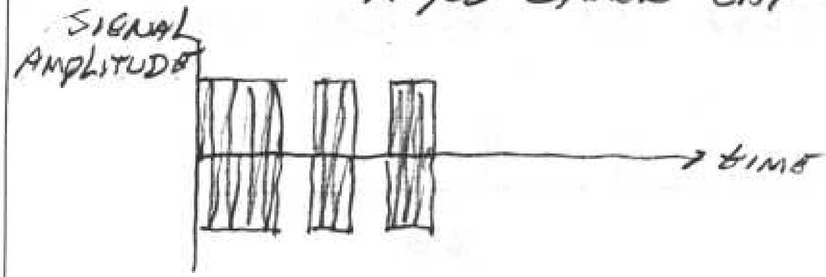
# NOTES FOR 6.002 LECTURE #25, MAY 13, 2003

## AMPLITUDE MODULATED RADIO SIGNAL RECEIVER

HISTORY: MARCONI 1895 – 1902
KEYED SPARK GAP SIGNAL

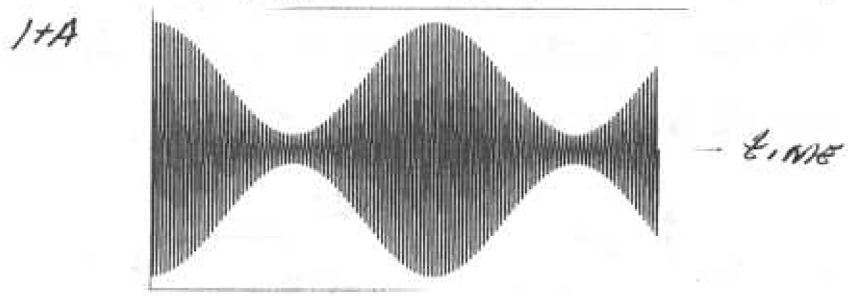



## AMPLITUDE MODULATION

GIVEN SIGNAL TO SEND $\cos(\omega_s t)$
CARRIER SIGNAL $\cos(\omega_c t)$ $\Big\}$ $\omega_c \gg \omega_s$

MODULATED SIGNAL $f(t) = \left(1 + A\cos(\omega_s t)\right)\cos\omega_c t$

A – MODULATION INDEX $0 < A < 1$

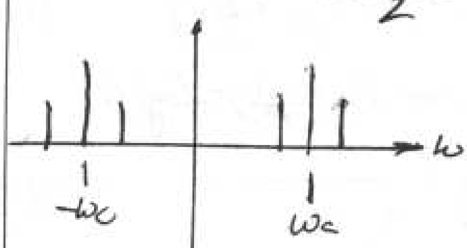



IN FREQUENCY DOMAIN:

$$f(t) = \left(1 + \frac{A}{2}\left(e^{j\omega_s t} + e^{-j\omega_s t}\right)\right)\left(\frac{e^{j\omega_c t} - e^{-j\omega_c t}}{2}\right)$$

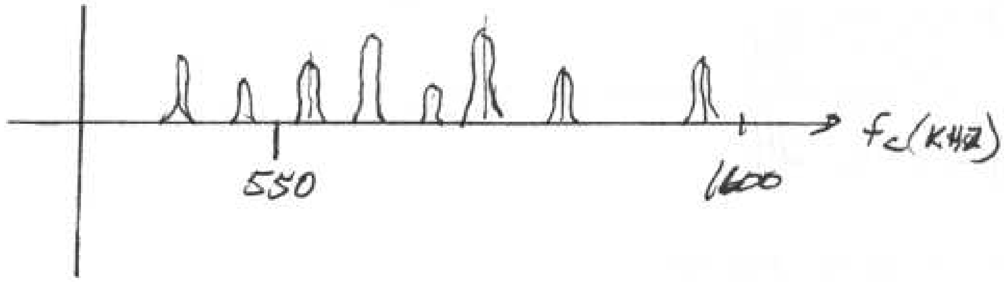
$$= \frac{e^{j\omega_c t}}{2} + \frac{A}{4}e^{j(\omega_c+\omega_s)t} + \frac{A}{4}e^{j(\omega_c-\omega_s)t}$$

$$+ \frac{e^{-j\omega_c t}}{2} + \frac{A}{4}e^{-j(\omega_c+\omega_s)t} + \frac{A}{4}e^{-j(\omega_c-\omega_s)t}$$



IN GENERAL $\omega_S$ REPRESENTS A SPECTRUM OF FREQUENCIES CONTAINED IN THE AUDIBLE RANGE $0 \le \omega_S \le 2\pi(5\text{-}10\,\text{KHZ})$

MANY STATIONS BROADCASTING AT ASSIGNED FREQUENCIES $\frac{\omega_c}{2\pi}$ IN RANGE 550KHZ TO 1600KHZ, USUALLY

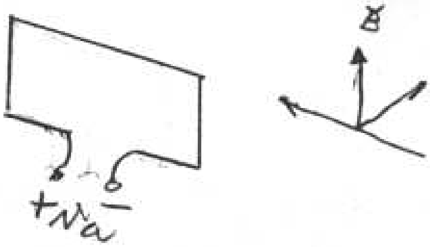



SEPARATED BY 10-20 KHZ.

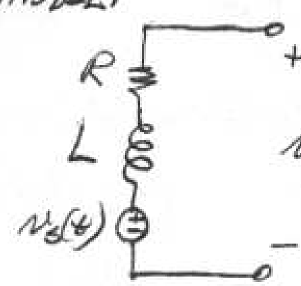
GOAL IS TO PROCESS SIGNAL FROM 1 STATION SO IT CAN BE HEARD.

ANTENNA THE MODULATED CARRIER IS FED TO AN ANTENNA WHICH EMITS ELECTROMAGNETIC WAVES AT $\omega_c \pm \omega_s$

USE LOOP ANTENNA TO RECEIVE SIGNAL.

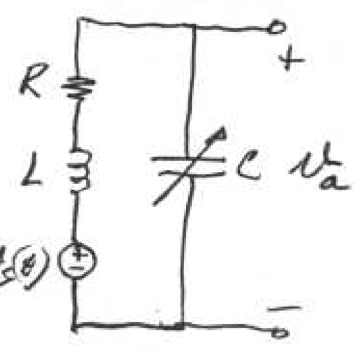



MODEL:

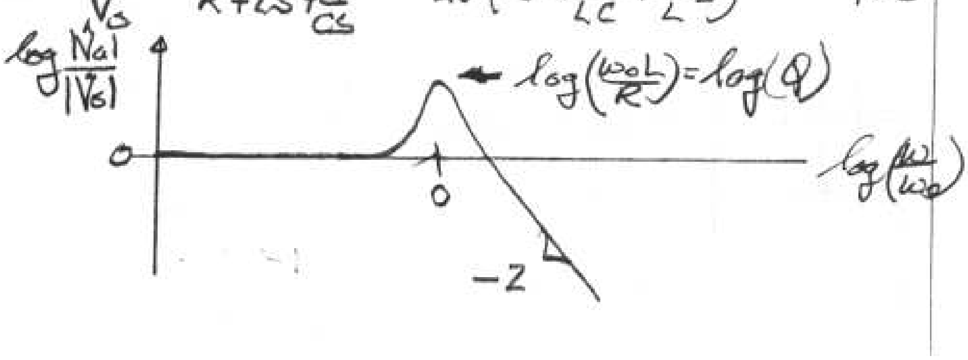



TUNER

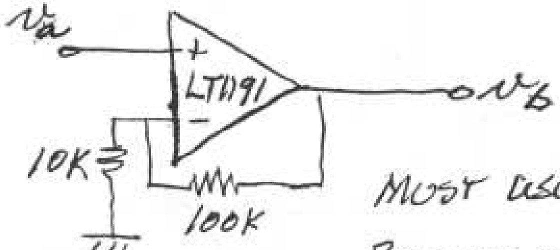
NEED BAND PASS FILTER WITH $Q = \frac{f_c}{2f_s} \approx \frac{1.0\times10^6}{2(5\times10^3)} \cong 100$




$$\frac{\hat{V}_a}{\hat{V}_s} = \frac{\frac{1}{Cs}}{R+Ls+\frac{1}{Cs}} = \frac{1}{LC\left(s^2+\frac{1}{LC}+\frac{R}{L}s\right)} \qquad \omega_0 = \frac{1}{\sqrt{LC}}$$



**AMPLIFIER** GIVE THE SIGNAL A BOOST TO GET IT TO A REASONABLE VOLTAGE LEVEL.



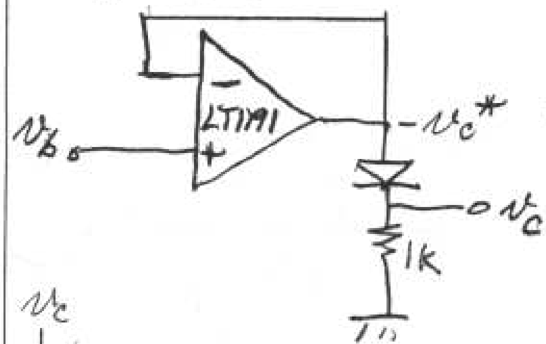

$$+\frac{v_b}{100K} = \frac{v_a}{10K} \Rightarrow v_b = +10 v_a$$

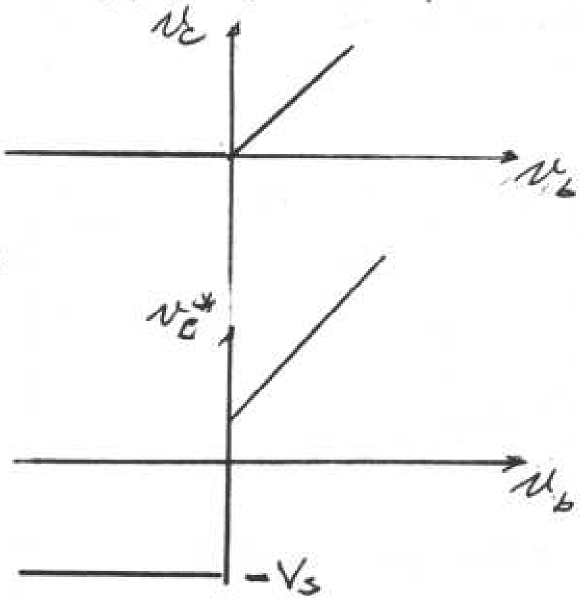
MUST USE OP AMP WITH HIGH GAIN-BANDWIDTH PRODUCT TO ACHIEVE HIGH GAIN @ 1.0 MHZ.

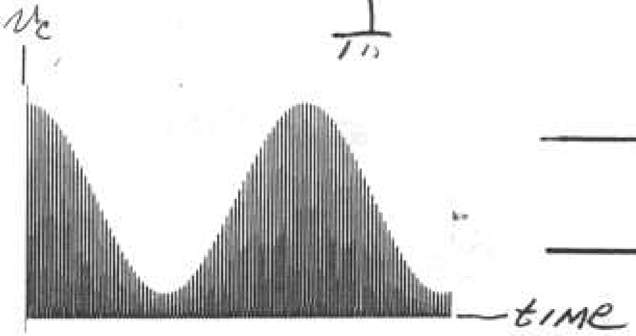
LT1191 $A\omega \cong 70 \times 10^6$

**DEMODULATOR** TO RECOVER $\omega_s$ FREQUENCIES WE FIRST CLIP OFF THE NEGATIVE PORTION OF THE SIGNAL.

"SUPER DIODE"

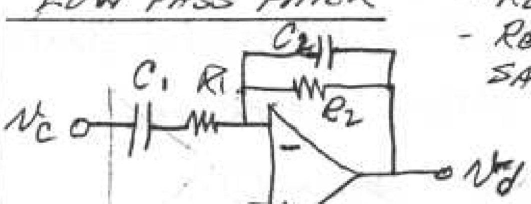


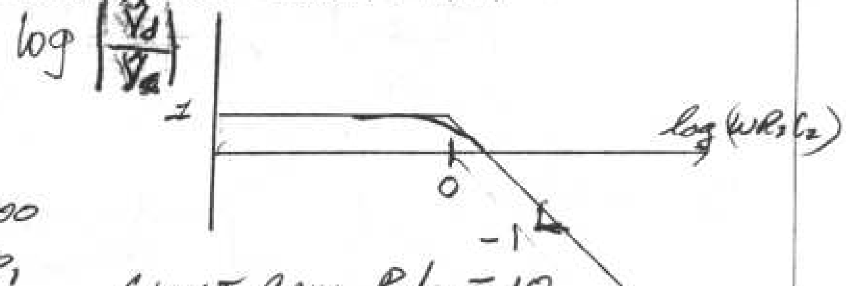




**LOW PASS FILTER**

- REMOVE REMAINING CARRIER FROM THE SIGNAL
- REMOVE CONSTANT COMPONENT TO AVOID SATURATING DOWNSTREAM AMPLIFIER




CHOOSE $\frac{1}{\omega C_1} \ll R_1$ @ $\omega = 100$

$$\frac{\hat{V}_d}{\hat{V}_c} = \frac{-\dfrac{R_2/C_2 s}{R_2 + 1/C_2 s}}{R_1} = \frac{-R_2/R_1}{1 + R_2 C_2 s}$$

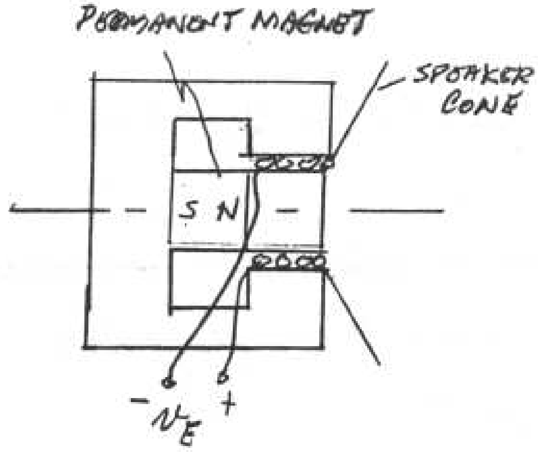
CHOOSE GAIN $R_2/R_1 = 10$

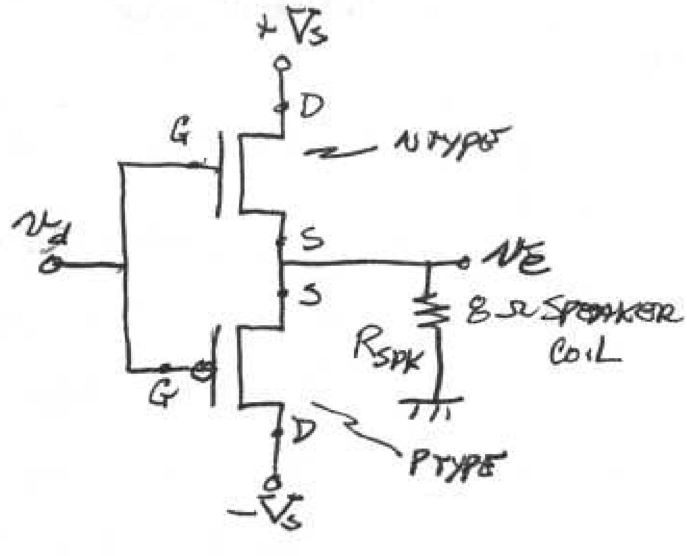
$R_1 = 10K$, $R_2 = 100K$

SET BREAKPOINT AT $\omega = 2\pi(3 \times 10^3) = \frac{1}{R_2 C_2}$

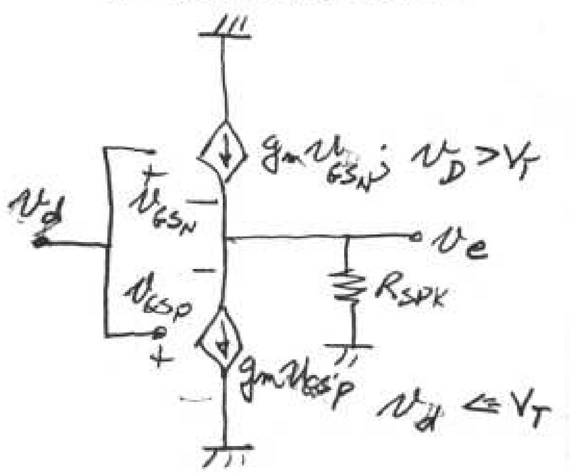
$C_2 = 5 \times 10^{-10}$; SET TO 470 pF

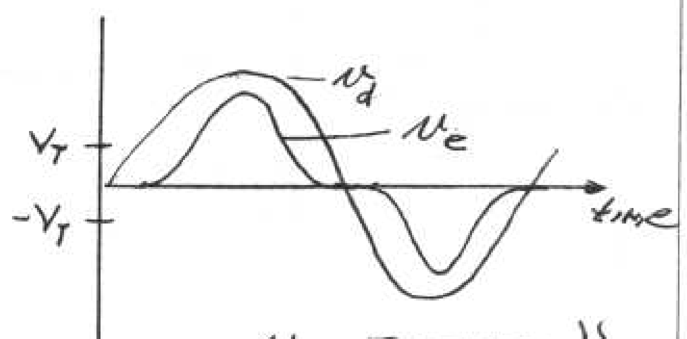
## POWER AMPLIFIER TO DRIVE 8 Ω SPEAKER




INCREMENTAL MODEL



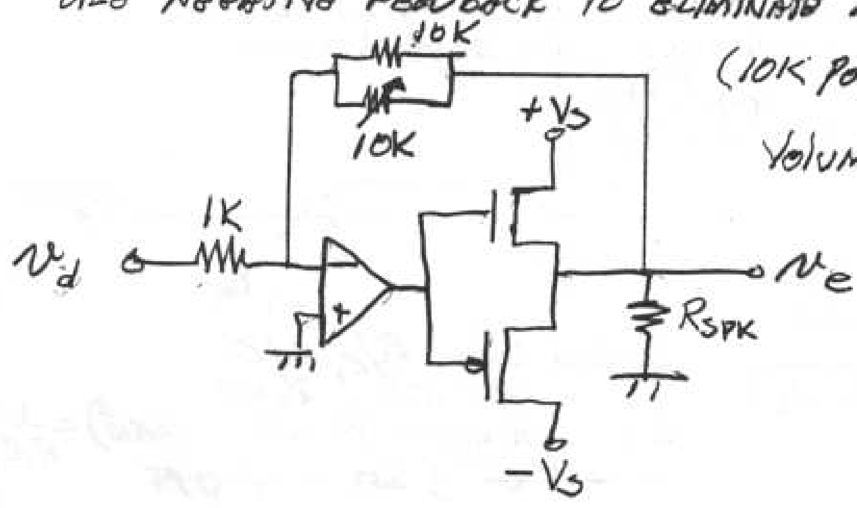

$v_E$ DISTORTED !!

$$v_e = +R_{SPK}\, g_m (v_d - v_e)$$

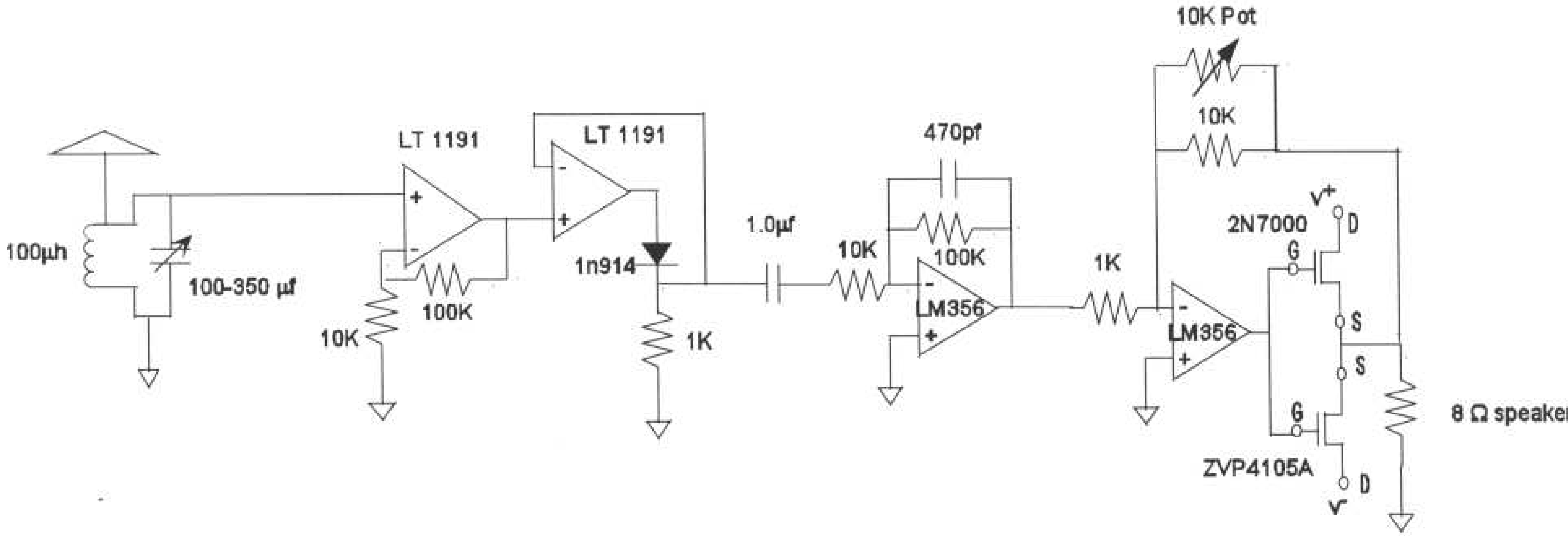
$$v_e = \frac{g_m R_{SPK} v_d}{1 + g_m R_{SPK}} \quad |v_d| > V_T$$

else $v_e = 0$

USE NEGATIVE FEEDBACK TO ELIMINATE DISTORTION AND GET GAIN.




(10K POTENTIOMETER FOR VOLUME CONTROL)




6.002 Radio Receiver

Revised 4/30/2003 GLW