*Name:*________________ *Roll#*________________

Laboratory Assignment 9

Marks: A: /3 B: /5 C: /2+3+2 Tot= /15

Emitter Follower as a transistor current amplifier

Exercises begin on Page 2.

Summary of Labs 5,6,7,8-9: We worked with the NPN BJT as a *voltage controlled voltage source VCVS*.Here are the main points we learnt in Lab in the past labs:

- The transistor *turns on* when the B-E junction is forward biased i.e. $V_{BE} > 0.7V$
- The transistor must be operated by setting up a bias circuit so that it remains in the 'Forward-Active' region of its characteristic as. The three regions of the characteristic are:
  - Cutoff: V_{BE} falls below 0.7V and the transistor is effectively off.
  - Forward-Active: When $0.1V_{CC} < V_{CE} < V_{CC}$, B-E junction is forward biased and C-B junction is reverse biased. In this region the transistor works as a linear amplifier with $I_C = \beta I_B$, $\beta \sim 100$ Note that you should not think of the collector *current* as current due to *diode conduction*. This is because C-B junction normally has reverse bias voltage applied across it.
  - Saturation: When $V_{CE} < 0.25V$, the transistor acts as a 'switch' By varying I_B the transistor can be made to switch rapidly between cutoff (off) and forward-active (on).
- Amplifier circuit design requires you to place the stable operating point at a suitable point in the forward-active region by applying the appropriate bias voltages to the CB and BE junctions.
  Simple resistor-divider biasing network is shown in Fig 1b [as used in Lab 6]
  Other biasing circuits are also possible that automatically compensate for load variation [Labs 8,9 – collector feedback bias]
  Today we will work with the simple resistor divider bias.
- The transistor in Forward-Active mode can be regarded as a little can with a sailor inside it as shown in the cartoon in Fig 1c: The sailor's job is to keep looking at I_B and 'steer' I_C so that $I_C = \beta I_B$
  The sailor's working conditions are that the transistor must be biased in forward active mode, i.e. $V_{BE} > 0.7V$ and $V_{CE} > 0.25V$

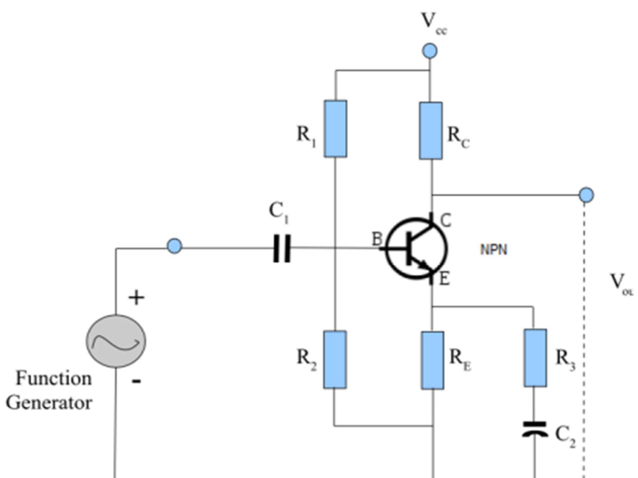

Fig 1a: CE amplifier (resistor divider bias)

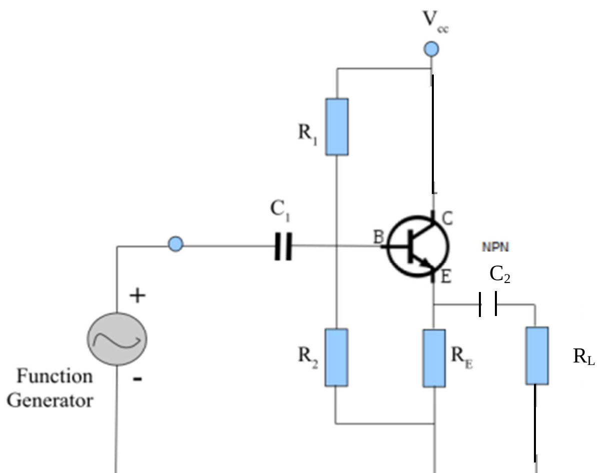

Fig 1b: Emitter Follower (resistor divider bias)

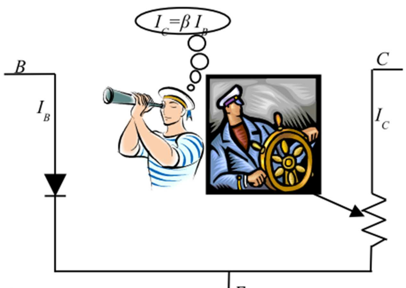

Fig 1c

All the circuits we designed so far extracted the output from the collector of the transistor.
In this lab, we will extract the output from the emitter where $I_E \sim I_C$ is the amplified current.

Design steps for an emitter follower:

As discussed in the last lecture, the steps for designing an Emitter follower are very similar to thoseused for a CE voltage amplifier – in fact some of the steps are simpler.

Step 1: Choose to draw the output from the emitter instead of the collector

a) In common collector mode, Collector is directly connected to V_{CC} omitting R_C

b) C_2 acts as a decoupling capacitor to the load resistance R_L

Step 2: Choose the quietoperating point Q for the collector current: I_Q

Choice of $I_Q$is governed by the load – how much maximum RMS power does the load $R_L$need? The maxiumum RMS power is given by $(2I_Q)^2R_L/8$

Step 3: Choose R_E

R_E is calculated to place $V_E$at the center between V_{CC} and 0.

Step 4: Determine bias resistors R_1&R_2

Choose $R_1$and $R_2$to set$V_B$at ~ $V_E+0.7V$

The ratio R_1/R_2 acts as a voltage divider between $V_{CC}$and *GND.* For negligible current flow into base at DC we must satisfy $(R_1||R_2) << R_{base} = \beta(r_e+R_E)$ *. Here 'much less than'→ 0.1 is usually enough.*

Step 5: Determine C_1 C_2 :

In combination with the amplifier DC input resistance, C_1 acts as a high-pass filter to block low frequencies:

$R_{inp} = (R_1||R_2) || \beta(r_e+R_E||R_L)$ *where* $r_e = 25mV/I_Q$

So: $C_1 = \frac{1}{2\pi f_{3dB} R_{inp}}$

C_2 is determined similarly taking the resistors in the emitter leg into account (be careful of making approximations!)

Part A: Design

Suppose you like to listen to music at ear-splittingly loud volume on your headphones.

1. Measure the dc load resistance of each of the left & right channel in yourheadphones. A 3.8mm stereo headphone connector has three connector bands: by convention, the Tip is left channel, the middleRing is right channel and outer Sleeve is ground. (this is called the TRS convention). For a hands-free headset type headphone, there is a fourth band TRS+Mic.
   Your R_L =

2. Let us assume that 10 mW of power is adequate to drive the headphone to ear-splitting loud volume.

The answers to Q1 and Q2 determine your R_L and load power requirements as input to your design.
For uniformity (and safety of your headphones), we will work with a dummy load resistor R_L = 200Ω

Let us further assume that your amplifier is built into your cellphone, so we are working with $V_{CC}=5V$

Design an emitter follower *current* amplifier with a transistor of $\beta=100$ as outlined in steps 1 to 5 above.
Use f_{3dB} =4000 Hz (so you will miss out most of the 'bass' parts of an audio signal which are not good for your health anyway!)
Calculate the bias resistors and input/output decoupling capacitor values

Part B: Circuit building

Build the circuit designed in part A and demonstrate its operation with a triangle input signal. In particular, check if the voltage at the circuit output V_E is able to swing through the full range between ~0 and V_{CC}

Part C: Analysis

1. What is the power dissipated by your circuit when *no input signal* is present $V_{in}=0$? i.e., the circuit is idle with no input.
   The amplifier circuit consists of the BJT, R_E, R_1, R_2, C_1, C_2
   The load R_L is to be considered as a separate component.
   Calculate:

   a. Power dissipated in Amplifier circuit at idle:

   b. Power dissipated in Load R_L at idle:

2. Applying a triangular input signal V_{in} , observe carefully the *voltage* gain V_L/V_{in}:

   a. What is the maximum amplitude of V_{in} you can apply before V_{out} distorts

   b. What is the *current* gain I_L/I_{in} ?

   c. What is the power dissipated in the amplifier circuit and Load R_L at max loud output:

In both cases, what is the ratio of useful power delivered to load over the power dissipated as heat within the amplifier circuit?

3. Does this make the simple emitter follower a viable current amplifier to use in your cellphone? With a 4000mAh battery in the cellphone, calculate how long the battery would last if you were to play music at maximum loudness continuously with the headphones driven by this emitter follower (assuming you are using the device for exclusively listening to music without any phone calls)