

# Function generator

Date: Jun 2024



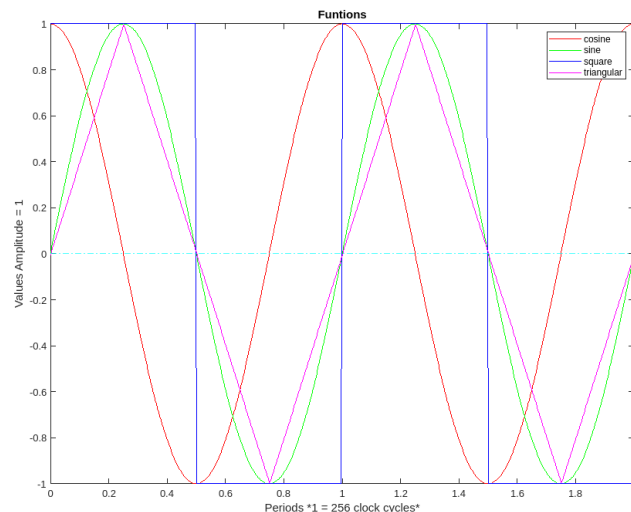
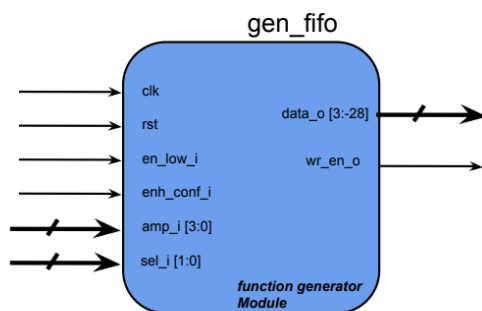
# RTL

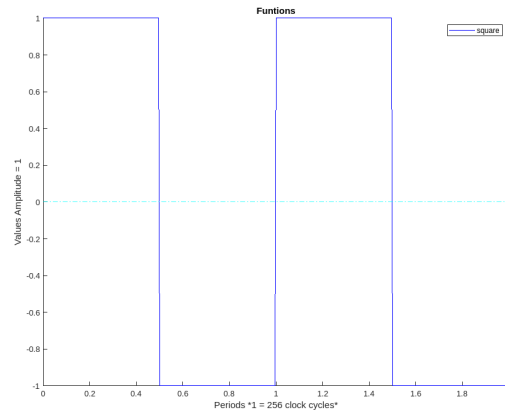
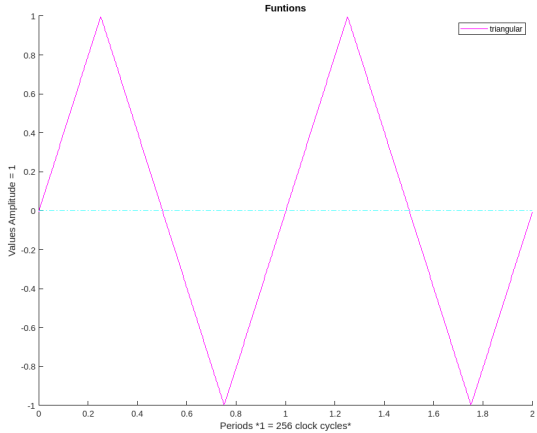
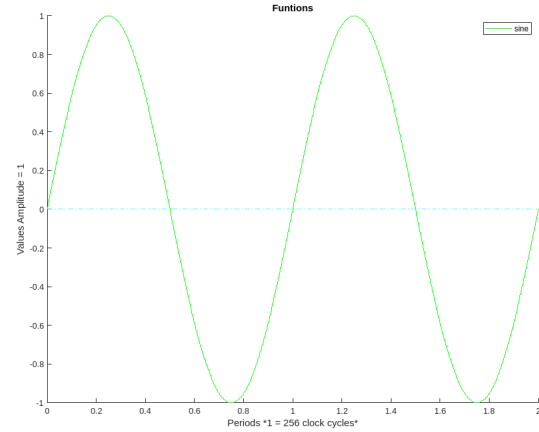
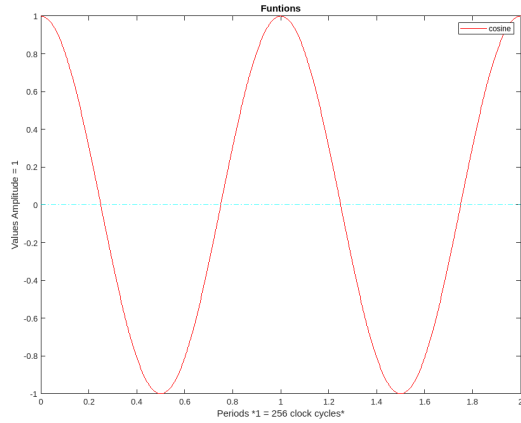
## Description

Function generator module. The module has a selector to choose between the following four functions:

- Sine
- Cosine
- Triangular
- Square

- 1) It is possible to set the output signal amplitude with a integer range from 1 to 7. When amplitude is change, the function is reset. When the amplitude takes negative values , it allows the output signal to be inverted.
- 2) To modify the amplitude, the configuration enable must be set to 1. During the period that enh\_conf\_i is set, no signal will be generated and wr\_en\_o will be disabled.
- 3) The function period is 256 clock cycles. Considering a clock frequency of 100MHz (Period = 10ns), each period of the generated function would be 2.56us and its frequency would be approximately 390.6 KHz.
- 4) When the reset is activated all the signals are initialized at the position 0 of their respective LUT, which for each signal is as follows:
  - Sine = 0
  - Cosine = Amplitude
  - Square = Amplitude
  - Triangular = 0
- 5) When the enable is activated the signal at the output will continue at the point where it stopped previously, if a different function is selected, the new waveform will continue in the direction of the LUT where the previous function stopped since all four functions will use the same direction.
- 6) The format used to represent the values of the functions is fixed point 4.28. Where QI=4 and QF=28. This analysis was performed with Matlab and the code is shown in the corresponding section below.





<i><b>Input</b></i>	<i><b>Size</b></i>	<i><b>Description</b></i>	<i><b>Source</b></i>
clk	1	Clock	Clock source
rst	1	Asynchronous reset activated	Main input
en_low_i	1	Operation enable. This enable activates the operation of the module when it is set to zero. When en_low_i = 1, the module stops its operation at the point where it was and data_o retain their value until the enable is re-asserted.	Main input (full / FIFO)
enh_conf_i	1	Configuration enable. This signal enables the amplitud change.	Main inout
amp_i	4	Amplitude of the function. It can take the integer values -7, -6, -5, -4, -3, -2, -1, 1, 2, 3, 4, 5, 6 and 7 in	Main input

		a 2's complement format. It determines the amplitude of the output signal. Binary values 0000 and 1000 are forbidden, when the input takes these values and enh_config_i=1, the amplitude will not be modified.	
sel_i	2	Function selector Allows to select which waveform is the one we want to obtain in the output of the module. The function of each value of this signal is described in a table below.	Main input
Output	Size	Description	Source
data_o	32	Data of the generated function	Top module
wr_en_o	1	This signal indicates that the data at the output are valid and will be written to a destination memory.	Top module

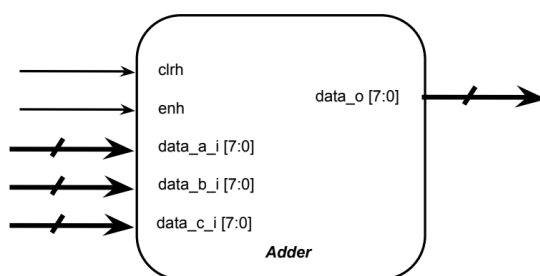
Table 1: Inputs/Outputs description

Internal sub-modules:

- Adder module
- Multiplication module
- Register module
- LUT
- FSM module
- Mux module

## Sub-modules

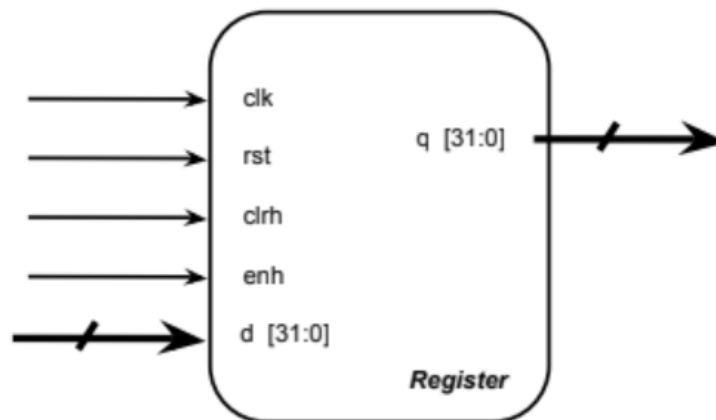
1. Adder: 3-input adder with enable and clear. The addition is performed combinationaly when the enable is active. The output is zero when the clear is activated. The clear signal has priority.



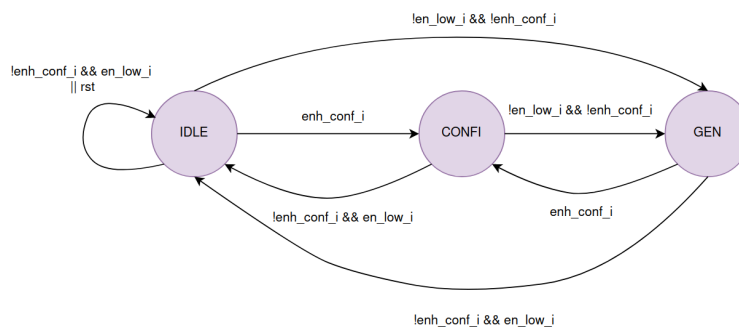
- Multiplier: 2-input multiplier with enable. Multiplication is performed combinational when the enable is active.



- Register: Type D flip flop register activated on positive clock edge with enable active high and clear active high

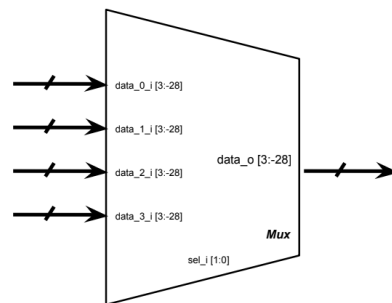


- FSM: The state machine will control the enable of the internal modules, when to clear the information from the registers and the sequential operation of the whole RTL.



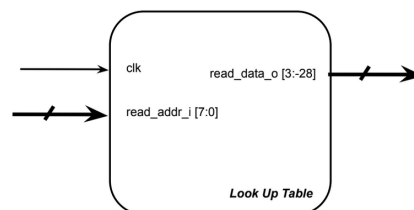
State	Signals
IDLE	clrh_addr_fsm = 1 enh_gen_fsm = 0 enh_config_fsm = 0
CONFI	clrh_addr_fsm = 1 enh_gen_fsm = 0 enh_config_fsm = 1
GEN	clrh_addr_fsm = 0 enh_gen_fsm = 1 enh_config_fsm = 0

5. Mux: 4-input 1-output multiplexer with a 2-bit selector switch. The output signal corresponds to the selector value (0 to 3). Inputs and outputs are signed.



sel_i value	Output signal
0	Sine
1	Cosine
2	Triangular
3	Square

6. LUT: Stores the values of the functions. It only has the operation of reading by means of an address. Its content is loaded by means of a txt file in hexadecimal. The reading is sequential on the positive edge of the clock. Information on each function can be found in the annexes section.



## Fixed point analysis

```
2 fmax = 1; Fs = fmax*255;
3 Time = 0:1/Fs:1; %%
4 amplitud=1;
5
6 %signals
7 cosine_s = amplitud*cos(2*pi*fmax*Time);
8 sine_s = amplitud*sin(2*pi*fmax*Time);
9 triangular_s = amplitud*sawtooth(2*pi*fmax*Time+1.561, 1/2);
10 square_s = amplitud*square(2*pi*fmax*Time);
11
12 %Analysis
13 WordLength = 32;
14 QI_sinusoid = 4; %%Integers
15 QF_sinusoid = WordLength-QI_sinusoid; %%Fraction
16
17 signal_sin_dec = fi(sine_s,1,WordLength,QF_sinusoid)
18 signal_sin_bin = bin(fi(sine_s,1,WordLength,QF_sinusoid))
19 fileSINE = fopen('sin_dec.txt','w');
20 fprintf(fileSINE,'%1.4f \n',signal_sin_dec);
21
22 signal_cos_dec = fi(cosine_s,1,WordLength,QF_sinusoid)
23 signal_cos_bin = bin(fi(cosine_s,1,WordLength,QF_sinusoid))
24 fileCOSINE = fopen('cos_dec.txt','w');
25 fprintf(fileCOSINE,'%1.4f \n',signal_cos_dec);
26
27 signal_trian_dec = fi(triangular_s,1,WordLength,QF_sinusoid)
28 signal_trian_bin = bin(fi(triangular_s,1,WordLength,QF_sinusoid));
29 fileTRIAN = fopen('triangular_dec.txt','w');
30 fprintf(fileTRIAN,'%1.4f \n',signal_trian_dec);
31
32 signal_squa_dec = fi(square_s,1,WordLength,QF_sinusoid)
33 signal_squa_bin = bin(fi(square_s,1,WordLength,QF_sinusoid));
34 fileSQUA = fopen('square_dec.txt','w');
35 fprintf(fileSQUA,'%1.4f \n',signal_squa_dec);
```

Binary type: signed 8-bit ▼

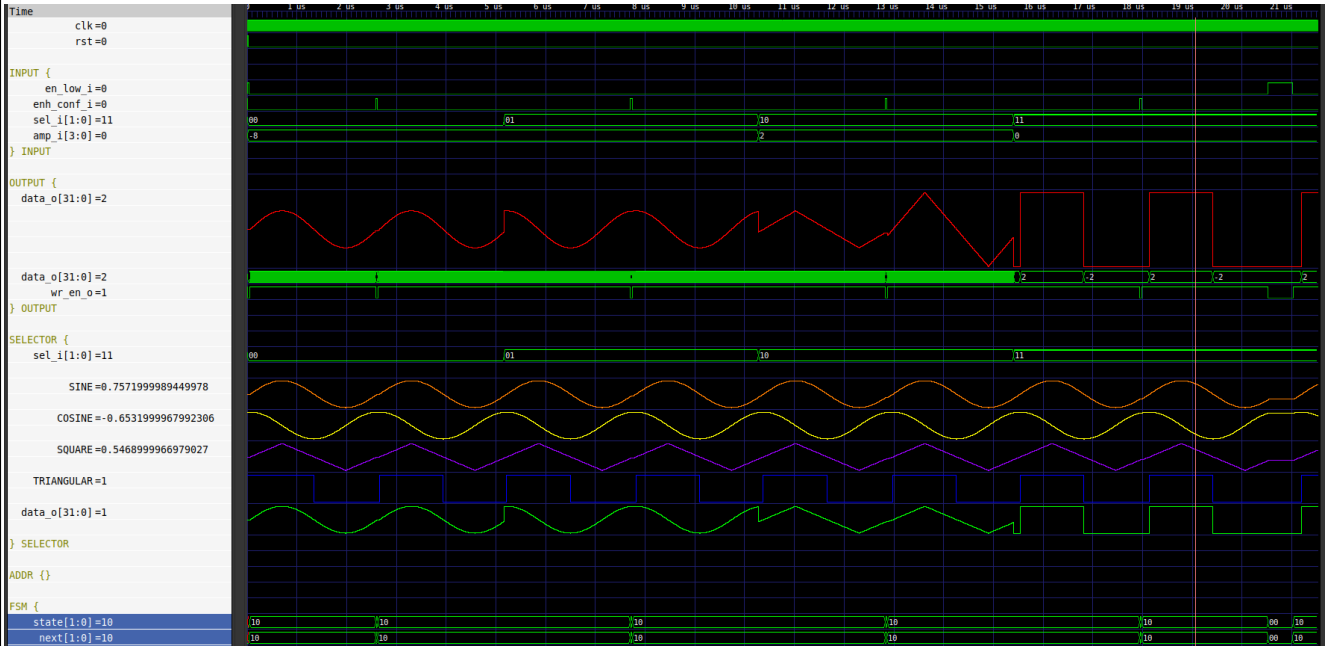
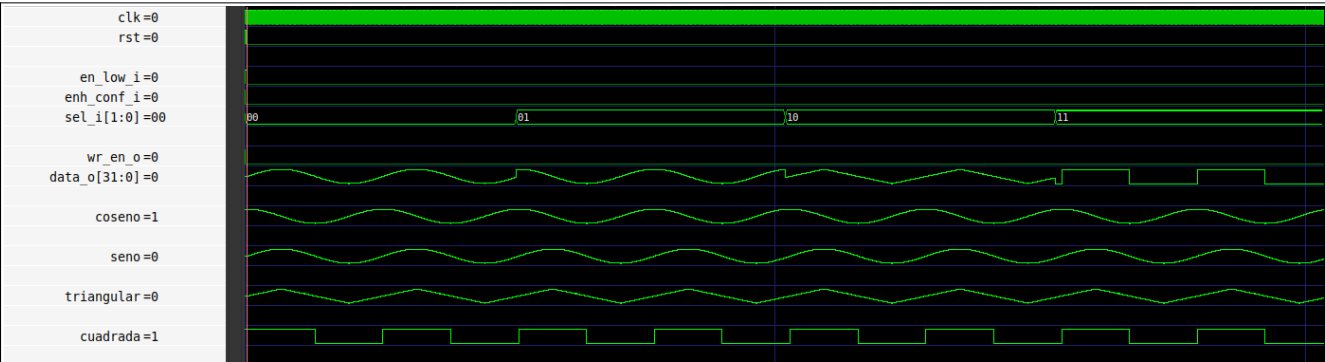
**Binary:** 0.00000000000000000000000000000001

**Decimal:** 0.00000000372529029846 + -

**Hexadecimal:** 0.0000001

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## Results



# Anexos:

## LUT data



LUT	Square				Triangular			
	Dec	Bin	Hex	Dec	Bin	Hex	Hex	
0	1.0000	0001 000000000000000000000000	10000000	0.0000	0000 000000000000000000000000	00000000	00000000	
1	1.0000	0001 000000000000000000000000	10000000	0.0156	0000 0000001111111110010111001001	003FE5C9	003FE5C9	
2	1.0000	0001 000000000000000000000000	10000000	0.0312	0000 0000011111111100101110010010	007FCB92	007FCB92	
3	1.0000	0001 000000000000000000000000	10000000	0.0469	0000 0000110000000001101000110110	00C01A36	00C01A36	
4	1.0000	0001 000000000000000000000000	10000000	0.0625	0000 00010000000000000000000000	01000000	01000000	
5	1.0000	0001 000000000000000000000000	10000000	0.0781	0000 0001001111111110010111001001	013FE5C9	013FE5C9	
6	1.0000	0001 000000000000000000000000	10000000	0.0938	0000 0001100000000011010001101101	0180346D	0180346D	
7	1.0000	0001 000000000000000000000000	10000000	0.1094	0000 0001110000000001101000110110	01C01A36	01C01A36	
8	1.0000	0001 000000000000000000000000	10000000	0.1250	0000 00100000000000000000000000	02000000	02000000	
9	1.0000	0001 000000000000000000000000	10000000	0.1406	0000 0010001111111110010111001001	023FE5C9	023FE5C9	
10	1.0000	0001 000000000000000000000000	10000000	0.1562	0000 00100111111111100101110010010	027FCB92	027FCB92	
11	1.0000	0001 000000000000000000000000	10000000	0.1719	0000 0010110000000001101000110110	02C01A36	02C01A36	
12	1.0000	0001 000000000000000000000000	10000000	0.1875	0000 00011000000000000000000000	03000000	03000000	
13	1.0000	0001 000000000000000000000000	10000000	0.2031	0000 0011001111111110010111001001	033FE5C9	033FE5C9	
14	1.0000	0001 000000000000000000000000	10000000	0.2188	0000 0011100000000011010001101101	0380346D	0380346D	
15	1.0000	0001 000000000000000000000000	10000000	0.2344	0000 0011110000000001101000110110	03C01A36	03C01A36	
16	1.0000	0001 000000000000000000000000	10000000	0.2500	0000 01000000000000000000000000	04000000	04000000	
17	1.0000	0001 000000000000000000000000	10000000	0.2656	0000 0100001111111110010111001001	043FE5C9	043FE5C9	
18	1.0000	0001 000000000000000000000000	10000000	0.2812	0000 01000111111111100101110010010	047FCB92	047FCB92	
19	1.0000	0001 000000000000000000000000	10000000	0.2969	0000 0100110000000001101000110110	04C01A36	04C01A36	
20	1.0000	0001 000000000000000000000000	10000000	0.3125	0000 01010000000000000000000000	05000000	05000000	
21	1.0000	0001 000000000000000000000000	10000000	0.3281	0000 0101001111111110010111001001	053FE5C9	053FE5C9	
22	1.0000	0001 000000000000000000000000	10000000	0.3438	0000 0101100000000011010001101101	0580346D	0580346D	
23	1.0000	0001 000000000000000000000000	10000000	0.3594	0000 0101110000000001101000110110	05C01A36	05C01A36	
24	1.0000	0001 000000000000000000000000	10000000	0.3750	0000 01100000000000000000000000	06000000	06000000	
25	1.0000	0001 000000000000000000000000	10000000	0.3906	0000 0110001111111110010111001001	063FE5C9	063FE5C9	
26	1.0000	0001 000000000000000000000000	10000000	0.4062	0000 01100111111111100101110010010	067FCB92	067FCB92	
27	1.0000	0001 000000000000000000000000	10000000	0.4219	0000 0110110000000001101000110110	06C01A36	06C01A36	
28	1.0000	0001 000000000000000000000000	10000000	0.4375	0000 01110000000000000000000000	07000000	07000000	
29	1.0000	0001 000000000000000000000000	10000000	0.4531	0000 0111001111111110010111001001	073FE5C9	073FE5C9	
30	1.0000	0001 000000000000000000000000	10000000	0.4688	0000 0111100000000011010001101101	0780346D	0780346D	
31	1.0000	0001 000000000000000000000000	10000000	0.4844	0000 0111110000000001101000110110	07C01A36	07C01A36	
32	1.0000	0001 000000000000000000000000	10000000	0.5000	0000 10000000000000000000000000	08000000	08000000	
33	1.0000	0001 000000000000000000000000	10000000	0.5156	0000 1000001111111110010111001001	083FE5C9	083FE5C9	
34	1.0000	0001 000000000000000000000000	10000000	0.5312	0000 10000111111111100101110010010	087FCB92	087FCB92	
35	1.0000	0001 000000000000000000000000	10000000	0.5469	0000 1000110000000001101000110110	08C01A36	08C01A36	
36	1.0000	0001 000000000000000000000000	10000000	0.5625	0000 10010000000000000000000000	09000000	09000000	
37	1.0000	0001 000000000000000000000000	10000000	0.5781	0000 1001001111111110010111001001	093FE5C9	093FE5C9	
38	1.0000	0001 000000000000000000000000	10000000	0.5938	0000 1001100000000011010001101101	0980346D	0980346D	
39	1.0000	0001 000000000000000000000000	10000000	0.6094	0000 1001110000000001101000110110	09C01A36	09C01A36	
40	1.0000	0001 000000000000000000000000	10000000	0.6250	0000 10100000000000000000000000	0A000000	0A000000	
41	1.0000	0001 000000000000000000000000	10000000	0.6406	0000 1010001111111110010111001001	0A3FE5C9	0A3FE5C9	
42	1.0000	0001 000000000000000000000000	10000000	0.6562	0000 10100111111111100101110010010	0A7FCB92	0A7FCB92	
43	1.0000	0001 000000000000000000000000	10000000	0.6719	0000 1010110000000001101000110110	0AC01A36	0AC01A36	
44	1.0000	0001 000000000000000000000000	10000000	0.6875	0000 10110000000000000000000000	0B000000	0B000000	
45	1.0000	0001 000000000000000000000000	10000000	0.7031	0000 1011001111111110010111001001	0B3FE5C9	0B3FE5C9	
46	1.0000	0001 000000000000000000000000	10000000	0.7188	0000 1011100000000011010001101101	0B80346D	0B80346D	
47	1.0000	0001 000000000000000000000000	10000000	0.7344	0000 1011110000000001101000110110	0BC01A36	0BC01A36	
48	1.0000	0001 000000000000000000000000	10000000	0.7500	0000 11000000000000000000000000	0C000000	0C000000	
49	1.0000	0001 000000000000000000000000	10000000	0.7656	0000 1100001111111110010111001001	0C3FE5C9	0C3FE5C9	
50	1.0000	0001 000000000000000000000000	10000000	0.7812	0000 11000111111111100101110010010	0C7FCB92	0C7FCB92	
51	1.0000	0001 000000000000000000000000	10000000	0.7969	0000 1100110000000001101000110110	0CC01A36	0CC01A36	
52	1.0000	0001 000000000000000000000000	10000000	0.8125	0000 11010000000000000000000000	0D000000	0D000000	
53	1.0000	0001 000000000000000000000000	10000000	0.8281	0000 1101001111111110010111001001	0D3FE5C9	0D3FE5C9	
54	1.0000	0001 000000000000000000000000	10000000	0.8438	0000 1101100000000011010001101101	0D80346D	0D80346D	
55	1.0000	0001 000000000000000000000000	10000000	0.8594	0000 1101110000000001101000110110	0DC01A36	0DC01A36	
56	1.0000	0001 000000000000000000000000	10000000	0.8750	0000 11100000000000000000000000	0E000000	0E000000	
57	1.0000	0001 000000000000000000000000	10000000	0.8906	0000 1110001111111110010111001001	0E3FE5C9	0E3FE5C9	
58	1.0000	0001 000000000000000000000000	10000000	0.9062	0000 11100111111111100101110010010	0E3FE5C9	0E3FE5C9	
59	1.0000	0001 000000000000000000000000	10000000	0.9219	0000 1110110000000001101000110110	0EC01A36	0EC01A36	

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183	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8594	1111	0010001111111110010111001010	F23FE5CA
184	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8750	1111	00100000000000000000000000000000	F2000000
185	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8906	1111	0001110000000001101000110111	F1C01A37
186	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9062	1111	00011000000000011010001101110	F180346E
187	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9219	1111	00010011111111110010111001010	F13FE5CA
188	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9375	1111	00010000000000000000000000000000	F1000000
189	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9531	1111	0000110000000001101000110111	F0C01A37
190	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9688	1111	00000111111111100101110010011	F07FCB93
191	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9844	1111	0000001111111110010111001010	F03FE5CA
192	-1.0000	1111	00000000000000000000000000000000	F0000000	-1.0000	1111	00000000000000000000000000000000	F0000000
193	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9844	1111	0000001111111110010111001010	F03FE5CA
194	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9688	1111	00000111111111100101110010011	F07FCB93
195	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9531	1111	0000110000000001101000110111	F0C01A37
196	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9375	1111	00010000000000000000000000000000	F1000000
197	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9219	1111	0001001111111110010111001010	F13FE5CA
198	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.9062	1111	00011000000000011010001101110	F180346E
199	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8906	1111	0001110000000001101000110111	F1C01A37
200	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8750	1111	00100000000000000000000000000000	F2000000
201	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8594	1111	0010001111111110010111001010	F23FE5CA
202	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8438	1111	00100101111111100101110010011	F27FCB93
203	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8281	1111	0010110000000001101000110111	F2C01A37
204	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.8125	1111	00110000000000000000000000000000	F3000000
205	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.7969	1111	0011001111111110010111001010	F33FE5CA
206	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.7812	1111	00111000000000011010001101110	F380346E
207	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.7656	1111	0011110000000001101000110111	F3C01A37
208	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.7500	1111	01000000000000000000000000000000	F4000000
209	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.7344	1111	0100001111111110010111001010	F43FE5CA
210	-1.0000	1111	00000000000000000000000000000000	F0000000	-0.7188	1111	01000111111111100101110010011	F4

245	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.1719	1111 1101001111111110010111001010	FD3FE5CA
246	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.1562	1111 1101100000000011010001101110	FD80346E
247	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.1406	1111 1101110000000001101000110111	FDC01A37
248	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.1250	1111 11100000000000000000000000000000	FE000000
249	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.1094	1111 1110001111111110010111001010	FE3FE5CA
250	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.0938	1111 11100111111111100101110010101	FE7FCB93
251	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.0781	1111 1110110000000001101000110111	FEC01A37
252	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.0625	1111 11110000000000000000000000000000	FF000000
253	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.0469	1111 1111001111111110010111001010	FF3FE5CA
254	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.0312	1111 1111100000000011010001101110	FF80346E
255	-1.0000	1111 00000000000000000000000000000000	F0000000	-0.0156	1111 1111110000000001101000110111	FFC01A37

LUT	Sine			Cosine		
	Dec	Bin	Hex	Dec	Bin	Hex
0	0.0000	0000 00000000000000000000000000000000	00000000	1.0000	0001 00000000000000000000000000000000	10000000
1	0.0245	0000 0000011001000101101000011100	00645A1C	0.9997	0000 111111111110110001010110110101	0FFEC56D
2	0.0491	0000 0000110010010001110100010100	00C91D14	0.9988	0000 111111111011000101011011010101	0FFB15B5
3	0.0736	0000 0001001011010111011100110001	012D7731	0.9973	0000 1111111101001111000011011000	0FF4F0D8
4	0.0980	0000 0001100100010110100001110010	01916872	0.9952	0000 111111101100010101101101010101	0FEC56D5
5	0.1224	0000 0001111101010101100110110011	01F559B3	0.9925	0000 111111100001010001110101110	0FE147AE
6	0.1467	0000 0010010110001110001000011001	0258E219	0.9892	0000 1111110100111100001101100001	0FD3C361
7	0.1710	0000 0010101111000110101001111110	02BC6A7E	0.9853	0000 111111000011110010011101110	0FC3C9EE
8	0.1951	0000 0011000111110010000100101101	031F212D	0.9808	0000 1111101100010101101101010111	0FB15B57
9	0.2191	0000 0011110000001011011110000000	03816F00	0.9757	0000 1111100111000111011110011010	0F9C779A
10	0.2430	0000 0011111000110101001111110111	03E353F7	0.9700	0000 1111100001010001111010111000	0F851EB8
11	0.2667	0000 0100010001000110011100111000	04446738	0.9638	0000 1111011010111011100110001100	0F6BB98C
12	0.2903	0000 0100101001010001000110011100	04A5119C	0.9569	0000 1111010011110111011001011101	0F4F765F
13	0.3137	0000 0101000001001110101001001010	0504EA4A	0.9495	0000 1111001100010010011011011101	0F3126E9
14	0.3369	0000 0101011000111111000101000001	0563F141	0.9415	0000 1111000100000110001001001101	0F10624D
15	0.3599	0000 0101110000100010011010000000	05C22680	0.9330	0000 1110111011011001000101101000	0EED9168
16	0.3827	0000 0110000111111000101000001001	061F8A09	0.9239	0000 1110110010000100101101011101	0EC84B5D
17	0.4052	0000 0110011110111011001011111110	067BB2FE	0.9142	0000 1110101000001001000000101101	0EA0902D
18	0.4276	0000 0110110101110111001100011000	06D77318	0.9040	0000 1110011101101100100010110100	0E76C8B4
19	0.4496	0000 0111001100011000111111000101	07318FC5	0.8932	0000 1110010010101000110000010101	0E4A8C15
20	0.4714	0000 011100010101101101010111001	078ADAB9	0.8819	0000 1110000111000100000110010100	0E1C432C
21	0.4929	0000 0111111000101110101100011100	07E2EB1C	0.8701	0000 1101111010111110110111111010	0DEBEDFA
22	0.5141	0000 1000001110011100000011101011	0839C0EB	0.8577	0000 1101101110010010001110100010	0DB923A2
23	0.5350	0000 1000100011110101110000101000	088F5C28	0.8449	0000 1101100001001011010111011100	0D84B5DC
24	0.5556	0000 1000111000111011110011010011	08E3BCD3	0.8315	0000 1101010011011101001011110001	0D4DD2F1
25	0.5758	0000 1001001101100111101000001111	09367A0F	0.8176	0000 1101000101001110001110111100	0D14E3BC
26	0.5957	0000 100110000111111110010111001	0987FCB9	0.8032	0000 1100110110011110100000111110	0CD9E83E
27	0.6152	0000 1001110101111010111110100	09D7DBF4	0.7883	0000 1100100111001110000001110101	0C9CE075
28	0.6344	0000 1010001001101000000010011101	0A26809D	0.7730	0000 1100010111100011010100111111	0C5E353F
29	0.6532	0000 1010011100111000000111010111	0A7381D7	0.7572	0000 1100000111010111110110111111	0C1D7DBF
30	0.6716	0000 10101011111010111110100100	0ABEDFA4	0.7410	0000 1011110110110010001011010000	0BDB22D0
31	0.6895	0000 1011000010000011000100100110	0B083126	0.7242	0000 1011100101100101001010111101	0B9652BD
32	0.7071	0000 1011010100000100100000010110	0B504816	0.7071	0000 1011010100000100100000010110	0B504816
33	0.7242	0000 1011100101100101001010111101	0B9652BD	0.6895	0000 1011000010000011000100100110	0B083126
34	0.7410	0000 1011110110110010001011010000	0BDB22D0	0.6716	0000 1010101111101101111110100100	0ABEDFA4
35	0.7572	0000 1100000011101011111011011111	0C1D7DBF	0.6532	0000 1010011100111000000111010111	0A7381D7
36	0.7730	0000 1100010111100011010100111111	0C5E353F	0.6344	0000 1010001001101000000010011101	0A26809D
37	0.7883	0000 1100100111001110000001110101	0C9CE075	0.6152	0000 1001110101111101101111110100	09D7DBF4
38	0.8032	0000 1100110110011110100000111110	0CD9E83E	0.5957	0000 1001100001111111110010111001	0987FCB9
39	0.8176	0000 1101000101001110001110111100	0D14E3BC	0.5758	0000 1001001101100111101000001111	09367A0F
40	0.8315	0000 1101010011011101001011110001	0D4DD2F1	0.5556	0000 1000111000111011110011010011	08E3BCD3
41	0.8449	0000 1101100001001011010111011100	0D84B5DC	0.5350	0000 1000100011110101110000101000	088F5C28
42	0.8577	0000 110101110010010001110100010	0DB923A2	0.5141	0000 1000001110011100000011101011	0839C0EB
43	0.8701	0000 110111101011111011011111010	0DEBEDFA	0.4929	0000 0111111000101110101100011100	07E2EB1C
44	0.8819	0000 1110000111000100001100101100	0E1C432C	0.4714	0000 0111100010101101101010111001	078ADAB9
45	0.8932	0000 1110010010101000110000010101	0E4A8C15	0.4496	0000 0111001100011000111111000101	07318FC5

46	0.9040	0000 1110011101101100100010110100	0E76C8B4	0.4276	0000 0110110101110111001100011000	06D77318
47	0.9142	0000 1110101000001001000000101101	0EA0902D	0.4052	0000 0110011110111011001011111110	067BB2FE
48	0.9239	0000 11101100100001001011011101	0EC84B5D	0.3827	0000 0110000111111000101000001001	061F8A09
49	0.9330	0000 1110111011011001000101101000	0EED9168	0.3599	0000 0101110000100010011010000000	05C22680
50	0.9415	0000 1111000100000110001001001101	0F10624D	0.3369	0000 0101011000111111000101000001	0563F141
51	0.9495	0000 1111001100010010011011101001	0F3126E9	0.3137	0000 0101000001001110101001001010	0504EA4A
52	0.9569	0000 1111010011110111011001011111	0F4F765F	0.2903	0000 0100101001010001000110011100	04A5119C
53	0.9638	0000 1111011010111011100110001100	0F6BB98C	0.2667	0000 0100010001000110011100111000	04446738
54	0.9700	0000 1111100001010001111010111000	0F851EB8	0.2430	0000 0011111000110101001111110111	03E353F7
55	0.9757	0000 1111100111000111011110011010	0F9C779A	0.2191	0000 0011100000010110111100000000	03816F00
56	0.9808	0000 1111101100010101101101010111	0FB15B57	0.1951	0000 0011000111110010000100101101	031F212D
57	0.9853	0000 1111110000111100100111101110	0FC3C9EE	0.1710	0000 0010101111100010101001111110	02BC6A7E
58	0.9892	0000 1111110100111100001101100001	0FD3C361	0.1467	0000 0010010110001110001000011001	0258E219
59	0.9925	0000 1111111000010100011110101110	0FE147AE	0.1224	0000 0001111101010101100110110011	01F559B3
60	0.9952	0000 1111111011000101011011010101	0FEC56D5	0.0980	0000 0001100100010110100001110010	01916872
61	0.9973	0000 1111111101001111000011011000	0FF4F0D8	0.0736	0000 0001001011010111011100110001	012D7731
62	0.9988	0000 1111111110110001010110110101	0FFB15B5	0.0491	0000 0000110010010001110100010100	00C91D14
63	0.9997	0000 1111111111101100010101101101	0FFEC56D	0.0245	0000 0000011001000101101000011100	00645A1C
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84	0.8819	0000 1110000111000100001100101100	0E1C432C	-0.4714	1111 1000011101010010010101000111	F8752547
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91	0.7883	0000 1100100111001110000001110101	0C9CE075	-0.6152	1111 0110001010000010010000001100	F628240C
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93	0.7572	0000 1100000111010111110110111111	0C1D7DBF	-0.6532	1111 01011000110001111111000101001	F58C7E29
94	0.7410	0000 1011110110110010001011010000	0BDB22D0	-0.6716	1111 0101010000010010000001011100	F541205C
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99	0.6532	0000 1010011100111000000111010111	0A7381D7	-0.7572	1111 00111111000101000001001000001	F3E28241
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125	0.0736	0000 0001001011010111011100110001	012D7731	-0.9973	11110000000010110000111100101000	F00B0F28
126	0.0491	0000 0000110010010001110100010100	00C91D14	-0.9988	1111 0000000001001110101001001011	F004EA4B
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136	-0.1951	1111 1100111000001101111011010011	FCE0DED3	-0.9808	1111 0000010011101010010010101001	F04EA4A9
137	-0.2191	1111 1100011111101001000111111111	FC7E91FF	-0.9757	1111 0000011000111000100001100110	F0638866
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147	-0.4496	1111 1000110011100111000000111011	F8CE703B	-0.8932	1111 0001101101010111001111101011	F1B573EB
148	-0.4714	1111 1000011101010010010101000111	F8752547	-0.8819	1111 0001111000111011110011010100	F1E3BCD4
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151	-0.5350	1111 0111011100001010001111011000	F770A3D8	-0.8449	1111 0010011110110100101000100100	F27B4A24
152	-0.5556	1111 0111000111000100001100101101	F71C432D	-0.8315	1111 0010101100100010110100001111	F2B22D0F
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193	-0.9997	1111 0000000000010011101010010011	F0013A93	0.0245	0000 0000011001000101101000011100	00645A1C
194	-0.9988	1111 0000000001001110101001001011	F004EA4B	0.0491	0000 0000110010010001110100010100	00C91D14
195	-0.9973	11110000000010110000111100101000	F00B0F28	0.0736	0000 0001001011010111011100110001	012D7731
196	-0.9952	1111 0000000100111010100100101011	F013A92B	0.0980	0000 0001100100010110100001110010	01916872
197	-0.9925	1111 0000000111101011100001010010	F01EB852	0.1224	0000 0001111101010101100110110011	01F559B3
198	-0.9892	1111 0000001011000011110010011111	F02C3C9F	0.1467	0000 0010010110001110001000011001	0258E219
199	-0.9853	1111 0000001111000011011000010010	F03C3612	0.1710	0000 0010101111000110101001111110	02BC6A7E
200	-0.9808	1111 0000001110101001001010101001	F04EA4A9	0.1951	0000 0011000111110010000100101101	031F212D
201	-0.9757	1111 0000011000111000100001100110	F0638866	0.2191	0000 0011100000010110111100000000	03816F00
202	-0.9700	1111 0000011110101110000101001000	F07AE148	0.2430	0000 0011111000110101001111110111	03E353F7
203	-0.9638	1111 0000100101000100011001110100	F0944674	0.2667	0000 0100010001000110011100111000	04446738
204	-0.9569	1111 0000101100001000100110100001	F0B089A1	0.2903	0000 0100101001010001000110011100	04A5119C
205	-0.9495	1111 0000110011101101100100010111	F0CED917	0.3137	0000 0101000001001110101001001010	0504EA4A
206	-0.9415	1111 000011101111001110110110011	F0EF9DB3	0.3369	0000 0101011000111111000101000001	0563F141
207	-0.9330	1111 0001000100100110110100110001	F1126E98	0.3599	0000 0101110000100010010100000000	05C22680
208	-0.9239	1111 0001001101111011010010100011	F137B4A3	0.3827	0000 0110000111111000101000001001	061F8A09
209	-0.9142	1111 000101011111011011111010011	F15F6FD3	0.4052	0000 0110011110111011001011111110	067BB2FE
210	-0.9040	1111 0001100010010011011101001100	F189374C	0.4276	0000 0110110101110111001100011000	06D77318
211	-0.8932	1111 0001101101010111001111101011	F1B573EB	0.4496	0000 0111001100011000111111000101	07318FC5
212	-0.8819	1111 0001111000111011110011010100	F1E3BCD4	0.4714	0000 0111100010101101101010111001	078ADAB9
213	-0.8701	1111 0010000101000001001000000110	F2141206	0.4929	0000 0111111000101110101100011100	07E2EB1C
214	-0.8577	1111 0010010001101101110001011110	F246DC5E	0.5141	0000 1000001110011100000011101011	0839C0EB
215	-0.8449	1111 0010011110110100101000100100	F27B4A24	0.5350	0000 1000100011110101110000101000	088F5C28
216	-0.8315	1111 0010101100100010110100001111	F2B22D0F	0.5556	0000 1000111000111011110011010011	08E3BCD3
217	-0.8176	1111 0010111010110001110001000100	F2EB1C44	0.5758	0000 1001001101100111101000001111	09367A0F
218	-0.8032	1111 0011001001100001011111000010	F32617C2	0.5957	0000 1001100001111111110010111001	0987FCB9
219	-0.7883	1111 0011011000110001111110001011	F3631F8B	0.6152	0000 1001110101111101101111110100	09D7DBF4
220	-0.7730	1111 0011101000011100101011000001	F3A1CAC1	0.6344	0000 1010001001101000000010011101	0A26809D
221	-0.7572	1111 0011111000101000001001000001	F3E28241	0.6532	0000 1010011100111000000111010111	0A7381D7
222	-0.7410	1111 0100001001001101110100110000	F424DD30	0.6716	0000 1010101111101011111101001000	0ABEDFA4
223	-0.7242	1111 0100011010011010110101000011	F469AD43	0.6895	0000 1011000010000011000100100110	0B083126
224	-0.7071	1111 0100101011111011011111101010	F4AFB7EA	0.7071	0000 1011010100000100100000010110	0B504816
225	-0.6895	1111 0100111101111100111011011010	F4F7CEDA	0.7242	0000 1011100101100101001010111101	0B9652BD
226	-0.6716	1111 0101010000010010000001011100	F541205C	0.7410	0000 1011110110110010001011010000	0BDB22D0
227	-0.6532	1111 01011000110001111111000101001	F58C7E29	0.7572	0000 1100000111010111110110111111	0C1D7DBF
228	-0.6344	1111 0101110110010111111101100011	F5D97F63	0.7730	0000 1100010111100011010100111111	0C5E353F



229	-0.6152	1111 0110001010000010010000001100	F628240C	0.7883	0000 1100100111001110000001110101	0C9CE075
230	-0.5957	1111 011001111000000001101000111	F6780347	0.8032	0000 1100110110011110100000111110	0CD9E83E
231	-0.5758	1111 0110110010011000010111110001	F6C985F1	0.8176	0000 1101000101001110001110111100	0D14E3BC
232	-0.5556	1111 0111000111000100001100101101	F71C432D	0.8315	0000 11010100110111101001011110001	0D4DD2F1
233	-0.5350	1111 0111011100001010001111011000	F770A3D8	0.8449	0000 1101100001001011010111011100	0D84B5DC
234	-0.5141	1111 0111110001100011111100010101	F7C63F15	0.8577	0000 1101101110010010001110100010	0DB923A2
235	-0.4929	1111 1000000111010001010011100100	F81D14E4	0.8701	0000 1101111010111110110111111010	0DEBEDFA
236	-0.4714	1111 1000011101010010010101000111	F8752547	0.8819	0000 1110000111000100001100101100	0E1C432C
237	-0.4496	1111 1000110011100111000000111011	F8CE703B	0.8932	0000 1110010010101000110000010101	0E4A8C15
238	-0.4276	1111 1001001010001000110011101000	F9288CE8	0.9040	0000 1110011101101100100010110100	0E76C8B4
239	-0.4052	1111 1001100001000100110100000010	F9844D02	0.9142	0000 1110101000001001000000101101	0EA0902D
240	-0.3827	1111 1001111000000111010111110111	F9E075F7	0.9239	0000 1110110010000100101101011101	0EC84B5D
241	-0.3599	1111 1010001111011101100110000000	FA3DD980	0.9330	0000 1110111011011001000101101000	0EED9168
242	-0.3369	1111 1010100111000000111010111111	FA9C0EBF	0.9415	0000 1111000100000110001001001101	0F10624D
243	-0.3137	1111 1010111110110001010110110110	FAFB15B6	0.9495	0000 1111001100010010011011101001	0F3126E9
244	-0.2903	1111 1011010110101110111001100100	FB5AEE64	0.9569	0000 1111010011110111011001011111	0F4F765F
245	-0.2667	1111 1011101110111001100011001000	FBBB98C8	0.9638	0000 1111011010111011100110001100	0F6BB98C
246	-0.2430	1111 1100000111001010110000001001	FC1CAC09	0.9700	0000 1111100001010001111010111000	0F851EB8
247	-0.2191	1111 1100011111101001000111111111	FC7E91FF	0.9757	0000 1111100111000111011110011010	0F9C779A
248	-0.1951	1111 1100111000001101111011010011	FCE0DED3	0.9808	0000 1111101100010101101101010111	0FB15B57
249	-0.1710	11111101010000111001010110000010	FD439582	0.9853	0000 1111110000111100100111101110	0FC3C9EE
250	-0.1467	1111 1101101001110001110111100111	FDA71DE7	0.9892	0000 1111110100111100001101100001	0FD3C361
251	-0.1224	1111 1110000010101010011001001101	FE0AA64D	0.9925	0000 1111111000010100011110101110	0FE147AE
252	-0.0980	1111 1110011011101001011110001110	FE6E978E	0.9952	0000 1111111011000101011011010101	0FEC56D5
253	-0.0736	1111 1110110100101000100011001111	FED288CF	0.9973	0000 1111111101001111000011011000	0FF4F0D8
254	-0.0491	1111 1111001101101110001011101100	FF36E2EC	0.9988	0000 1111111110110001010110110101	0FFB15B5
255	-0.0245	1111 1111100110111010010111100100	FF9BA5E4	0.9997	0000 1111111111101100010101101101	0FFE56D

## module code