Communications Electronics: Superheterodyne Receiver

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INTRODUCTION

The radio project was based on a superheterodyne design of a radio tuned for a carrier at 7.335 MHz. This is a simple radio design that consists of five main blocks, namely an RF amplifier, local oscillator, mixer, IF amplifier, and demodulator. The course of this project involved the construction and integration of four blocks (if the IF amplifier and detector are treated as one block).

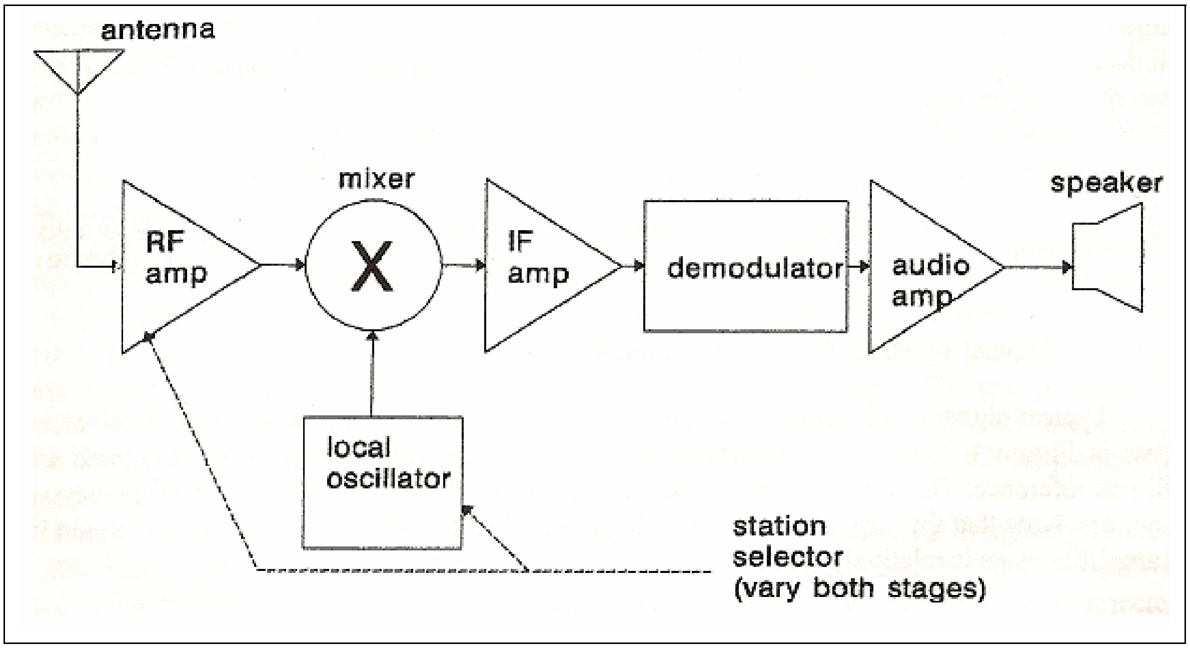


Figure 1 – Stages in a superheterodyne

OVERALL CIRCUIT DESIGN

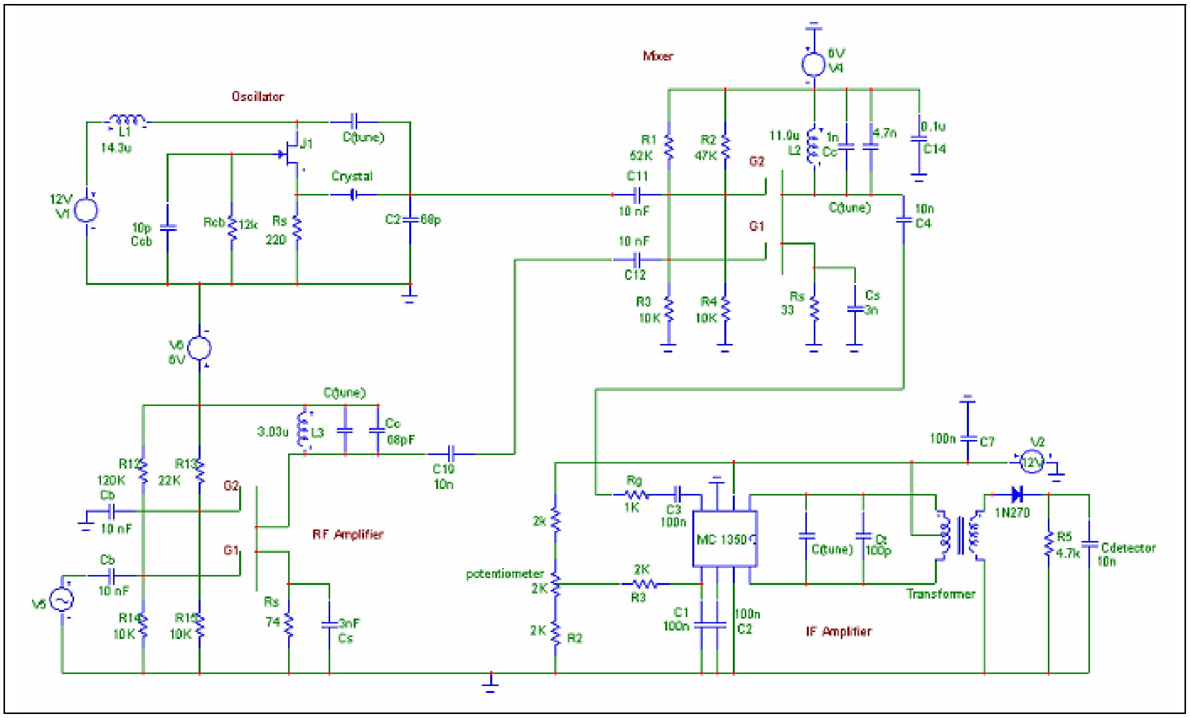


Figure 2 – Overall Circuit Design

RADIO SPECIFICATIONS

Parameter		Measurement	Units
Sensitivity		22.7 [pre-diode] 71 [post-diode]	μV
Bandwidth		13.0	kHz
Power Consumption		0.42	W
Image Rejection		-0.31	dB
Audio Output Level		40	μV
Gains	RF Stage	25.0	dB
	IF Stage	40.3	dB
	Overall	64.9	dB

PART LIST

Block	Component	Value	Units	Precision
RF Amplifier	C_c	68	pF	
	Variable Capacitor	5 - 65	pF	
	L	3.03	µH	Q = 31.9
	R_3, R_4	10	kΩ	±5%
	R_1, R_2	120, 22	kΩ	±5%
	R_p	10	Ω	±5%
	R_s	18 + 56	Ω	±5%
	Dual Gate MOSFET	NE25139		
	C_s	3	nF	
Mixer	L	11.9	µH	Q = 13.4
	R_3, R_4	10	kΩ	±5%
	R_1, R_2	52, 47	kΩ	±5%
	R_s	33	Ω	±5%
	Dual Gate MOSFET	NE25139		
	C_s	3	nF	
	C_c	1 + 4.7	nF	
Local Oscillator	Variable Capacitor	5 - 65	pF	
	Quartz Crystal	8	Mhz	
	JFET	2N5457 N		
	C_{cb}	10	pF	
	R_{cb}	12	kΩ	±5%
	R_s	220	Ω	±5%
	C_2	68	pF	
	L	14.3	µH	Q = 17
IF Amplifier (with detector)	C_b (4x)	100	nF	
	R_g	1.0	kΩ	±5%
	C_t	100	pF	
	Potentiometer	2	kΩ	
	4 resistors	2, 2, 2, 4.7	kΩ	±5%
	Germanium Diode	NTE109		
	$C_{detector}$	47	nF	
	Variable Capacitor	5 - 65	pF	

RADIO PICTURE

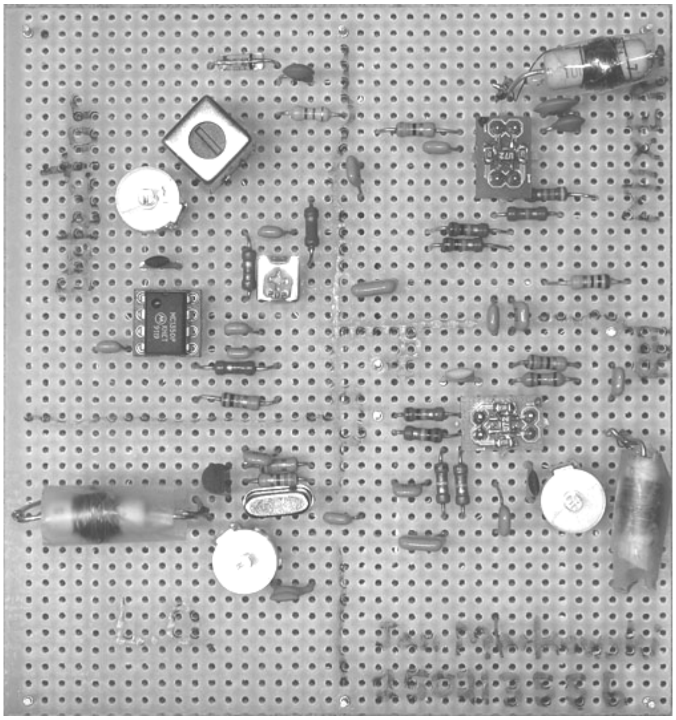
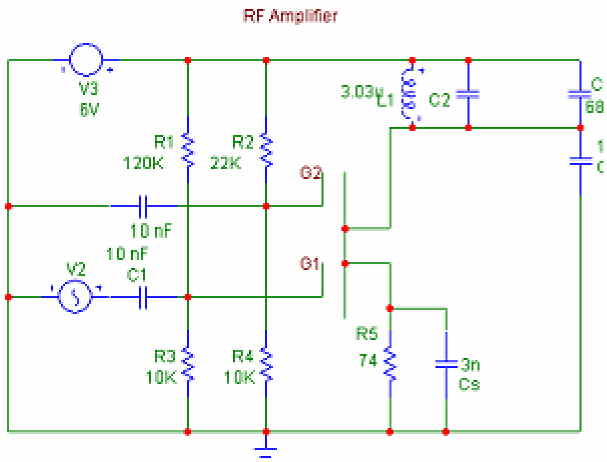
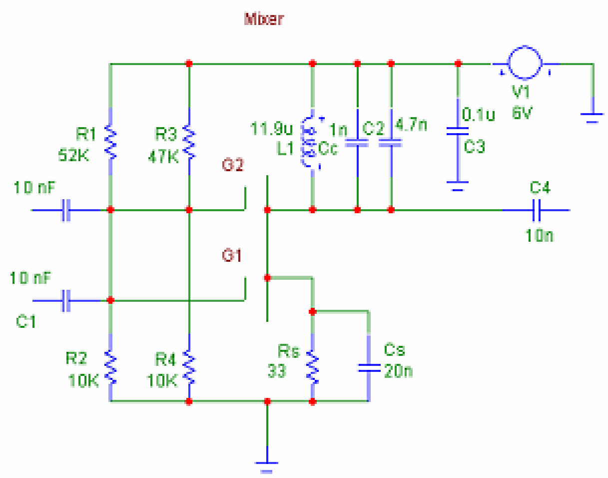
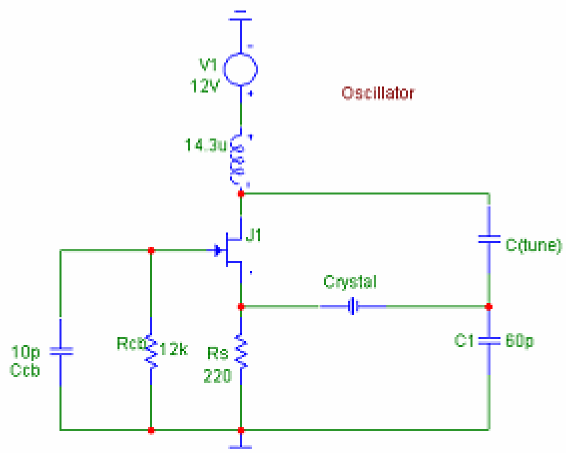
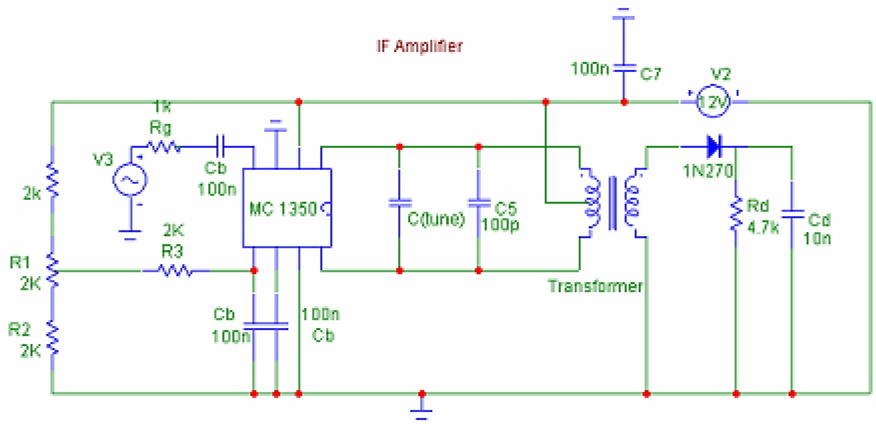


Figure 2 – Complete Radio (Not to scale)

DESIGN AND CALCULATIONS

Block	**Design and Calculations**
RF Amplifier	 Refer to *Appendix B: RF Amplifier* for calculations

Mixer	 Refer to *Appendix C: Mixer* for calculations
Local Oscillator	 DC Bias: From Figure 4, V_{gs} = -0.8V, I_D = 2mA $R_S = V_S / I_D$ Resonant contour: $g_m = -2*I_{DSS}*V_{GS0}/V_P^2$ $I_{DSS}/2 = I_{DSS}*(1 – V_{GS0}/V_P)^2$ $\omega_0*L = 700\ \Omega$ $A_v = R_{eff}*g_m$ Where $R_{eff} = R_{out}/\beta^2 \parallel Q*\omega_0*L$ $C_1 = 1 / (\omega_0^2*L*\beta)$ $1 / \beta = (C_1 + C_2)/C_2$

<table>
<tr>
<td>IF Amplifier (with Detector)</td>
<td>

Refer to Appendix D: IF Amplifier for calculations</td>
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CONCLUSIONS AND RECOMMENDATIONS

During production, it is highly recommended that each of the stages are soldered onto the breadboard one at a time, starting in reverse order, so that you may allow sufficient room for a matching circuit. Be sure to test each stage after soldering it on. Because of a difference in the stray capacitance, it is necessary that all the stages become tuned again (especially the oscillator) as well as the IF amplifier stage (self oscillation occurs with the transformer when the potentiometer is set for too high of a gain). Other common problems involve the burning out of the major components such as the transistors or the transformer. Ensure that connections exist between stages and within components using a digital multimeter. Usually when you have trouble achieving the gain that you want from an intermediate amplification stage, it is advised that the user make intuitive changes to the biasing resistors, and this may take several tries. When these precautions are taken into account, the radio should work and pick up a signal from the official time signal station of CHU Ottawa.

APPENDIX A

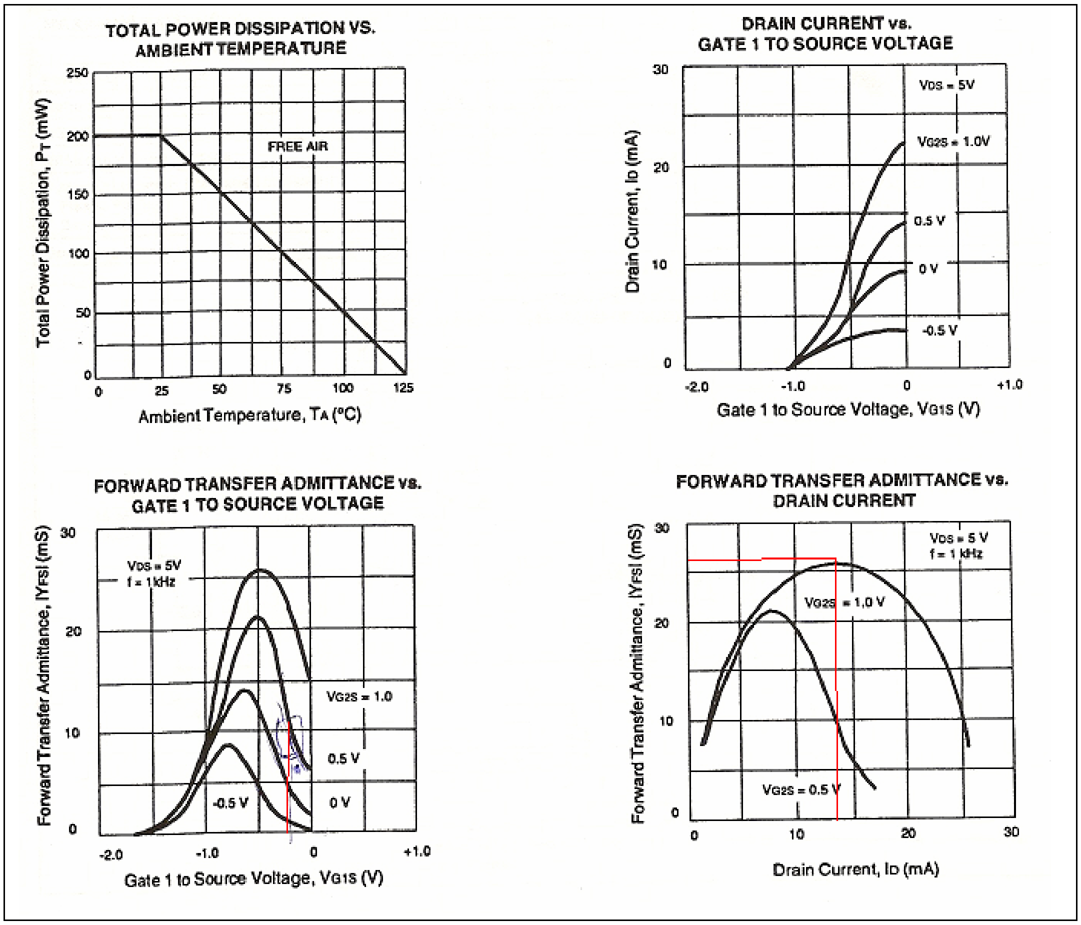

Figure 3 – Typical Performance Curves for the NE25139 Dual Gate MOSFET (T_A = 25ºC)

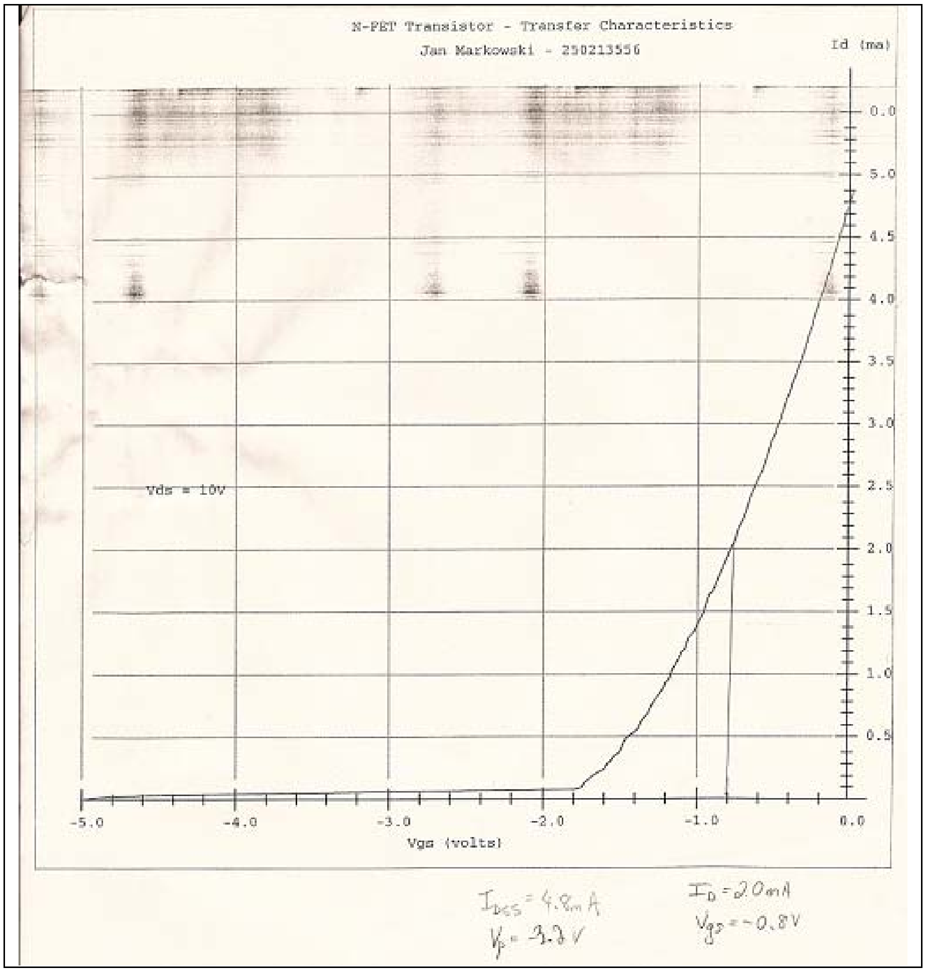

Figure 4 – 2N5457 JFET Transfer Characteristics

APPENDIX B: RF Amplifier

(MATLAB code)

```
%   Q = 10
%   1/w*Cs << RS
%   1/w*Cs <= Rs/10

w = 2*pi*7.335e6;

Cs = 10 /(w*Rs);
Cs

%   1/w*Cb << Rin = R1 // R2
%   R1//R2 = 18.71e3 ohm

Rin = 18.71e3; %ohm

Cb = 10e-9;          %F
L = 3.1e-6;          %H
C = 1/((L)*(w)^2);  %F
C

%   calculation for contour

Ca_max = 65e-12;    %F

Cc = C - 0.9*Ca_max; %F
Cc

%   Calculation for n turns

a= (2.5 + 0.254 + 0.035 );
b= 7.5;
n =sqrt( (3.1*(230*a + 250*b)) / a^2 );
n
```

APPENDIX C: Mixer

(MATLAB code)

```
R2 = 10e3;      %[ohm]
R4 = 10e3;      %[ohm]

V_G1S = -0.1;   %[V]
V_G2S = 0;      %[V]
V_DS = 5;       %[V]
Vcc = 6;        %[V]

Id = 9e-3;      %[A]

Rs = (Vcc-V_DS)/Id;     %[ohm]

Vs_grd = Id*Rs;         %[V]

VG1_grd = V_G1S + Vs_grd;   %[V]
VG2_grd = V_G2S + Vs_grd;   %[V]

I1 = VG1_grd/R2;        %[A]
I2 = VG2_grd/R4;        %[A]
R1 = (Vcc - VG1_grd)/I1;     %[ohm]
R3 = (Vcc - VG2_grd)/I2;     %[ohm]

w = 2*pi*0.665e6;
L = 10e-6;          %[H]

Cs = 10/(w*Rs)      %[F]
Cb = 10e-9;         %[F]

Cc = 1/(L*w^2);      %[F]
```

APPENDIX D: IF Amplifier

(MATLAB code)

```
Cds = 2e-12;
Cgd = 3e-12;
Cgs = 1e-12;

R1 = 140e3;
R3 = 10e3;

w = 2*pi*(10e3);
rd = 100e3;

yi = j*w*(Cgs+Cgd);% + (1/R1) + (1/R3);
yr = -j*w*Cgd;
yf = 25e-3 - (j*w*Cgd);
yo = 1/rd + j*w*(Cds+Cgd);

yi
yr
yf
yo

RL = 4.7e3;
yload = 1/RL;
ysource = 1/50;
Yin = yi - yr*yf/(yo + yload);
Yout = yo - yr*yf/(yi + ysource);

Yin
Yout

f = 10000;
m = 0.9;

C = ((sqrt((1/m)^2 - 1)) / (2*pi*f*RL));
C
```