TMS320C62x Algorithm: Sine Wave Generation

ABSTRACT

This application report shows how to implement the 2nd-order IIR filter that generates a sinusoid signal on the TMS320C62x™ DSP.

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1 Design Problem

This application report shows how to implement the 2nd-order IIR filter that generates a sinusoid signal on TMS320C62x DSP.

2 Solution

There are several ways to implement the sine wave generator on DSP processor such as a lookup table, interpolation, polynomials, etc. One efficient technique is using an IIR filter, making it oscillating by locating its poles in the unit circle of the Argand diagram. A typical 2nd order IIR filter can be established as illustrated in Figure 1.
Give this IIR two initial values as below based on the assumption of 40 samples to make up a complete sine wave, then disconnect the $x[n]$ from the input. At time interval $n=2$,

\[
y_2 = x[0] = \sin\left(\frac{2\pi}{40} \cdot 0\right) = 0
\]
\[
y_1 = x[1] = \sin\left(\frac{2\pi}{40} \cdot 1\right) \approx 0.1564
\]

Properly choose filter coefficients $A$ and $B$, so that this IIR will oscillate by itself. The formal proof can be found in the DSP related text book. You can take a short cut to find the value of $A$ and $B$ simply by solving the difference equations:

\[
y[n] = A \cdot y[n-1] + B \cdot y[n-2]
\]

For example:

\[
y[2] = A \cdot y[1] + B \cdot y[0],
\]
\[
\]

Substitute $y[n]$ with known values as below:

\[
y[0] = \sin\left(\frac{2\pi}{40} \cdot 0\right) = 0
\]
\[
y[1] = \sin\left(\frac{2\pi}{40} \cdot 1\right) \approx 0.1564
\]
\[
y[2] = \sin\left(\frac{2\pi}{40} \cdot 2\right) \approx 0.3090
\]
\[
y[3] = \sin\left(\frac{2\pi}{40} \cdot 3\right) \approx 0.4540
\]
That is
\[
0.3090 = A \times 0.1564 + B \times 0, \\
0.4540 = A \times 0.3090 + B \times 0.1564,
\]
therefore \( A=1.9754 \) and \( B=-1 \). Examining the behavior of this IIR filter by its transfer function as below:
\[
y[n] = 1.9754 \times y[n-1] - y[n-2] + x[n]
\]
Take a Z-transform:
\[
Y[Z](1 - 1.9754Z^{-1} + Z^{-2}) = X[Z].
\]
The transfer function is
\[
H(z) = \frac{Y[Z]}{X[Z]} = \frac{1}{1-1.9754z^{-1}+z^{-2}}
\]

![Figure 2. Location of the IIR Poles](image)

Its has two poles \( Z=0.9877+j0.1564 \) and \( Z=0.9877-j0.1564 \) and are located in the unit circle as shown above. The following program codes show how to program the TMS320C6x using Assembly language and C language to implement the IIR Sine wave generator. You can utilize the *Probe point* feature available in the Code Composer Studio by connecting the varying “output” of the sine wave to a graphical display.
Figure 3. Graphical Display of the Sine Wave
Example 1. Code Listing in Assembly

```
.title "fir.asm"       ;
.def    int
int .equ 4
half .equ 2
.data
a_half .short 32768*1975/2000
y1 .short 32768*1409/10000
y2 .short 0
.bss   output,40*half,half
       buffer,2*half,2*half
.text
init:  MVK     .S1     a_half,A0       ; load coeff A_HALF
       VMKH    .S1     a_half,A0
       LDH     .D1     *A0,A2          ; load coeff A_HALF
       MVK     .S1     0x0001,A0       ; setup circular buf AMR=0001_0001h
       MVKVLH  .S1     0x0001,A0       ; setup circular buf AMR=0001_0001h
       MVC     .S2X    A0,AMR         ; blk size is 4 bytes, pointer is A4
       MVK     .S1     output,A3       ; memory for store sine wave
       VMKH    .S1     output,A3
       MVK     .S1     0,A0
       STH     .D1     A0,*A3++        ; output y(0)=0 to IOPORT
       MVK     .S1     buffer,A4
       MVK     .S1     y1,A0
       LDH     .D1     *A0++,A1        ; load y1
       NOP
       STH     .D1     A1,*A4++        ; y(n-1)=y1, point to y(n-2)
       STH     .D1     A1,*A3++        ; output y(1)=y1 to IOPORT
       LDH     .D1     *A0,A1         ; load y2
       NOP
       STH     .D1     A1,*A4++        ; y(n-2)=y2, point to y(n-1)
main:  MVK     .S1     40,A1           ; calculate 40 samples
       LDH     .D1     *A4++,B1        ; ld y(n-1) to B1, point to y(n-2)
       LDH     .D1     *A4,B2         ; ld y(n-2) to B2, point to y(n-2)
       NOP   3                       ; <-- try optimizing here
       SMPY    .M1X    A2,B1,A0       ; A_HALF*y(n-1)
       SUB     .L1     A1,1,A1
       [A1] B .S1 loop
       SHR     .S1     A0,16,A0       ; <-- try optimizing here
       SADD    .L1     A0,A0,A0       ; A_HALF*y(n-1)*2
       SSUB    .L2X    A0,B2,B0       ; A_HALF*y(n-1)*2-y(n-2)
       STH     .D1     B0,*A4         ; st y(n) to y(n-2) as y(n-1)
       STH     .D1     B0,*A3++       ; st y(n) to Sine wave IOPORT
end:   B .S1 $
       NOP  5
```
Example 2. Code Listing in C

short output;
main()
{
    int i;
    const short A=0x7e66; /* A=(1.975/2 * 32768) */
    short y[3]=(0,0x1209,0); /* (y0,y1,y2), y1=(0.1409*32768) */
    for (i=0; i<40; i++) {
        y[0] = (((A*y[1])>>15) + ((A*y[1])>>15)) - y[2];
        y[2] = y[1]; /* y2 <-- y1 */
        y[1] = y[0]; /* y1 <-- y0 */
        output = y[0];
    }
}
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