Problems for Chapter 11 of 'Ultra Low Power Bioelectronics'

Problem 11.1

Derive Equation (11.1) which pertains to Figure 11.1 (a).

Problem 11.2

Derive the relationship shown in Figure 11.3 as follows: Draw two floating light-dependent current sources, each of value $I_1/2$ from base to emitter and from base to collector respectively that attempt to forward bias the two junctions in the phototransistor of Figure 11.3.

a) Convert the floating current sources into a grounded current source at the emitter and a grounded current sink at the base.
b) Amplify the base current sink by $(\beta+1)$ and use Kirchoff's Current Law at the emitter to obtain the $\left(\beta+\frac{1}{2}\right)I_1$ current shown in Figure 11.3.

Problem 11.3

The value of solar power received over a day at the hottest and brightest places on earth averages to nearly 330 W/m^2. If the quantum efficiency of a photodiode is 0.3, estimate the maximum photo-current that can be obtained from a 100 μm x 100 μm pn junction.

Problem 11.4

Derive Equation (11.21) using the normalized magnitude rule of root locus (see Chapter 2), the definition of Q shown in Figure 11.11 (a), and a root-locus plot.

Problem 11.5

From Chapter 9 and Figure 11.12 (b), show why the last line of Equation (11.16) is a special case of the two-pole τ -rule and two-pole Q-rule for closed-loop feedback systems.

Problem 11.6

In the bio-inspired photoreceptor of Figure 11.8 (a) if C_1 = 10 fF, C_2 = 250 fF, C_{in} = 1 pF, κ = 0.7, A_{lp} = 35 and there are no other capacitances, parasitic or intentional,

a) Compute the transient ac voltage change at the output when the light level abruptly increases by 5%.
b) Compute the final dc voltage change at the output when the light level abruptly increases by 5%.
c) Compute the closed-loop bandwidth for I_l = 220 pA assuming that amplifier dynamics are negligible.
d) Computer the minimum detectable contrast.

Problem 11.7

Derive Equation (11.25) from Equation (11.24).

Problem 11.8

Modify the circuit of Figure 11.8 (a) such that the biasing of amplifier current I_A (that flowing through M_4) is adaptive with light level. Is the adaptive response to a dim-to-bright transient faster or slower than that to a bright-to-dim transient?

Problem 11.9

Practical photoreceptors are often followed by a low pass filter to remove 120 Hz lighting flicker. Why is the lighting flicker at 120 Hz rather than at 60 Hz (the U.S. power-line frequency)?

Problem 11.10

Design a photoreceptor circuit topology whose closed-loop response is not limited by the C_{gs} parasitic of M_3 as in Figure 11.8 (a), and as discussed in Section 11.9.