CENG4480 Homework 2

Due: Nov. 03, 2020

Q1 (15%) The circuit shown in Figure 1 represents an n-bit weighted digital-to-analog converter. Each switch S_i is controlled by the corresponding bit of the digital number D_i if the bit is 1 the switch is up; if the bit is 0 the switch is down. Please answer the following two questions:

(1) Determine an expression relating V_0 to the binary input bits D_i and V_{ref}.

(2) If $n = 8$, $V_{ref} = -10V$ and input digits$(D_{n-1}...D_0)_2$ is 32_{10}, please caulate V_0.

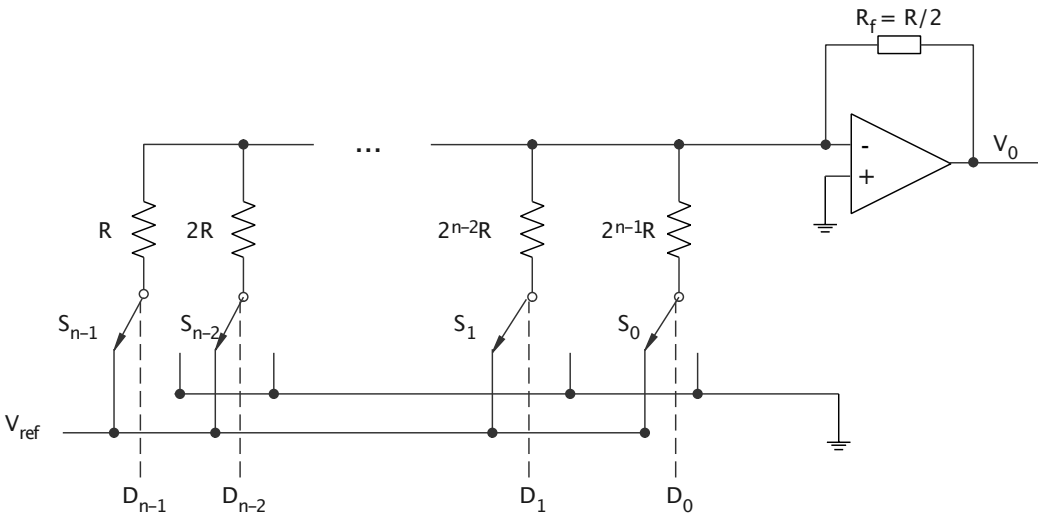

Figure 1: n-bit DAC.

Q2 (10%) For R-2R DAC showed in Figure 2, please calculate V_1.

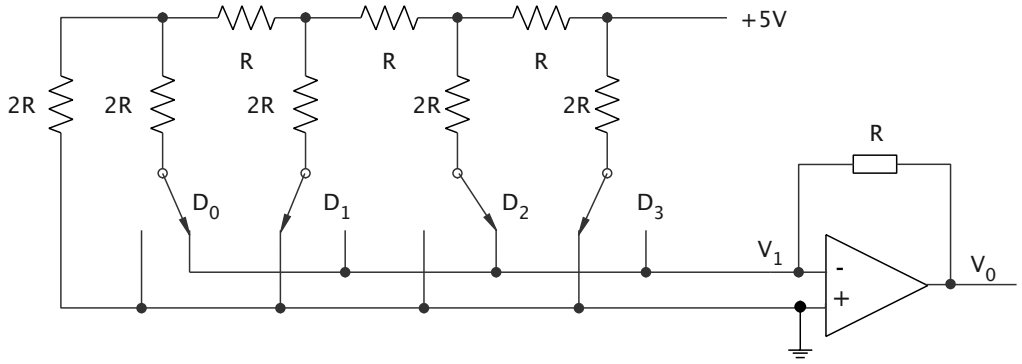

Figure 2: R-2R DAC.

Q3 (15%) A 8-bit analog-to-digital converter (ADC) has the analog input voltage ranging from 0 to +10V. Please answer the following questions.

(1) When the input voltage is 4.48V, calculate the binary output.

(2) What is the smallest voltage step size that can be discerned by this ADC?

(3) What is the function of sample-and-hold amplifier?

Q4 (10%) A simple Infra-Red Sensor system to detect passing human is presented as in Figure 3. 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.

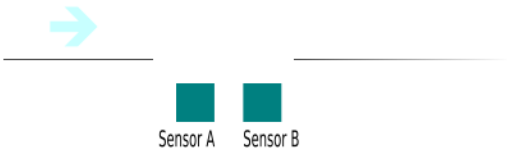

Figure 3: IR-System.

Q5 (10%) Exemplify the working principles of sensors that measure: (1) Flow; (2) Temperature; (3) Pressure; (4) Motion; (5) Liquid Level.

Q6 (10%) Briefly describe how PID affects motor control.

Q7 (15%) Given two Gaussian distributions $N\left(x_0; \mu_0, \sigma_0\right)$ and $N\left(x_1; \mu_1, \sigma_1\right)$, try to give the expectation and variance of a new distribution which is the product of these two Gaussian distributions.

Q8 (15%) Assume the liner estimate system equation is $\mathbf{x}_{t+1} = \mathbf{A}\mathbf{x}_t + \mathbf{w}_t$. Given a second-autoregression random series:

$$x(t) = 1.48x(t-1) - 0.52x(t-2) + \omega_t \tag{1}$$

Kalman Filter is used to estimate $x(t)$ (Here $x(t)$ is a scalar). Try to give the formulations of state transition matrix $\mathbf{A}$ and noise vector $\mathbf{w}_t$.