Signal Generator Library

Module user's Guide

C28x Foundation Software

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Acronyms

xDAIS : eXpress DSP Algorithm Interface Standard
IALG : Algorithm interface defines a framework independent interface for the creation of algorithm instance objects
STB : Software Test Bench
QMATH: Fixed Point Mathematical computation
CcA : C-Callable Assembly
FIR : Finite Impulse Response Filter
IIR : Infinite Impulse Response Filter
FFT : Fast Fourier Transform

Contents

1. Introduction

The signal generator module repository contains SIN generation, ramp generation and trapezoidal generation modules. The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency. This strategy is adopted for all signal generator modules

2. SIN Generation

The signal generator repository contains comprehensive set of SIN generation modules viz., Single channel, Dual channel, 3ϕ and dual 3ϕ SIN generator to cater to various application requirements. Single and Dual channel modules are available in three forms viz., Standard THD version (SGENT_xx, Low THD version (SGENTI_xx) and High precision version (SGENHP_xx). The 3ϕ and dual 3ϕ SIN generator are available in two forms viz., Standard THD version (SGENT_xx) and Low THD version (SGENTI_xx).

2.1. Standard THD sin generator (SGENT_1, SGENT_2, SGENT_3& SGENT_3D)

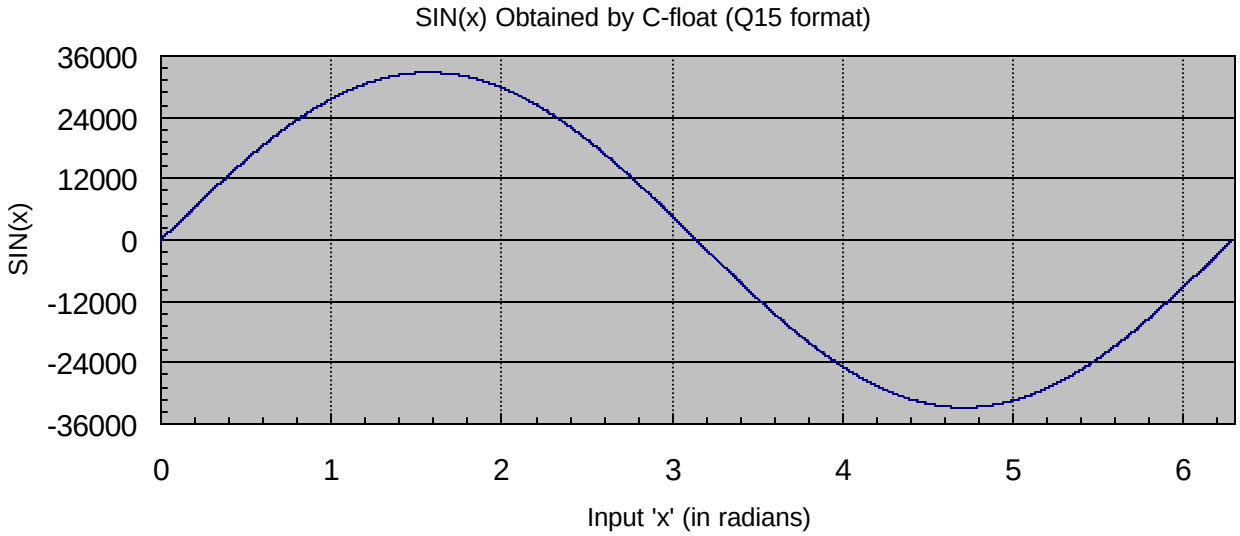
The standard THD sine generators are implemented using direct table look-up technique and it uses 16-bit modulo counter. Although a 16-bit counter is used, the upper byte (8-bits) is used to index the 256-point look-up table and hence to obtain the SIN value. Thus, by changing how quickly values overflow from lower byte (i.e., manipulating step value) the frequency of the sine wave can be changed. Modulo counter ignores the overflow or carry out of 16-bit counter and retains only the remainder. The graph shown in page 2 exemplifies the error of the SIN output obtained using direct table look-up technique with respect to the floating point results.

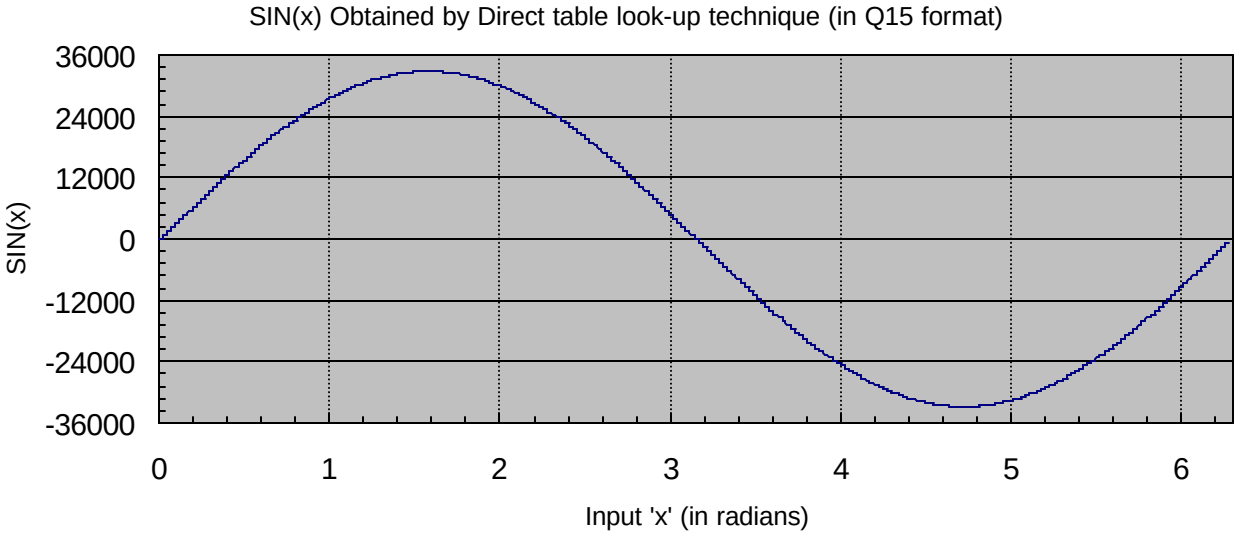
2.2. Low THD sin generator (SGENTI_1, SGENTI_2, SGENTI_3& SGENTI_3D)

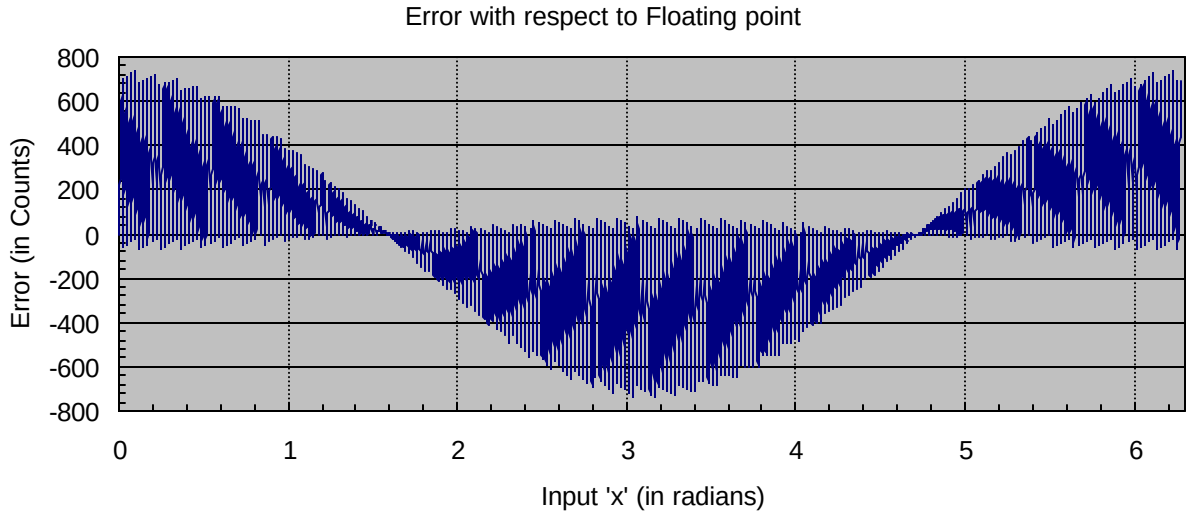
The low THD sin generators are implemented using Table look-up and linear interpolation technique and it uses 16-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and lower byte (8-bits) used to interpolate between the look-up table entries. The graph shown in page 3 exemplifies the error of the SIN output obtained using table look-up with linear interpolation technique with respect to the floating point results.

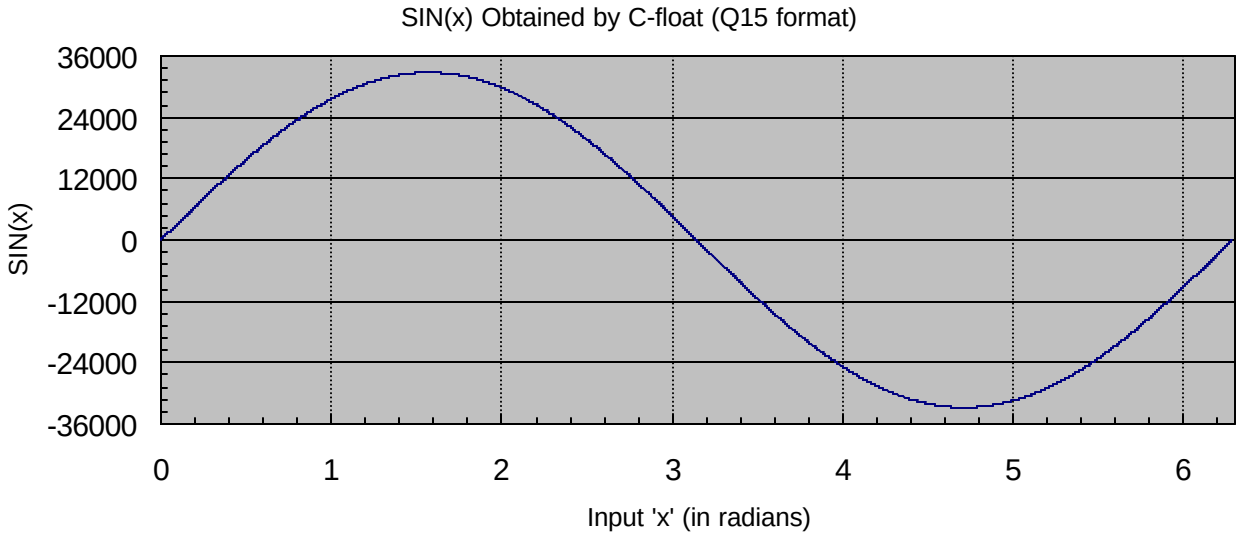
2.3. High Precision sin generator (SGENHP_1 & SGENHP_2)

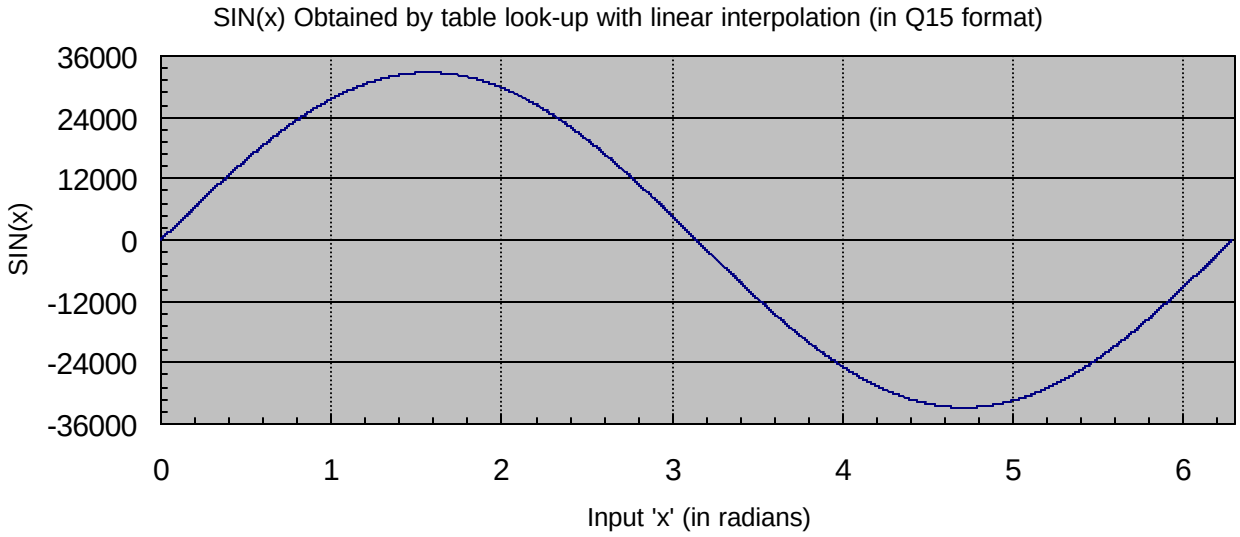
The high precision sin generators are implemented using Table look-up and linear interpolation technique and it uses 32-bit modulo counter. The high precision modules allow precise frequency control because of the fact that it uses 32-bit value for frequency input and also uses 32-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and the 15-bits following the upper byte are used to interpolate between the look-up table entries. The graph shown in page 4 exemplifies the error of the SIN output obtained with this implementation with respect to the floating-point results.

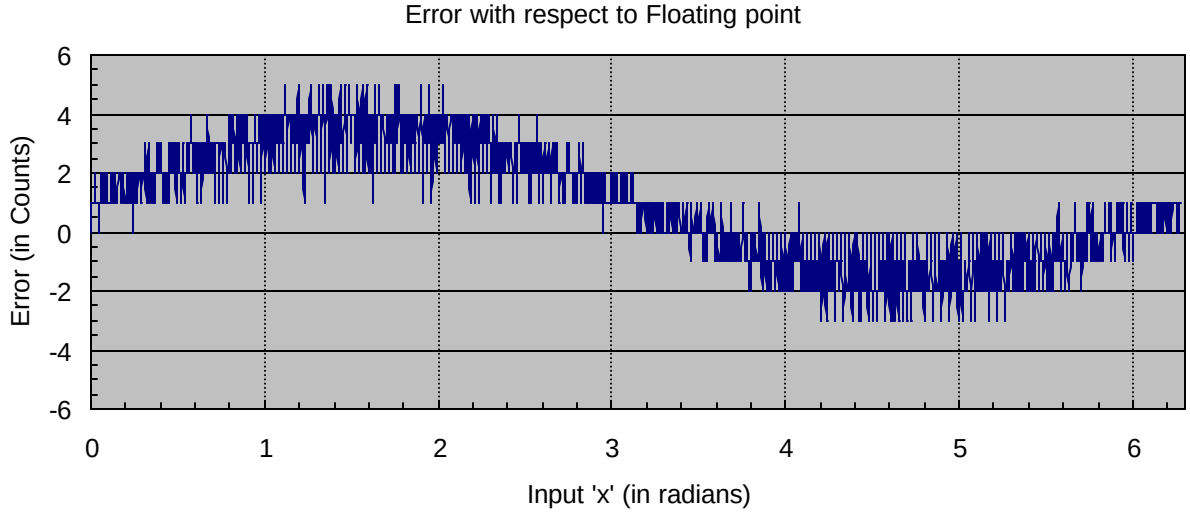


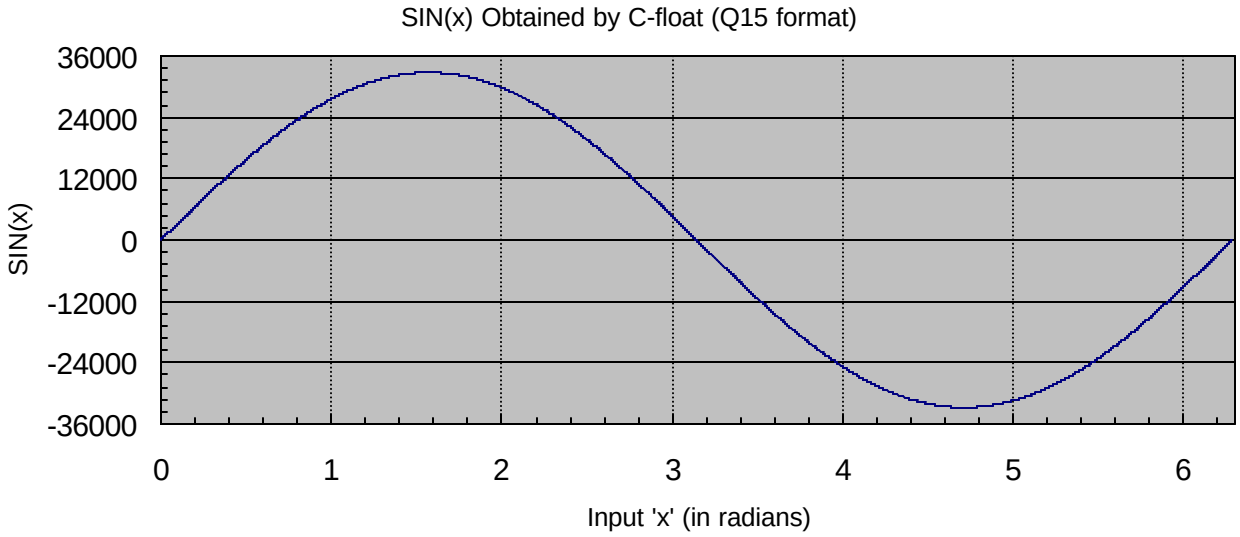


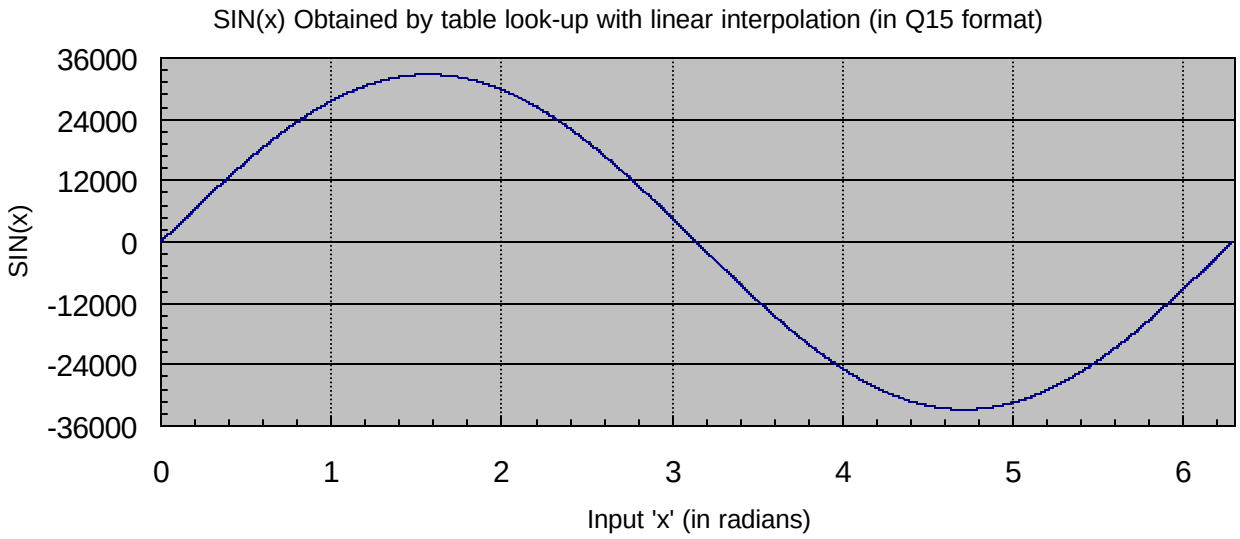


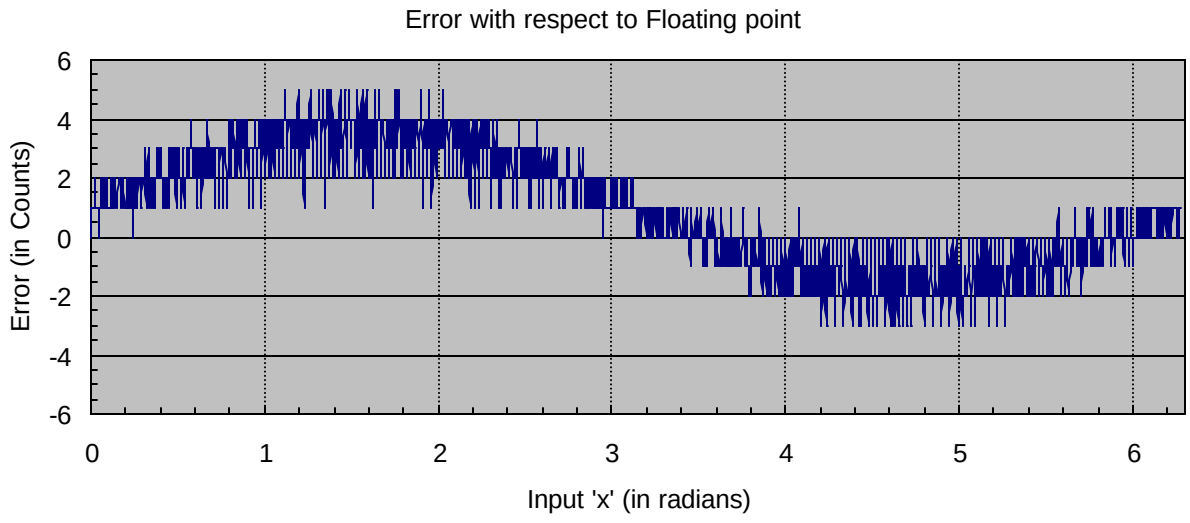








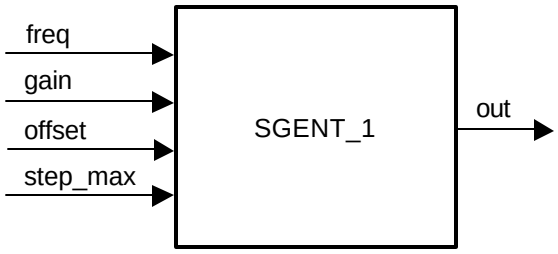




SGENT_1	***Single Channel SIN Generator (Table look-up)***

Description

This module generates single channel digital SIN signal using direct table look-up technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly Files: sgt1c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	16 +257words + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENT_1 structure consumes 8 words in the data memory and 11 words in the ***cinit*** section

[D] Each instance of SGENT_1 module consumes 8 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENT_1 object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out;
        void (*calc)(void *);
} SGENT_1;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out	SIN Output	Q15	8000-7FFF

Special Constants and Data types

SGENT_1
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENT_1

SGENT_1_handle
User defined Data type of pointer to SGENT_1 Module

SGENT_1_DEFAULTS
Structure symbolic constant to Initialize SGENT_1 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);
This function implements the single channel digital SIN signal generation using direct table look-up technique.

Module Usage

Instantiation

The following example instances empty signal generator object

```
SGENT_1  sgen;
```

Initialization

To Instance pre-initialized object

```
SGENT_1 sgen = SGENT_1_DEFAULTS;
```

Invoking the computation function

```
sgen.calc(&sgen);
```

Example

The following pseudo code exemplifies, 50Hz single channel digital SIN signal generation using SGENT_1 module.

```
#include <sgen.h>

SGENT_1 sgen=SGENT_1_DEFAULTS;
int x1;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain=1 in Q15                                    */
        sgen.freq=5369;         /* freq = (Required Freq/Max Freq)*2^15             */
                                /*      = (50/305.17)*2^15 = 5369                   */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
SINTBL          > PROG  PAGE 0
```

Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The standard THD sine generators are implemented using direct table look-up technique and it uses 16-bit modulo counter. Although a 16-bit counter is used, the upper byte (8-bits) is used to index the 256-point look-up table and hence to obtain the SIN value. Thus, by changing how quickly values overflow from lower byte (i.e., manipulating step value) the frequency of the sine wave can be changed. Modulo counter ignores the overflow or carry out of 16-bit counter and retains only the remainder. The graph shown in page 2 exemplifies the error of the SIN output obtained using direct table look-up technique with respect to the floating point results.

The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (1)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (2)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate. The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (2)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

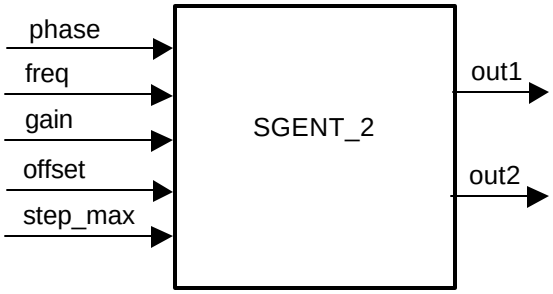
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENT_2 — *Dual Channel SIN Generator (Table look-up)*

Description

This module generates dual channel digital SIN signal with phase control using direct table look-up technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly files: sgt2c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	24 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENT_2 structure consumes 10 words in the data memory and 13 words in the ***cinit*** section

[D] Each instance of SGENT_2 module consumes 10 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENT_2 object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out1;
        unsigned int phase;
        int out2;
        void (*calc)(void *);
} SGENT_2;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	phase	Phase angle between the two SIN outputs $[-\pi,+\pi]$ is normalized to $[-1,+1]$	Q15	8000-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out1	SIN Output 1 → $\sin(\theta)$	Q15	8000-7FFF
	out2	SIN Output 2 → $\sin(\theta + phase)$	Q15	8000-7FFF

Special Constants and Data types

SGENT_2
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENT_2

SGENT_2_handle
User defined Data type of pointer to SGENT_2 Module

SGENT_2_DEFAULTS
Structure symbolic constant to Initialize SGENT_2 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);
This function implements the dual channel digital SIN signal generation with phase control using direct table look-up technique.

Module Usage

Instantiation

The following example instances empty signal generator object
SGENT_2 sgen;

Initialization

To Instance pre-initialized object
SGENT_2 sgen = SGENT_2_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

The following pseudo code exemplifies, two 50Hz digital SIN signal generation with 90deg phase shift using SGENT_2 module.

```
#include <sgen.h>

SGENT_2 sgen=SGENT_2_DEFAULTS;

Int x1, x2;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain = 1 in Q15                                  */
        sgen.freq=5369;         /* freq  = (Required Freq/Max Freq)*2^15            */
                                /*       = (50/305.17)*2^15 = 5369                  */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
        sgen.phase=4000h        /* Phase = (required Phase)/180 in Q15              */
                                /*         =  (+90/180) in Q15 = 4000h              */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out1;
        x2=sgen.out2;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
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```

Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The standard THD sine generators are implemented using direct table look-up technique and it uses 16-bit modulo counter. Although a 16-bit counter is used, the upper byte (8-bits) is used to index the 256-point look-up table and hence to obtain the SIN value. Thus, by changing how quickly values overflow from lower byte (i.e., manipulating step value) the frequency of the sine wave can be changed. Modulo counter ignores the overflow or carry out of 16-bit counter and retains only the remainder. The graph shown in page 2 exemplifies the error of the SIN output obtained using direct table look-up technique with respect to the floating point results.

The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (1)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (2)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate. The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (2)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

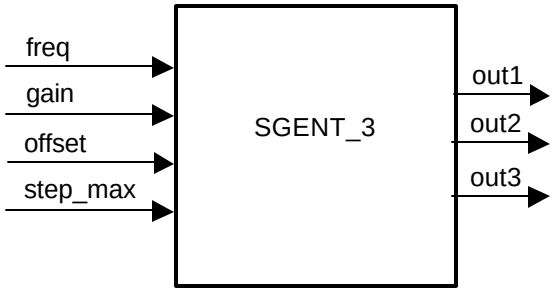
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENT_3 — *Three Phase SIN Generator (Table look-up)*

Description

This module generates 3-phase digital SIN signal with fixed 120° phase shift between the channels using direct table look-up technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly files: sgt3c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	34 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENT_3 structure consumes 10 words in the data memory and 13 words in the ***cinit*** section

[D] Each instance of SGENT_3 module consumes 10 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENT_3 object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out1;
        int out2;
        int out3;
        void (*calc)(void *);
} SGENT_3;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out1	SIN Output 1 → $\sin(\theta)$	Q15	8000-7FFF
	out2	SIN Output 2 → $\sin(\theta + 120^\circ)$	Q15	8000-7FFF
	out3	SIN Output 3 → $\sin(\theta + 240^\circ)$	Q15	8000-7FFF

Special Constants and Data types

SGENT_3
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENT_3

SGENT_3_handle
User defined Data type of pointer to SGENT_3 Module

SGENT_3_DEFAULTS
Structure symbolic constant to Initialize SGENT_3 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);

This function implements 3-phase digital SIN signal generation with fixed 120° phase shift between the channels using direct table look-up technique.

Module Usage

Instantiation

The following example instances empty generic signal generator object

SGENT_3 sgen;

Initialization

To Instance pre-initialized object

SGENT_3 sgen = SGENT_3_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

The following pseudo code exemplifies, 3-phase digital SIN signal (50Hz) generation using SGENT_3 module.

```
#include <sgen.h>

SGENT_3 sgen=SGENT_3_DEFAULTS;

Int x1, x2, x3;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain = 1 in Q15                                  */
        sgen.freq=5369;         /* freq  = (Required Freq/Max Freq)*2^15            */
                                /*       = (50/305.17)*2^15 = 5369                  */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
        sgen.phase=4000h        /* Phase = (required Phase)/180 in Q15              */
                                /*         =  (+90/180) in Q15 = 4000h              */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out1;
        x2=sgen.out2;
        x3=sgen.out3;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
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```

Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The standard THD sine generators are implemented using direct table look-up technique and it uses 16-bit modulo counter. Although a 16-bit counter is used, the upper byte (8-bits) is used to index the 256-point look-up table and hence to obtain the SIN value. Thus, by changing how quickly values overflow from lower byte (i.e., manipulating step value) the frequency of the sine wave can be changed. Modulo counter ignores the overflow or carry out of 16-bit counter and retains only the remainder. The graph shown in page 2 exemplifies the error of the SIN output obtained using direct table look-up technique with respect to the floating point results.

The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (1)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (2)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate. The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (2)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

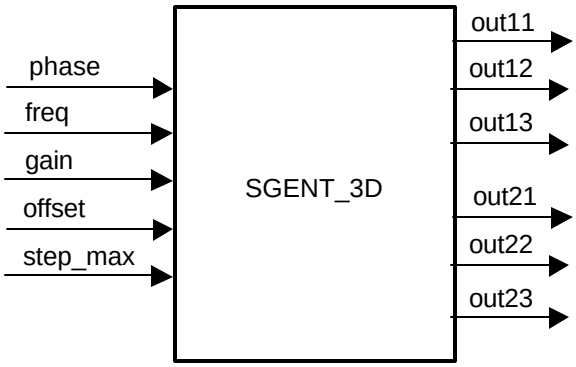
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENT_3D — *Dual, three Phase SIN Generator (Table look-up)*

Description

This module generates dual, 3-phase digital SIN signal with fixed 120° phase shift between the channels and phase control between the two three phase signals using direct table look-up technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly files: sgt3dc.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	63 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENT_3D structure consumes 14 words in the data memory and 17 words in the ***cinit*** section

[D] Each instance of SGENT_3D module consumes 14 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENT_3D object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out11;
        int out12;
        int out13;
        unsigned int phase;
        int out21;
        int out22;
        int out23;
        void (*calc)(void *);
} SGENT_3D;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range (Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out11	SIN Output 11 → $\sin(\theta)$	Q15	8000-7FFF
	out12	SIN Output 12 → $\sin(\theta + 120^\circ)$	Q15	8000-7FFF
	out13	SIN Output 13 → $\sin(\theta + 240^\circ)$	Q15	8000-7FFF
	out21	SIN Output 21 → $\sin(\theta + phase)$	Q15	8000-7FFF
	out22	SIN Output 22 → $\sin(\theta + 120^\circ + phase)$	Q15	8000-7FFF
	out23	SIN Output 23 → $\sin(\theta + 240^\circ + phase)$	Q15	8000-7FFF

Special Constants and Data types

SGENT_3D
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENT_3D

SGENT_3D_handle
User defined Data type of pointer to SGENT_3D Module

SGENT_3_DEFAULTS
Structure symbolic constant to Initialize SGENT_3D Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);
This function implements two, 3-phase digital SIN signal generation with phase control between the three phase signals using direct table look-up technique.

Module Usage

Instantiation
The following example instances empty generic signal generator object
SGENT_3D sgen;

Initialization
To Instance pre-initialized object
SGENT_3D sgen = SGENT_3D_DEFAULTS;

Invoking the computation function
sgen.calc(&sgen);

Example
The following pseudo code exemplifies, dual 3-phase digital SIN signal (50Hz) generation with 90deg phase shift between the three phase signals using SGENT_3D module.

```
#include <sgen.h>

SGENT_3D sgen=SGENT_3D_DEFAULTS;

Int x11, x12, x13, x21, x22, x23;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain = 1 in Q15                                  */
        sgen.freq=5369;         /* freq  = (Required Freq/Max Freq)*2^15            */
                                /*       = (50/305.17)*2^15 = 5369                  */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536 */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
        sgen.phase=4000h        /* Phase = (required Phase)/180 in Q15              */
                                /*         =  (+90/180) in Q15 = 4000h              */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x11=sgen.out11;
        x12=sgen.out12;
        x13=sgen.out13;
        x21=sgen.out21;
        x22=sgen.out22;
        x23=sgen.out23;

}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
SINTBL          > PROG  PAGE 0
```

Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized req" allows the user to control the frequency of the signal between 0 to maximum frequency.

The standard THD sine generators are implemented using direct table look-up technique and it uses 16-bit modulo counter. Although a 16-bit counter is used, the upper byte (8-bits) is used to index the 256-point look-up table and hence to obtain the SIN value. Thus, by changing how quickly values overflow from lower byte (i.e., manipulating step value) the frequency of the sine wave can be changed. Modulo counter ignores the overflow or carry out of 16-bit counter and retains only the remainder. The graph shown in page 2 exemplifies the error of the SIN output obtained using direct table look-up technique with respect to the floating point results.

The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (1)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (2)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate. The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (2)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

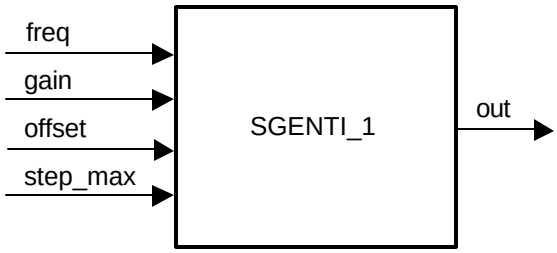
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENTI_1 — *Single Channel SIN Generator (Table look-up and interpolation)*

Description

This module generates single channel digital SIN signal using table look-up and linear interpolation technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly Files: sgti1c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	26 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENTI_1 structure consumes 8 words in the data memory and 11 words in the ***cinit*** section

[D] Each instance of SGENTI_1 module consumes 8 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENTI_1 object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out;
        void (*calc)(void *);
} SGENTI_1;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out	SIN Output	Q15	8000-7FFF

Special Constants and Data types

SGENTI_1
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENTI_1

SGENTI_1_handle
User defined Data type of pointer to SGENTI_1 Module

SGENTI_1_DEFAULTS
Structure symbolic constant to Initialize SGENTI_1 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);
This function implements the single channel digital SIN signal generation using table look-up and linear interpolation technique.

Module Usage

Instantiation

The following example instances empty signal generator object

```
SGENTI_1  sgen;
```

Initialization

To Instance pre-initialized object

```
SGENTI_1 sgen = SGENTI_1_DEFAULTS;
```

Invoking the computation function

```
sgen.calc(&sgen);
```

Example

The following pseudo code exemplifies, 50Hz single channel digital SIN signal generation using SGENTI_1 module.

```
#include <sgen.h>

SGENTI_1 sgen=SGENTI_1_DEFAULTS;
int x1;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain=1 in Q15                                    */
        sgen.freq=5369;         /* freq = (Required Freq/Max Freq)*2^15             */
                                /*      = (50/305.17)*2^15 = 5369                   */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
SINTBL          > PROG  PAGE 0
```

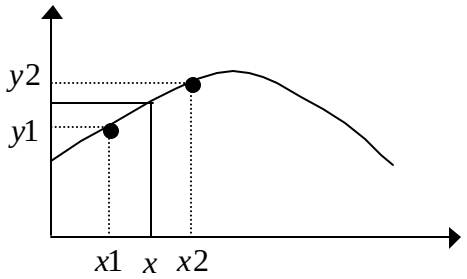
Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The low THD sin generators are implemented using Table look-up and linear interpolation technique and it uses 16-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and lower byte (8-bits) used to interpolate between the look-up table entries.

$$y = y1 + \frac{y2 - y1}{x2 - x1} \times (x - x1) \qquad (1)$$



The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (2)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (3)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate.

The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (3)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

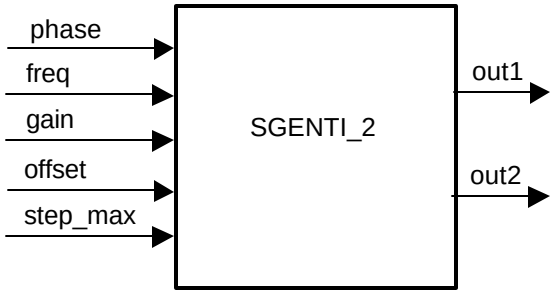
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENTI_2 — *Dual Channel SIN Generator (Table look-up and Interpolation)*

Description

This module generates dual channel digital SIN signal with phase control using table look-up and linear interpolation technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly files: sgti2c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	45 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENTI_2 structure consumes 10 words in the data memory and 13 words in the ***cinit*** section

[D] Each instance of SGENTI_2 module consumes 10 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENTI_2 object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out1;
        unsigned int phase;
        int out2;
        void (*calc)(void *);
} SGENTI_2;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	phase	Phase angle between the two SIN outputs $[-\pi,+\pi]$ is normalized to $[-1,+1]$	Q15	8000-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out1	SIN Output 1 → $\sin(\theta)$	Q15	8000-7FFF
	out2	SIN Output 2 → $\sin(\theta + phase)$	Q15	8000-7FFF

Special Constants and Data types

SGENTI_2
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENTI_2

SGENTI_2_handle
User defined Data type of pointer to SGENTI_2 Module

SGENTI_2_DEFAULTS
Structure symbolic constant to Initialize SGENTI_2 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);

This function implements the dual channel digital SIN signal generation with phase control using table look-up and linear interpolation technique.

Module Usage

Instantiation

The following example instances empty signal generator object

SGENTI_2 sgen;

Initialization

To Instance pre-initialized object

SGENTI_2 sgen = SGENTI_2_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

The following pseudo code exemplifies, two 50Hz digital SIN signal generation with 90deg phase shift using SGENTI_2 module.

```
#include <sgen.h>

SGENTI_2 sgen=SGENTI_2_DEFAULTS;

Int x1, x2;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain = 1 in Q15                                  */
        sgen.freq=5369;         /* freq  = (Required Freq/Max Freq)*2^15            */
                                /*       = (50/305.17)*2^15 = 5369                  */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
        sgen.phase=4000h        /* Phase = (required Phase)/180 in Q15              */
                                /*         =  (+90/180) in Q15 = 4000h              */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out1;
        x2=sgen.out2;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
SINTBL          > PROG  PAGE 0
```

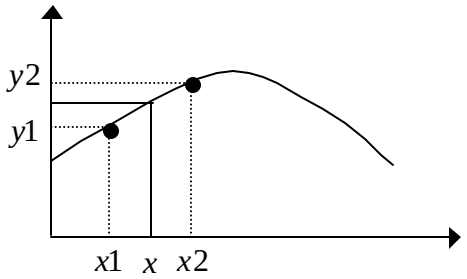
Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The low THD sin generators are implemented using Table look-up and linear interpolation technique and it uses 16-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and lower byte (8-bits) used to interpolate between the look-up table entries.

$$y = y1 + \frac{y2 - y1}{x2 - x1} \times (x - x1) \qquad (1)$$



The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (2)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (3)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate.

The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (3)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

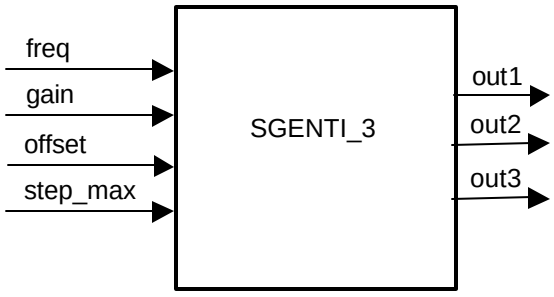
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at-least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENTI_3 — *Three Phase SIN Generator (Table look-up and interpolation)*

Description

This module generates 3-phase digital SIN signal with fixed 120° phase shift between the channels using table look-up and linear interpolation technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly files: sgti3c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	66 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENTI_3 structure consumes 10 words in the data memory and 13 words in the ***cinit*** section

[D] Each instance of SGENTI_3 module consumes 10 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENTI_3 object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out1;
        int out2;
        int out3;
        void (*calc)(void *);
} SGENTI_3;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out1	SIN Output 1 → $\sin(\theta)$	Q15	8000-7FFF
	out2	SIN Output 2 → $\sin(\theta + 120^\circ)$	Q15	8000-7FFF
	out3	SIN Output 3 → $\sin(\theta + 240^\circ)$	Q15	8000-7FFF

Special Constants and Data types

SGENTI_3
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENTI_3

SGENTI_3_handle
User defined Data type of pointer to SGENTI_3 Module

SGENTI_3_DEFAULTS
Structure symbolic constant to Initialize SGENTI_3 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);

This function implements 3-phase digital SIN signal generation with fixed 120° phase shift between the channels using table look-up and linear interpolation technique.

Module Usage

Instantiation

The following example instances empty generic signal generator object

SGENTI_3 sgen;

Initialization

To Instance pre-initialized object

SGENTI_3 sgen = SGENTI_3_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

The following pseudo code exemplifies, 3-phase digital SIN signal (50Hz) generation using SGENTI_3 module.

```
#include <sgen.h>

SGENTI_3 sgen=SGENTI_3_DEFAULTS;

Int x1, x2, x3;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain = 1 in Q15                                  */
        sgen.freq=5369;         /* freq  = (Required Freq/Max Freq)*2^15            */
                                /*       = (50/305.17)*2^15 = 5369                  */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
        sgen.phase=4000h        /* Phase = (required Phase)/180 in Q15              */
                                /*         =  (+90/180) in Q15 = 4000h              */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out1;
        x2=sgen.out2;
        x3=sgen.out3;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
SINTBL          > PROG  PAGE 0
```

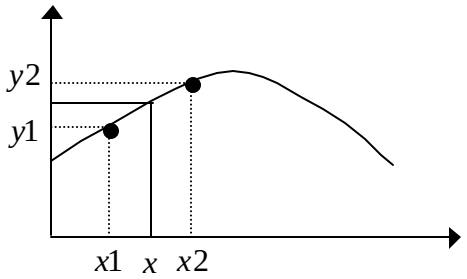
Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The low THD sin generators are implemented using Table look-up and linear interpolation technique and it uses 16-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and lower byte (8-bits) used to interpolate between the look-up table entries.

$$y = y1 + \frac{y2 - y1}{x2 - x1} \times (x - x1) \qquad (1)$$



The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (2)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (3)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate.

The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (3)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

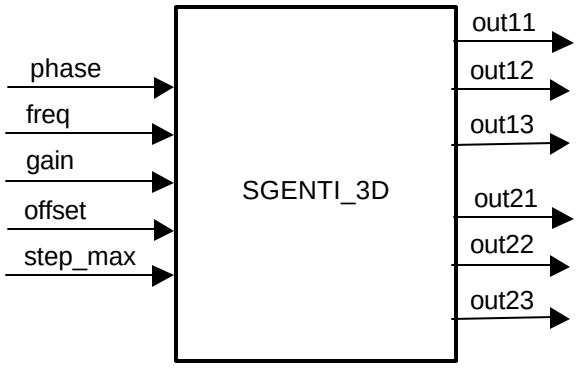
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENTI_3D — *Dual, three Phase SIN Generator (Table look-up and interpolation)*

Description

This module generates dual, 3-phase digital SIN signal with fixed 120° phase shift between the channels and phase control between the two three phase signals using table look-up and linear interpolation technique.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly Files: sgti3dc.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	128 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENTI_3D structure consumes 14 words in the data memory and 17 words in the ***cinit*** section

[D] Each instance of SGENTI_3D module consumes 14 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENTI_3D object is defined by the following structure definition

```
typedef struct {
        unsigned int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out11;
        int out12;
        int out13;
        unsigned int phase;
        int out21;
        int out22;
        int out23;
        void (*calc)(void *);
} SGENTI_3D;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range (Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0-7FFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out11	SIN Output 11 → $\sin(\theta)$	Q15	8000-7FFF
	out12	SIN Output 12 → $\sin(\theta + 120^\circ)$	Q15	8000-7FFF
	out13	SIN Output 13 → $\sin(\theta + 240^\circ)$	Q15	8000-7FFF
	out21	SIN Output 21 → $\sin(\theta + phase)$	Q15	8000-7FFF
	out22	SIN Output 22 → $\sin(\theta + 120^\circ + phase)$	Q15	8000-7FFF
	out23	SIN Output 23 → $\sin(\theta + 240^\circ + phase)$	Q15	8000-7FFF

Special Constants and Data types

SGENTI_3D
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENTI_3D

SGENTI_3D_handle
User defined Data type of pointer to SGENTI_3D Module

SGENTI_3_DEFAULTS
Structure symbolic constant to Initialize SGENTI_3D Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);
This function implements two, 3-phase digital SIN signal generation with phase control between the three phase signals using table look-up and linear interpolation technique.

Module Usage

Instantiation
The following example instances empty generic signal generator object
SGENTI_3D sgen;

Initialization
To Instance pre-initialized object
SGENTI_3D sgen = SGENTI_3D_DEFAULTS;

Invoking the computation function
sgen.calc(&sgen);

Example
The following pseudo code exemplifies, dual 3-phase digital SIN signal (50Hz) generation with 90deg phase shift between the three phase signals using SGENTI_3D module.

```
#include <sgen.h>

SGENTI_3D sgen=SGENTI_3D_DEFAULTS;

Int x11, x12, x13, x21, x22, x23;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain = 1 in Q15                                  */
        sgen.freq=5369;         /* freq  = (Required Freq/Max Freq)*2^15            */
                                /*       = (50/305.17)*2^15 = 5369                  */
        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
        sgen.phase=4000h        /* Phase = (required Phase)/180 in Q15              */
                                /*         =  (+90/180) in Q15 = 4000h              */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x11=sgen.out11;
        x12=sgen.out12;
        x13=sgen.out13;
        x21=sgen.out21;
        x22=sgen.out22;
        x23=sgen.out23;

}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
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```
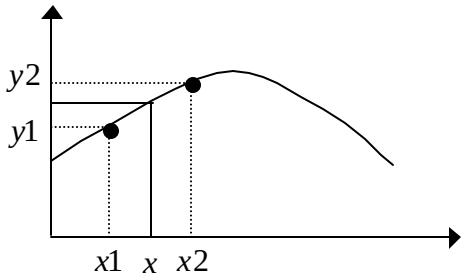

Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The low THD sin generators are implemented using Table look-up and linear interpolation technique and it uses 16-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and lower byte (8-bits) used to interpolate between the look-up table entries.

$$y = y1 + \frac{y2 - y1}{x2 - x1} \times (x - x1) \qquad (1)$$



The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (2)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (3)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate.

The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (3)

$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

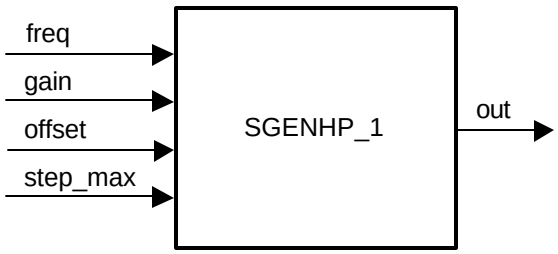
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate SIN signal of frequency f, initialize the “freq” element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the SIN generator module.

SGENHP_1 — *Single Channel SIN Generator (High precision)*

Description

This module generates single channel digital SIN signal using table look-up and linear interpolation technique and it uses 32-bit integration counter for high precision SIN generation.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly files: sghp1c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	34 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENHP_1 structure consumes 12 words in the data memory and 15 words in the ***cinit*** section

[D] Each instance of SGENHP_1 module consumes 12 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENHP_1 object is defined by the following structure definition

```
typedef struct {
        void (*calc)(void *);
        unsigned long int freq;
        unsigned long int step_max;
        unsigned long int alpha;
        int gain;
        int offset;
        int out;
} SGENHP_1;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q31	0-7FFFFFFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{2^{32}}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0-7FFFFFFF
Output	out	SIN Output	Q15	8000-7FFF

Special Constants and Data types

SGENHP_1
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENHP_1

SGENHP_1_handle
User defined Data type of pointer to SGENHP_1 Module

SGENHP_1_DEFAULTS
Structure symbolic constant to Initialize SGENHP_1 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);
This function implement the single channel digital SIN signal generation using table look-up and linear interpolation technique and it uses 32-bit integrator to generate high precision SIN signal.

Module Usage

Instantiation

The following example instances empty signal generator object
SGENHP_1 sgen;

Initialization

To Instance pre-initialized object
SGENHP_1 sgen = SGENHP_1_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

The following pseudo code exemplifies, 50Hz single channel digital SIN signal generation using SGENHP_1 module.

```
#include <sgen.h>

SGENHP_1 sgen=SGENHP_1_DEFAULTS;
int x1;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;               /* gain=1 in Q15                                */
        sgen.freq=0x14F8CF92;           /* freq = (Required Freq/Max Freq)*2^31         */
                                        /*      = (50/305.17)*2^31 = 0x14f8cf92         */
        sgen.step_max=0x3E7FB26;        /* Max Freq= (step_max * sampling freq)/2^32 */
                                        /*           =(0x3E7FB26*20k)/2^32 = 305.17  */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
SINTBL          > PROG  PAGE 0
```

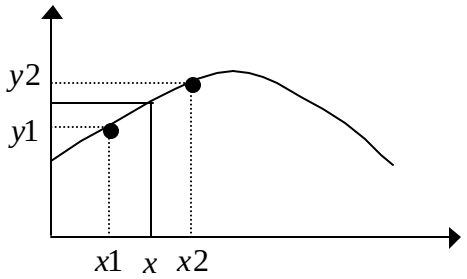
Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The high precision sin generators are implemented using Table look-up and linear interpolation technique and it uses 32-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and the 15-bits following the upper byte are used to interpolate between the look-up table entries.

$$y = y1 + \frac{y2 - y1}{x2 - x1} \times (x - x1) \qquad (1)$$



The amount of time it takes for the 32-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{32}}{step} \times T_{ISR} \qquad (2)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{2^{32}} \times F_{ISR} \qquad (3)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate.

The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (3)

$$step = \frac{500 \times 2^{32}}{20000} = 107374182.4$$

This step value of 107374182 is used to initialize the "step_max" element of the signal generator module. The normalized control variable "freq" helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution given by equation (4)

The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$ (4)

Hence the "step_max" should be high to get good frequency resolution. It should be set to at least "100" for reasonable frequency resolution.

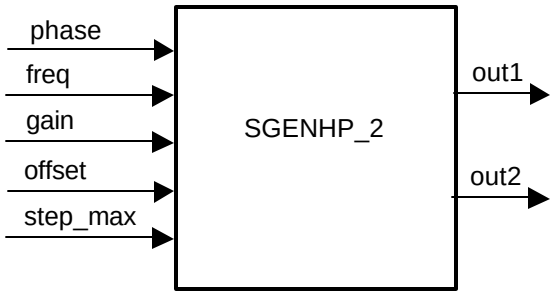
To generate SIN signal of frequency f, initialize the "freq" element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{31}$. Thus the required frequency is normalized with respect to the maximum frequency as set by "step_max" and input as Q31 number to the SIN generator module.

Since the frequency control variable is represented in Q31 format, we can precisely generate the required frequency.

SGENHP_2 — *Dual Channel SIN Generator (High precision)*

Description

This module generates single channel digital SIN signal using table look-up and linear interpolation technique with phase control and it uses 32-bit integration counter for high precision SIN generation.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly files: sghp2c.asm, sintb360.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	57 words + 257 + cinit[•]	257 Look-up Table entries
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized SGENHP_2 structure consumes 14 words in the data memory and 17 words in the ***cinit*** section

[D] Each instance of SGENHP_2 module consumes 14 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of SGENHP_2 object is defined by the following structure definition

```
typedef struct {
        unsigned long int freq;
        unsigned long int step_max;
        unsigned long int alpha;
        int gain;
        int offset;
        int out1;
        int out2;
        unsigned long int phase;
        void (*calc)(void *);
} SGENHP_2;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q31	0-7FFFFFFF
	offset	DC offset in the SIN signal	Q15	8000-7FFF
	gain	Gain of the SIN signal	Q15	0-7FFF
	phase	Phase angle between the two SIN outputs $[-\pi,+\pi]$ is normalized to $[-1,+1]$	Q15	8000-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{2^{32}}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0-7FFFFFFF
Output	out1	SIN Output 1 → $\sin(\theta)$	Q15	8000-7FFF
	out2	SIN Output 2 → $\sin(\theta + phase)$	Q15	8000-7FFF

Special Constants and Data types

SGENHP_2
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type SGENHP_2

SGENHP_2_handle
User defined Data type of pointer to SGENHP_2 Module

SGENHP_2_DEFAULTS
Structure symbolic constant to Initialize SGENHP_2 Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);

This function implements the dual channel digital SIN signal generation using table look-up and linear interpolation technique with phase control and it uses 32-bit integrator to generate high precision SIN signal.

Module Usage

Instantiation

The following example instances empty signal generator object

SGENHP_2 sgen;

Initialization

To Instance pre-initialized object

SGENHP_2 sgen = SGENHP_2_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

The following pseudo code exemplifies, two 50Hz digital SIN signal generation with 90deg phase shift using SGENHP_2 module.

```
#include <sgen.h>

SGENHP_2 sgen=SGENHP_2_DEFAULTS;

int x1, x2;
main( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;               /* gain=1 in Q15                                */
        sgen.freq=0x14F8CF92;           /* freq = (Required Freq/Max Freq)*2^31         */
                                        /*      = (50/305.17)*2^31 = 0x14f8cf92         */
        sgen.step_max=0x3E7FB26;        /* Max Freq= (step_max * sampling freq)/2^32 */
                                        /*              =(0x3E7FB26*20k)/2^32 = 305.17  */
        sgen.phase=0x40000000;          /* Phase= (required Phase)/180 in Q31           */
                                        /*      =  (+90/180) in Q31 = 40000000h         */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out1;
        x2=sgen.out2;
}
```

Note: Edit Linker Command file, to place the look-up table in Program memory.

```
SINTBL          > PROG  PAGE 0
```

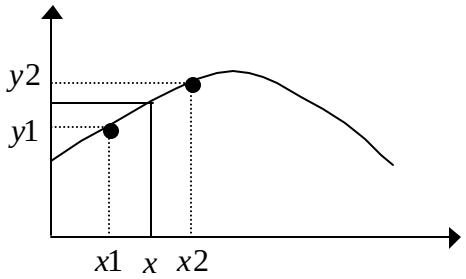
Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The high precision sin generators are implemented using Table look-up and linear interpolation technique and it uses 32-bit modulo counter. The upper byte (8-bits) is used to index the 256-point look-up table and the 15-bits following the upper byte are used to interpolate between the look-up table entries.

$$y = y1 + \frac{y2 - y1}{x2 - x1} \times (x - x1) \qquad (1)$$



The amount of time it takes for the 32-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{32}}{step} \times T_{ISR} \qquad (2)$$

The frequency of the generated SIN wave is reciprocal of the time, hence

$$F = \frac{step}{2^{32}} \times F_{ISR} \qquad (3)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the SIN wave is determined by the "step" value used to increment the modulo-counter and the ISR execution rate.

The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (3)

$$step = \frac{500 \times 2^{32}}{20000} = 107374182.4$$

This step value of 107374182 is used to initialize the "step_max" element of the signal generator module. The normalized control variable "freq" helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution given by equation (4)

The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$ (4)

Hence the "step_max" should be high to get good frequency resolution. It should be set to at least "100" for reasonable frequency resolution.

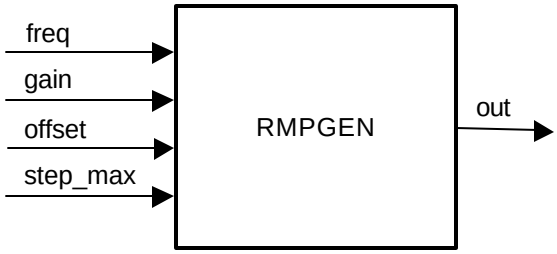
To generate SIN signal of frequency f, initialize the "freq" element of the SIN generator module to $\frac{f}{f_{MAX}} \times 2^{31}$. Thus the required frequency is normalized with respect to the maximum frequency as set by "step_max" and input as Q31 number to the SIN generator module.

Since the frequency control variable is represented in Q31 format, we can precisely generate the required frequency.

RMPGEN — *Ramp Generator*

Description

This module generates ramp output (Positive or Negative ramp) of adjustable gain, frequency and DC offset.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly Files: rampgc.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	12 words + cinit[•]	
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized RMPGEN structure consumes 8 words in the data memory and 11 words in the ***cinit*** section

[D] Each instance of RMPGEN module consumes 8 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of RMPGEN object is defined by the following structure definition

```
typedef struct {
        int freq;
        unsigned int step_max;
        unsigned int alpha;
        int gain;
        int offset;
        int out;
        void (*calc)(void *);
} RMPGEN;
```

Module Terminal Variables/ Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[-F_{MAX}, F_{MAX}]$ normalized to $[-1,1]$. The positive frequency input generates ramp up (+ve Ramp) and negative frequency input generates ramp down output (-ve Ramp)	Q15	8000-7FFF
	offset	DC offset in the ramp signal	Q15	8000-7FFF
	gain	Gain of the ramp signal	Q15	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{65536}$. The default value is set to 1000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop.	Q0	0000-7FFF
Output	out	SIN Output	Q15	8000-7FFF

Special Constants and Data types

RMPGEN

The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type RMPGEN.

RMPGEN_handle

User defined Data type of pointer to RMPGEN Module

SGENTI_1_DEFAULTS

Structure symbolic constant to Initialize RMPGEN Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*calc)(void *);

This function generates ramp output with adjustable gain, frequency and DC offset.

Module Usage

Instantiation

The following example instances empty signal generator object

```
RMPGEN  sgen;
```

Initialization

To Instance pre-initialized object

```
RMPGEN sgen = RMPGEN_DEFAULTS;
```

Invoking the computation function

```
sgen.calc(&sgen);
```

Example

The following pseudo code exemplifies, 50Hz negative ramp signal generation using RMPGEN module.

```
#include <sgen.h>

RMPGEN sgen=RMPGEN_DEFAULTS;
int x1;
main ( )
{
        sgen.offset=0;
        sgen.gain=0x7fff;       /* gain=1 in Q15                                    */
        sgen.freq=-5369;        /* freq = (Required Freq/Max Freq)*2^15             */
                                /*      = (50/305.17)*2^15 = 5369                   */
                                /* Negate freq input for –ve ramp                   */

        sgen.step_max=1000;     /* Max Freq= (step_max * sampling freq)/65536       */
                                /* Max Freq = (1000*20k)/65536 = 305.17             */
}

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out;
}
```

Background Information

The signal generator modules are implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The frequency of the generated signal is reciprocal of the time it takes for successive overflow of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The amount of time it takes for the 16-bit modulo counter to overflow, assuming that the counter is incremented in ISR.

$$T = \frac{2^{16}}{step} \times T_{ISR} = \frac{65536}{step} \times T_{ISR} \qquad (1)$$

The frequency of the generated ramp signal is reciprocal of the time, hence

$$F = \frac{step}{65536} \times F_{ISR} \qquad (2)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus the actual frequency of the ramp is determined by the "step" value used to increment the modulo-counter and the ISR execution rate. The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop. Then the step value to generate 500Hz is determined using equation (2)

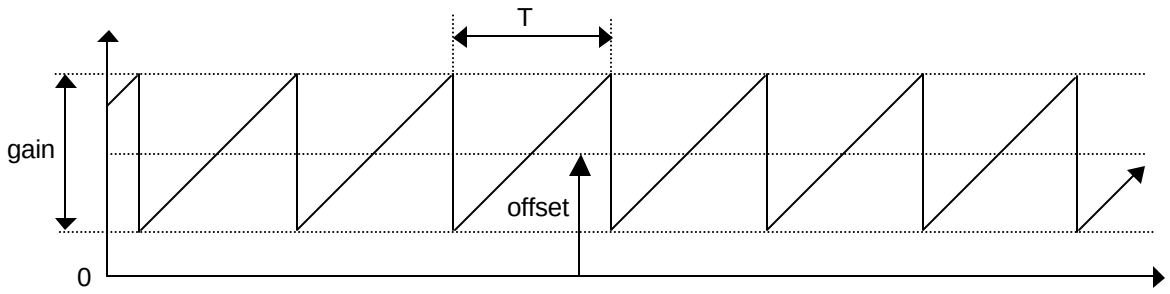
$$step = \frac{500 \times 65536}{20000} = 1638.4$$

This step value of 1638 is used to initialize the "step_max" element of the signal generator module. The normalized control variable "freq" helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 0.305Hz

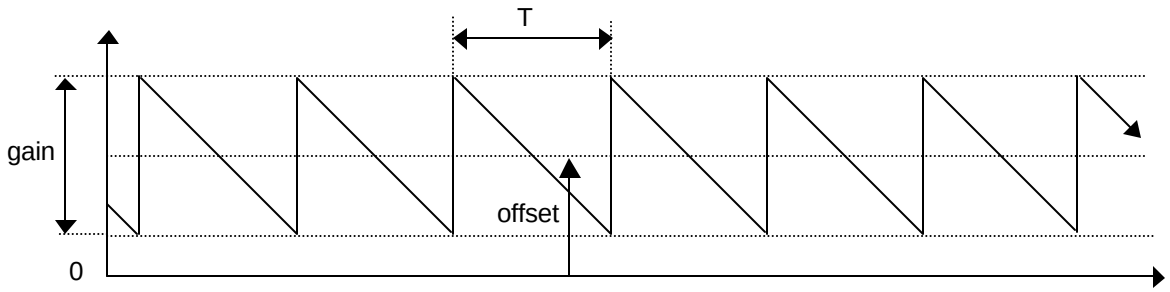
The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the "step_max" should be high to get good frequency resolution. It should be set to at least "100" for reasonable frequency resolution.

To generate RAMP signal of frequency f , initialize the “freq” element of the ramp generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the ramp generator module. The negative frequency input generates negative ramp output.

Positive Ramp Output:



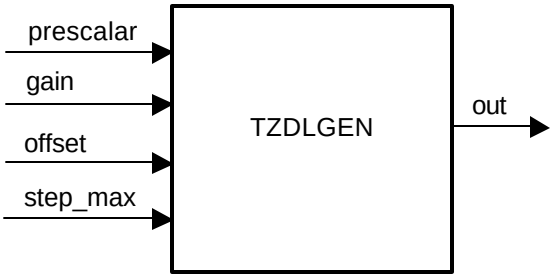
Negative Ramp Output:



TZDLGEN — *Trapezoidal Generator*

Description

This module generates trapezoidal output of adjustable gain, frequency and DC offset. Input pre-scalar is provided to generate very low frequency output.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly Files: tzdlgc.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	89 words + cinit[•]	
Data RAM	0 words[•]	
xDAIS ready	Yes	
xDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

• Each pre-initialized TZDLGEN structure consumes 14 words in the data memory and 17 words in the ***cinit*** section

Ð Each instance of TZDLGEN module consumes 14 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of TZDLGEN object is defined by the following structure definition

```
typedef struct {
        unsigned int skip_cntr;
        unsigned int prescalar;
        unsigned int freq;
        unsigned int step_max;
        unsigned int task;
        unsigned int alpha;
        int gain;
        int offset;
        int out;
        void (*init)(void *);
        void (*calc)(void *);
} TZDLGEN;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0000-7FFF
	offset	DC offset in the trapezoidal signal	Q15	8000-7FFF
	gain	Gain of the trapezoidal signal	Q15	0-7FFF
	prescalar	Prescalar for modulo counter, used to generate very low frequency.	Q0	0-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{4 \times 65536 \times prescalar}$. The default value is set to 4000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop and unity prescalar.	Q0	0000-7FFF
Output	out	Trapezoidal Output	Q15	8000-7FFF

Special Constants and Data types

TZDLGEN
The module definition is created as a data type. This makes it convenient to instance an interface to the signal generator module. To create multiple instances of the module simply declare variables of type TZDLGEN.

TZDLGEN_handle
User defined Data type of pointer to TZDLGEN module

TZDLGEN_DEFAULTS
Structure symbolic constant to Initialize TZDLGEN Module. This provides the initial values to the terminal variables as well as method pointers.

Methods

void (*init)(void *);
This function initializes the trapezoidal module.

void (*calc)(void *);
This function generates trapezoidal output with adjustable gain, frequency and DC offset.

Module Usage

Instantiation

The following example instances empty signal generator object
TZDLGEN sgen;

Initialization

To Instance pre-initialized object
TZDLGEN sgen = TZDLGEN_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

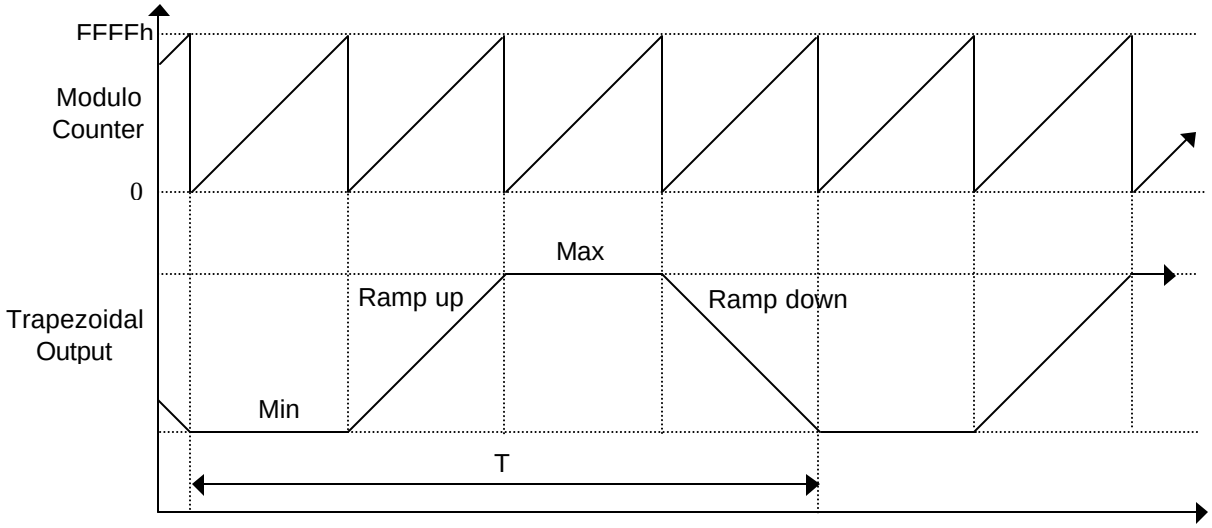
The following pseudo code exemplifies, 50Hz trapezoidal signal generation, using TZDLGEN module.

```
#include <sgen.h>

TZDLGEN sgen=TZDLGEN_DEFAULTS;
int x1;
main ( )
{
        sgen.prescalar=1;
        sgen.freq=5369;         /* freq = (Required Freq/Max Freq)*2^15          */
                                /*      = (50/305.17)*2^15 = 5369                */
        sgen.step_max=4000;  /* Max Freq= (step_max*Fs)/(4*65536*prescalar)  */
                                /* Max Freq = (4000*20k)/(4*65536*1) = 305.17   */
        sgen.gain=0x7fff;       /* ~1 in Q15 format                             */
        sgen.offset=0;
        sgen.init(&tgen);
 }

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out;
}
```

Background Information

The trapezoidal module is implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The trapezoidal signal consists of four states viz., MIN, RAMP UP, MAX and RAMP DOWN. The module is initialized to "MIN" state by the initialization routine and state switching is performed during the overflow of the modulo counter. Hence, the modulo counter overflows four times to complete one cycle of trapezoidal output. As a result the frequency of the generated signal is reciprocal of the time it takes for 4 overflows of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.



The modular counter have software prescalar to reduce the increment rate in order to generate very low frequency trapezoidal signal. The prescalar essentially increases the time to overflow, thereby reducing the frequency. The amount of time it takes for the 16-bit modulo counter to overflow 4 times, for a given prescalar is given by

$$T = \frac{4 \times 2^{16} \times prescalar}{step} \times T_{ISR} = \frac{4 \times 65536 \times prescalar}{step} \times T_{ISR} \qquad (1)$$

The frequency of the generated trapezoidal signal is reciprocal of the time, hence

$$F = \frac{step}{4 \times 65536 \times prescalar} \times F_{ISR} \qquad (2)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus, the actual frequency of the trapezoidal signal is determined by the incremental step value, prescalar and ISR execution rate. The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop and unity prescalar. Then the step value to generate 500Hz is determined using equation (2)

$$step = \frac{500 \times 4 \times 65536 \times 1}{20000} = 6553.6$$

This step value of 6553 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 76.3mHz

The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate trapezoidal signal of frequency f, initialize the “freq” element of the ramp generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the trapezoidal generator module.

Prescalar:
From equation (2), the minimum frequency is generated for unity prescalar, if the step increment is “1”.

$$F_{MIN} = \frac{1}{4 \times 65536 \times 1} \times F_{ISR} = \frac{20000}{4 \times 65536} = 76\text{mHz}$$

Hence, the minimum frequency is 76mHz or 13.1sec time period for 20Khz ISR.

If the pre-scalar value is set to 2, then the minimum frequency is 38mHz or 26.2sec time period for 20K ISR.

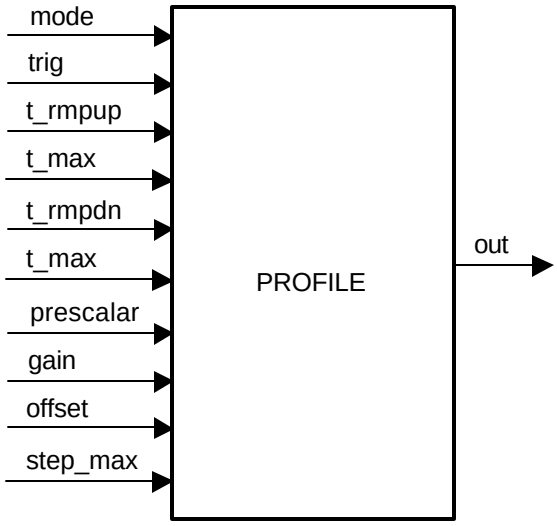
$$F_{MIN} = \frac{1}{4 \times 65536 \times 2} \times F_{ISR} = \frac{20000}{4 \times 65536 \times 2} = 38\text{mHz}$$

Thus, the pre-scalar is essentially used to generate very low frequency signal by increasing the value.

PROFILE — *Profiling Signal Generator*

Description

This module generates profiling signal of adjustable gain, frequency and DC offset. It can generate continuos or triggered single shot output. Input pre-scalar is provided to generate very low frequency.



Availability

C-Callable Assembly (CcA)

Module Properties

Type: Target Independent, Application Dependent

Target Devices: x28xx

C-Callable Assembly Files: profilec.asm, sgen.h

Item	C-Callable ASM	Comments
Code Size[ÿ]	156 words + cinit[•]	
Data RAM	0 words[•]	
XDAIS ready	Yes	
XDAIS component	No	IALG layer not implemented
Multiple instances	Yes	
Reentrancy	Yes	
Multiple Invocation	Yes	
Stack usage	2 words	Stack grows by 2 words

[•] Each pre-initialized PROFILE structure consumes 20 words in the data memory and 23 words in the ***cinit*** section

[D] Each instance of PROFILE module consumes 20 words in Data memory.

C/C-Callable ASM Interface

Object Definition

The structure of PROFILE object is defined by the following structure definition

```
typedef struct {
        int mode;
        int trig;
        unsigned int skip_cntr;
        unsigned int prescalar;
        unsigned int freq;
        unsigned int step_max;
        int t_rmpup;
        int t_max;
        int t_rmpdn;
        int t_min;
        unsigned int task;
        unsigned int alpha;
        int gain;
        int offset;
        int out;
        void (*init)(void *);
        void (*calc)(void *);
} PROFILE;
```

Module Terminal Variables/Functions

Item	Name	Description	Format	Range(Hex)
Input	mode	1: Continuous Signal generation 0: Single Shot operation	Binary	0 or 1
	trig	Trigger input for single shot operation	Binary	0 or 1
	prescalar	Prescalar for modulo counter, used to generate very low frequency.	Q0	0-7FFF
	freq	Frequency in hertz between $[0,F_{MAX}]$ normalized to $[0,1]$	Q15	0000-7FFF
	step_max	$F_{MAX} = \frac{step\_\max \times F_S}{4 \times 65536 \times prescalar}$. The default value is set to 4000 to generate the maximum frequency of 305.17Hz using 20KHz sampling loop and unity prescalar.	Q0	0000-7FFF
	offset	DC offset in the trapezoidal signal	Q15	8000-7FFF
	gain	Gain of the trapezoidal signal	Q15	0-7FFF
	t_min	Ratio of minimum state time with respect to the time period (T) in Q8 format	Q8	0000-0100
	t_rmpup	Ratio of ramp up state time with respect to the time period (T) in Q8 format	Q8	0000-0100
	t_max	Ratio of max state time with respect to the time period (T) in Q8 format	Q8	0000-0100
	t_rmpdn	Ratio of ramp down state time with respect to the time period (T) in Q8 format	Q8	0000-0100
Output	out	Profile Output	Q15	8000-7FFF

Methods

void (*init)(void *);
This function initializes the profile module.

void (*calc)(void *);
This function generates profile signal of adjustable gain, frequency and DC offset. It provides option for single shot or continuos signal generation.

Module Usage

Instantiation

The following example instances empty signal generator object
PROFILE sgen;

Initialization

To Instance pre-initialized object
PROFILE sgen = PROFILE_DEFAULTS;

Invoking the computation function

sgen.calc(&sgen);

Example

The following pseudo code exemplifies 50Hz profile signal generation with the following properties using PROFILE module (Assuming 20KHz sampling frequency).

1) Min State time: 10% of T. 2) Ramp up state time: 20% of T.
3) Max state time: 30% of T. 4) Ramp down state time: 40% of T.

```
#include <sgen.h>

PROFILE sgen=PROFILE_DEFAULTS;
int x1;
main ( )
{
                                /* Signal Generator module initialization              */
    sgen.mode=1;                /* Set Mode bit for Continuous signal Generation   */

    sgen.prescalar=1;
    sgen.freq=5369;             /* freq = (Required Freq/Max Freq)*2^15              */
                                /*      = (50/305.17)*2^15 = 5369                    */
    sgen.step_max=4000;         /* Max Freq= (step_max * sampling freq)/(4*65536) */
                                /* Max Freq = (4000*20k)/(4*65536) = 305.17        */
    sgen.gain=0x7fff;           /* ~1 in Q15 format                                */
    sgen.offset=0;
    sgen.t_rmpup=51;            /* 20% of T, 0.2 in Q8    */
    sgen.t_max=77;              /* 30% of T, 0.3 in Q8    */
    sgen.t_rmpdn=102;           /* 40% of T, 0.4 in Q8    */
    sgen.t_min=25;              /* 10% of T, 0.1 in Q8    */
    sgen.init(&sgen);
 }

void interrupt isr_20khz()
{
        sgen.calc(&sgen);
        x1=sgen.out;
}
```

Background Information

The profile signal generator is implemented using modulo arithmetic counter (i.e. Any overflow is ignored and only the remainder is kept) to precisely control the frequency. The profile signal consists of four states viz., MIN, RAMP UP, MAX and RAMP DOWN. The module is initialized to "MIN" state by the initialization routine and state switching is performed during the overflow of the modulo counter. Hence, the modulo counter overflows four times to complete one cycle of profile output. As a result the frequency of the generated signal is reciprocal of the time it takes for 4 overflows of modulo counter, which in turn commensurate with the step value added to the counter. Thus by changing the step value, one can precisely control the frequency.

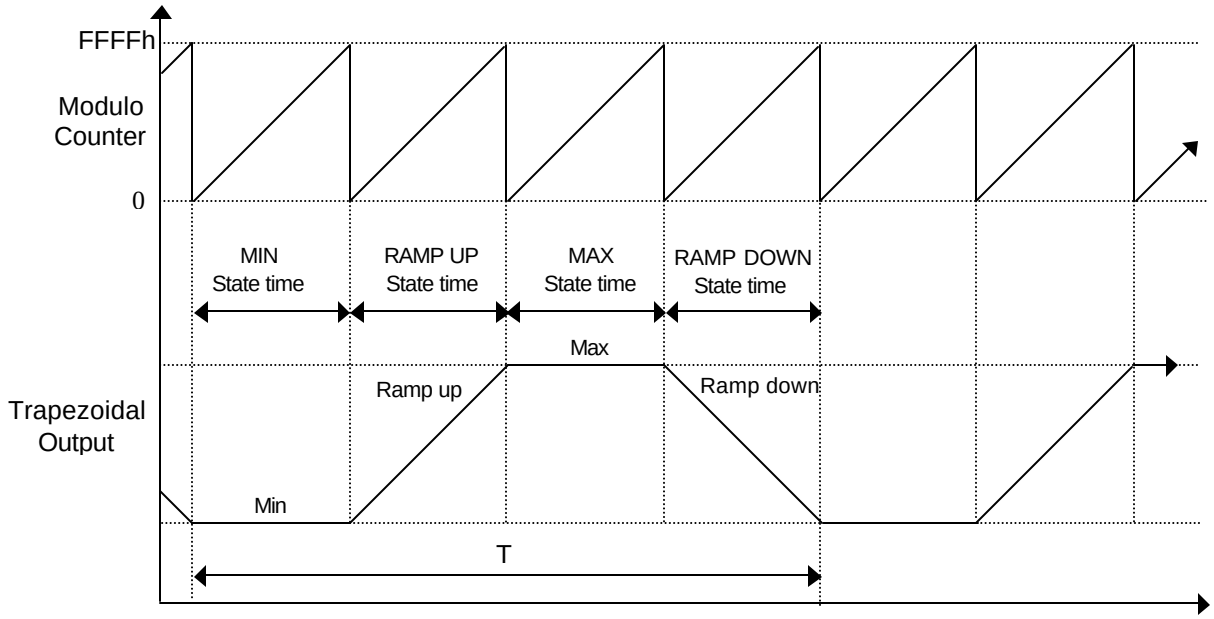
The step value is not directly commanded to vary the frequency, instead the modulation of frequency is performed using the normalized variable "freq" which is normalized to the maximum frequency. The maximum required frequency is predetermined based on the application requirement and it set by initializing the "step_max" input. Thus, the normalized variable "freq" allows the user to control the frequency of the signal between 0 to maximum frequency.

The step value is calculated using the following equation

$$step = freq \times step\_\max \qquad (1)$$

Where, $freq = 0:1$ in Q15 format

Adding the same step value continuously to the modulo counter provides equal time period ($T/4$ or 25% of T) for each state of the profile viz., MIN, RAMP UP, MAX and RAMP DOWN resulting in trapezoidal output as given below. Profile generator requires the traversal time for each state modifiable. This is done by providing 4 parameters describing the MIN state time, RAMP UP state time, MAX state time and RAMP DOWN state time. The time input for each state is specified as the ratio with respect to the Profile time period (T) in Q8 format.



The modular counter have software pre-scalar to reduce the increment rate in order to generate very low frequency trapezoidal signal. The pre-scalar essentially increases the time to overflow, thereby reducing the frequency. The amount of time it takes for the 16-bit modulo counter to overflow 4 times, for a given pre-scalar is given by

$$T = \frac{4 \times 2^{16} \times prescalar}{step} \times T_{ISR} = \frac{4 \times 65536 \times prescalar}{step} \times T_{ISR} \qquad (2)$$

The frequency of the generated trapezoidal signal is reciprocal of the time, hence

$$F = \frac{step}{4 \times 65536 \times prescalar} \times F_{ISR} \qquad (3)$$

Where $F_{ISR} = \frac{1}{T_{ISR}}$ is the ISR invocation frequency.

Thus, the actual frequency of the trapezoidal signal is determined by the incremental step value, pre-scalar and ISR execution rate. The signal generator modules use the normalized control variable to modulate the frequency instead of directly commanding the step value. The frequency control variable is normalized with respect to the maximum frequency.

Assuming that the application requires the maximum frequency of 500Hz using 20Khz ISR loop and unity pre-scalar. Then the step value to generate 500Hz is determined using equation (3)

$$step = \frac{500 \times 4 \times 65536 \times 1}{20000} = 6553.6$$

This step value of 6553 is used to initialize the “step_max” element of the signal generator module. The normalized control variable “freq” helps to control the frequency from 0 to 500Hz by varying it between 0 to 1 (Q15 format) with the frequency resolution of 76.3mHz

The frequency resolution is = $\frac{F_{MAX}}{step\_\max}$, hence the “step_max” should be high to get good frequency resolution. It should be set to at least “100” for reasonable frequency resolution.

To generate trapezoidal signal of frequency f, initialize the “freq” element of the trapezoidal generator module to $\frac{f}{f_{MAX}} \times 2^{15}$. Thus the required frequency is normalized with respect to the maximum frequency as set by “step_max” and input as Q15 number to the trapezoidal generator module.

Pre-scalar

From equation (2), the minimum frequency is generated for unity pre-scalar, if the step increment is “1”.

$$F_{MIN} = \frac{1}{4 \times 65536 \times 1} \times F_{ISR} = \frac{20000}{4 \times 65536} = 76\text{mHz}$$

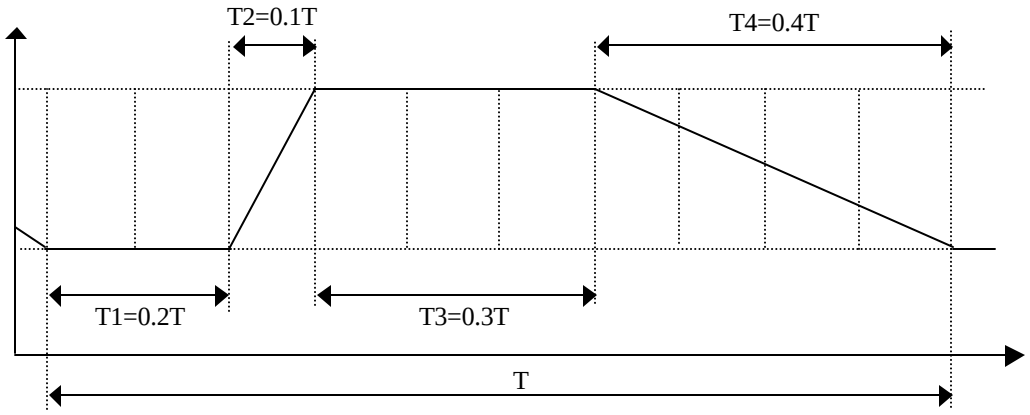
Hence, the minimum frequency is 76mHz or 13.1sec time period for 20Khz ISR.

If the pre-scalar value is set to 2, then the minimum frequency is 38mHz or 26.2sec time period for 20K ISR.

$$F_{MIN} = \frac{1}{4 \times 65536 \times 2} \times F_{ISR} = \frac{20000}{4 \times 65536 \times 2} = 38\text{mHz}$$

Thus, the pre-scalar is essentially used to generate very low frequency signal by increasing the value.

Time Specification



The state traversal time for MIN, RAMP_UP, MAX and RAMP DOWN are input to the module as ratio with respect to the profile time period in Q8 format and it is given below. The sum of the time parameter expressed as ratio with respect to the profile time period, must be unity. Otherwise the generated frequency will be different from the one set by the “freq” input.

$$\text{t\_min} = \left| \frac{T_1}{T} \times 2^8 \right| \qquad (4)$$

$$\text{t\_rmpup} = \left| \frac{T_2}{T} \times 2^8 \right| \qquad (5)$$

$$\text{t\_max} = \left| \frac{T_3}{T} \times 2^8 \right| \qquad (6)$$

$$\text{t\_rmpdn} = \left| \frac{T_4}{T} \times 2^8 \right| \qquad (7)$$

To generate the profile given in the last page, initialize the time parameters as given below,

1) t_min= $\left|\frac{0.2T}{T}\times 2^8\right| = 51$ 2) t_rmpup= $\left|\frac{0.1T}{T}\times 2^8\right| = 26$

3) t_max= $\left|\frac{0.3T}{T}\times 2^8\right| = 77$ 4) t_rmpdn= $\left|\frac{0.4T}{T}\times 2^8\right| = 102$

The step value in equation (1), if added to modulo counter will provide ($T/4$ or 25% of T) for each state. To get the required traversal time for each state, the step value is scaled up/down before adding to modulo counter. The step value is scaled up, if the state time parameter is less the 0.25 the scaled down if the state time parameter is greater then 0.25.

Actual step value added during ramp up phase is give by the following equation

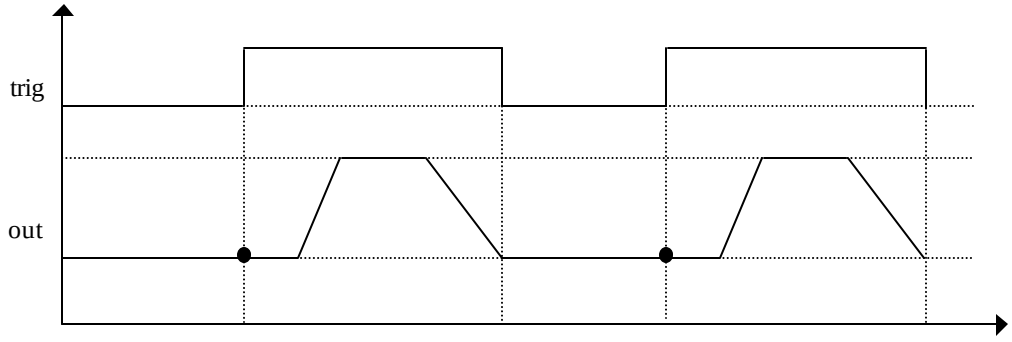
$$= \frac{step\times 0.25}{t\_rmpup} \qquad (8)$$

Similarly for the other state of the profile output, actual step values are calculated based on time parameter and added to modulo counter.

Single shot & Continuous profile generation:

The profile generator operates in two modes viz., Single shot mode and Continuos mode. It is selected by using “mode” element. Setting the “mode” element will generate continuous profile output, resetting to “zero” will allow the module to work in single shot mode. In single shot mode, the profile generator generates one cycle of profile, if “trig” element is set to “1”. Trigger element

e of profile output.



Wave Generation:

The profile generator can be used to generate ramp and triangular waveform by appropriately initializing the state time parameters

Positive ramp generation:

1) t_rmpup=256 (1 in Q8) 2) t_max=0,
3) t_min=0 4) t_rmpdn=0

Negative ramp generation:

1) t_rmpup=0 2) t_max=0,
3) t_min=0 4) t_rmpdn=256 (1 in Q8)

Triangular wave generation:

1) t_rmpup=128 (0.5 in Q8) 2) t_max=0,
3) t_min=0 4) t_rmpdn=128 (0.5 in Q8)

