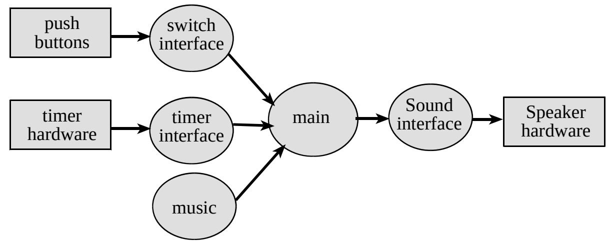
Recap

Synchronization: hardware/software, between threads
SCI interrupts
Fifo queue: what why how



Overview

Design a DAC
Experimental method
Output a sine wave

Digital to Analog Conversion

Signal generation (sound, image, touch…)
Output to affect external devices (power, flow, heat…)

The DAC *precision* is the number of distinguishable DAC outputs
(e.g., 16 alternatives, 4 bits).

The DAC *range* is the maximum and minimum DAC output
(0 to 5V).

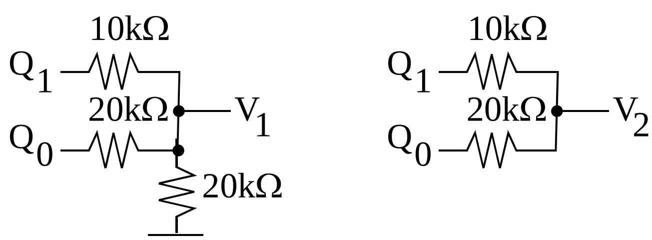
The DAC *resolution* is the smallest distinguishable change in output.
(5V/16 =0.31V)

Range(volts) = Precision(alternatives) • Resolution(volts)

The DAC *accuracy* is (Actual - Ideal) / Ideal

For example, if we were to build a 2-bit DAC. Assume V_{OH} of the 9S12 is 5, and its V_{OL} is 0

N	Q_1	Q_0	V_1(V)	V_2(V)
0	0	0	0.00	0.00
1	0	5	1.25	1.67
2	5	0	2.50	3.33
3	5	5	3.75	5.00



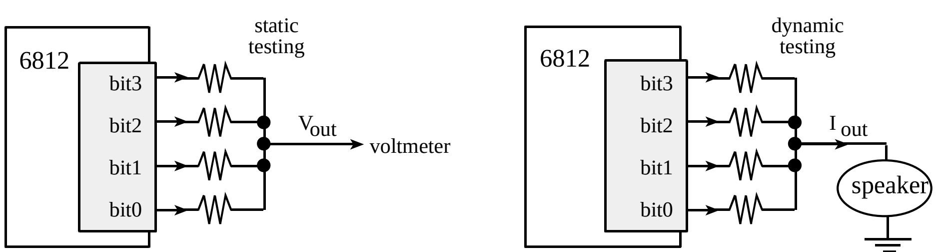


Figure 8.1. DAC allows the software to create music.

You can realistically build a 4-bit DAC using this method. Q_n is 5V or 0V.
Two alternatives (four resistors)

$$V_{out} = (8*Q_3 + 4*Q_2 + 2*Q_1 + Q_0)/15$$

Assume V_{OH} of the 9S12 is 5V, and its V_{OL} is 0

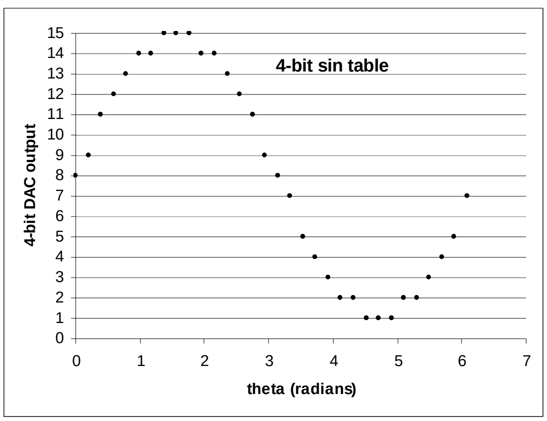
N	Q_3	Q_2	Q_1	Q_0	theory	V_{out}(V)
0	0	0	0	0	5*0/15	0.00
1	0	0	0	5	5*1/15	0.33
2	0	0	5	0	5*2/15	0.67
8	5	0	0	0	5*8/15	2.67
15	5	5	5	5	5*15/15	5.00

or (five resistors)

$$V_{out} = (8*Q_3 + 4*Q_2 + 2*Q_1 + Q_0)/16$$

Assume V_{OH} of the 9S12 is 5V, and its V_{OL} is 0

N	Q_3	Q_2	Q_1	Q_0	theory	V_{out}(V)
0	0	0	0	0	5*0/16	0.00
1	0	0	0	5	5*1/16	0.31
2	0	0	5	0	5*2/16	0.63
8	5	0	0	0	5*8/16	2.50
15	5	5	5	5	5*15/16	4.69

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SinTab    fcb  8,9,11,12,13,14,14,15,15,15,14
          fcb  14,13,12,11,9,8,7,5,4,3,2
          fcb  2,1,1,1,2,2,3,4,5,7
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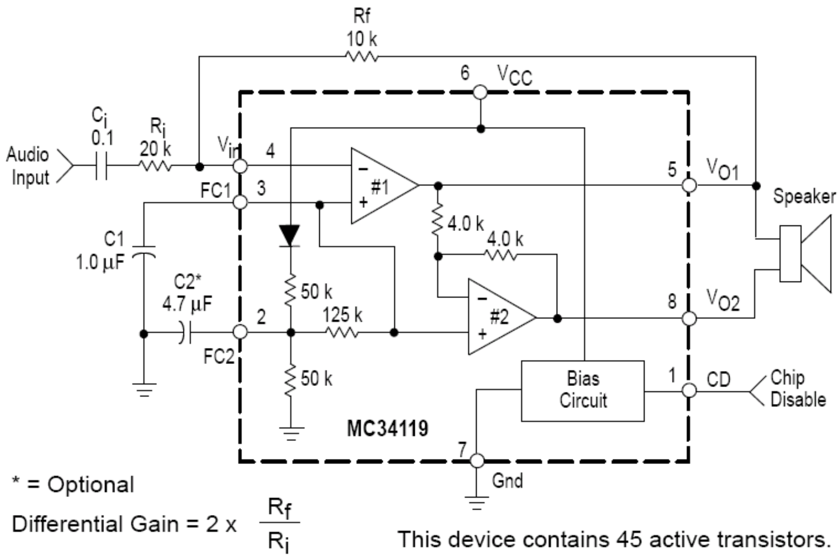
How to create a sin wave with period T?

Periodic interrupt every T/32
Output next entry in table

What happens to the voltage when your DAC is connected to the headphones?

In EE445L we will

Interface a 12-bit DAC
Use this amplifier (Rf=10k, Ri=20k) to drive the speaker
Play songs
Include melody and harmony
Change instruments
Add envelops



Using Ohm's law and fact that the digital output voltages will be approximately 0 and 5 V, make a table of the theoretical DAC voltage and as a function of digital value (without the speaker attached). Calculate resolution, range, precision and accuracy

DAC parameters

Range, resolution, precision
Speed
Cost (is it easy to manufacture?)
Monotonic (always increasing)
Accuracy

Try to use this method to build an 8-bit DAC

Becomes expensive to use very high tolerance resistors
or DAC becomes non-monotomic

Show R-2R ladder, and implement an 8-bit DAC

The bottom line

DAC: precision, range, resolution, monotonic
Use OC interrupts and a DAC to create waveforms
Measurement of accuracy