Lab 7 - Digital to Analog Conversion

Objectives

In this lab you will build and test simple D/A converters. You will also learn how to use and program the digital outputs from the ADALM2000.

Laboratory Equipment

You will use the following components:

- Resistors, Op amps

All measurements can be performed using:

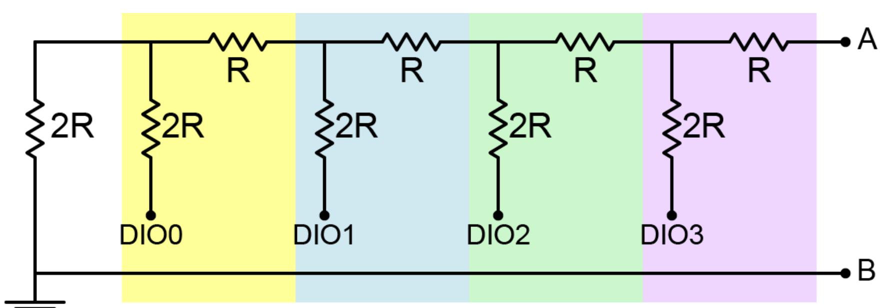
- Digital multimeter
- ADALM2000 (Scopy)

Pre-lab Preparation

Watch the following video, which explains the principle of the the R-2R digital to digital to analog converter:

- https://vimeo.com/61398001

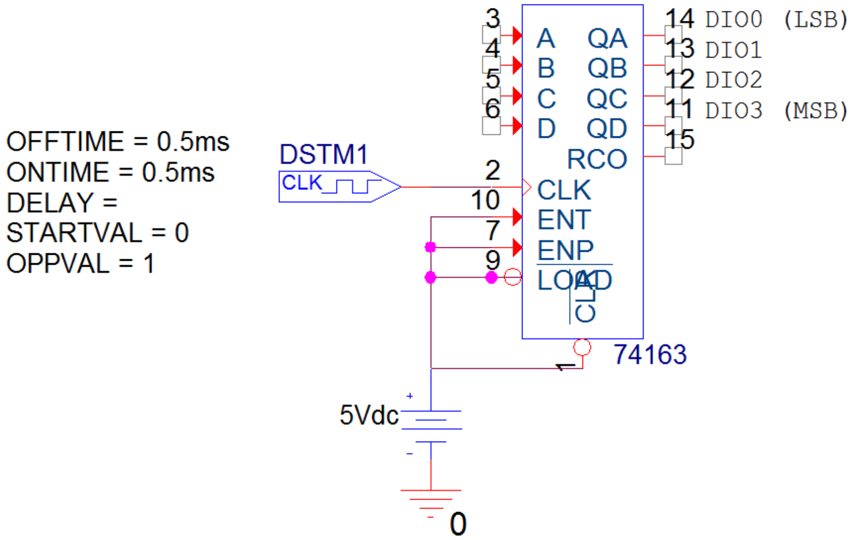
Simulate the following four-bit R-2R DAC using PSpice.



The four digital outputs DIO0...DOI3 can be simulated in PSpice using the 74163 counter, which is a four-bit counter. Below is how to connect the 74163 to produce four digital outputs. You will need to place and connect the following PSpice parts:

- DigClock (found in Library►Source►Stimulus Sources►Clock)
  Set off-time to 0.5ms and on-time to 0.5ms, to produce a square wave with a frequency of 5 kHz.
- 74163 (found in Library►Logic►Counters)
- VDC (Set to 5 VDC)

- change DIGINITSTATE to "0"

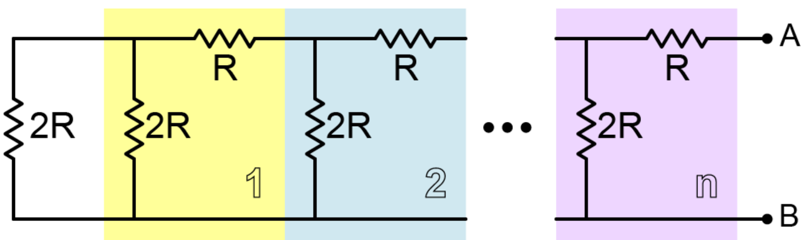


Make a plot showing the output voltage $v_{AB}(t)$ as a function of time.

Instructions

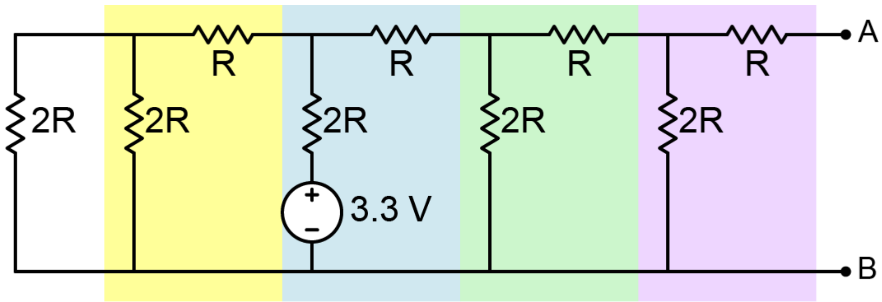
Ladder Circuits

Build the R-2R ladder circuit, using R=1 kΩ and 2R = 2 kΩ resistors. Measure and record the equivalent resistance R_{AB} as a function of n, the number of stages, for n = 1, 2, 3 and 4 stages:

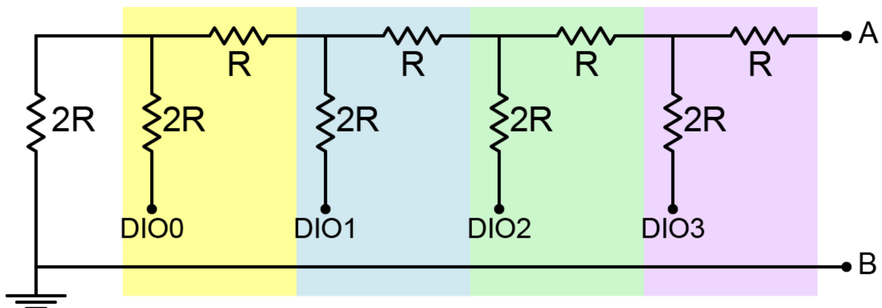


R-2R Passive DAC

1. Now insert a 3.3V DC output voltage source into the circuit just below each of the 2R resistors, one at a time. (For example, below we show one case, where it is inserted in the second stage.) You will need to connect B to ground



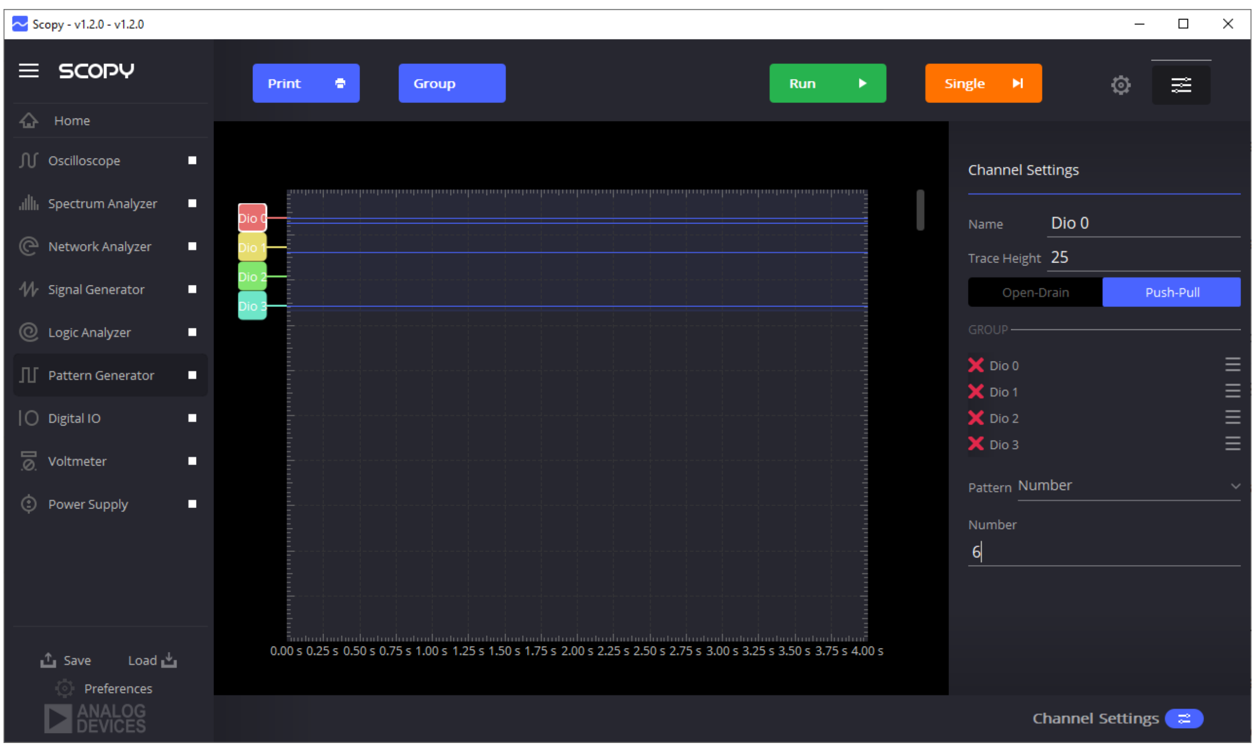
2. Measure and record the output voltage v_{AB} produced in each case.
3. Now connect the four outputs DIO0 … DIO3 just below each of the 2R resistors, to form a 4-bit digital-to-analog converter:



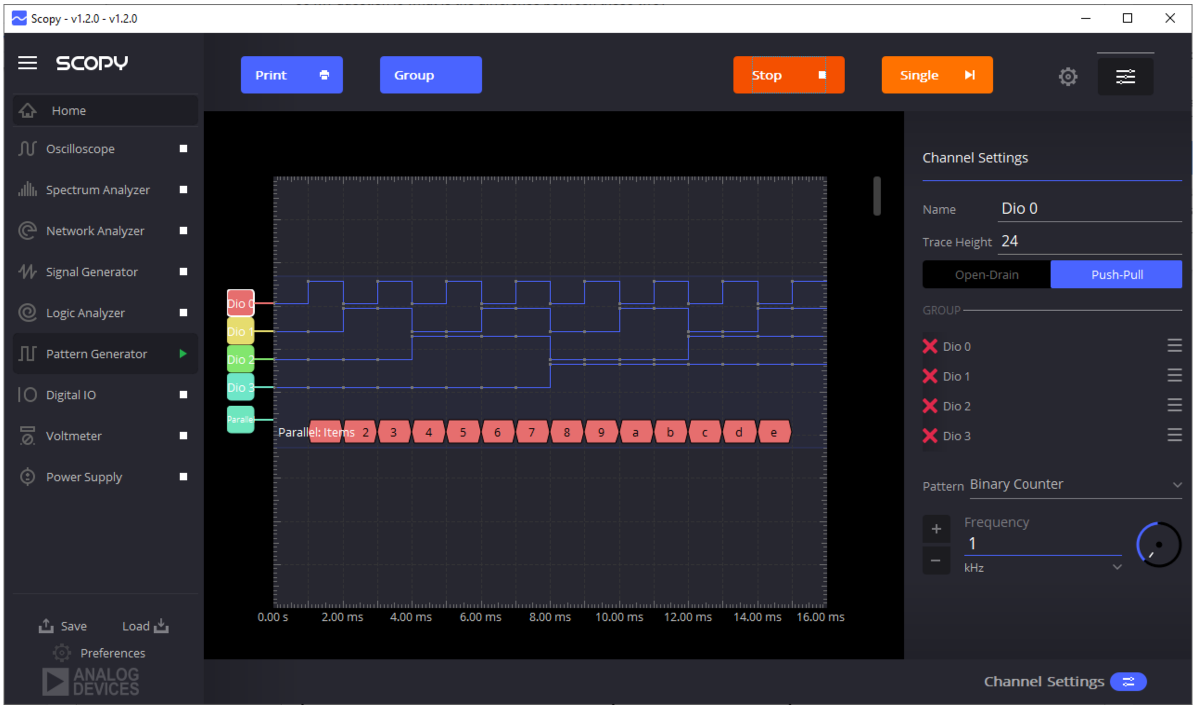
4. In the Digital IO menu, you can turn each of the digital outputs on or off one at a time by clicking on the “0” or “1”. You will need to click “Run” to enable the digital outputs. Measure and record the output voltage v_{AB} for the following cases (i.e., by enabling each of the inputs one at a time):
   - {DIO3,DIO2,DIO1,DIO0} = {0,0,0,1}
   - {DIO3,DIO2,DIO1,DIO0} = {0,0,1,0}
   - {DIO3,DIO2,DIO1,DIO0} = {0,1,0,0}
   - {DIO3,DIO2,DIO1,DIO0} = {1,0,0,0}
5. In the Pattern Generator menu, configure the four output channels to produce a four-bit binary counter. This will repeatedly cycle through all 16 bit combinations.

- Start by enabling the four digital output channels:

- Next, use the “group” button to combine the four available channels into a set. (press “done” after double-clicking to highlight all of the active DIO channels.)



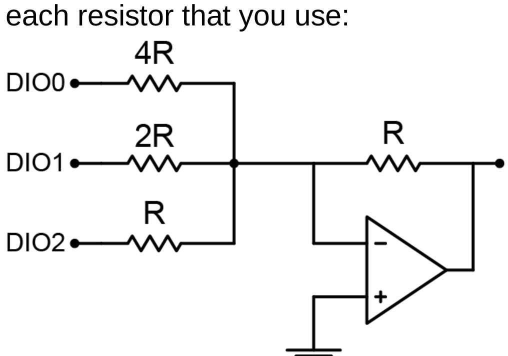
- Then use the Channel Settings menu to program the four channels to produce a 4-bit counter, with a frequency of 5 kHz:



6. With the counter running, use the oscilloscope to measure and record the DAC output voltage waveform $v_{out}(t)$
7. Change the Pattern from “Binary Counter” to “Number”, which allows you to easily generate any desired 4-bit number. Record the output voltage for all numbers from 0… 15.
8. In integrated R-2R DAC circuits, the resistors are precisely adjusted to achieve accurate results. To investigate the effect of errors in your DAC, increase one of the 2R resistors by 5% (by adding a small series resistor.) Take note of which resistor you alter. Change back to the binary counter and measure the voltage waveform $v_{out}(t)$ again.

Active Op-Amp DAC

1. Use a three-input summing amplifier to build a 3-bit DAC. Measure the actual values of each resistor that you use:



2. Measure and record the output voltage for each input combination from 0 to 7.
Hint: In the Scopy pattern generator, you can simply set Pattern = Number, which will allow you to output a specific digital number

Post-lab Analysis

Generate a lab report “following” the sample report provided. Mention any difficulties encountered during the lab. Describe any results that were unexpected and try to account for the origin of these results (i.e. explain what happened). In ADDITION, answer the following questions:

Ladder Circuits

1. Does the actual measured resistance change as you go from n = 0 to n = 4 ladder stages in your resistor network?
2. The n=2 ladder circuit uses 5 resistors: three 2 kΩ resistors and two 1 kΩ resistors. These resistors are accurate to 1%. Write a program, or create an excel table, or perform a calculation to estimate the uncertainty of the net resistance R_{AB}, assuming that each of the resistors has a random, independent tolerance of 1%

R-2R Passive DAC

1. In the lab, you measured the output of the passive DAC when each of the four digital inputs was separately enabled. For an arbitrary binary input pattern, the output can be calculated as a superposition of these four cases. Make a table that shows the predicted output voltage (based on the four measurements) for all 16 possible input combinations from {0,0,0,0} to {1,1,1,1}.
2. How do the predicted voltages compare to the actual measured voltages obtained for binary inputs from 0 to 15?
3. How does your counter behave when one of the resistors is altered? Simulate your altered circuit in PSpice (see instructions in the pre-lab) and verify this behavior.

Active Op-Amp DAC

1. How might one improve the performance of the D/A converter?
2. How do the measured results compare with the PSpice simulations?

General Questions

If you were to build a 12-bit D/A converter, would you choose the active or passive DAC? Why?