LABORATORY REPORT - CHAPTER 3

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Total Grade	/100

Remarks: Record all your measurements and write all your answers in the boxes provided.

Preliminary Work

1. Microphone Amplifier

1. Consider the TRC-11 microphone amplifier circuit shown in Fig. 1, making use of one of the two OPAMPs in LM358 integrated circuit. Since the OPAMP operates with a single supply voltage, the input DC voltages of the OPAMP should be shifted to a voltage somewhere between V_{CC} and GND. For this purpose, we use the regulated voltage, +6V.

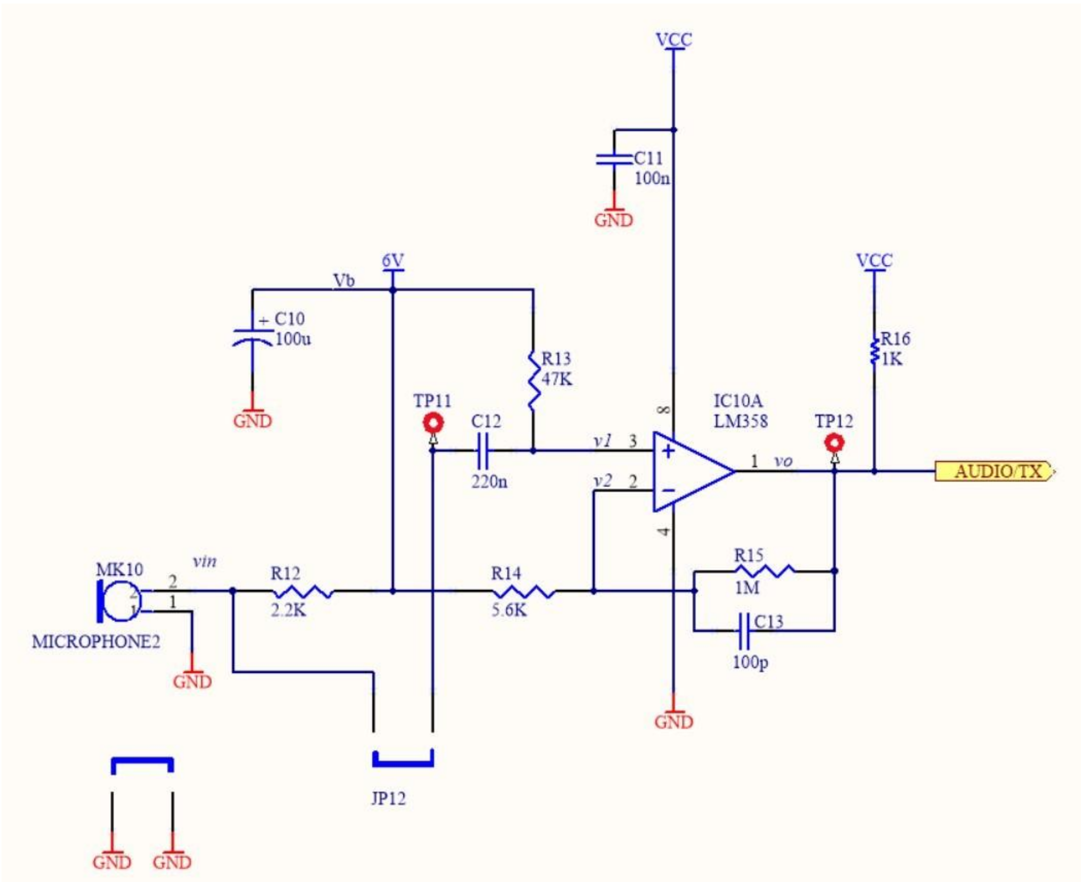


Figure 1: Schematic of microphone amplifier

Designator	Comment	Description

C10	100u	Electrolytic Capacitor, 16V
C11	100n	Capacitor, ceramic disk, 50V
C12	220n	Capacitor, ceramic disk, 50V
C13	100p	Capacitor, ceramic disk, 50V
IC10	LM358	Dual OPAMP
MK10	MICROPHONE2	Microphone Capsule
R12	2.2K	Resistor, carbon film, axial leaded, 1/4W
R13	47K	Resistor, carbon film, axial leaded, 1/4W
R14	5.6K	Resistor, carbon film, axial leaded, 1/4W
R15	1M	Resistor, carbon film, axial leaded, 1/4W
R16	1K	Resistor

Figure 2: Bill of materials for the microphone amplifier

2. We can find the output voltage, v_o, of this OPAMP circuit using the superposition principle for two sources: A DC source of V_b and an AC source of v_{in} (with a source resistance of R_{12}). First, let us kill the AC source v_{in} and find the output voltage, v_o. Since the capacitor is open-circuit at DC, we write the node equations at v_2 and v_1 as

$$\frac{v_2 - V_b}{R_{14}} + \frac{v_2 - v_o}{R_{15}} = 0 \qquad \text{and } v_1 = V_b$$

Assuming that the OPAMP is not saturated, we should have $v_1 = v_2$, and hence we find $v_o = V_b$ (from the datasheet of the OPAMP, we determine that if $0 < v_o < V_{CC} - 2$, the OPAMP is not saturated. Since $V_b < V_{CC} - 2$ our assumption is correct).

Now, we kill the DC source V_b (set V_b=0) and assume that the input signal $v_{in}(t)$ is sinusoidal: $v_{in} = V_P \cos(\omega t)$. For this case, we can use the phasors: We write $v_{in} = V_P$. Since the relatively large valued capacitor C_{12} can be assumed a short-circuit and the source resistance, R_{12} is much smaller than R_{13}

$$v_1 = V_P \qquad \text{and } \frac{v_2}{R_{14}} + \frac{v_2 - v_o}{R_{15}} = 0$$

Again we assume the OPAMP is not saturated, hence $v_1 = v_2 = V_P$. Now, we find

$$v_o = \left(1 + \frac{R_{15}}{R_{14}}\right) V_P$$

We note that the OPAMP acts like a non-inverting amplifier of voltage gain

$$A_v = \left(1 + \frac{R_{15}}{R_{14}}\right)$$

Using superposition, the output voltage is

$$v_o = V_b + A_v V_P$$

The output is equal to an amplified version of the input AC signal shifted by V_b. Calculate the value of voltage gain, A_v, from the resistor values.

Because of C12 and R13, the gain decreases at frequencies lower than the corner frequency of

$$f_1 = \frac{1}{2\pi R_{13} C_{12}}$$

Because of C13 and R15, the gain decreases at frequencies higher than the corner frequency of

$$f_2 = \frac{1}{2\pi R_{15} C_{13}}$$

Calculate these frequencies.

A_v= 179.6	f_1= 15.42 Hz	f_2= 1.58 kHz

1.2. GRADE:

3. The gain function in decibels is plotted in Fig. 3. If $f_1 \ll f \ll f_2$, then $|v_o/v_{in}| = A_v = 20\log_{10}A_v = A_{vdB}$. If $f = f_1$ of $f = f_2$, then $|v_o/v_{in}| = A_v/\sqrt{2} = A_{vdB} - 3\text{dB}$ (3 dB less than the low frequency value).

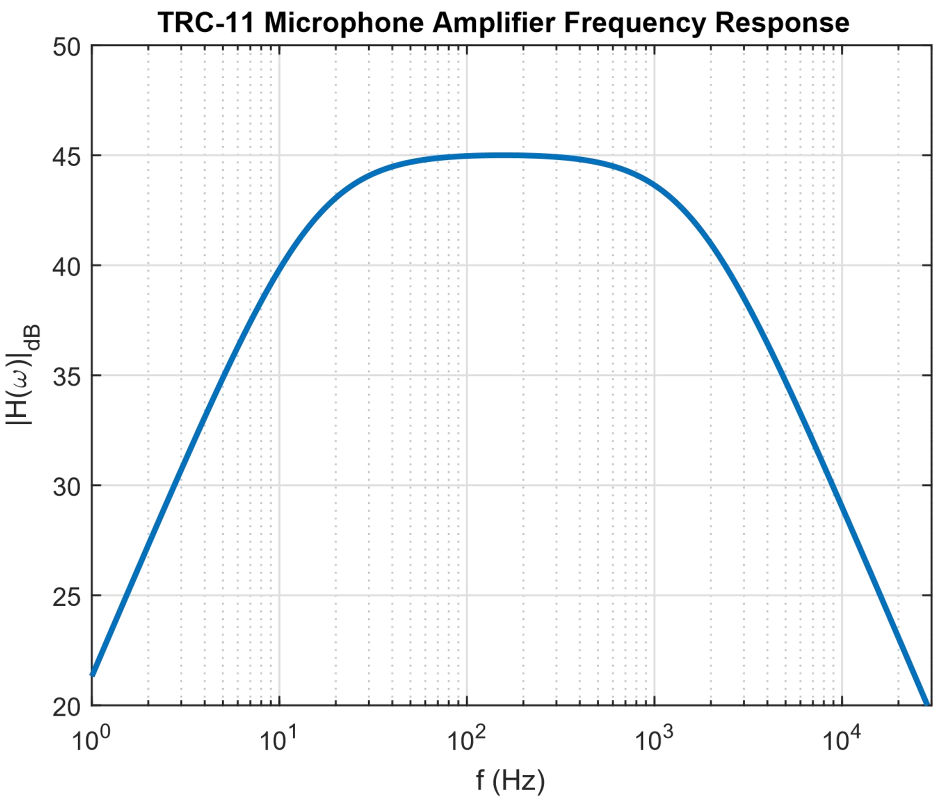


Figure 3: Calculated Frequency Response of the Microphone Amplifier

The MATLAB code to plot this function is

```
% MATLAB code to plot the transfer function %
    of the Microphone amplifier clear all % clear all
variables in MATLAB hold off
```

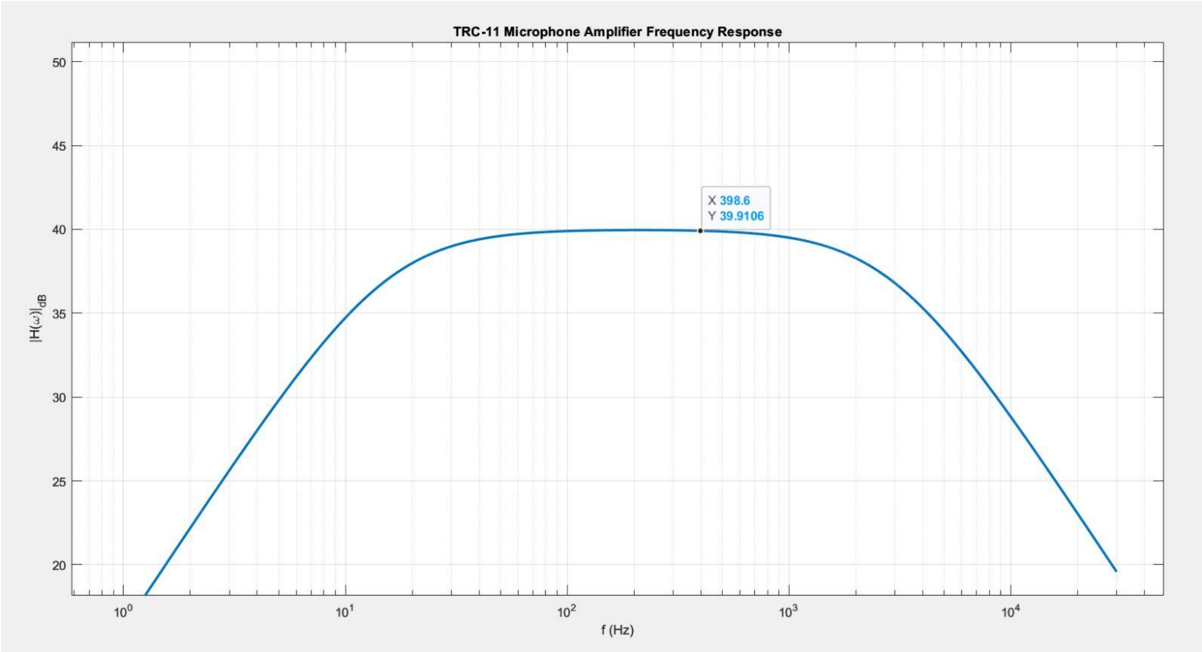
```
fmin=1; %minimum frequency in Hz
fmax=30e3; %maximum frequency in Hz C12=220e-
9; % C12 capacitor value in F
C13=100e-12; % C13 capacitor value in F
R13=47e3; % R13 resistance in Ohms
R15=1000e3; % R15 resistance in Ohms
R14=5.6e3; % R14 resistance in Ohms Av=1+R15/R14;

f=fmin:fmin/5:fmax; % Frequency vector w=2*pi*f; %
angular frequency vector
H=Av./((1+j*w*R15*C13).*(1+j./(w*C12*R13)));
% MATLAB performs an array operation
% Note that we need a "." in front of operators
% to perform array operations
Hdb=20*log10(abs(H)); % calculate the magnitude of
% the transfer function in dB

semilogx(f,Hdb,’LineWidth’,2) % plot on a logarithmic x-axis
% with a linewidth of 2 grid on % to plot the grid lines xlabel(’f (Hz)’) %
to place the x-label on the plot ylabel(’|H(\omega)|_{dB}’) % to place
the y-label title(’TRC-11 Microphone Amplifier Frequency Response’)
% to place a title hold on
axis([fmin fmax 20 50]); % define the axes limits
```

Find the value of the resistor R_{15} to have a mid-band gain of A_v=40 dB. Plot the corresponding frequency response using the modified MATLAB code.

R_{15}= 554.4 KΩ



1.3. GRADE:

4. From the datasheet of the OPAMP LM358 on page 355, the typical gain factor A of the OPAMP is found as 110 dB. What is this amplifier's approximate supply current, I_S, from +12 V supply?
   What is the open-loop voltage gain, A_0, at 10 kHz in dB (page 355)?

I_S= 0.75 mA A_0= 40dB

1.4. GRADE:

2. Loudspeaker/Earphone Amplifier

1. A schematic diagram of the loudspeaker amplifier is given in Fig. **??**.

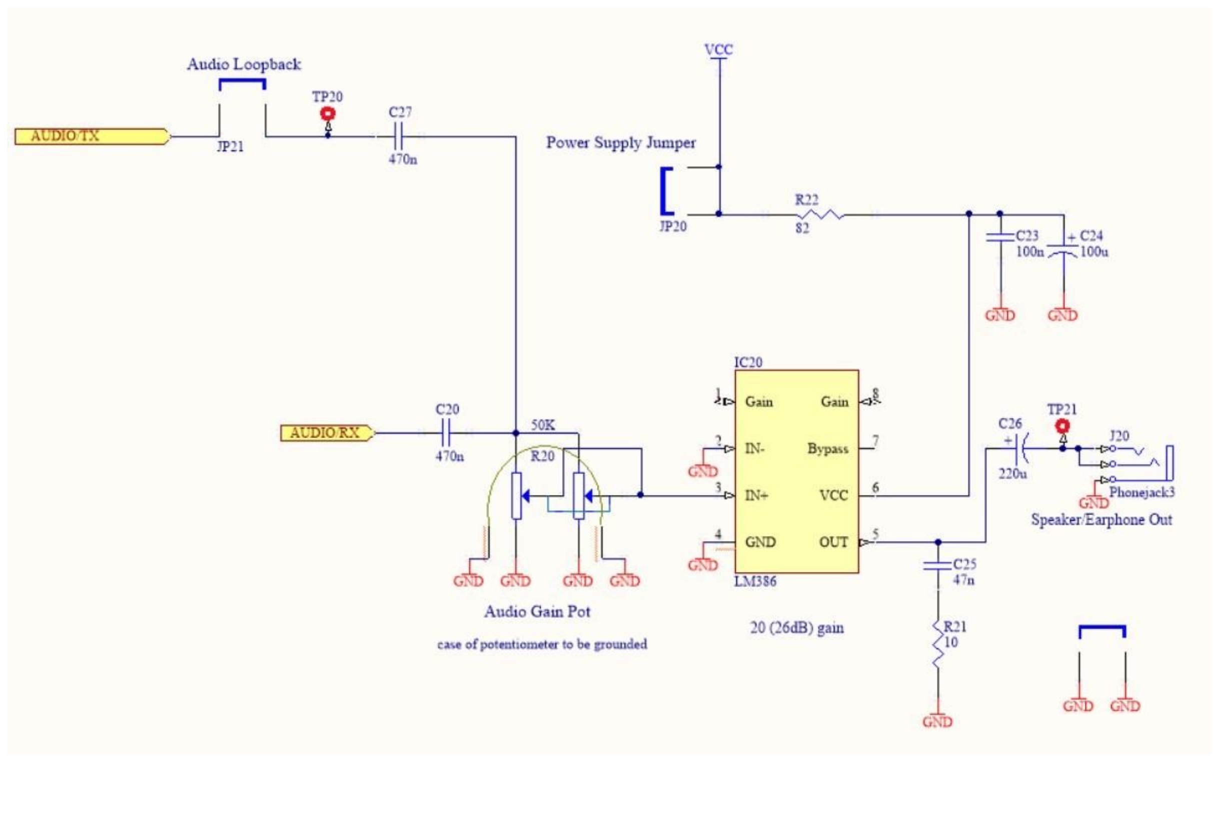


Figure 4: Schematic of the loudspeaker/earphone amplifier

2. IC20 is (LM386) a low-voltage audio amplifier integrated circuit. Examine the datasheet given on page 357. Which type of package is your integrated circuit? What is the supply voltage range of this IC?

Package type	DIP-8
Min. Supply voltage	4V
Max. Supply voltage	12V

2.2. GRADE:

Designator	Comment	Description
C20, C27	470n	Capacitor, ceramic disk, 50V
C23	100n	Capacitor, ceramic disk, 50V
C24	100u	Electrolytic Capacitor, 16V
C25	47n	Capacitor, ceramic disk, 50V
C26	220u	Electrolytic Capacitor, 16V
IC20	LM386	Low Voltage Audio amplifier
J20	Phonejack3	Speaker/Earphone jack, PCB mount
R20	50K	Potentiometer, Stereo

R21	10	Resistor, carbon film, axial leaded, 1/4W
R22	82	Resistor, carbon film, axial leaded, 1/4W