}} = 3.14$, V_{out} is in phase with V_+ still

$V_c = \frac{1}{2}(99.78 + 0) = 49.89\ mV$

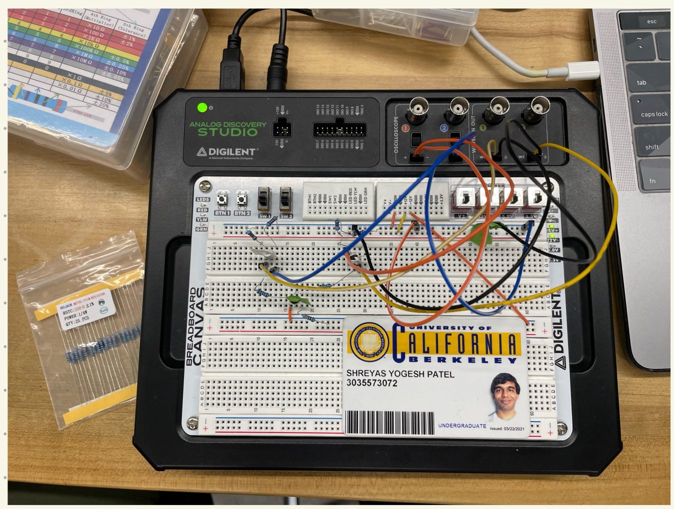
d) $V_+ = 0V$, $V_{out} = 0.36V$, $V_- = -100.8\ mV \Rightarrow V_\Delta = \frac{1}{2}(100.8) = 50.4\ mV \Rightarrow G_\Delta = \frac{V_{out}}{V_\Delta} = 7.14$

V_{out} is $180°$ out of phase with V_-

e) $V_+ = 99.89\ mV$, $V_{out} = -0.121\ V$, $V_- = 98.9\ mV \Rightarrow V_\Delta = 0.495\ mV$, $V_c = 99.395\ mV \Rightarrow G_c = \frac{V_{out}}{V_c} = -1.22$

$G_c = \frac{R_D}{2R_1 + R_s} = \frac{3k\Omega}{2(10k\Omega) + 100\Omega} = 0.149$, The gain is an order magnitude of 10 off.

Problem R5.13



a) $V_+ = 99.15\ mV$, $V_- = -100.76\ mV$

$V_{out} = 1.1619\ V$

$V_\Delta = \frac{1}{2}(V_+ - V_-) = \frac{1}{2}(99.15 + 100.76) = 99.955\ mV$

$V_c = \frac{1}{2}(V_+ + V_-) = \frac{1}{2}(99.15 - 100.76) = -0.805\ mV$

$G_\Delta = \frac{V_{out}}{V_\Delta} = \frac{1.1619\ V}{99.955\ mV} = 11.6$

$G_c = \frac{V_{out}}{V_c} = \frac{1.1619\ V}{-0.805\ mV} = -1441$

The performance improves because the current source is self-biased and mory strictly regulates the current flow through the differential amplifier

b) We warmed the JFET with an input of V_+ and it decreased $V_{out\,inv}$, creating an offset between V_{out} and $V_{out\,inv}$.

When both JFETs are warmed simultaneously, there is no change.

c) JFETs that are unmatched causes a difference between V_{out} and $V_{out\,inv}$ in order of magnitude of several volts.