Lab 4 – Two Bit Digital to Analog (D/A) Converter (DAC)

ECE 4330-5330 - Fall 2018

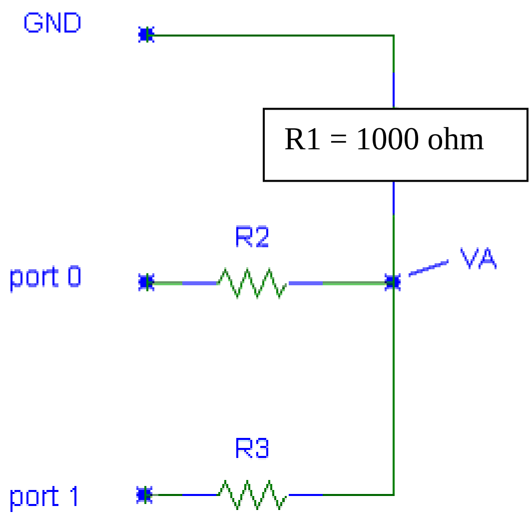

Figure 1: A Two-Bit DAC (For ECE 5330 students a 4-bit DAC is also required)

The requirement for this D/A converter is that it needs to generate at V_A voltages of $0.0V_S$, $0.30V_S$, $1.0V_S$ and a value approximately halfway between $0.30V_S$ and $1.0V_S$. This midway voltage is left as a variable so that the resulting calculations have an extra degree of freedom. The value of V_S is, in this case, 80% the reference voltage of the board.

A. Background:

Typically, a D/A chip is used to convert a digital value into an analog signal. Many D/A chips use similar 2R-R ladders, although other methods are possible. Understanding the internal structure of a D/A converter does assist the designer even when using standard packages/chips.

The Pre-Lab Questions require circuit analysis to derive the values for resistors R_2 and R_3 in Figure 1. For this lab, use a value of 1000 Ohms for R1. This lab description sets up two analyses of equivalent circuits for the digital values 2’b11 and 2’b00. You will have to analyze the circuits for the remaining two values and solve a system of equations to determine the unknown resistor values.

You can solve the system of equations manually.

Optional: For this lab you can use a Computer Algebra System (CAS). Here at UCCS we use mostly MATLAB or Maple.

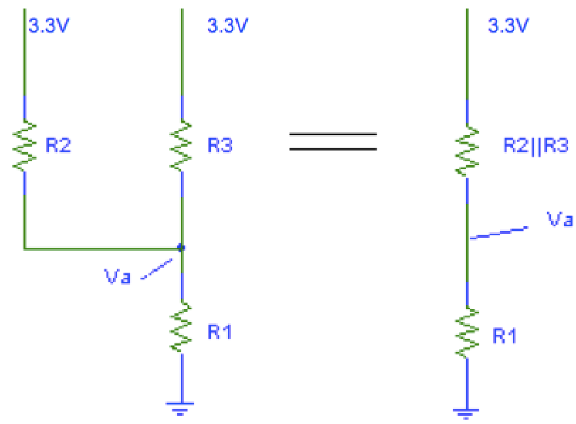

Figure 2: An Equivalent Circuit when $Port_0$=$Port_1$='1'

When ports 0 and 1 are both logical "1" they set a 3.3V value on their respective pins. Since they have the same supply voltage and have one connection in common they appear as if they are in parallel. V_S = .8*3.3V = 2.64V.

$$V_A = \frac{R_1}{\left(R_2 \| R_3\right) + R_1} 3.3V \tag{1}$$

V_A is required to be ≥ 2.64 Volts when the D/A is set to 2'b11, therefore:

$$2.64 = \frac{R_1}{(R_2 \| R_3) + R_1} 3.3V \tag{2}$$

The port values of 2'b00 correspond to circuit that has no potential drops. Therefore, the resistors can have any value. Use equation (2), along with others that you will derive to solve for R_2 and R_3.

You need to derive equivalent circuit equations for the remaining two values of ports 0 and 1. That is, when $port_1$=1 and $port_0$=0 (2'b10) and for 2'b01. At this point you could use Maple to solve the 3 equations for 3 unknowns. For 2'b10 let the voltage for V_A be a parameter, say V_2 and let Maple tell you what values V_2 can be given the constraint $0.30V_S<V_2<1.0V_S$. Be sure to include a copy of the output from the CAS with your lab write-up if you use Maple or Matlab. Alternately you can choose V_2 to be 0.70*Vs and solve 2 equations with and 2 unknowns.

Note: Grad Students must also create a **4-bit DAC**. The steps above can be adapted to 4 inputs to determine the resistance values for 4 resistors, with R_1 = 1KΩ. You can not use a R-2R ladder to create a 4-bit DAC.

1. Pre-Lab Assignments:

1. Read the necessary sections from Nuvoton Technical Reference Manual.
2. Complete the Pre-Lab Questions.

Note: Each student must conduct the labs by themselves. You are not allowed to copy codes/content or to pair-up with other students to complete the labs. Each student must demonstrate individual tasks (after completion) to the professor and teaching assistant to get the full marks for the demo.

2. In-Lab Tasks:

1. Construct the circuit in Figure 1 with appropriate values of resistance. Do NOT connect the circuit to the MCU yet.
2. Given your computed values of R_2 and R_3, with R1 = 1KΩ, verify the voltage of V_A for the four possible port values.
3. Connect the above circuit to the MCU.
4. Write software for the NUC140 MCU that sets analog voltages at V_A. Have the software loop through the voltages from $0.0V_S$, $0.30V_S$, xV_S, $1.0V_S$ and step back down to $0.0V_S$. Include a delay between each value.
5. Verify and document the resulting voltages of V_A.
6. LCD needs to display the binary output, ADC digital value, and ADC voltage.
7. Include the heartbeat signal as usual.
8. **Note:** Grad students must repeat the steps above to also implement a 4-bit DAC, with 16 voltage steps (0.0V to $1.0V_S$).
9. Go through the Lecture Notes for Lab 4, and complete any additional requirements presented during the lecture.

3. Parts List:

1. 1KΩ resistor
2. 2 resistors, sizes to be computed by the student.
3. Grad students will require an additional 4 resistors, sizes to be computed by the student.
4. **Note:** If certain components are not included in your lab kit, and/or if some components are not working, ask the instructor for new parts.

4. Deliverables:

1. **To sign-off:** Demonstrate to your professor/lab instructor how your D/A circuit functions and steps through the possible values.
2. **Lab write-up.** Follow the Lab Report Format and the rubric for Lab 4. The report should include:
   a. Introduction including summary of the lab tasks
   b. In lab tasks, problems encountered, your solutions, including hardware and software.
   c. The write-up should also include how you characterized the device and include explanations of any problems encountered/fixed. Include your circuit analysis of the 2-bit D/A converter. Also 4-bit D/A converter for the grad students.
   d. Table and the Graph of your data for measured vs. theoretical values, as detailed in the lecture notes.

e. Discussion and conclusion.
f. Program/code listing for each task.

NOTE: All the lab reports should be typed and turned in as a hard copy on time (check the syllabus for the due date), and a soft copy should be forwarded to the Teaching Assistant: Srikanth Ramadurgam on the due date and time.

Pre-Lab Questions for Lab 4

Name: ___________________________

Examine the Figure 1 on page 1 and answer the following questions. Be sure to include your work and show units, as appropriate, on your answers. 2+2+6 points each, 10 points possible.

1. Based on the electrical characteristics of the NUC140 (see the TRM), given that V_{DD}=4.5V what is the source current for (PA, PB, PC, PD, PE) when in quasi-bidirectional mode?

   What is the sink current (V_{DD}=4.5V) for (PA, PB, PC, PD, PE) in quasi-bidirectional mode?

2. How much current can the ports source and sink in the push-pull mode when Vdd=4.5 V.

3. Derive the values for R_2 and R_3 in Figure 1 as defined previously in the lab handout. If you do this via Matlab or Maple, please include the results and the code used.