Homework Assignments

November 22, 2017

1 Homework 1 - Due Oct 20

From the text: 1.2 (p5), 1.4 (p6), 1.5 (p6), 1.6 (p6), 1.11 (p11), 1.15 (p21), 1.17(p23)

Additional Problem 1.1:
Show that the root-mean-square average

$$V_{\rm rms} \equiv \sqrt{< V^2(t) >}$$

for a sinusoidal AC current given by:

$$V(t) = V_0 \sin(\omega t)$$

is:

$$V_{\rm rms} = V_0/\sqrt{2}$$

2 Homework 2 - Due Nov 3

From text: 1.20 (p33), 1.31 (p51), 1.33 (p52), 1.35 (p54), 1.39 (p66), 1.43 (p67)

Notes: For problem 1.20, instead of "Chose the appropriate AC input voltage" it should read "assume you will power this device from a 115 V AC wall outlet, and choose the turns ratio of the transformer appropriately."

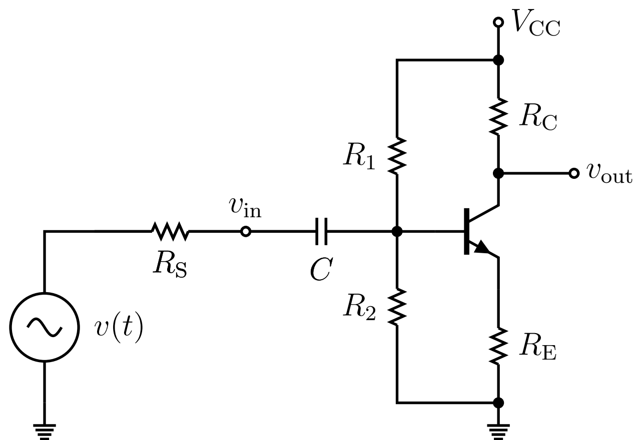
3 Homework 3 - Due Dec 4

Note: I promise that I will never (in an exam or homework) ask a question that requires using the hybrid-pi small signal model for the transistor without explicitly mentioning it and providing the diagram. Most circuits can be analyzed for basic design purposes without using the hybrid-pi model.

This assignment is a bit longer, and counts for twice as much as each of the previous two homework assignments. Leave plenty of time!

From text: 2.5 (p 81), 2.8 (p 85), 2.9 and 2.10 (p 86), and 4.1 (p 227). Note that for exercise 2.9 and 2.10 the current source here is simply a voltage source with a large resistor in series! Note for 4.1 that the INA105 is shown in Fig. 4.9, it is an integrated circuit (IC) that already includes precision resistors.

Additional Problem 3.1:
Consider the following CE amplifier driven by a sinusoidal voltage source with input impedance R_S and where we we will take $C = \infty$ (i.e. it is a short circuit for the AC signal):



(A) Suppose that we have a source impedance $R_S = 500\ \Omega$. What is the maximum possible value for $R_1||R_2$ (parallel resistance of R_1 and R_2) that will keep the attenuation of v_{in} relative to $v(t)$ at no more than 10%?

(B) Suppose we decide to keep $R_1||R_2 = 10$ kΩ. Assume for this calculation that $R_2 \sim 10$ kΩ and that we are using a transistor with $\beta = 100$. What is the minimum value of R_E that we can use which will prevent R_E from significantly (more than 10%) affecting the DC bias point?

(C) Suppose that $V_{CC} = 10\ V$ and that we wish to bias the transistor with $I_C^Q = 10$ mA. Calculate the value of R_C that puts the quiescent output voltage at $\frac{1}{2}V_{CC}$. Using the minimum value of R_E from part B,what is the maximum gain that you can achieve with this circuit?

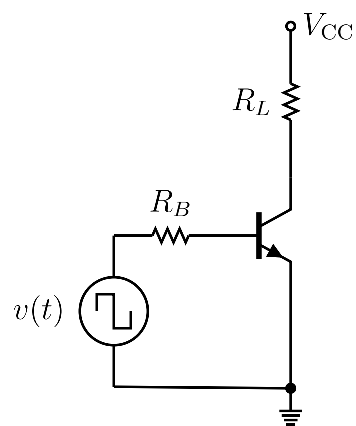
(D) Suppose that isn't enough! You actually have a few options, but you will need to sacrifice something. First, suppose that your input signal is quite small, so even when amplified by a gain of 5, it will stay safely below 1 V peak to peak. Show that by moving the quiescent output point for v_{out} to 1 V (instead of $\frac{1}{2}V_{CC}$) by varying R_C, you can obtain a gain of 5.

(E) You can also crank up V_{CC}! Show that by raising V_{CC} you can return the quiescent operating point of v_{out} to 5 V while still keeping the larger value of R_C and a gain of 5.

(F) Suppose you must keep $V_{\text{CC}} = 10$ V. Another option is to place a capacitor parallel to R_E. This will reduce the impedance at R_E at high frequency and therefore increase the gain. Calculate the value of the capacitance needed to obtain a gain of 5 at 10 kHz.

(G) Design a CE amplifier using a single transistor, with an input impedance of 100 kΩ, that provides a gain of 5 at 100 kHz. Assume you want $I_C^Q = 1$ mA for this device and $\beta = 100$. Set V_{CC} as you like. Provide values for R_1, R_2, R_C, R_E, C and any other components that you use.

Additional Problem 3.2:
(A) Design a transistor switch:



capable of driving a 1 kΩ load (R_L) at $V_{\text{CC}} = 10$ V from a control signal with value of either 0 or 1 V. The design here involves choosing the correct value of R_B to provide enough base current to drive the transistor into saturation. Assume $\beta \sim 10$ at saturation.

(B) Suppose that at saturation $V_{\text{CE}} = 0.2$ V. How much power is your transistor consuming?

(C) For $V_{\text{CC}} = 10$ V what is the smallest resistance R_L you could drive at 10 V, assuming that your transistor is rated at 1 W and $V_{\text{CE}} = 0.2$ V.

Additional Problem 3.3:
An import limitation for real operational amplifiers is their *gain-bandwidth limit*. This limits the gain at high-frequency by placing a limit on the product of the frequency times the gain provided by the device. In most ICs, this is due to a low-pass filter intentionally included in the design to avoid high-frequency instabilities and provide consistent response from device to device. For the LM714 op amps used in lab, the gain bandwidth product is around 1 MHz.

(A) Design an LM714 op-amp based circuit that has (nearly) infinite input impedance, and an overall inverting gain of 100 for frequencies up to 100 kHz. *Hint: use multiple op amps to overcome the gain bandwidth limitations!*

(B) Design a non-inverting amplifier based on the LM714 with (nearly) infinite input impedance, and an overall gain of 100 for frequencies up to 100 kHz.