CENG4480 Homework 2

Solutions

Q1 Given the following system as shown in Fig. 1. Q_1 is so-call NPN bipolar device, which has following voltage-current characteristic:

$$I_C = I_S e^{\frac{kV_X}{T}} \tag{1}$$

where, T is temperature, k and I_S is constant. Suppose R_2 is a temperature-sensitive resister and has resistor value of $R_{2,0}$ at temperature T_0, determine the R_2 in terms of T, so that V_Y is stable as temperature changes.

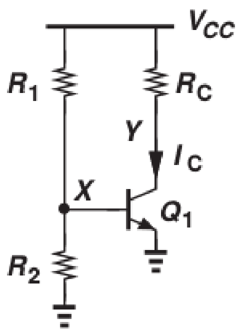

Figure 1: Resistive Divider Biased System

A1 As required $\frac{V_X}{T}$ is constant,

$$V_X = CT \tag{2}$$

Besides,

$$V_X = \frac{R_2}{R_1 + R_2} \tag{3}$$

We have,

$$C = \frac{R_{2,0}}{T_0 R_1 + T_0 R_{2,0}} \tag{4}$$

Combine Eq. (2)–(4),

$$R_{2,0} = \frac{R_1 R_{2,0} T}{T_0(R_1 + R_{2,0}) - T R_{2,0}} \tag{5}$$

Q2 A simple Infra-Red Sensor system to detect passing human is presented as in Fig. 2. A and B are IR Sensors which will generate different output voltages for different infra-red intensity, and higher voltage level corresponds to high light intensity.

(1) Explain how this system works for counting passing pedestrians.

(2) To increase counting accuracy, usually B is covered with materials that can reflect infra-red light. Explain why.

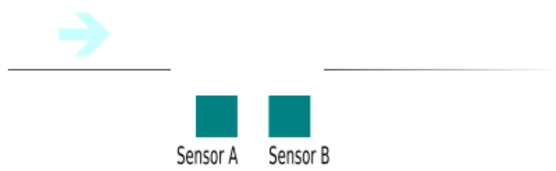

Figure 2: IR-System

A2 (1) When pedestrians pass over IR Sensor, they will approach and deviate the sensor, which corresponds to voltage pulses V_A at the output of it. We can simply count pulse number for passing pedestrian.

(2) When Sensor B is covered with infra-red reflection materials, it can generate pulses V_B caused by non-infra-red wave. We can reduce wrongly counted number by subtract V_B from V_A to avoid counting noise signal.

Q3 Considering the 4-bit DAC in Fig. 3, calculate the output scope of v_a, and the minimum voltage change it can generate.

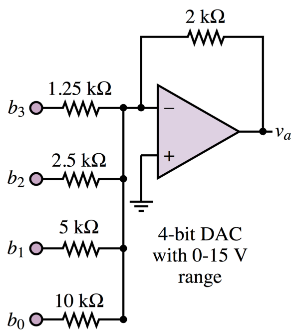

Figure 3: 4-bit DAC

A3 Boundary of v_a occurs at digital input (0000) and (1111), thus the scope of output is 0–3V. Minimum voltage change occurs when the least significant bit changes, at this occasion, v_a has 0.2V change.

Q4 Design a fully paralleled ADC, please provide ADC details. ADC should satisfy: (1) Detect input range 0–3V and (2) Generate 4-bit digital output.

A4 Type: Flash ADC.
For 4-bit output, ADC should be able to sense 0.2V input change, thus total 15 comparators are needed with reference voltage 3.2V.

Q5 For the 4-bit R-2R DAC, calculate V_0 in terms of $V_{b,0} - V_{b,4}$ if V_{ref} is grounded (Fig. 4).

A5 As shown in Fig 5, first we calculate the equivalence seen from V_{o3},

$$R_{eq} = R \tag{6}$$

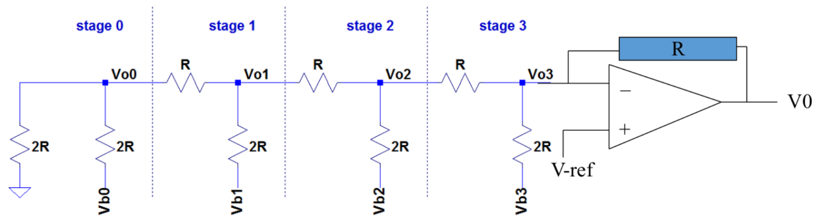

Figure 4: R-2R DAC

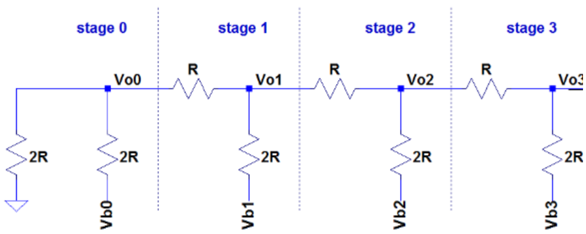

Figure 5: Load of R-2R ADC

Get contribution at V_{o3i} of each digital input V_{bi}, i=0,1,2,3 separately, it's easy to derive from Thevenin equivalent analysis,

$$V_{o30} = \frac{V_{b0}}{16} \quad (7)$$

$$V_{o31} = \frac{V_{b1}}{8} \quad (8)$$

$$V_{o32} = \frac{V_{b2}}{4} \quad (9)$$

$$V_{o33} = \frac{V_{b3}}{2} \quad (10)$$

$$\quad (11)$$

then, we have,

$$V_{o3} = \frac{V_{b0}}{16} + \frac{V_{b1}}{8} + \frac{V_{b2}}{4} + \frac{V_{b3}}{2} \quad (12)$$

Using the quality of op amp,

$$V_o = \frac{V_{b0}}{16} + \frac{V_{b1}}{8} + \frac{V_{b2}}{4} + \frac{V_{b3}}{2} \quad (13)$$

Q6 Briefly describe how PID affects motor control.

A6 TRIVIAL

Q7 Elaborate motion sensors you know.

A7 TRIVIAL

Q8 Describe how Sample and Hold Amp works.

A8 When sampling signal comes, FET switch open, Capacitor will be charged by v_a and v_{SH}=$v_a(t)$ Repeat previous procedure, continuous analog signal is converted into step signals for further quantization process.