XMUT204 Electronic Design

Practice Final Exam Questions

Section A **Bipolar Junction Transistors** **[42.5 marks]**

1. Answer the following questions on the structure of an NPN BJT:

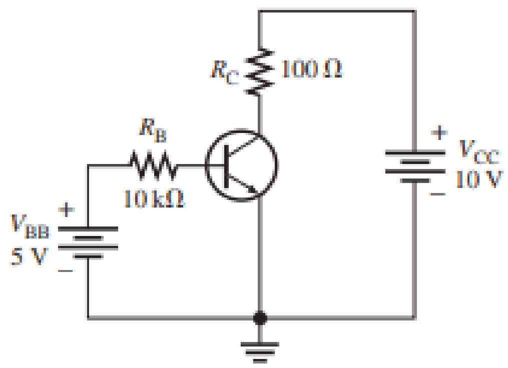
   a. Show (sketch) how you can use two power supplies in order to provide suitable bias and operating conditions for an NPN transistor to operate in the **forward active region**. Explain the conditions at each of the two junctions of the device and how these operating conditions enable diode operation.
   [2.5 marks]

   b. On your sketch in part (a) indicate the currents that will flow in/out of the different regions of the transistor by using conventional current notation. Write down the expression(s) that relates these different currents and define the DC current gain of the transistor. [5 marks]

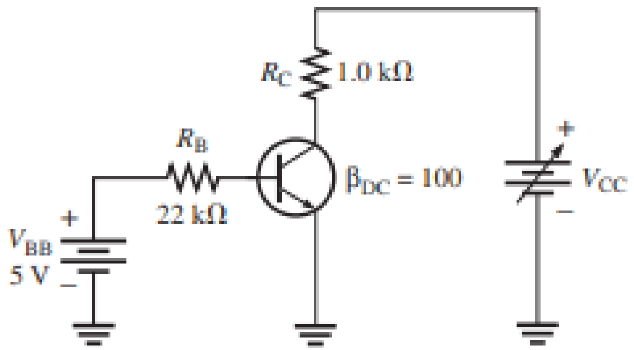
   c. Sketch the current-voltage characteristics of a BJT (I_C vs V_{CE} for constant I_B) and indicate the three important regions of operation. [2.5 marks]

   d. Contrast the bias and operating conditions in the saturation region to those of the forward active region in order to explain the shape of the I-V curve in this region.
   [2.5 marks]

2. Determine I_B, I_C, I_E, V_{BE}, V_{CE}, and V_{CB} in the circuit of given below. The transistor has a β_{DC} = 150. [15 marks]

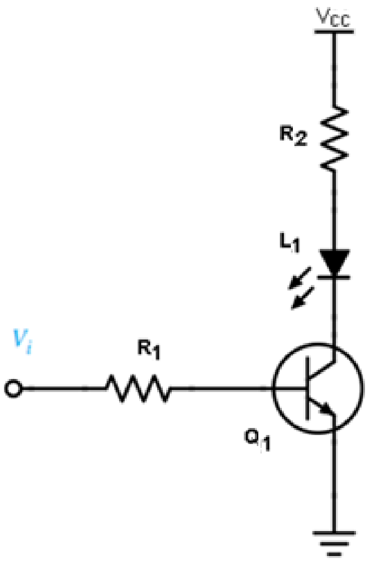


3. The transistor in the figure below has the following maximum ratings: $P_{D(\max)}$ = 800 mW, $V_{CE(\max)}$ = 15 V, and $I_{C(\max)}$ = 100 mA. Determine the maximum value to which V_{CC} can be adjusted without exceeding a rating. Which rating would be exceeded first? [15 marks]

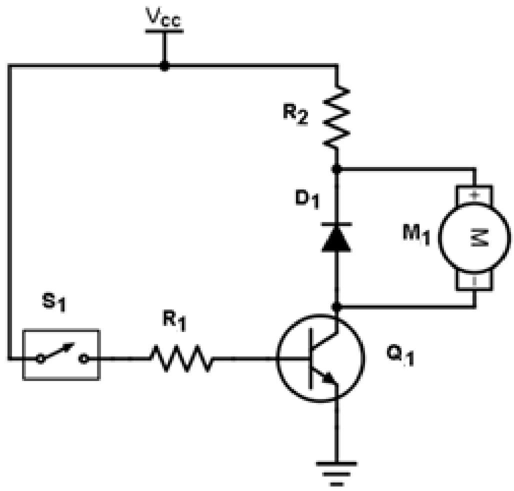


Section B **Switching Applications** **[17.5 marks]**

1. BJT can be designed for switching applications such as digital logic circuits.
   a. Describe the regions of operation of BJT for switching application. [2.5 marks]
   b. Calculate values of the resistors in the biasing configuration of the following BJT switching circuit. The LED in circuit given below requires 30 mA to emit a sufficient level of light. Use double of the minimum value of base current as a safety margin to ensure saturation knowing V_{CC} = 9 V, $V_{CE(\text{sat})}$ = 0.3 V, β_{DC} = 50, V_{LED} = 1.6 V, and V_{IN} = 5 V. [7.5 marks]

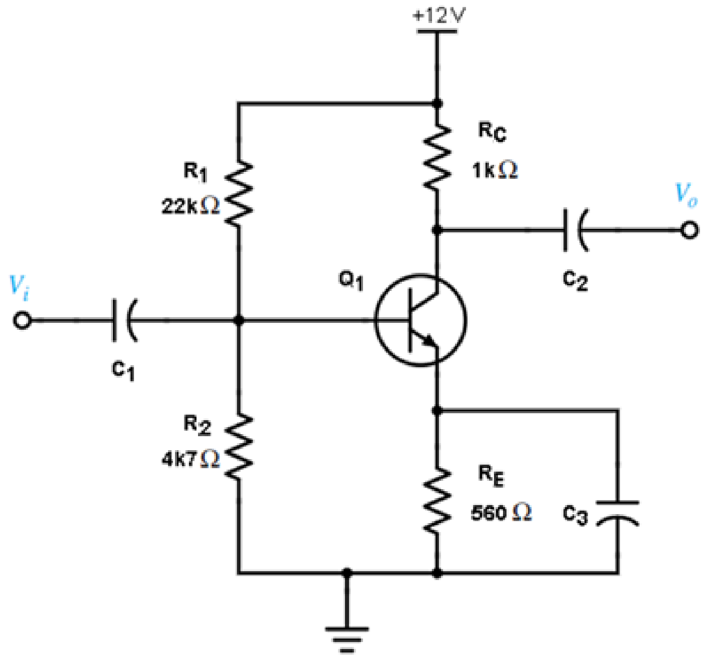


2. Describe how a BJT can be used to control the speed of the DC motor as shown in the circuit given in the figure below. Referring to this circuit, is it possible to regulate the speed of the motor from standstill to full speed? Describe briefly the role of the diode in the circuit. [7.5 marks]



Section C **BJT Amplifiers** **[62.5 marks]**

1. BJT transistors are typically used in applications such as pulse switching and signal amplification. Study the circuit below and then answer the questions that follow:



a. Calculate the DC operating conditions (V_B, V_E, I_E, I_C and V_C) of the circuit.
[12.5 marks]

b. Calculate the small signal voltage gain of the circuit without capacitor C_3 in place. [5 mark]

c. Calculate the small signal voltage gain with capacitor C_3 in place.
[2.5 marks]

d. A small ac signal with V_{RMS} = 10 mV is now placed at the input. Sketch the expected output signal with C_3 in place assuming a high impedance load at the output. [2.5 marks]

e. Sketch the expected frequency response of the small signal voltage gain magnitude for the cases with and without the bypass capacitor C_3.
[5 marks]

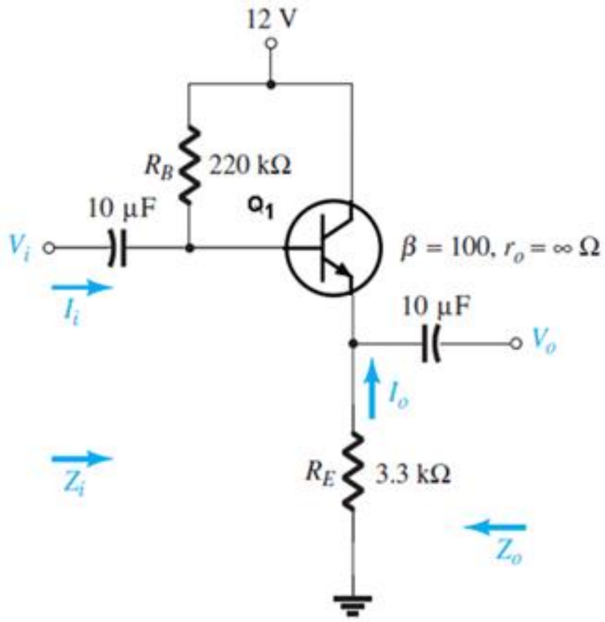
f. If the operating frequency of the amplifier is between 500 Hz to 10 MHz, calculate value of the input decoupling capacitor. [7.5 marks]

g. As part (f), calculate value of the output decoupling capacitor.
[7.5 marks]

h. Describe also how the value that you have chosen for the bypass capacitor will affect the bandwidth of frequency response of the amplifier. [12.5 marks]

i. Sketch and briefly describe the voltage gain vs. frequency of the amplifier.
[7.5 marks]

1. For a common collector amplifier circuit as shown in the figure below, assume the BJT is a Silicon transistor and its DC gain (β_{DC}) is 100 and r_o is ∞.



Determine:

a. AC internal emitter resistance, r_e. [7.5 marks]

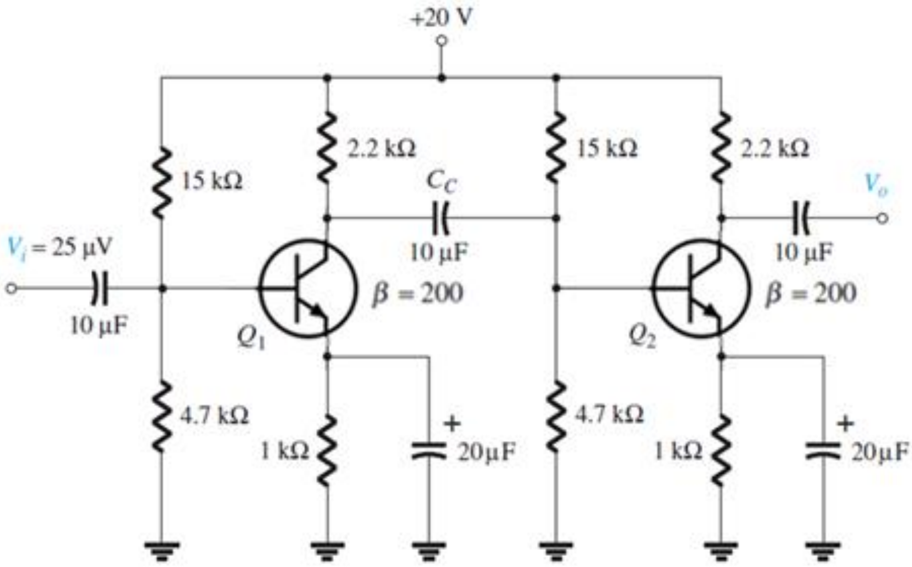
b. Input impedance, Z_i. [5 marks]

c. Output impedance, Z_o. [2.5 marks]

d. Voltage gain, A_v. [2.5 marks]

e. Repeat parts (b) to (d) with r_o = 25 kΩ and compare the results. [12.5 marks]

2. In the following BJT multistage amplifier, the DC and AC gains of transistors Q_1 and Q_2 are $\beta_{DC1} = \beta_{AC1} = 200$ and $\beta_{DC2} = \beta_{AC2} = 200$. The amplifier's input is connected to a 25 µV voltage source. Assume the BJTs are Silicon transistors.



a. Calculate the no load voltage gain and output voltage of the amplifier. [25 marks]

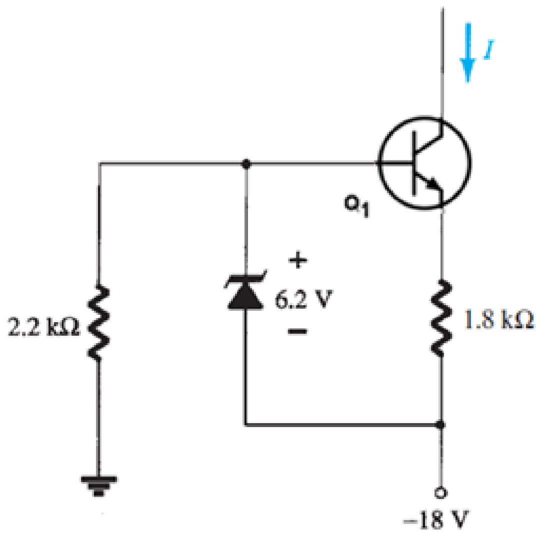
b. Calculate the overall gain and output voltage if a 4.7 kΩ load is applied to the second stage and compare with the results of part (a). [5 marks]

c. Calculate the input impedance of the first stage and the output impedance of the second stage. [5 marks]

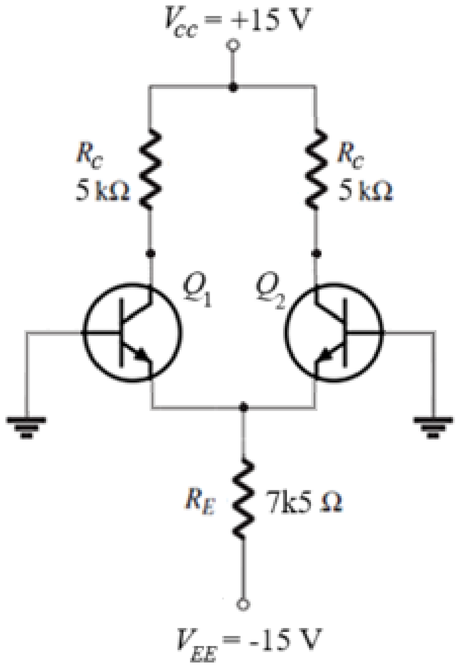
3. In the Zener based current source circuit as shown in the figure below, the rated operating voltage of Zener diode is 6.2 V.

   a. What type of current source circuit is this? Describe the disadvantage and advantage using Zener diode in the circuit, instead of a resistor. [5 marks]

   b. Calculate the constant current I. [2.5 marks]



4. Given the following BJT differential amplifier circuit, perform the following circuit analysis tasks.



a. What are the ideal currents and voltages in the circuit? [10 marks]

b. One of the inputs in the circuit in part (a) is given 1 mV voltage source, what is the AC output voltage? If $\beta = 300$, what is the input impedance of the circuit? [15 marks]

Useful Formulae

The E12 resistor series:

1.0	1.2	1.5	1.8	2.2	2.7	3.3	3.9	4.7	5.6	6.8	8.2

BJT (Small Signal Model Common Emitter):

Parameter	**Formulae**
Emitter current, I_E	$I_E = I_C + I_B$
DC gain of BJT Transistor, β_{DC}	$\beta_{DC} = \frac{I_C}{I_B}$
The internal emitter resistance, r_e	$r_e \cong \frac{25\text{ mV}}{I_E}$
The ac input resistance into the base, R_{in}	$R_{in} \cong \beta_{ac} r_e$
The total input resistance into the transistor, $R_{in}(tot)$	$R_{in}(tot) = R_1//R_2\ //R_{in}$
The total output resistance at the collector, R_{out}	$R_{out} \cong R_C//R_L$
Voltage gain of amplifier, A_v (without emitter bypass capacitor)	$A_v = \frac{R_{out}}{r_e + R_E}$
Voltage gain of amplifier, A_v (with emitter bypass capacitor)	$A_v = \frac{R_{out}}{r_e}$
Power gain of amplifier, A_p	$A_p = A_v A_i$
First order RC circuit for cut-off frequency	$f_C = \frac{1}{2\pi RC}$
Miller capacitance at the input of BJT	$C_{in(Miller)} = C_{bc}(A_v - 1)$
Miller capacitance at the output of BJT	$C_{out(Miller)} = C_{bc}\left(\frac{A_v + 1}{A_v}\right)$