Name: *Roll #*

Laboratory 7 – Digital to Analog Converter

Procedure:

This assignment has a single Exercise with several Questions. Work out the solution to the design problem first on paper and implement it on a breadboard. You are required to submit the complete question and answer sheet with your design and answers filled in where asked, and show your working circuit to a TA.

Designing a Digital-to-Analog Converter:

Introduction:

A Digital-to-Analog Converter (DAC) converts a digital input code into an analog output voltage. It takes a digital input signal as an n-bit number represented by TTL logic levels, and produces a proportional analog output voltage in a fixed range. For example, a 4-bit parallel DAC would have four input lines, and have an input range corresponding to (0000-1111) (0-15). If we fix the analog output voltage range of this DAC to be 0 V to 4 V, then any input code between 0000 and 1111 would give a proportionally intermediate value of output voltage, as shown in Fig. 1. The larger, the number of bits, the smaller the 'step size' in Fig 1 – i.e. the response of the DAC suffers from lesser *quantization* error as you increase the number of bits.

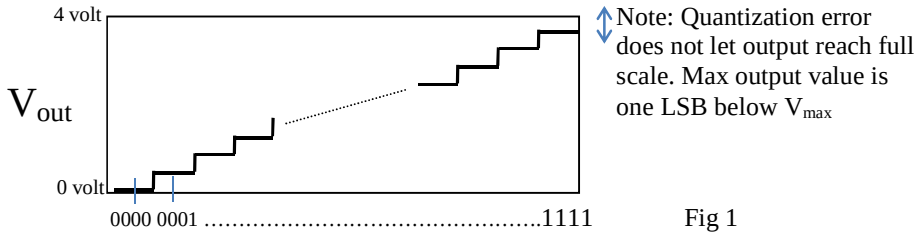

Fig 1

There are many different types of DAC's – the designs have different trade-offs between linearity, speed of conversion, output drive capability etc. We will design and analyze a very basic DAC.

Problem Statement:

Design a 4-bit DAC using the following parameters:

- It must have only passive components. Note that passive components → R,L,C.
  Of these, R is the only *linear* passive – and linearity is a desirable property of a DAC as seen in Fig 1. So we will build our DAC using resistors. In particular, we will use only two values of resistors.
- The DAC's output voltage is controlled by a combination of 4 digital bits: $Bit_3Bit_2Bit_1Bit_0$
- The analog voltage range of the DAC must be set externally.

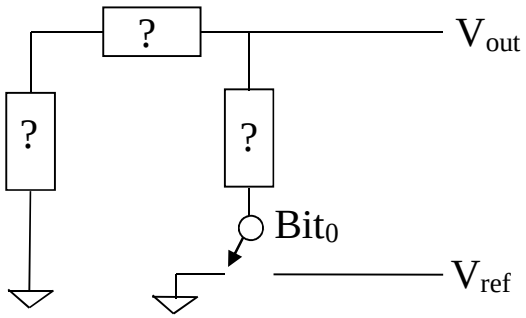

Fig 1: Simple 1-bit DAC.
Design a 1-bit DAC Controlled by Bit_0 [Questions 1-4]

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Questions 1 to 4 refer to Fig 1 as the simple starting point of your design

1: What are the components you would put in the blocks marked with a '?', and what are their values, *relative* to each other? Do the actual values of the components matter? /1

2: Work out the equation that determines V_{out} as a function of Bit_0, V_{max} and the component values you have set for the 1-bit DAC. /1

3.1: What is the maximum output voltage of the DAC? /1
How would you change the maximum output voltage?

3.2: What is the minimum value of the DAC output voltage? /1
How would you change the minimum output voltage?

4: What is the output impedance of this circuit? What restrictions does it place it on the load? /2

5: Now extend your design from a 1-bit DAC into a 4-bit DAC. Draw the DAC design below with the appropriate component values filled in, and work out the full equation for the 4-bit DAC as in Question 2 /7
Hint: You are only allowed to use two values of components.

6: Wire up the DAC on a breadboard using any suitable component values. Demonstrate its operation to a TA with three or four suitable inputs from the 0000-1111 range. Use wires connected to V_{min} or V_{max} as Switches representing $B_3B_2B_1B_0$ Be neat! /2
It should be possible for us to understand your circuit design by simple inspection.
Leave the circuit connected on your breadboard for future use.

7: Although we have used the term 'voltage' in all the above questions, /1 bonus
Is the output of the DAC a voltage output or a current output?

Total: /15+1