MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering

6.331 Advanced Circuit Techniques

Fall Term 2011 — Issued : Thursday, September 8, 2011
Problem Set 1 — Due : *Tuesday*, September 13, 2011

You should feel comfortable (although not necessarily ecstatic) with these problems if you intend to take 6.331.

Problem 1 The circuit shown in Figure 1.1 is excited with a rectangular pulse of current, 1A for 2π seconds, as shown. Sketch and dimension $v(t)$ for all time. $R = 1\text{k}\Omega$.

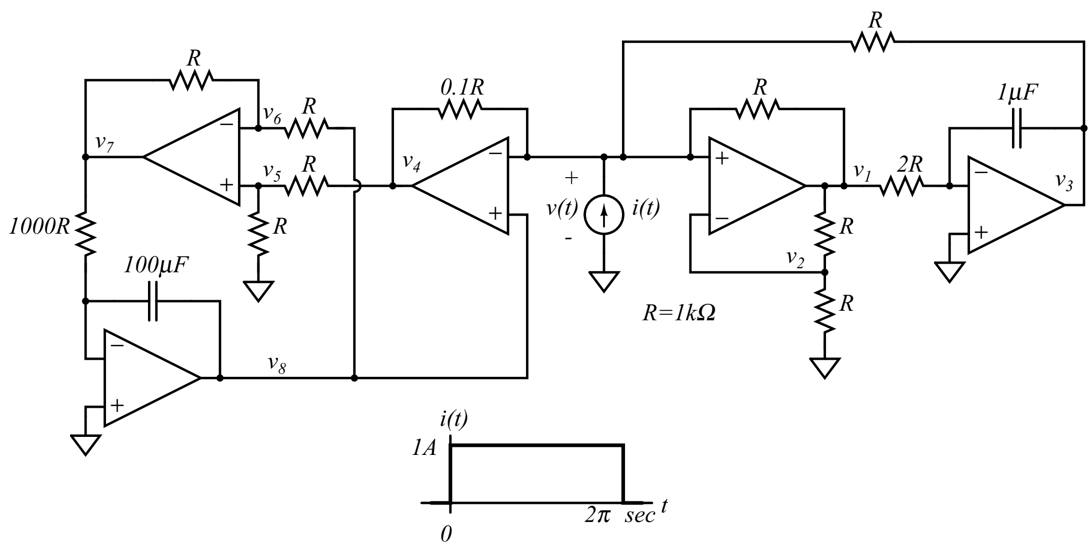

Figure 1.1: Circuit

Problem 2 The circuit in Figure 1.2 is to function as an AGC (Automatic Gain Control). The amplitude of the sinewave output, V_A, is to be held at 0.5 volts (peak), independent of the input sinewave amplitude, V_I, for 2.5 mV $< V_I <$ 25 mV (peak).

A. One problem with an AGC is that the gain element may not have enough dynamic range to accomodate all changes in input level. Show that for the two extremes of input amplitude, transistor Q_2 (on the right) neither saturates nor cuts off. (Note: the result is independent of the value of R_L.)

B. The function of the series combination of blocks B and C is to develop a DC voltage, e_C, proportional to the AGC output amplitude, V_A. If the high frequency cutoff of block C is ω_f, and the frequency of the input is ω_o, what is the ratio e_C/V_A, if $\omega_f \ll \omega_o$? What must e_{ref} be if V_A is to be 0.5 volts peak?

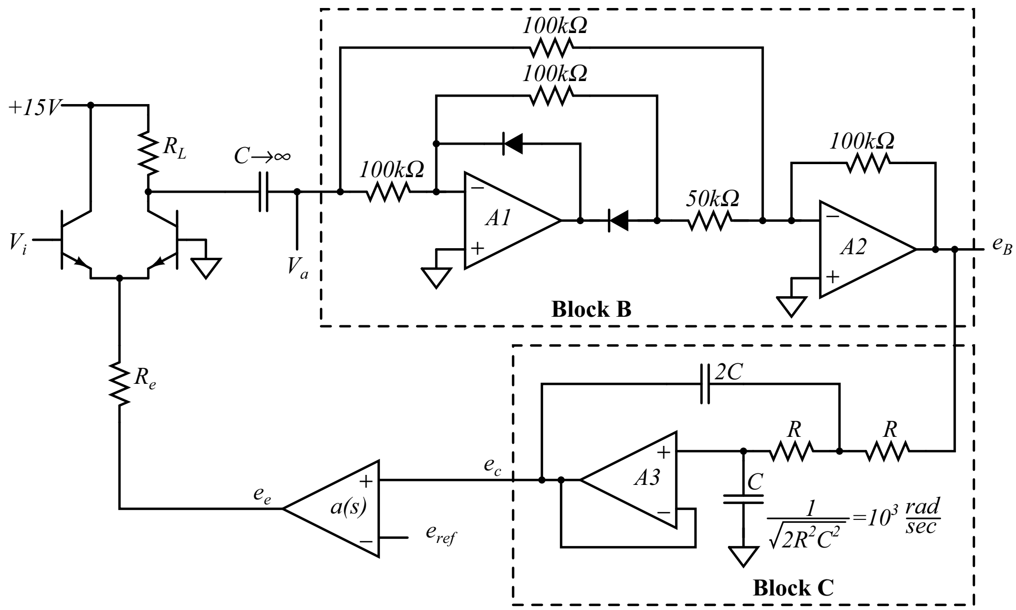

Figure 1.2: Automatic Gain Control

C. Draw a block diagram of the system including the frequency dependence of block C (= $f(s)$) and $a(s)$. You may assume: Q_1, Q_2, A_1, A_2, and A_3 contribute no dynamics; $R_L = 2\text{k}\Omega$, $R_e = 500\Omega$; V_{BE1} and $V_{\text{BE2}} \ll |e_E|$. Convince yourself (and us) that the system acts in such a way as to stabilize the voltage V_A, despite input perturbations. Please include the following variables in your diagram: e_{ref}, V_A, e_C, V_I, $f(s)$, and $a(s)$. (Note: the gain of a block may depend on V_I.)

D. Suppose now that the dynamics of the problem are considered. If the op amp transfer function is

$$a(s) = \frac{500\pi}{s}$$

What is the approximate crossover frequency and phase margin for $V_I = 2.5$ mV? For $V_I = 25$ mV?

E. In reality, the voltage e_C is not a true DC voltage. It has AC components (not necessarily sinusoidal). What is the effect on V_A associated with these AC components? One way to decrease the effect is to increase the frequency, or to decrease the amplitude of the AC components. Sketch and compare $e_B(t)$ for the circuit when block B of Figure 1.3 is used, versus that of the original circuit in Figure 1.2. What happens to the magnitude of the loop transmission? What happens to the period and amplitude of the AC components?

Problem 3 A bipolar transistor with $f_T = 100$ GHz is operating a $I_C = 0.1$ μA. Using the charge control model, find the forward charge in the base, q_F. How many electrons is this?

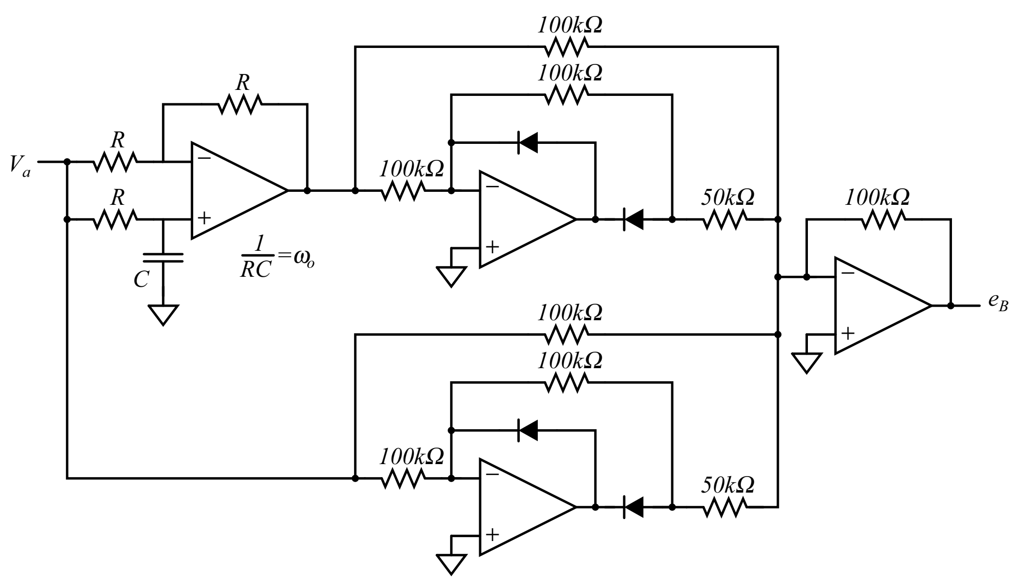

Figure 1.3: New Block B for AGC