1500 + 33 ≈ 1500

LABORATORY REPORT - CHAPTER 4

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

Preliminary Work

1. First IF Amplifier

1. An RF amplifier can be built using a BJT. Refer to the circuit given in Fig. 1. TRC-11 uses two of such amplifiers. The values of the resistors and capacitors should be calculated as described below.

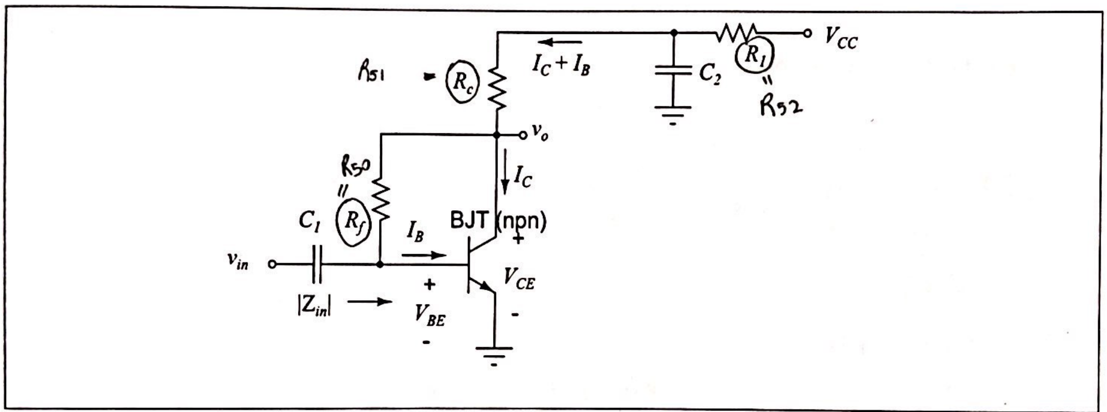

Figure 1: Schematic of an RF amplifier using a BJT.

2. BJT to be used is KSP10, an NPN transistor. Take a look at its datasheet given in [365]. It is a high-frequency transistor. β (or h_{FE}) of the transistor is a minimum of 60. Once the operating point (collector current, I_C, and the collector-emitter voltage, V_{CE}) is set, the values of the bias resistors can be calculated as follows:

$$\overset{R_{51}}{R_c} + \overset{R_{52}}{R_2} = \frac{V_{CC} - V_{CE}}{I_C + I_B} \approx \frac{V_{CC} - V_{CE}}{I_C} = 1.5K \quad (1)$$

$$R_{50} \quad R_f = \frac{V_{CE} - \overset{0.8}{V_{BE}}}{I_B} \approx \beta \frac{V_{CE} - 0.8}{I_C} \quad (2)$$

where we assumed $V_{BE} \approx 0.8$. For the first amplifier, calculate the values of resistors, $\boxed{R_{50} = R_f}$ and $R_{51} + R_{52} = R_c + R_1$, choosing a DC operating point of I_C a value in the

$$R_{50} = \frac{V_{CE} - 0.8}{I_B} = \frac{\overset{6V}{V_{CE}} - 0.8}{I_C = 4mA} \quad \beta = 80 \Rightarrow R_{50} = \frac{6 - 0.8}{0.004} \cdot 80$$

$$R_{51} + R_{52} = \frac{V_{CC} - V_{CE}\,6V}{I_C = 4mA}$$

$R_{51} + \underbrace{R_{52}}_{33\Omega} = 1.5K$ $\quad R_{51} = 1.5K - 33\Omega$

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range 2 mA to 8 mA and $V_{CE}=V_{CC}/2$. The operating voltage V_{CE} is chosen to be half the supply voltage to provide a maximum voltage swing at the collector. Choose V_{CC}=12 V. Take β=80 for the purpose of this calculation. Choose $R_{52}=R_1$ in the range 22 to 56 Ω. Select the resistors using among the closest standard resistor values: 1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, and 8.2.

56
22
781

3. The DC block capacitor, C_1, at the input is used to block DC voltages from affecting the base voltage of the transistor. It value can be should be large enough so that there is no AC voltage drop across it. Its value can be found from

$$C_{50} > \frac{10}{2\pi \cdot 15 \cdot 10^6 \cdot 50}$$

$$C_{50} > 2.122\,nF$$

$$C_1 > \frac{10}{2\pi f_0 |Z_{in}|} \tag{3}$$

$|Z_{in}| \to 50$, $f_0 \to 15 \cdot 10^6$

where f_0 is the operating frequency of 15 MHz. Assume $|Z_{in}|$=50 Ω and choose $C_{50}=C_1$ using the standard capacitor values: 1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, and 8.2.

4. The power supply bypass capacitor, C_2, and the resistor, R_1, forms a low-pass-filter. They are used to to provide a clean power supply voltage to the amplifier. Choose a corner frequency f_1 at least 100 times smaller than f_0.

$C_2 \approx 330\,nF$

$$f_1 = f_0 \cdot \frac{1}{10^3} = 15 \cdot 10^3, \quad f_0 = 15 \cdot 10^6$$

$$C_2 \approx \frac{1}{2\pi f_1 R_1} \tag{4}$$

$R_1 = R_{52}$

$$= 3.21 \cdot 10^{-7}$$

$$321 \cdot 10^{-9}$$

Choose $C_{51}=C_2$ using the standard capacitor values.

5. Repeat the procedure for the second IF amplifier. For the second amplifier, choose I_C in the range 5 mA to 10 mA (higher than the first).

$$R_{60} = \frac{V_{CE} - 0.8}{I_C}\,\beta$$

6V, 80, 8 mA

First amplifier: I_C= 4 mA V_{CE}= 6 V
R_{50}= 104 kΩ ≈ 100k R_{51}= 1467 Ω → ≈ 1.5 kΩ R_{52}= 33 Ω
C_{50}= 3.3 nF C_{51}= 330 nF

$R_{51} + R_{52} = 1.5\,k\Omega$
$R_C + R_1 =$
33 Ω
1500 − 33 = 1467 Ω

Second amplifier: I_C= 8 mA V_{CE}= 6 V
R_{60}= 52K ≈ 56K R_{61}= 717 Ω ≈ 680 Ω R_{62}= 33 Ω
C_{60}= 3.3 nF C_{61}= 330 nF

$$R_{61} + R_{62} = \frac{V_{CC} - V_{CE}}{I_C} = 750\,\Omega$$

12, 6, 33, 0.008

R_{61} = 750 − 33 = 717 Ω

8.2 Ω

1.5. GRADE:

6. The gain of the BJT amplifiers can be calculated using LTSpice. SPICE model of the KSP10 is given as

```
.model KSP10TA NPN(IS=1E-11 ISE=70e-11 NE=2.5 VAF=100 BF=110
+ NF=1.3 IKF=0.065 NK=0.45 XTB=0 BR=3 CJC=1.56E-12
+ CJE=2E-12 TR=50e-9 TF=1.85E-10 ITF=0 VTF=0 XTF=0
+ RB=42 RC=.3 RE=.2 Vceo=25 Icrating=100m mfg=OnSemi)
```


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Place these lines in LTSpice as a SPICE directive. Define the NPN transistor's "Value" (seen after CTRL-right click on the transistor) as KSP10TA (the same label used in the model statement). Enter the schematic of the first amplifier in LTSpice using the calculated values of components. Determine the DC voltages V_{CE} and V_{BE} using "DC opt pnt" analysis.

7. Determine $|Z_{in}|_1$ of the first amplifier at 15 MHz by connecting an AC *current* source of unity magnitude and performing a small-signal AC analysis. The voltage of the current source gives the input impedance, $|Z_{in}|$. Change the default display of the y-axis to "Bode/linear" to read the magnitude of the impedance (specified in V). Refer to Appendix on LTSpice Tutorial on page 282.

8. Determine the small-signal gain, $|v_o/v_{in}|_1$, in dB at 15 MHz also by using small-signal AC analysis. You should define an AC *voltage* source of unity magnitude at the input with a series source resistance of 50 Ω. (The signal generators at the lab has an internal source resistance of 50 Ω.) Place a 10 pF capacitor to ground at the output to simulate the probe capacitance of the oscilloscope (to be compared with measurements later). Set the y-axis to its default: "Bode/decibel" to read the gain in dB.

$V_{CE1}=$ 6.11 V	$V_{BE1}=$ 667.0 mV
$\|Z_{in1}\|=$ 94.7 Ω	$\|v_{o1}/v_{in1}\|_{dB}=$ 38.4 dB

1.8. GRADE:

2. The second IF Amplifier

1. Repeat the LTSpice simulations for the second amplifier.

$V_{CE2}=$ 6.43 V	$V_{BE2}=$ 695.16 mV
$\|Z_{in2}\|=$ 91.6 Ω	$|v_{o2}/v_{in2}|_{dB}=$36.87 dB

2.1. GRADE:

2. Connect the second amplifier's input to the first amplifier's output. Determine the input impedance, the gain of the first amplifier and the overall gain in dB at 15 MHz. Note that the input impedance and the gain of the first amplifier is not the same as that determined when the amplifier is stand-alone. The reason is that the output load impedance of the first amplifier is changed. The input of the second amplifier is loading the output of the first amplifier, reducing the gain of the first amplifier and also changing the input impedance. The input impedance of a BJT is influenced by the load impedance at the output, especially at high frequencies. At very low frequencies, the input impedance does not get affected by the output load.

$\|Z_{in1}\|=$ 338.3 Ω	$\|v_{o1}/v_{in1}\|_{dB}=$ 17.74 dB
Overall gain: $\|v_{o2}/v_{in1}\|_{dB}=$ 57.75 dB	

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