

Function generator

Date: Jun 2024



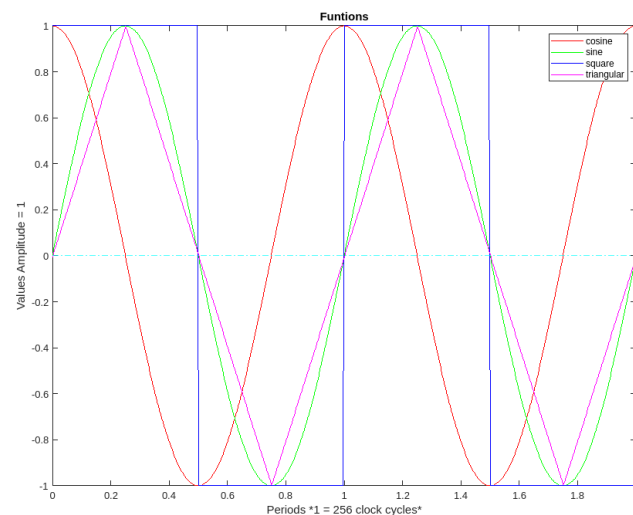
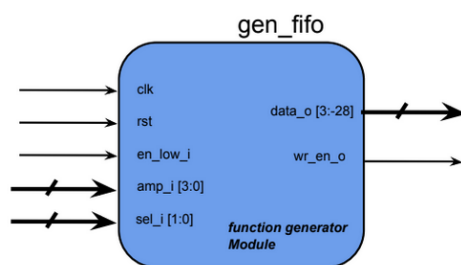
RTL

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 range from 1 to 4.
- 2) 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.
- 3) When the reset is activated all the initial signals in position 0 which for each signal is as follows:
 - Sine = 0
 - Cosine = Amplitude
 - Square = Amplitude
 - Triangular = 0
- 4) 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.



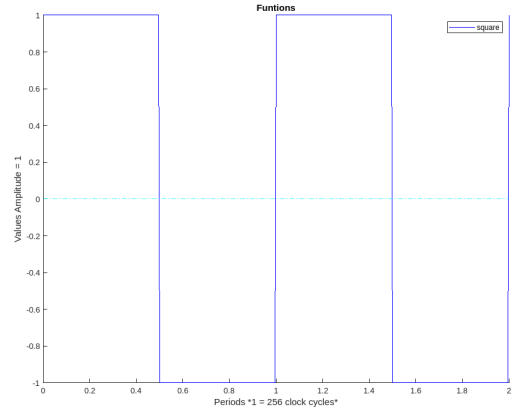
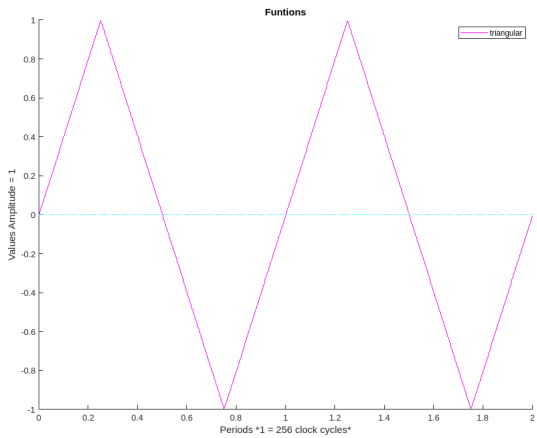
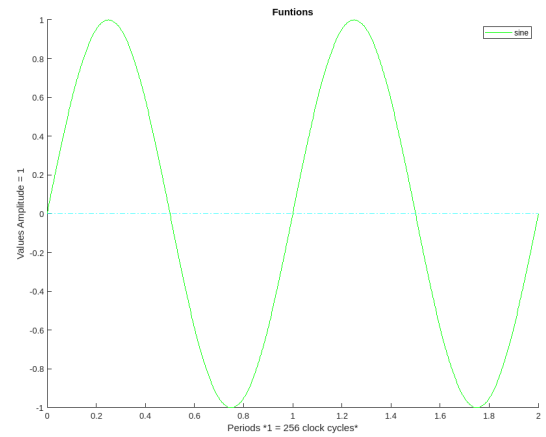
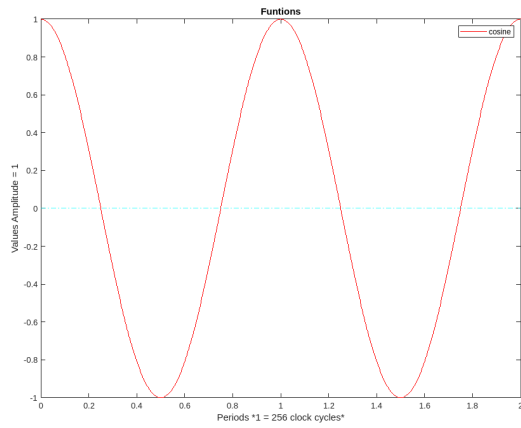


Table 1: Inputs/Outputs description

| Input | Size | Description | Source |
|----------|------|---|--------------|
| 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 all signals retain their value until the enable is re-asserted. | full / FIFO |
| amp_i | 4 | Amplitude of the function. It can take the integer | Main input |

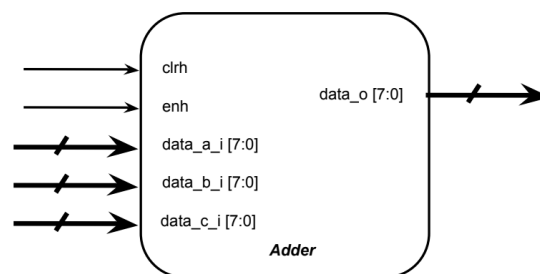
| | | values 1, 2, 3 and 4. It determines the amplitude of the output signal. | |
|---------|------|--|------------|
| sel_i | 2 | Function selector Allows to select which waveform is the one we want to obtain in the output of the module. The function of each value of this signal is described in a table 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 |

Internal sub-modules:

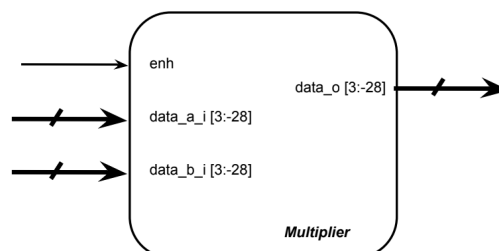
- Adder module
- Multiplication module
- Register module
- LUT
- FSM module
- Mux module

Sub-modules

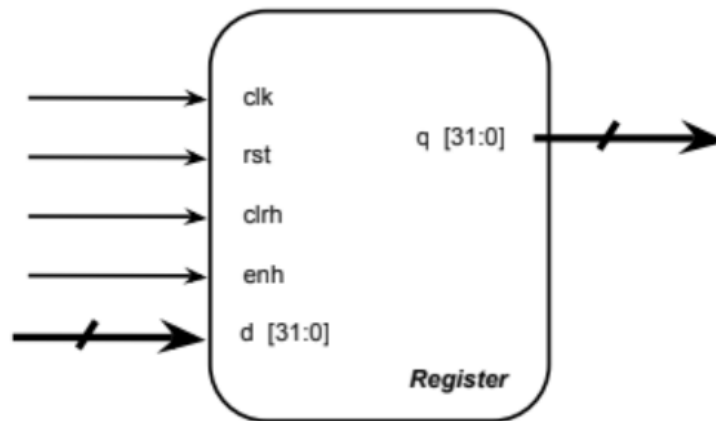
1. Adder: 3-input adder with enable and clear. The addition is performed combinatorially when the enable is active. The output is zero when the clear is activated. The clear signal has priority.



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

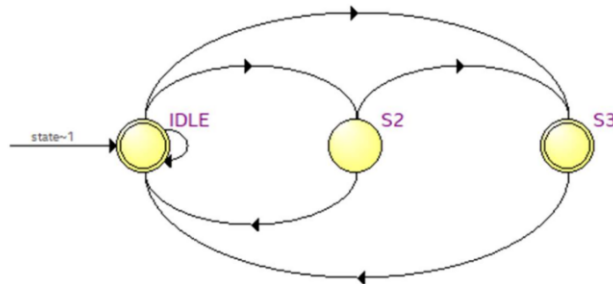


- Register: Type D flip flop register activated on positive clock edge with enable active high and clear active high

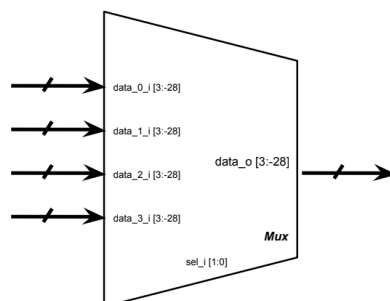


- FSM: The state machine will control the enable of the internal modules, when to clear the information from the registers and the sequential operation of the whole RTL.

(Diagrama temporal- falta descripcion de los estados)

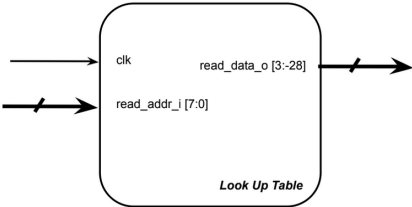


- Mux: 4-input 1-output multiplexer with a 2-bit selector switch. The output signal corresponds to the selector value (0 to 3). Inputs and outputs are signed.



| 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.



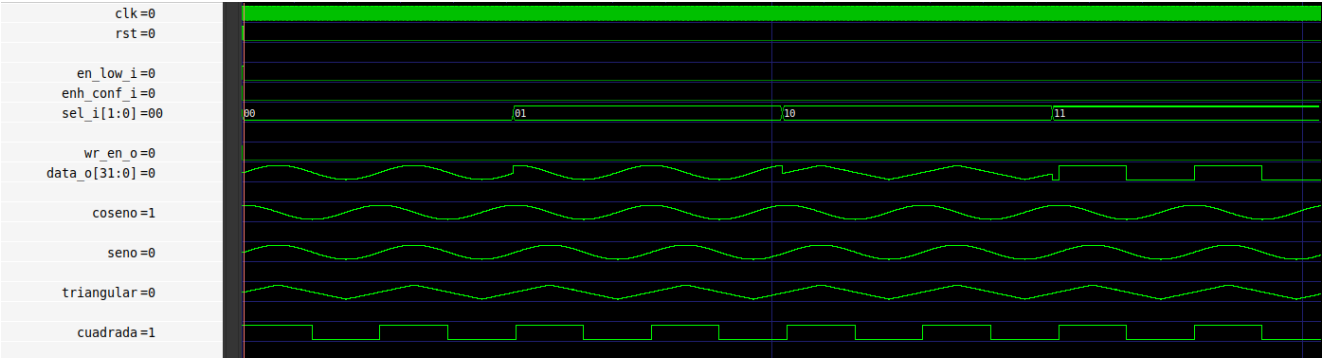
Verification

Formal

| N# | Name | Description | Code |
|-------------|------|-------------|------|
| Assumptions | | | |
| 1 | | | |
| Covers | | | |
| 1 | | | |
| 2 | | | |
| 1 | | | |

Table 2: Properties description

Results



Anexos:

LUT data

| LUT | Square | | | | Triangular | | | |
|-----|--------|------|--------------------------|----------|------------|------|-------------------------------|----------|
| | Dec | | Bin | Hex | Dec | | Bin | Hex |
| 0 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.0000 | 0000 | 000000000000000000000000 | 00000000 |
| 1 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.0156 | 0000 | 0000001111111110010111001001 | 003FE5C9 |
| 2 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.0312 | 0000 | 00000111111111100101110010010 | 007FCB92 |
| 3 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.0469 | 0000 | 0000110000000001101000110110 | 00C01A36 |
| 4 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.0625 | 0000 | 00010000000000000000000000 | 01000000 |
| 5 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.0781 | 0000 | 0001001111111110010111001001 | 013FE5C9 |
| 6 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.0938 | 0000 | 0001100000000011010001101101 | 0180346D |
| 7 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.1094 | 0000 | 0001110000000001101000110110 | 01C01A36 |
| 8 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.1250 | 0000 | 00100000000000000000000000 | 02000000 |
| 9 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.1406 | 0000 | 0010001111111110010111001001 | 023FE5C9 |
| 10 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.1562 | 0000 | 00100111111111100101110010010 | 027FCB92 |
| 11 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.1719 | 0000 | 0010110000000001101000110110 | 02C01A36 |
| 12 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.1875 | 0000 | 00110000000000000000000000 | 03000000 |
| 13 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.2031 | 0000 | 0011001111111110010111001001 | 033FE5C9 |
| 14 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.2188 | 0000 | 0011100000000011010001101101 | 0380346D |
| 15 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.2344 | 0000 | 0011110000000001101000110110 | 03C01A36 |
| 16 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.2500 | 0000 | 01000000000000000000000000 | 04000000 |
| 17 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.2656 | 0000 | 0100001111111110010111001001 | 043FE5C9 |
| 18 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.2812 | 0000 | 01000111111111100101110010010 | 047FCB92 |
| 19 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.2969 | 0000 | 0100110000000001101000110110 | 04C01A36 |
| 20 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.3125 | 0000 | 01010000000000000000000000 | 05000000 |
| 21 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.3281 | 0000 | 0101001111111110010111001001 | 053FE5C9 |
| 22 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.3438 | 0000 | 01011000000000011010001101101 | 0580346D |
| 23 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.3594 | 0000 | 0101110000000001101000110110 | 05C01A36 |
| 24 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.3750 | 0000 | 01100000000000000000000000 | 06000000 |
| 25 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.3906 | 0000 | 0110001111111110010111001001 | 063FE5C9 |
| 26 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.4062 | 0000 | 01100111111111100101110010010 | 067FCB92 |
| 27 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.4219 | 0000 | 0110110000000001101000110110 | 06C01A36 |
| 28 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.4375 | 0000 | 01110000000000000000000000 | 07000000 |
| 29 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.4531 | 0000 | 0111001111111110010111001001 | 073FE5C9 |
| 30 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.4688 | 0000 | 0111100000000011010001101101 | 0780346D |
| 31 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.4844 | 0000 | 0111110000000001101000110110 | 07C01A36 |
| 32 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.5000 | 0000 | 10000000000000000000000000 | 08000000 |
| 33 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.5156 | 0000 | 1000011111111110010111001001 | 083FE5C9 |
| 34 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.5312 | 0000 | 10000111111111100101110010010 | 087FCB92 |
| 35 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.5469 | 0000 | 1000110000000001101000110110 | 08C01A36 |
| 36 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.5625 | 0000 | 10010000000000000000000000 | 09000000 |
| 37 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.5781 | 0000 | 1001001111111110010111001001 | 093FE5C9 |
| 38 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.5938 | 0000 | 10011000000000011010001101101 | 0980346D |
| 39 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.6094 | 0000 | 1001110000000001101000110110 | 09C01A36 |
| 40 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.6250 | 0000 | 10100000000000000000000000 | 0A000000 |
| 41 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.6406 | 0000 | 1010001111111110010111001001 | 0A3FE5C9 |
| 42 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.6562 | 0000 | 10100111111111100101110010010 | 0A7FCB92 |
| 43 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.6719 | 0000 | 1010110000000001101000110110 | 0AC01A36 |
| 44 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.6875 | 0000 | 10110000000000000000000000 | 0B000000 |
| 45 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.7031 | 0000 | 1011001111111110010111001001 | 0B3FE5C9 |
| 46 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.7188 | 0000 | 1011100000000011010001101101 | 0B80346D |
| 47 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.7344 | 0000 | 1011110000000001101000110110 | 0BC01A36 |
| 48 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.7500 | 0000 | 11000000000000000000000000 | 0C000000 |
| 49 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.7656 | 0000 | 1100001111111110010111001001 | 0C3FE5C9 |
| 50 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.7812 | 0000 | 11000111111111100101110010010 | 0C7FCB92 |
| 51 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.7969 | 0000 | 1100110000000001101000110110 | 0CC01A36 |
| 52 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.8125 | 0000 | 11010000000000000000000000 | 0D000000 |
| 53 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.8281 | 0000 | 1101001111111110010111001001 | 0D3FE5C9 |
| 54 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.8438 | 0000 | 1101100000000011010001101101 | 0D80346D |
| 55 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.8594 | 0000 | 1101110000000001101000110110 | 0DC01A36 |
| 56 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.8750 | 0000 | 11100000000000000000000000 | 0E000000 |
| 57 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.8906 | 0000 | 1110001111111110010111001001 | 0E3FE5C9 |
| 58 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.9062 | 0000 | 11100111111111100101110010010 | 0E3FE5C9 |
| 59 | 1.0000 | 0001 | 000000000000000000000000 | 10000000 | 0.9219 | 0000 | 1110110000000001101000110110 | 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 | 00100111111111100101110010011 | 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 00011111010101100110110011 | 01F559B3 | 0.9925 | 0000 111111100001010001110101110 | 0FE147AE |
| 6 | 0.1467 | 0000 00100101110001110001000011001 | 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 1111010011110111011001011111 | 0F4F765F |
| 13 | 0.3137 | 0000 0101000001001110101001001010 | 0504EA4A | 0.9495 | 0000 11110011000100100110110110101 | 0FD3126E9 |
| 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 1110000111000100001100101100 | 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 10011101011110110111110100 | 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 101010111110101111110100100 | 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 |
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| 202 | -0.9700 | 1111 000001110101110000101001000 | F07AE148 | 0.2191 | 0000 0011100000010110111100000000 | 03816F00 |
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| 204 | -0.9569 | 1111 0000101100001000100110100001 | F0B089A1 | 0.2667 | 0000 0100010001000110011100111000 | 04446738 |
| 205 | -0.9495 | 1111 0000110011101101100100010111 | F0CED917 | 0.2903 | 0000 0100101001010001000110011100 | 04A5119C |
| 206 | -0.9415 | 1111 000011101111001110110110011 | F0EF9DB3 | 0.3137 | 0000 0101000001001110101001001010 | 0504EA4A |
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| 208 | -0.9239 | 1111 0001001101111011010010100011 | F137B4A3 | 0.3599 | 0000 0101110000100010010100000000 | 05C22680 |
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| 210 | -0.9040 | 1111 0001100010010011011101001100 | F189374C | 0.4052 | 0000 0110011110111011001011111110 | 067BB2FE |
| 211 | -0.8932 | 1111 0001101101010111001111101011 | F1B573EB | 0.4276 | 0000 0110110101110111001100011000 | 06D77318 |
| 212 | -0.8819 | 1111 0001111000111011110011010100 | F1E3BCD4 | 0.4496 | 0000 0111001100011000111111000101 | 07318FC5 |
| 213 | -0.8701 | 1111 0010000101000001001000000110 | F2141206 | 0.4714 | 0000 0111100010101101101010111001 | 078ADAB9 |
| 214 | -0.8577 | 1111 0010010001101101110001011110 | F246DC5E | 0.4929 | 0000 0111111000101110101110001100 | 07E2EB1C |
| 215 | -0.8449 | 1111 0010011110110100101000100100 | F27B4A24 | 0.5141 | 0000 1000001110011100000011101011 | 0839C0EB |
| 216 | -0.8315 | 1111 0010101100100010110100001111 | F2B22D0F | 0.5350 | 0000 1000100011110101110000101000 | 088F5C28 |
| 217 | -0.8176 | 1111 0010111010110001110001000100 | F2EB1C44 | 0.5556 | 0000 1000111000111011110011010011 | 08E3BCD3 |
| 218 | -0.8032 | 1111 0011001001100001011111000010 | F32617C2 | 0.5758 | 0000 1001001101100111101000001111 | 09367A0F |
| 219 | -0.7883 | 1111 0011011000110001111110001011 | F3631F8B | 0.5957 | 0000 1001100001111111110010111001 | 0987FCB9 |
| 220 | -0.7730 | 1111 0011101000011100101011000001 | F3A1CAC1 | 0.6152 | 0000 1001110101111101101111110100 | 09D7DBF4 |
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| 223 | -0.7242 | 1111 0100011010011010110101000011 | F469AD43 | 0.6716 | 0000 1010101111101011111101001000 | 0ABEDFA4 |
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| 229 | -0.6152 | 1111 0110001010000010010000001100 | F628240C | 0.7883 | 0000 1100100111001110000001110101 | 0C9CE075 |
| 230 | -0.5957 | 1111 0110011110000000001101000111 | F6780347 | 0.8032 | 0000 1100110110011110100000111110 | 0CD9E83E |
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module code