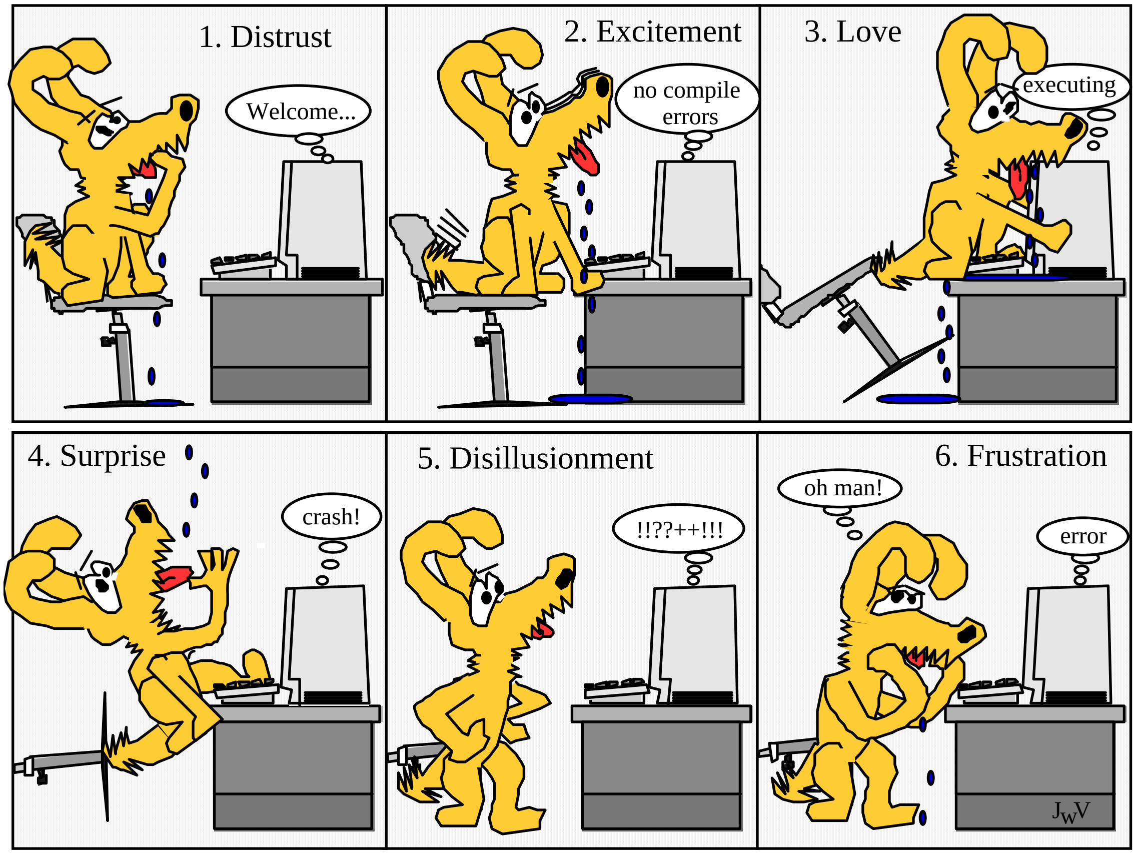


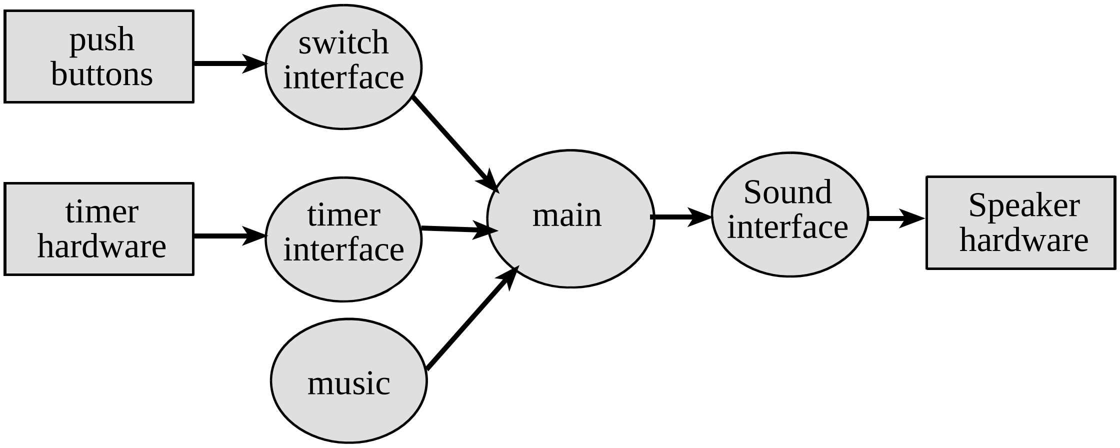
Interrupt programming can be frustrating.

Recap

Synchronization: hardware/software, between threads
Output compare interrupts
C projects

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	Q1	Q0	V1(V)	V2(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

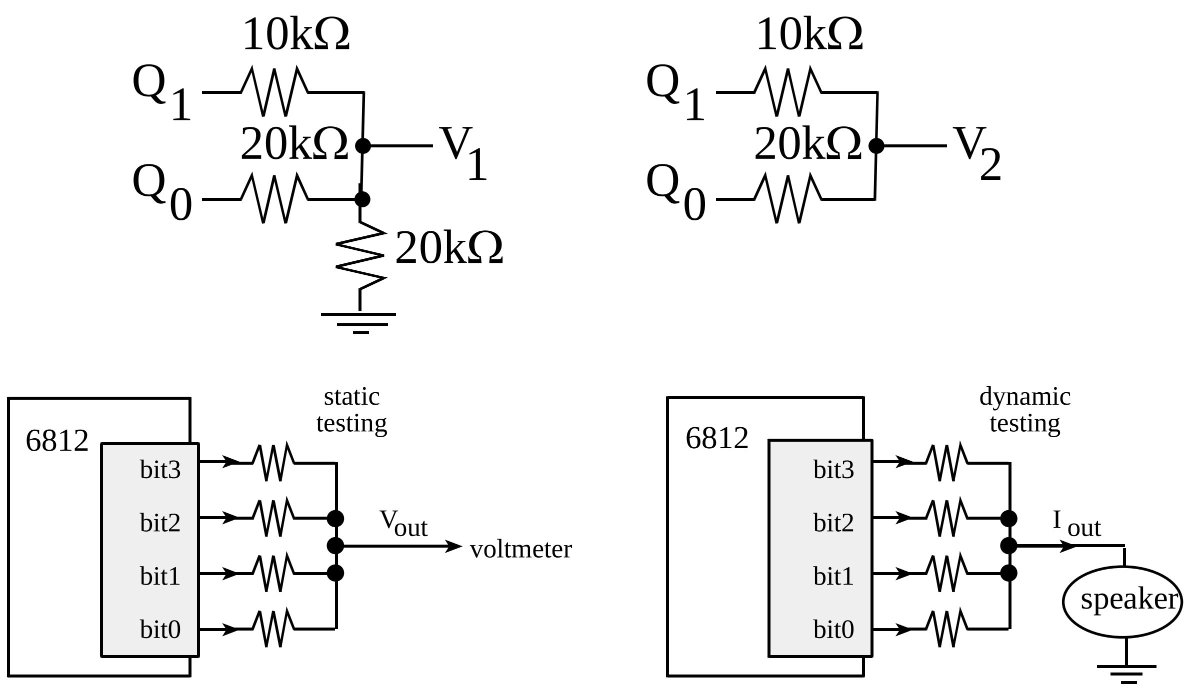


Figure 7.1. DAC allows the software to create music.

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

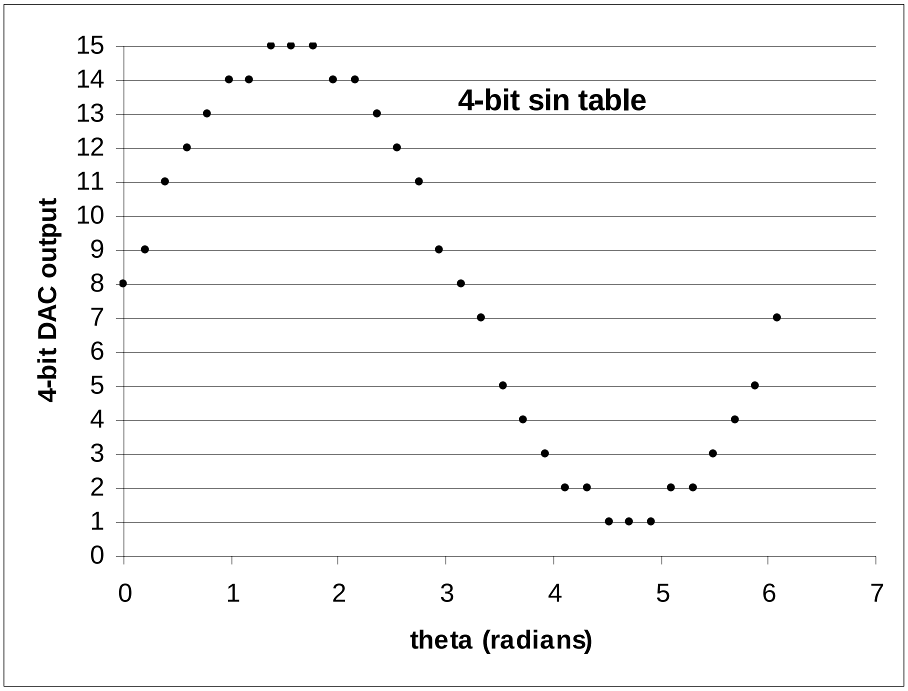
N	Q3	Q2	Q1	Q0	theory	Vout(V)
0	**0**	**0**	**0**	**0**	5*0/15	0.00
1	**0**	**0**	**0**	**5**	5*1/15	0.33
2	**0**	**0**	**5**	**0**	5*2/15	0.67
8	**5**	**0**	**0**	**0**	5*8/15	2.67
15	**5**	**5**	**5**	**5**	5*15/15	5.00

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	Q3	Q2	Q1	Q0	theory	Vout(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




```
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
```

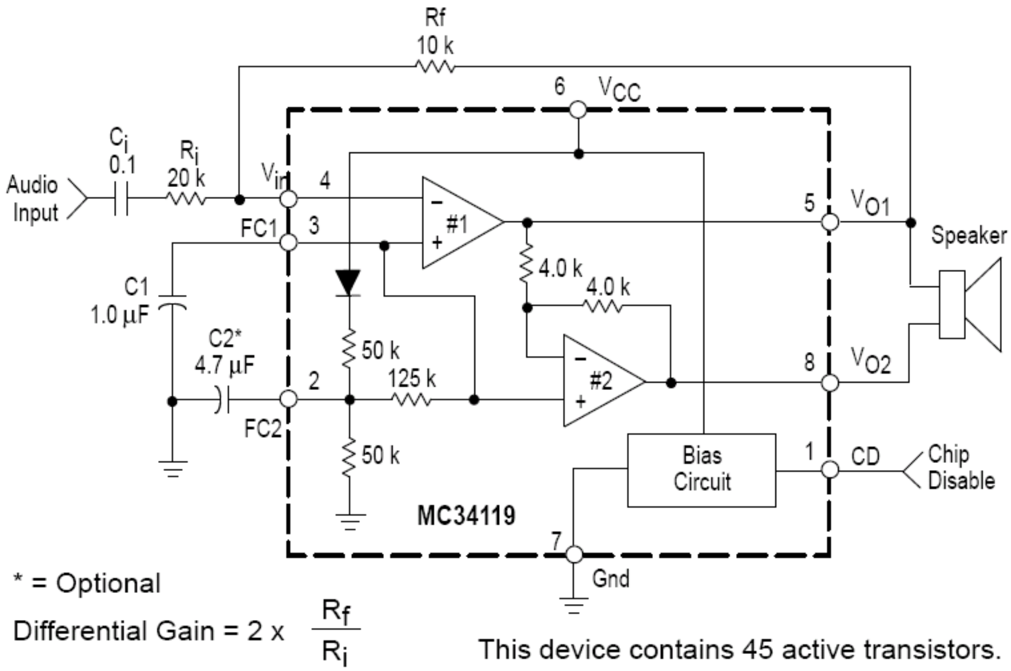
How to create a sin wave with period T?

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

Bit3 -0	Theoretical DAC voltage	Measured DAC voltage
0		
1		
2		
3		
4		
5		
6		
7		
8		

9		
10		
11		
12		
13		
14		
15		

Table 7.2. Static performance evaluation of the DAC.

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