SINGAPORE POLYTECHNIC
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING

ET0104 Embedded Computer Systems Laboratory

Laboratory 6 - Digital to Analogue, Analogue to Digital Interfacing

1. Introduction

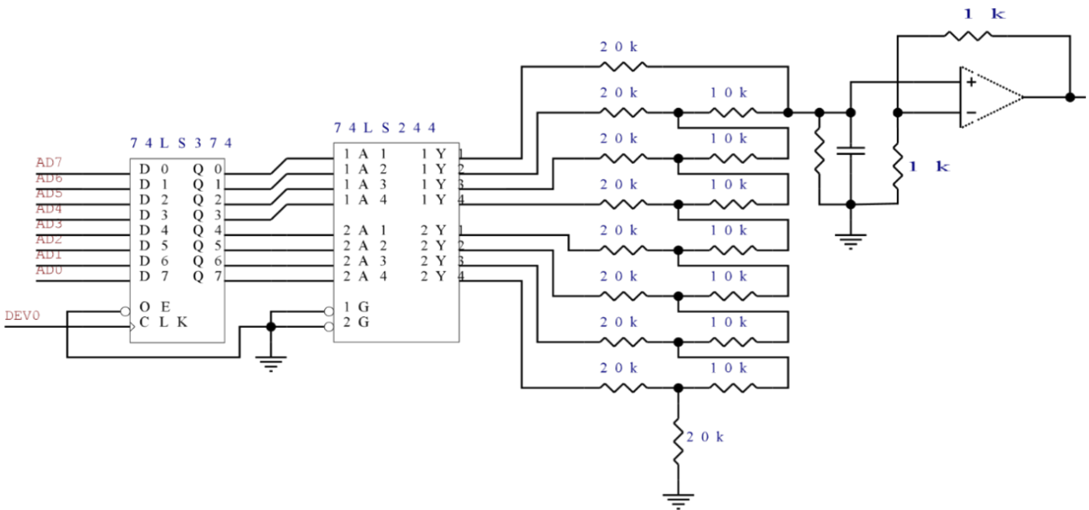
In this lab, you will use the SBC to output various values to an R-2R network.

2. Objectives

- To configure a latch and buffer to work with a R-2R network
- To anticipate the output of a D/A converter given various digital inputs
- To observe the working of a A/D converter

3. Digital to Analogue conversion

1) Digital to Analogue (D/A) interfacing allows a microcontroller to perform analogue control, as opposed to on-off control for purely digital systems. Most D/A converters are made of integrated circuits. These circuits are made up of R-2R networks anyway, with various degrees of quality in the integrated components. In this lab we are using a voltage mode converter. Note the use of the 74LS244 which increases the current drive of the 74LS373 latch. The opamp acts as a buffer and provides a gain of 2.



R-2R ladder in voltage conversion mode

2) First we need to find out the resolution of the D/A converter. This will help us in various calculations later. The resolution is the smallest change in the analogue output, for the smallest change in the digital input. The following program lab6.C will generate a certain waveform: what is its shape?

Sawtooth Wave

```
#define DACPort 0x30
unsigned char DACout;

void main()
{
DACout = 0;
while TRUE
    {
        CM3_output(DACPort, DACout);    /* DAC Port */
        DACout++;                       /* increment */
    }
}
```

3) To answer this, consider the smallest and largest values DACout will take.

4. Initial observations

Now power up the I/O Board, and load the program lab6.C. Run the program and this time, power on the oscilloscope and attach a probe at the connector DA_OUT, located near the top left of the board.

What is the maximum *digital* value that will be output to the R-2R circuit? 255

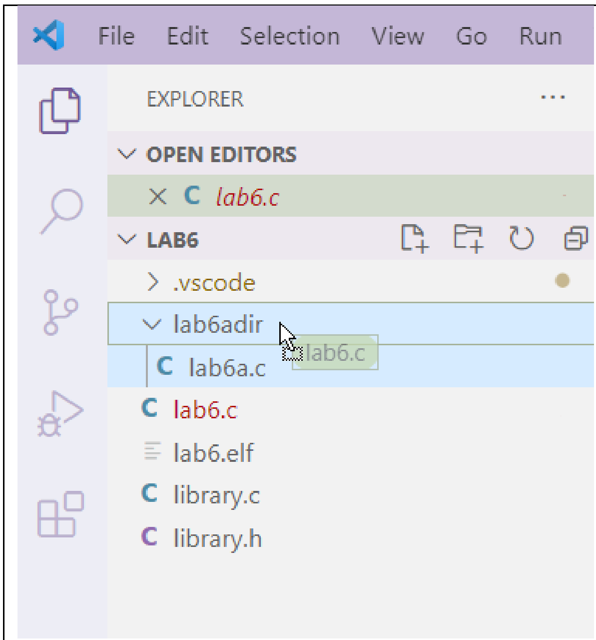
What is the maximum *analog* value of the wave you see? 5V

What is the resolution of the D/A circuit? 8 Bit

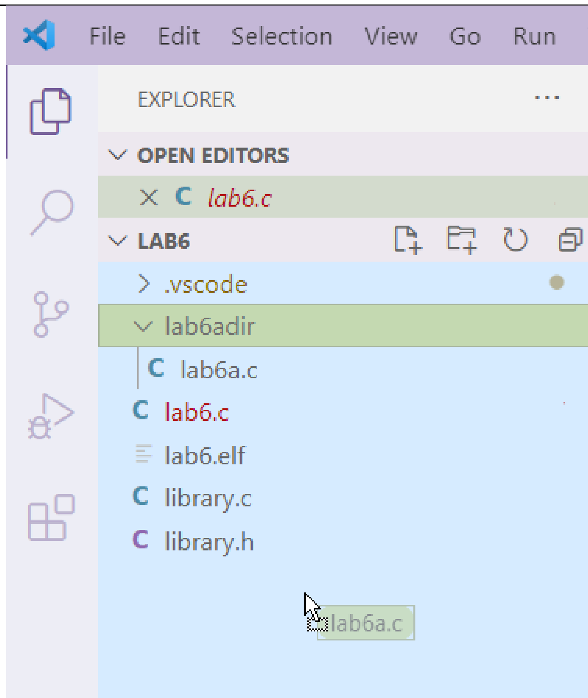
Note that if the waveform was distorted, we should only use the linear portion.

5. Generating a sine wave

We want to bring in another program to generate a sine wave. In our setup, we cannot have two C programs having a `main` function in the same directory. For convenience, we have kept this program in a separate sub-directory called lab6a in lab6. We have to *move* lab6.c into the sub-directory lab6a and *move* the file lab6a.c to the directory lab6.



i) ***Drag*** the file lab6.c to *folder* lab6adir. Click on the ***Move*** button when prompted.



ii) ***Drag*** the file lab6a.c from *folder* lab6adir to *folder* lab6 – bring the mouse cursor past the last file in the folder. Click on the ***Move*** button when prompted.

Check to make sure `lab6a.c` is in *folder* lab6 and `lab6.c` is in the *subfolder* lab6adir.

1) Using the program LAB6A.C, we put in data and count values so we can see a sine wave at the DAC output.

We note that:

i) This hardware configuration cannot output a negative voltage. If we need to generate a sine wave, we need to add an offset to it.

ii) In order to minimize the quantization error, we want the maximum value of the waveform to be reached when the maximum digital value is output.

2) In general, the equation of a sine wave with offset is:

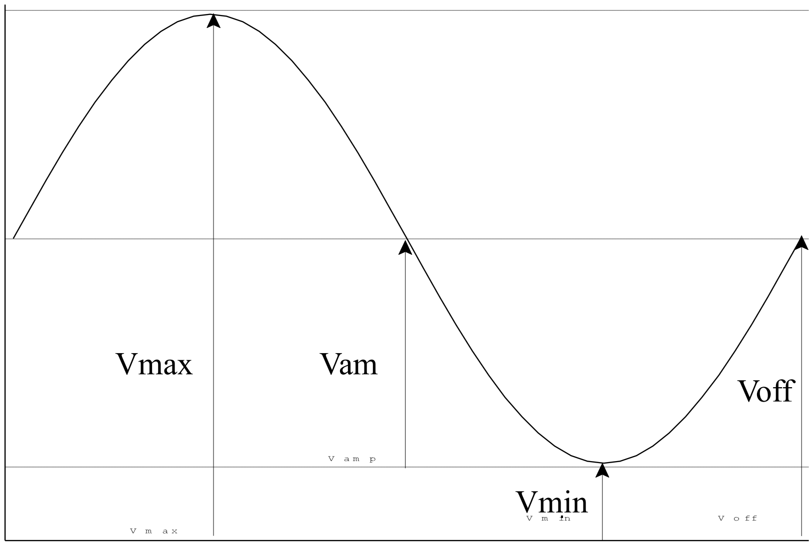
$$\text{Vout} = \text{Voff} + \text{Vamp} * \sin\theta$$

3) From the diagram, the value of the offset voltage,

$$\text{Voff} = (\text{Vmax} + \text{Vmin}) / 2$$

4) Hence the amplitude,

$$Vamp = (Vmax - Vmin) / 2$$



General equation of a sine wave with offset

5) For our lab, we let the minimum be zero, so the sine wave is:

$$V = (Vamp * \sin\theta) + Voff \quad \text{or; } Vmax/2\ (1+ \sin\theta)$$

6) We have seen that the resolution 1 / ρ, is the voltage represented by one bit for the DAC. The *scale factor* F_{scale} is the digital value for one volt and is the reciprocal of the resolution, 1 / ρ.

7) From the previous measurement, the value of F_{scale} is: 255/5 = 51

8) The table below will assist you in the calculation of the necessary values for the generation of a sine wave using 12 equal intervals

θ	0	30	60	90	120	150	180	210	240	270	300	330
$\sin\theta$	0	0.5	0.87	1	0.87	0.5	0	-0.5	-0.87	-1	-0.87	-0.5
$V=(V_{max}/2)*(1+\sin\theta)$	2.5V	3.75	4.675	5	4.675	3.75	2.5	1.25	0.325	0	0.325	1.25
$F_{scale} * V$	127.5	191.25	238.425	255	238.425	191.25	127.5	63.75	16.575	0	16.575	63.75

6. Instructions

1) Substitute the calculated values into the appropriate data locations in LAB6B.C. Execute the program and observe the output on the oscilloscope.

2) What would we have to change in order to obtain

   i) a smoother sine wave?

   Low Pass Filter

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   ii) a higher/lower frequency waveform?

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7. Optional Exercise

1) Generate a half wave rectified sine signal, display and show your lecturer.