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April 1\(^{st}\), 2010
Renesas Electronics Corporation

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SH7000 Series

Affine Transform

Label: AFIN

Functions Used: MAC.W Instruction
Post-Increment Register Indirect Addressing

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1. Function

Performs matrix operations of the affine transform. A the data table of the sort shown below must be prepared beforehand.

\[
\begin{bmatrix}
A & B & t_x & 0 \\
C & D & t_y & 0 \\
0 & 0 & 1 & 1
\end{bmatrix}
\begin{bmatrix}
X \\
Y \\
1
\end{bmatrix}
=
\begin{bmatrix}
X' \\
Y' \\
1
\end{bmatrix}
\]

\( (X, Y) \) : Coordinate values before affine transform
\( (X', Y') \) : Coordinate values after affine transform
A, B, C, D : Affine transform parameters
\( t_x, t_y \) : Amount of X/Y coordinate shift during affine transform

2. Arguments

<table>
<thead>
<tr>
<th>Description</th>
<th>Storage Location</th>
<th>Data Length (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>R0</td>
<td>4</td>
</tr>
<tr>
<td>Start address of affine transform parameter table</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage address of coordinates before affine transform</td>
<td>R1</td>
<td>4</td>
</tr>
<tr>
<td>Storage address of coordinates after affine transform</td>
<td>R2</td>
<td>4</td>
</tr>
</tbody>
</table>
### Internal Register Changes and Flag Changes

*(Before Execution) → (After Execution)*

<table>
<thead>
<tr>
<th>Register</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0</td>
<td>Start address of affine transform parameter table</td>
<td>Undefined</td>
</tr>
<tr>
<td>R1</td>
<td>Storage address of coordinates before affine transform</td>
<td>Undefined</td>
</tr>
<tr>
<td>R2</td>
<td>Storage address of coordinates after affine transform</td>
<td>Undefined</td>
</tr>
<tr>
<td>R3</td>
<td>Work</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R15</td>
<td></td>
<td>(SP)</td>
</tr>
</tbody>
</table>

| T  | — : No change
|    | * : Change
|    | 0 : Fixed 0
|    | 1 : Fixed 1
4. Programming Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program memory (bytes)</td>
<td>34</td>
</tr>
<tr>
<td>Data memory (bytes)</td>
<td>0</td>
</tr>
<tr>
<td>Stack (bytes)</td>
<td>4</td>
</tr>
<tr>
<td>Number of states</td>
<td>22</td>
</tr>
<tr>
<td>Reentrant</td>
<td>Yes</td>
</tr>
<tr>
<td>Relocation</td>
<td>Yes</td>
</tr>
<tr>
<td>Intermediate interrupt</td>
<td>Yes</td>
</tr>
</tbody>
</table>
5. Description

(1) Function

Details of the arguments are as follows.

R0: Set the affine transform parameter table start address as the input argument.
R1: Set the storage address of the coordinates before affine transform as the input argument.
R2: Set the storage address of the coordinates after affine transform as the input argument.

Figure 1 shows an execution example for the software AFIN instruction. In memory, affine transform parameters are allocated in advance from address H’1000 0000 through t_x, A, B, t_y, C, and D, in that order. Coordinates before affine transform are allocated from address H’1000 1000 in the order X, Y. The affine transform parameter table start address, storage address for coordinates before affine transform, and storage address for coordinates after affine transform are transferred to the software AFIN as the input argument. Transform matrix operations are performed in AFIN software and coordinates after affine transform are allocated as specified in the input argument from address H’1000 1100 in the order X’, Y’.

![Figure 1 Software AFIN Execution Example](image-url)
(2) Usage Notes

Affine transform parameters and coordinates should be allocated before the affine transform, as shown in figure 1.

(3) RAM Used

No RAM is used by the software AFIN instruction.

(4) Usage Example

After the affine transform parameter table start address, the storage address for coordinates before affine transform, and the storage address for coordinates after affine transform are set in input arguments, the AFIN software instruction is called from a subroutine.

```assembly
MOV.L DATA1,R0       ...Sets affine transform parameter table start address in input argument
MOV.L DATA2,R1       ...Sets the storage address for coordinates before affine transform in input argument
BSR AFIN             ...Subroutine call to software instruction AFIN
MOV.L DATA3,R2       ...Sets storage address for coordinates after affine transform in input argument
.
.
.
.ALIGN 4
DATA1 .data.l  H'10000000
DATA2 .data.l  H'10001000
DATA3 .data.l  H'10001100
```
(5) Operating Principle

(a) Expanding the affine transform matrix produces the following formulas:

\[ X' = AX + BY + t_x \]
\[ Y' = CX + DY = ty \]

(b) As shown in Figure 2, \( AX + BY + t_x \) and \( CX + DY + ty \) are determined using the multiply and accumulate instruction (MAC).

![Diagram of X' and Y' coordinate calculation](image-url)
6. Flowchart

AFIN

Set tx in MACL

Add AX to MACL using MAC instruction

Add BY to MACL using MAC instruction

Store result in memory

Set ty in MACL

Add CX to MACL using MAC instruction

Add DY to MACL using MAC instruction

Store result in memory

RTS
7. Program Listing

1---------1 ;***********************************************************************
2         2 ; *
3         3 ;* NAME : AFIN CONVERSION (AFIN) *
4         4 ; *
5         5 ;***********************************************************************
6         6 ; *
7         7 ;* ENTRY : R0 (TOP ADDRESS OF PARAMETER) *
8         8 ;* R1 (STORED ADDRESS OF BEFORE AFIN CONVERSION) *
9         9 ;* R2 (STOR ADDRESS OF AFTER AFIN CONVERSION) *
10        10 ; *
11        11 ;***********************************************************************
12 00001000 12 .SECTION A,CODE,LOCATE=H'1000
13 00001000 13 AFIN .EQU $ ; Entry point
14 00001000 14 MOV.L R3,R0,R15 ; Escape register
15 00001002 6305 15 MOV.W @R0+,R3 ; tx -> MACL
16 00001004 431A 16 LDS R3,MACL ;
17 00001006 410F 17 MAC.W @R0+,@R1+ ; A=X+MACL -> MACL(=AX+Tx)
18 00001008 410F 18 MAC.W @R0+,@R1+ ; B=Y+MACL -> MACL(=AX+BY+Tx)
19 0000100A 031A 19 STS MACL,R3 ; MACL -> X'
20 0000100C 2231 20 MOV.W R3,R1,R2 ;
21 0000100E 7202 21 ADD $2,R2 ;
22 00001010 6305 22 MOV.W @R0+,R3 ; Ty -> MACL
23 00001012 431A 23 LDS R3,MACL ;
24 00001014 71FC 24 ADD #4,R1 ;
25 00001016 410F 25 MAC.W @R0+,@R1+ ; C=X+MACL -> MACL(=CX+Ty)
26 00001018 410F 26 MAC.W @R0+,@R1+ ; D=Y+MACL -> MACL(=CX+DY+Ty)
27 0000101A 031A 27 STS MACL,R3 ; MACL -> Y'
28 0000101C 2231 28 MOV.W R3,R1,R2 ;
29 0000101E 000B 29 RTS ;
30 00001020 63F6 30 MOV.L @R15+,R3 ; Return register
31 31 .END

*****TOTAL ERRORS 0
*****TOTAL WARNINGS 0
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