An Inexpensive, Software-Defined IF Modulator

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- enum Age { OLD, NEW }
- enum Fractional { NUM, DEN }
- enum Argument { FREQ = 1, MODE, PL_TONE }
- enum ModulationType {
  ModulationType::DSB_LC, ModulationType::DSB_SC, ModulationType::USB_FILTERED, ModulationType↩
  ::USB_HILBERT,
  ModulationType::LSB_FILTERED, ModulationType::LSB_HILBERT, ModulationType::FM_NARROW,
  ModulationType::FM_WIDE }

Functions

- void ShowHelp ()
- void to_sint32 (float32 *data, uint32 size)
- ModulationType to_type (std::string str)
- void aconj (cfloat32 *data, uint32 size)
- void fft (cfloat32 *data, uint32 size)
- void hilbert (float32 *data, float32 *dest, uint32 size)
- void ifft (cfloat32 *data, uint32 size)
- void makeIQ (float32 *data, float32 *dest, uint32 size)

Variables

- fparams F_BASEBAND
- fparams F_LOWERSIDEBAND
- fparams F_UPPERSIDEBAND
- const uint32 FREQ_INTERMEDIATE = 20000
- const uint32 SAMPLING_RATE = 48000

6.1.1 Detailed Description

This namespace contains all the classes, functions, and enumerations used in the application.

6.1.2 Enumeration Type Documentation

6.1.2.1 enum radio::Age

Describes the age of a filter (from last Pass() or in this Pass()). Not currently used.

Enumerator

OLD
NEW

Definition at line 60 of file definitions.hpp.

6.1.2.2 enum radio::Argument

Describes the arguments in argv. Never actually used.

Enumerator

FREQ
MODE
PL_TONE

Definition at line 70 of file definitions.hpp.

6.1.2.3 enum radio::Fractional

Describes the numerator and denominator of a z-domain transfer function

Enumerator

NUM
DEN

Definition at line 65 of file definitions.hpp.

6.1.2.4 enum radio::ModulationType [strong]

Describes a form of modulation.

Enumerator

DSB_LC
DSB_SC
USB_FILTERED
USB_HILBERT
LSB_FILTERED
LSB_HILBERT
FM_NARROW
FM_WIDE

Definition at line 75 of file definitions.hpp.

6.1.3 Function Documentation

6.1.3.1 void radio::aconj (cfloat32 * *data*, uint32 *size*)

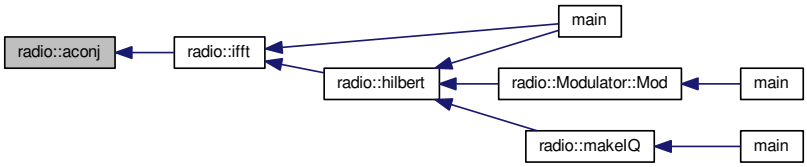
Replaces the values in an array of complex float32's with their respective conjugates.

Parameters

data	the array whose values should be replaced with their respective conjugates
size	the number of elements in the data array

Definition at line 84 of file zdomain.hpp.

Here is the caller graph for this function:



6.1.3.2 void radio::fft (cfloat32 * *data*, uint32 *size*)

Replaces the values of an array of cfloat32's with the array's DFT using a decimation-in-frequency algorithm.

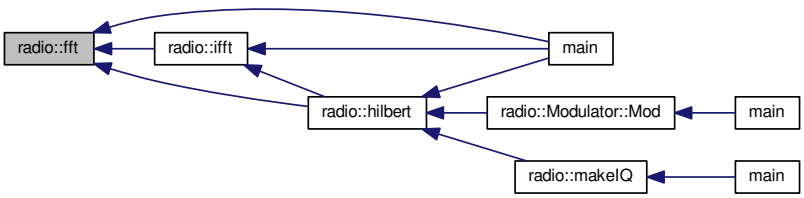
This code is based on code from http://rosettacode.org/wiki/Fast_Fourier_transform#C.↩2B.2B.

Parameters

data	the array whose values should be replaced with its DFT
size	the number of elements in the data array

Definition at line 90 of file zdomain.hpp.

Here is the caller graph for this function:



6.1.3.3 void radio::hilbert (float32 * *data*, float32 * *dest*, uint32 *size*)

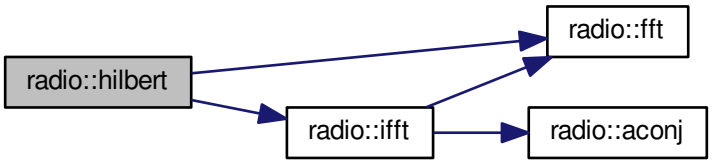
Performs the hilbert transfor of an array of float32's.

Parameters

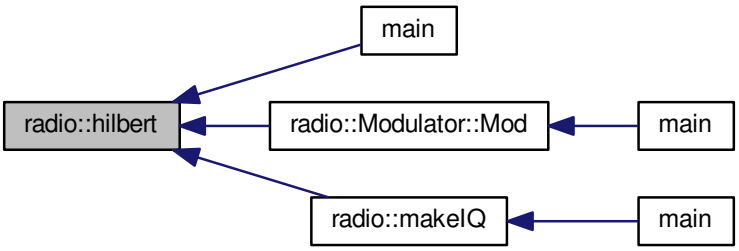
data	the source array of the REAL numbers of which to take the Hilbert transform
dest	the destination array of REAL numbers for the results of the Hilbert transform
size	the number of elements in the data and dest arrays

Definition at line 138 of file zdomain.hpp.

Here is the call graph for this function:



Here is the caller graph for this function:



6.1.3.4 void radio::ifft (cfloat32 * *data*, uint32 *size*)

Replaces the values of an array of cfloat32's with the array's inverse DFT.

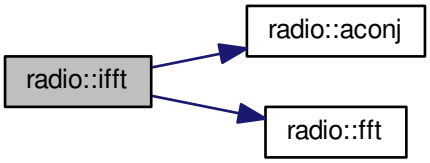
This code is based on code from http://rosettacode.org/wiki/Fast_Fourier_transform#C.↩2B.2B.

Parameters

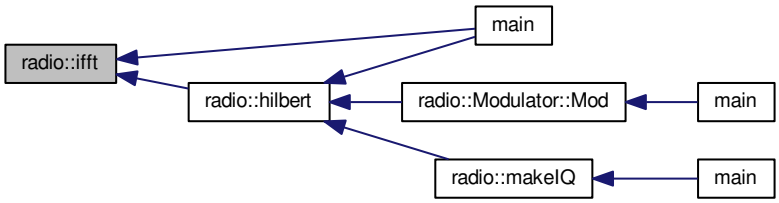
data	the array whose values should be replaced with its inverse DFT
size	the number of elements in the data array

Definition at line 161 of file zdomain.hpp.

Here is the call graph for this function:



Here is the caller graph for this function:



6.1.3.5 void radio::makeIQ (float32 * *data*, float32 * *dest*, uint32 *size*)

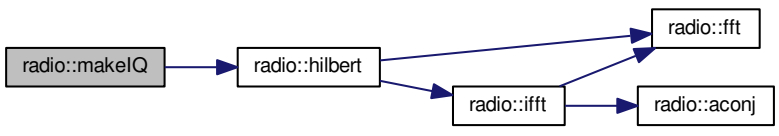
Produces an interleaved array with an element from an original array of data first and then an element from the original data's Hilbert transform second. This function is intended to generate a two-channel output (I/Q output) for mixing applications.

Parameters

data	the original data (left channel)
dest	the interleaved data (left channel original data, right channel transformed data) twice the size of the original data array
size	the number of elements in the data array (NOT in the destination array)

Definition at line 171 of file zdomain.hpp.

Here is the call graph for this function:



Here is the caller graph for this function:

6.1.3.6 void radio::ShowHelp ( )

Displays the help information and exits the program.

Definition at line 22 of file auxiliary.hpp.

Here is the caller graph for this function:

6.1.3.7 void radio::to_sint32 (float32 * *data*, uint32 *size*)

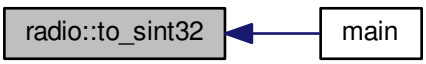
Replaces float32 samples with sint32 equivalents. Rounds conversion to nearest integer.

Parameters

data	the array containing the float32 samples that are directly replaced by their respective sint32 representations
size	the number of elements in the data array

Definition at line 62 of file auxiliary.hpp.

Here is the caller graph for this function:



6.1.3.8 ModulationType radio::to_type (std::string *str*)

Converts a string representation of the supported modulation types (see ShowHelp() documentation) to the enum class ModulationType value.

This function is not as elegant as it could be. Ideally, I would have used a std::map<string, ModulationType> rather than a long series of if-else's.

Parameters

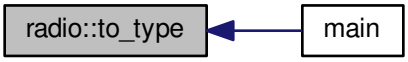
str	type of modulation in typed form

Returns

enum value of the type of modulation

Definition at line 80 of file auxiliary.hpp.

Here is the caller graph for this function:



6.1.4 Variable Documentation

6.1.4.1 fparams radio::F_BASEBAND

Initial value:

```
= { std::vector<float64> {
        0.0008977019461,
            -0.002215694636,
            0.001372192986,
            0.001372192986,
            -0.002215694636,
            0.0008977019461
    }, std::vector<float64> {
        1,
            -4.678616047,
            8.822912216,
            -8.379911423,
            4.007629871,
            -0.7719064355
    } }
```

Baseband filter coefficients. Generated with MATLAB 2015A.

Definition at line 20 of file fvectors.hpp.

6.1.4.2 fparams radio::F_LOWERSIDEBAND

Initial value:

```
= { std::vector<float64> {
        0.2758039069174,
            2.763578787693,
            12.83915022756,
```

```
            36.47584850651,
            70.37084637368,
            96.76893503179,
            96.76893503179,
            70.37084637368,
            36.47584850651,
            12.83915022756,
            2.763578787693,
            0.2758039069174
    }, std::vector<float64> {
        1,
            7.605497780083,
            27.34180552438,
            60.83375457605,
            92.60908886875,
            100.8363857,
            79.74796574736,
            45.4982252145,
            18.13566776308,
            4.690036472717,
            0.6617552879305,
            0.0281427334611
    } }
```

Lower-sideband filter coefficients. Generated with MATLAB 2015A.

Definition at line 39 of file fvectors.hpp.

6.1.4.3 fparams radio::F_UPPERSIDEBAND

Initial value:

```
= { std::vector<float64> {
        0.001690387681463,
            0.01145271586989,
            0.03591799189724,
            0.06576926098562,
            0.07119343282702,
            0.03156377419766,
            -0.03156377419766,
            -0.07119343282702,
            -0.06576926098562,
            -0.03591799189724,
            -0.01145271586989,
            -0.001690387681463
    }, std::vector<float64> {
        1,
            9.465175013624,
            41.62402815905,
            112.0971027069,
            205.2097686473,
            267.9378582311,
            254.486805213,
            175.7772755115,
            86.51619894548,
            28.89988093561,
            5.89781461091,
            0.5572910543053
    } }
```

Upper-sideband filter coefficients. Generated with MATLAB 2015A.

Definition at line 70 of file fvectors.hpp.

6.1.4.4 const uint32 radio::FREQ_INTERMEDIATE = 20000

The default intermediate carrier frequency

Definition at line 27 of file Modulator.hpp.

6.1.4.5 const uint32 radio::SAMPLING_RATE = 48000

The default sampling rate (frequency)

Definition at line 32 of file Modulator.hpp.

Chapter 7

Class Documentation

7.1 radio::Filter Class Reference

`#include <Filter.hpp>`

Public Member Functions

- Filter (float32 *data, uint32 size, fparams &diffEq)
- void Pass ()

Protected Attributes

- uint8 eqLength
- uint32 size
- float32 * data
- fparams diffEq

7.1.1 Detailed Description

This class implements a z-domain filter on a specified array of float32's (a.k.a. singles, floats). It requires the transfer function coefficients be already calculated (i.e., it does not generate the coefficients based on desired filter characteristics). MATLAB and its Signal Processing Toolbox can be used to generate the coefficients.

While this class is designed to implement a single-section filter, several instances of the class can be created and run over the data array in sequence to effectively implement a multi-section filter.

Definition at line 28 of file Filter.hpp.

7.1.2 Constructor & Destructor Documentation

7.1.2.1 radio::Filter::Filter (**float32** * *data,* **uint32** *size,* **fparams** & *diffEq*)

Initializes Filter based on a difference equation.

Parameters

data	array to be filtered. The filtered data will be placed here.
size	number of elements in the data array
diffEq	a vector containing two vectors of float32's (a.k.a. singles, floats), that contains the numerator and denominator coefficients, respectively, of the z-domain tranfer function of the filter in decending order (z^0, z^-1, z^-2, etc.).

Definition at line 80 of file Filter.hpp.

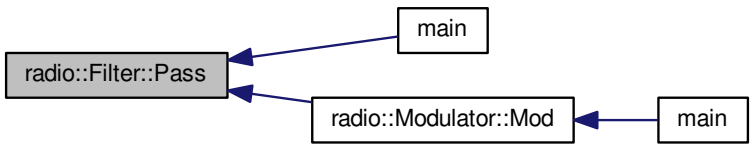
7.1.3 Member Function Documentation

7.1.3.1 void radio::Filter::Pass ( )

Passes the data array through the digital filter but does not account for previous x[n] and y[n] values from the previous call to Pass().

Definition at line 87 of file Filter.hpp.

Here is the caller graph for this function:



7.1.4 Member Data Documentation

7.1.4.1 float32* radio::Filter::data [protected]

A pointer to the start of the data array to be filtered when Pass() is called.

Definition at line 69 of file Filter.hpp.

7.1.4.2 fparams radio::Filter::diffEq [protected]

A vector containing two vectors of float32's (a.k.a. singles, floats), containing the numerator and denominator coefficients, respectively, of the z-domain tranfer function of the filter in decending order (z^0, z^-1, z^-2, etc.).

Definition at line 77 of file Filter.hpp.

7.1.4.3 uint8 radio::Filter::eqLength [protected]

The number of terms in the numerator (or denomenator) of the transfer function (i.e., function order + 1).

Definition at line 58 of file Filter.hpp.

7.1.4.4 uint32 radio::Filter::size [protected]

The number of elements in the data array.

Definition at line 63 of file Filter.hpp.

The documentation for this class was generated from the following file:

- src/Filter.hpp

7.2 radio::Gain Class Reference

`#include <Gain.hpp>`

Public Member Functions

- Gain (float32 *data, uint32 size, float32 gaindB)
- void Apply ()

7.2.1 Detailed Description

Increases the power of a (baseband) signal.

Definition at line 18 of file Gain.hpp.

7.2.2 Constructor & Destructor Documentation

7.2.2.1 radio::Gain::Gain (float32 * *data*, uint32 *size*, float32 *gaindB*)

Initializes a Gain object and converts gain from decibels to a standard value.

Parameters

data	the signal to which the gain is applied
size	the number of elements in the data array
gaindB	the desired gain in decibels (of power)

Definition at line 61 of file Gain.hpp.

7.2.3 Member Function Documentation

7.2.3.1 void radio::Gain::Apply ( )

Applies the gain to the signal contained in the data array.

Definition at line 67 of file Gain.hpp.

Here is the caller graph for this function:

The documentation for this class was generated from the following file:

- src/Gain.hpp

7.3 radio::Modulator Class Reference

`#include <Modulator.hpp>`

Public Member Functions

- Modulator (float32 data[], uint32 size, ModulationType type, float32 freqInter=FREQ_INTERMEDIATE, uint32 rate=SAMPLING_RATE)
- ~Modulator ()
- void Mod ()

7.3.1 Detailed Description

This class implements various types of modulation.

Definition at line 37 of file Modulator.hpp.

7.3.2 Constructor & Destructor Documentation

7.3.2.1 radio::Modulator::Modulator (float32 *data[]*, uint32 *size*, ModulationType *type*, float32 *freqInter* = FREQ_INTERMEDIATE, uint32 *rate* = SAMPLING_RATE)

Creates a Modulator with the specified parameters.

Parameters

freqInter	the frequency of the IF carrier sinusoid
rate	the sampling rate of the baseband and IF signals
data	the array holding initially the baseband signal
size	the number of elements in the data array
type	form of modulation to use

Definition at line 100 of file Modulator.hpp.

7.3.2.2 radio::Modulator::~Modulator ( )

Frees the memory needed for the Hilbert transform.

Definition at line 114 of file Modulator.hpp.

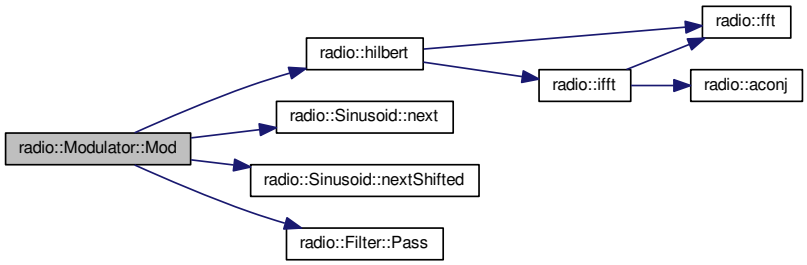
7.3.3 Member Function Documentation

7.3.3.1 void radio::Modulator::Mod ( )

Modulates the audio currently in the data array.

Definition at line 118 of file Modulator.hpp.

Here is the call graph for this function:



Here is the caller graph for this function:

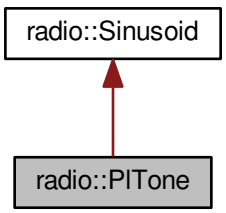
The documentation for this class was generated from the following file:

- src/Modulator.hpp

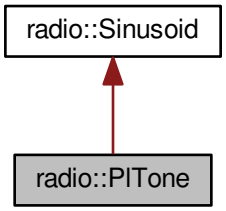
7.4 radio::PlTone Class Reference

`#include <PlTone.hpp>`

Inheritance diagram for radio::PlTone:



Collaboration diagram for radio::PlTone:



Public Member Functions

- PlTone (float32 amplitude, float32 *data, uint32 size, float32 frequency, uint32 samplingRate=48000)
- void Add ()

7.4.1 Detailed Description

This class creates a PL tone (CTCSS tone) at a specified frequency in a baseband signal.

Definition at line 18 of file PlTone.hpp.

7.4.2 Constructor & Destructor Documentation

7.4.2.1 radio::PlTone::PlTone (float32 *amplitude*, float32 * *data*, uint32 *size*, float32 *frequency*, uint32 *samplingRate* = 48000)

Creates a PlTone object.

Parameters

amplitude	the amplitude (0-1) of the subcarrier. Assumes baseband signal has a peak-to-peak range of -1 to 1.
data	an array containing a portion of the discrete baseband signal
size	the number of elemeents in the data array
frequency	the frequency of the CTCSS tone in the baseband (not in the IF or RF signals)
samplingRate	the sampling frequency of the baseband signal

Definition at line 63 of file PlTone.hpp.

7.4.3 Member Function Documentation

7.4.3.1 void radio::PlTone::Add ( )

Adds the PL tone to the baseband signal.

Definition at line 75 of file PlTone.hpp.

Here is the call graph for this function:

Here is the caller graph for this function:

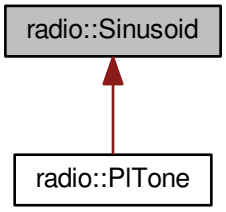
The documentation for this class was generated from the following file:

- src/PlTone.hpp

7.5 radio::Sinusoid Class Reference

`#include <Sinusoid.hpp>`

Inheritance diagram for radio::Sinusoid:



Public Member Functions

- Sinusoid (float32 frequency, uint32 samplingRate=48000)
- ~Sinusoid ()
- float32 next ()
- float32 nextShifted ()

Protected Attributes

- float32 frequency
- uint32 sinIndex = 0
- uint32 sinIndexShifted = 0
- uint32 samplingRate
- float32 * sinusoid
- float32 * sinusoidShift90

7.5.1 Detailed Description

This class creates an easy-to-call pair of sinusoids, pi/2 radians out of phase with each other, that will preserve its phase throughout its lifespan. Essentially, it is a ring buffer.

Definition at line 21 of file Sinusoid.hpp.

7.5.2 Constructor & Destructor Documentation

7.5.2.1 radio::Sinusoid::Sinusoid (float32 *frequency*, uint32 *samplingRate* = 48000)

Creates two ring-buffer sinusoids.

Definition at line 78 of file Sinusoid.hpp.

7.5.2.2 radio::Sinusoid::~Sinusoid ( )

Frees arrays malloc'ed in the constructor.

Definition at line 93 of file Sinusoid.hpp.

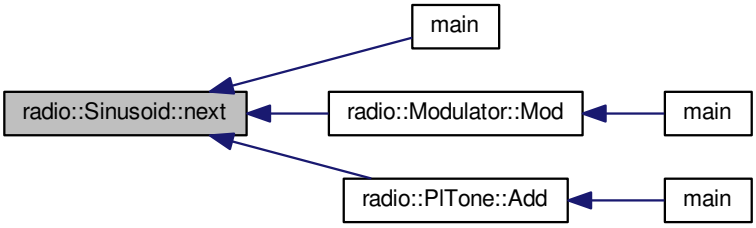
7.5.3 Member Function Documentation

7.5.3.1 float32 radio::Sinusoid::next ( )

Provides the next value of the sinusoid in a manner consistant with a ring buffer.

Definition at line 98 of file Sinusoid.hpp.

Here is the caller graph for this function:

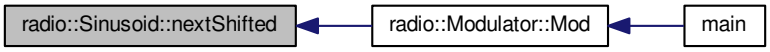


7.5.3.2 float32 radio::Sinusoid::nextShifted ( )

Provides the next value of the shifted sinusoid in a manner consistant with a ring buffer.

Definition at line 103 of file Sinusoid.hpp.

Here is the caller graph for this function:



7.5.4 Member Data Documentation

7.5.4.1 float32 radio::Sinusoid::frequency [protected]

The frequency of the sinusoid.

Definition at line 49 of file Sinusoid.hpp.

7.5.4.2 uint32 radio::Sinusoid::samplingRate [protected]

The sampling rate.

Definition at line 64 of file Sinusoid.hpp.

7.5.4.3 uint32 radio::Sinusoid::sinIndex = 0 [protected]

The current index of the sinusoid's unshifted array.

Definition at line 54 of file Sinusoid.hpp.

7.5.4.4 uint32 radio::Sinusoid::sinIndexShifted = 0 [protected]

The current index of the shifted sinusoid's array.

Definition at line 59 of file Sinusoid.hpp.

7.5.4.5 float32* radio::Sinusoid::sinusoid [protected]

Initialized as an array of the sinusoid values.

Definition at line 69 of file Sinusoid.hpp.

7.5.4.6 float32* radio::Sinusoid::sinusoidShift90 [protected]

Initialized as an array of the sinusoid values shifted 90 degrees.

Definition at line 75 of file Sinusoid.hpp.

The documentation for this class was generated from the following file:

- src/Sinusoid.hpp

Chapter 8

File Documentation

8.1 bin/bbftest File Reference

8.1.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file bbftest.

8.2 bbftest

```
00001 basebandfiltertest | aplay -c 2 -r 48000 -t raw -f S32_LE
```

8.3 bin/lsbftest File Reference

8.3.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file lsbftest.

8.4 lsbftest

```
00001 lowersidebandftest | aplay -c 2 -r 48000 -t raw -f S32_LE
```

8.5 bin/modtest File Reference

8.5.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file modtest.

8.6 modtest

```
00001 OPTIONS="-c 2 -r 48000 -t raw -f S32_LE -q"
00002 modulatortest $1 $2 $3 | aplay $OPTIONS -D plughw:0,0
```

8.7 bin/msintest File Reference

8.7.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file msintest.

8.8 msintest

```
00001 multisinusoidtest | aplay -c 2 -r 48000 -t raw -f S32_LE
```

8.9 bin/pltest File Reference

8.9.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file pltest.

8.10 pltest

```
00001 OPTIONS="-c 2 -r 48000 -t raw -f S32_LE"
00002 pltonetest $1 | aplay $OPTIONS
```

8.11 bin/radio File Reference

8.11.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file radio.

8.12 radio

```
00001 OPTIONS="-r 48000 -t raw -q"
00002 arecord $OPTIONS -c 1 -D plughw:1,0 -f FLOAT_LE | sdr $1 $2 $3 | \
00003 aplay $OPTIONS -c 2 -f S32_LE -D plughw:0,0
```

8.13 bin/sintest File Reference

8.13.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file sintest.

8.14 sintest

```
00001 OPTIONS="-c 2 -r 48000 -t raw -f S32_LE"
00002 sinusoidtest $1 | aplay $OPTIONS
```

8.15 bin/usbftest File Reference

8.15.1 Detailed Description

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file usbftest.

8.16 usbftest

```
00001 uppersidebandftest | aplay -c 2 -r 48000 -t raw -f S32_LE
```

8.17 etc/doxygen.config File Reference

Contains doxygen configuration.

8.17.1 Detailed Description

Contains doxygen configuration.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file doxygen.config.

8.18 doxygen.config

```
00001 PROJECT_NAME = "An Inexpensive, Software-Defined IF Modulator"
00002
00003 INPUT = makefile src/ etc/doxygen.config bin/bbftest bin/modtest bin/msintest bin/lsbftest bin/pltest
       bin/radio bin/sintest bin/usbftest
00004 OUTPUT_DIRECTORY = doc/
00005
00006 GENERATE_HTML = YES
00007 GENERATE_RTF = YES
```

```
00008 GENERATE_LATEX = YES
00009 GENERATE_MAN = YES
00010 GENERATE_XML = NO
00011 GENERATE_DOCBOOK = NO
00012
00013 USE_PDF_LATEX = YES
00014 USE_PDF_HYPERLINKS = YES
00015
00016 RECURSIVE = YES
00017 SOURCE_BROWSER = YES
00018 SOURCE_TOOLTIPS = YES
00019 EXTRACT_ALL = YES
00020 DISABLE_INDEX = NO
00021 GENERATE_TREEVIEW = YES
00022 SEARCHENGINE = YES
00023 SERVER_BASED_SEARCH = NO
00024
00025 LATEX_SOURCE_CODE = YES
00026 STRIP_CODE_COMMENTS = YES
00027 INLINE_SOURCES = NO
00028
00029 HAVE_DOT = YES
00030 CALL_GRAPH = YES
00031 CALLER_GRAPH = YES
```

8.19 makefile File Reference

Contains recipes to compile the main program and the tests programs as well as making documentation and counting total lines of code in src/.

8.19.1 Detailed Description

Contains recipes to compile the main program and the tests programs as well as making documentation and counting total lines of code in src/.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file makefile.

8.20 makefile

```
00001 GCC = g++ -g -std=gnu++14
00002
00003 alsa-test:
00004    $(GCC) src/alsa_test.cpp -o bin/alsatest -O0 -lasound
00005
00006 baseband-filter-test:
00007    $(GCC) src/baseband_filter_test.cpp -o bin/basebandfiltertest
00008
00009 count:
00010    grep -r "src/" -e "Samuel Andrew Wisner" -l | xargs wc -l
00011
00012 docs:
00013    rm -r doc/
00014    doxygen etc/doxygen.config
00015    cd doc/latex; make pdf;
00016    git reset
00017    git add doc/.
00018    git --no-pager log > etc/log.txt
00019    git add etc/log.txt
00020    git commit -m "Updated documentation."
00021    git push
00022
00023 fft-test:
00024    $(GCC) src/fft_test.cpp -o bin/fft-test
00025
00026 fft-test2:
00027    $(GCC) src/fft_test2.cpp -o bin/fft-test2
00028
00029 iq-test:
```

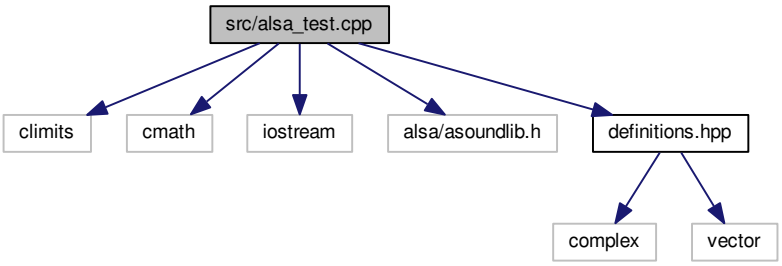
```
00030    $(GCC) src/iq_test.cpp -o bin/iqtest
00031
00032 multi-sinusoid-test:
00033    $(GCC) src/multi_sinusoid_test.cpp -o bin/multisinusoidtest
00034
00035 modulator-test:
00036    $(GCC) src/modulator_test.cpp -o bin/modulatortest
00037
00038 lsb-filter-test:
00039    $(GCC) src/lsb_filter_test.cpp -o bin/lowersidebandftest
00040
00041 pl-tone-test:
00042    $(GCC) src/pl_tone_test.cpp -o bin/pltonetest
00043
00044 radio:
00045    $(GCC) src/main.cpp -o bin/sdr
00046
00047 sinusoid-test:
00048    $(GCC) src/sinusoid_test.cpp -o bin/sinusoidtest
00049
00050 usb-filter-test:
00051    $(GCC) src/usb_filter_test.cpp -o bin/uppersidebandftest
00052
00053
```

8.21 src/alsa_test.cpp File Reference

Contains program to tests sinusoidal tone generation.

```
#include <climits>
#include <cmath>
#include <iostream>
#include <alsa/asoundlib.h>
#include "definitions.hpp"
```

Include dependency graph for alsa_test.cpp:



Functions

- int main ()

8.21.1 Detailed Description

Contains program to tests sinusoidal tone generation.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Bug Clicking noise from sinusoidal discontinuity

Definition in file alsa_test.cpp.

8.21.2 Function Documentation

8.21.2.1 int main ( )

This program tests sinusoidal speaker output through the ALSA API. Not sure if it currently works. When it did at least compile and run, it produced a sinusoid with an approximately twice-per-second clicking noise.

Definition at line 22 of file alsa_test.cpp.

8.22 alsa_test.cpp

```
00001
00008 #include <climits>
00009 #include <cmath>
00010 #include <iostream>
00011 #include <alsa/asoundlib.h>
00012
00013 #include "definitions.hpp"
00014
00015 using namespace std;
00016
00022 int main() {
00023     int ret;
00024
00025     snd_pcm_t* pcm_handle;  // device handle
00026     snd_pcm_stream_t stream = SND_PCM_STREAM_PLAYBACK;
00027     snd_pcm_hw_params_t* hwparams;  // hardware information
00028     char* pcm_name = strdup("plughw:1,0");  // on-board audio jack
00029     int rate = 48000;
00030
00031     const uint16 freq = 440;
00032     long unsigned int bufferSize = 4096*4;  // anything >8192 causes seg fault
00033     const uint32 len = bufferSize*100;
00034     const float32 arg = 2 * 3.141592 * freq / rate;
00035     sint16 vals[len];
00036
00037     long unsigned int count = 0;
00038
00039     for(uint32 i = 0; i < len; i = i + 2) {
00040         vals[i] = (sint16)(SHRT_MAX * cos(arg * i/2) + 0.5);
00041         vals[i+1] = vals[i];
00042     }
00043
00044     ret = snd_pcm_open(&pcm_handle, pcm_name, stream, 0);
00045     cout << "Opening: " << snd_strerror(ret) << endl;
00046
00047     ret = snd_pcm_hw_params_any(pcm_handle, hwparams);
00048     cout << "Initializing hwparams structure: " << snd_strerror(ret) << endl;
00049
00050     ret = snd_pcm_hw_params_set_access(pcm_handle, hwparams,
00051             SND_PCM_ACCESS_RW_INTERLEAVED);
00052     cout << "Setting access: " << snd_strerror(ret) << endl;
00053
00054     ret = snd_pcm_hw_params_set_format(pcm_handle, hwparams,
00055             SND_PCM_FORMAT_S16_LE);
00056     cout << "Setting format: " << snd_strerror(ret) << endl;
00057
00058     ret = snd_pcm_hw_params_set_rate(pcm_handle, hwparams,
00059             rate, (int)0);
00060     cout << "Setting rate: " << snd_strerror(ret) << endl;
00061
00062     ret = snd_pcm_hw_params_set_channels(pcm_handle, hwparams, 2);
00063     cout << "Setting channels: " << snd_strerror(ret) << endl;
00064
00065     ret = snd_pcm_hw_params_set_periods(pcm_handle, hwparams, 2, 0);
00066     cout << "Setting periods: " << snd_strerror(ret) << endl;
00067
00068     ret = snd_pcm_hw_params_set_buffer_size_near(pcm_handle, hwparams,
00069             &bufferSize);
00070     cout << "Setting buffer size: " << snd_strerror(ret) << endl;
00071
00072     ret = snd_pcm_hw_params(pcm_handle, hwparams);
00073     cout << "Applying parameters: " << snd_strerror(ret) << endl;
00074
00075 //  ret = snd_pcm_hw_params_get_period_size(hwparams, &count, 0);
00076     cout << "Actual period size: " << count << endl;
```

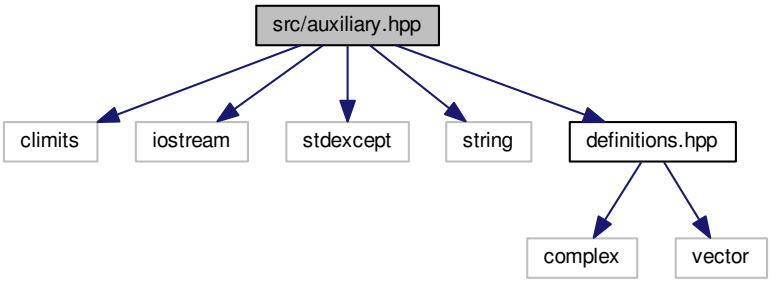
```
00077     cout << "Returned: " << snd_strerror(ret) << endl;
00078
00079
00080
00081     cout << endl << endl;
00082
00083
00084     const void* ptr[100];
00085
00086     for(int i = 0; i < 100; i++) {
00087         ptr[i] = (const void*)&vals + bufferSize*i;
00088     }
00089
00090     int err;
00091
00092     for(int i = 0; i < 100; i++) {
00093         do {
00094             ret = snd_pcm_writei(pcm_handle,
00095                     ptr[i], count);
00096
00097             if(ret < 0) {
00098                 err = snd_pcm_prepare(pcm_handle);
00099                 cout << "Preparing: " << snd_strerror(err)
00100                     << endl;
00101             }
00102         } while(ret < 0);
00103
00104         cout << "Writing data: " << ret << endl;
00105     }
00106 }
```

8.23 src/auxiliary.hpp File Reference

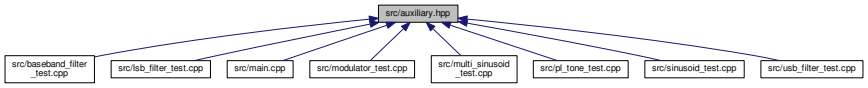
Contains helper-functions for main().

```
#include <climits>
#include <iostream>
#include <stdexcept>
#include <string>
#include "definitions.hpp"
```

Include dependency graph for auxiliary.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- radio

Functions

- void radio::ShowHelp ()
- void radio::to_sint32 (float32 *data, uint32 size)
- ModulationType radio::to_type (std::string str)

8.23.1 Detailed Description

Contains helper-functions for main().

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file auxiliary.hpp.

8.24 auxiliary.hpp

```
00001
00007 #ifndef auxiliary_H
00008 #define auxiliary_H
00009
00010 #include <climits>
00011 #include <iostream>
00012 #include <stdexcept>
00013 #include <string>
00014
00015 #include "definitions.hpp"
00016
00017 namespace radio {
00018
00022     void ShowHelp() {
00023         std::cerr << std::endl << "Usage: radio [MODE] [MIC GAIN] "
00024             "[PL TONE]" << std::endl << std::endl
00025             << "MODE: one of the following types "
00026             "of modulation" << std::endl << std::endl;
00027
00028         std::cerr << "dsblc\t\tDouble sideband, large carrier" << std::endl
00029             << "am\t\tAlias for dsblc" << std::endl
00030             << "dsbsc\t\tDouble sideband, suppressed carrier" << std::endl
00031             << "lsbhil\t\tLower sideband created via Hilbert transform"
00032             << std::endl
00033             << "lsbfilt\t\tLower sideband created via digital low-pass filter"
00034             << std::endl
00035             << "usbhil\t\tUpper sideband created via Hilbert transform"
00036             << std::endl
00037             << "usbfilt\t\tUpper sideband created via digital high-pass filter"
00038             << std::endl
00039 //          << "nfm\t\tFrequency modulation, 2.5 kHz bandwidth"
00040             << std::endl;
00041 //          << "wfm\t\tFrequency modulation, 5 kHz bandwidth" << std::endl
00042 //          << "fm\t\talias for wfm" << std::endl << std::endl;
00043
00044         std::cerr << "MIC GAIN: Microphone power gain expressed in decibels"
00045         << std::endl << std::endl;
00046
00047         std::cerr << "PL TONE: Optional specification for CTCSS tone from "
00048             "60-260 Hz" << std::endl << std::endl;
00049
00050         std::exit(ERROR);
00051     }
00052
00062     void to_sint32(float32* data, uint32 size) {
00063         for(uint32 i = 0; i < size; i++) {
00064             ((sint32*)data)[i] = (sint32)(data[i] * INT_MAX + 0.5);
00065         }
00066     }
00067
```

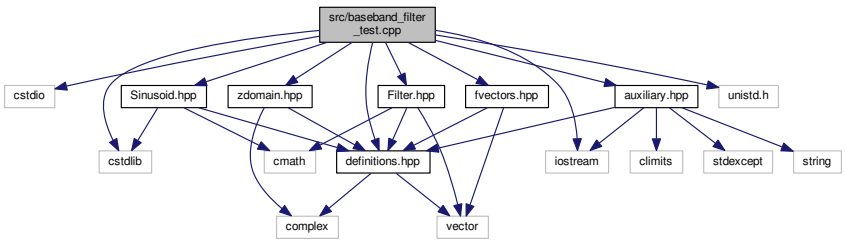
```
00080     ModulationType to_type(std::string str) {
00081         ModulationType type;
00082 
00083         if(str == "dsblc" || str == "am") {
00084             type = ModulationType::DSB_LC;
00085         } else if(str == "dsbsc") {
00086             type = ModulationType::DSB_SC;
00087         } else if(str == "lsbhil") {
00088             type = ModulationType::LSB_HILBERT;
00089         } else if(str == "lsbfilt") {
00090             type = ModulationType::LSB_FILTERED;
00091         } else if(str == "usbhil") {
00092             type = ModulationType::USB_HILBERT;
00093         } else if(str == "usbfilt") {
00094             type = ModulationType::USB_FILTERED;
00095         } else if(str == "wfm" || str == "fm") {
00096             type = ModulationType::FM_NARROW;
00097         } else if(str == "nfm") {
00098             type = ModulationType::FM_WIDE;
00099         } else {
00100             throw std::logic_error("The given modulation type is invalid!");
00101         }
00102 
00103         return type;
00104     }
00105 }
00106 
00107 #endif
```

8.25 src/baseband_filter_test.cpp File Reference

Contains a program to demonstrate the the baseband/AF filter.

```
#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <unistd.h>
#include "auxiliary.hpp"
#include "definitions.hpp"
#include "Filter.hpp"
#include "fvectors.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"
```

Include dependency graph for baseband_filter_test.cpp:



Functions

- int main (int argc, char ∗argv[])

8.25.1 Detailed Description

Contains a program to demonstrate the the baseband/AF filter.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file baseband_filter_test.cpp.

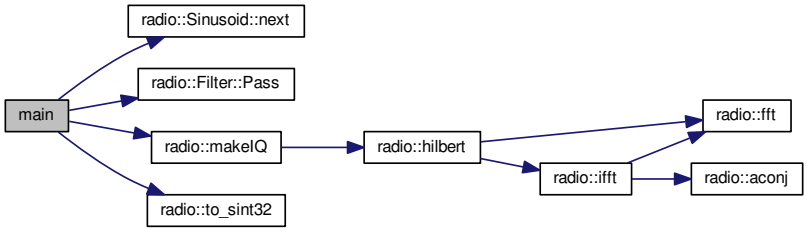
8.25.2 Function Documentation

8.25.2.1 int main (int *argc*, char * *argv[]*)

Program to test the Filter class and the baseband filter coefficients.

Definition at line 25 of file baseband_filter_test.cpp.

Here is the call graph for this function:



8.26 baseband_filter_test.cpp

```
00001
00007 #include <cstdio>
00008 #include <cstdlib>
00009 #include <iostream>
00010 #include <unistd.h>
00011
00012 #include "auxiliary.hpp"
00013 #include "definitions.hpp"
00014 #include "Filter.hpp"
00015 #include "fvectors.hpp"
00016 #include "Sinusoid.hpp"
00017 #include "zdomain.hpp"
00018
00019 using namespace std;
00020 using namespace radio;
00021
00025 int main(int argc, char* argv[]) {
00026
00027     // Constants
00028     const uint16 BUFFER_SIZE = 48000;
00029
00030     // Declare primative Variables
00031     uint8 i = 0;
00032     uint8 size = 0;
00033     uint16 delta = 250;
00034     float32 dataBuffer[BUFFER_SIZE];
00035     float32 iqBuffer[2 * BUFFER_SIZE];
00036
00037     // create 1 sec of audio
00038     for(uint16 f = delta; f <= 3000; f += delta, i++) {
00039         Sinusoid sinusoid(f);
00040
00041         for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00042             dataBuffer[i] += sinusoid.next();
00043         }
00044     }
00045
00046     size = i;
00047
```

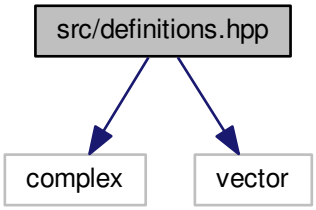
```
00048     // adjust dataBuffer so values are between -1 and 1
00049     for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00050         dataBuffer[i] /= size;
00051     }
00052
00053     Filter filter(dataBuffer, BUFFER_SIZE, F_BASEBAND);
00054     filter.Pass();
00055     makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00056     to_sint32(iqBuffer, 2 * BUFFER_SIZE);
00057
00058     while(true) {
00059         write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
00060     }
00061 }
```

8.27 src/definitions.hpp File Reference

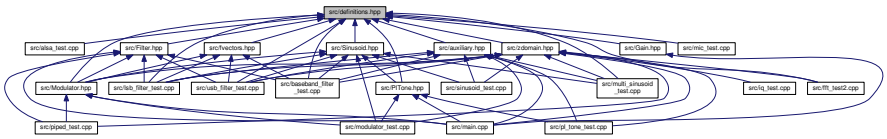
Contains declarations of system-independant (universal size) integers and float types, shortened type names for some commonly used types, and enumerations.

```
#include <complex>
#include <vector>
```

Include dependency graph for definitions.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- radio

Macros

- #define ENUM signed char
- #define ERROR -1

Typedefs

- typedef unsigned char byte
- typedef unsigned char uint8
- typedef signed char sint8
- typedef unsigned short uint16
- typedef signed short sint16
- typedef unsigned int uint32
- typedef signed int sint32
- typedef unsigned long long uint64
- typedef signed long long sint64
- typedef float float32
- typedef double float64
- typedef std::complex< float32 > cfloat32
- typedef std::vector < std::vector< float64 > > fparams

Enumerations

- enum radio::Age { radio::OLD, radio::NEW }
- enum radio::Fractional { radio::NUM, radio::DEN }
- enum radio::Argument { radio::FREQ = 1, radio::MODE, radio::PL_TONE }
- enum radio::ModulationType { radio::ModulationType::DSB_LC, radio::ModulationType::DSB_SC, radio::ModulationType::USB_FILTERED, radio::ModulationType::USB_HILBERT, radio::ModulationType::LSB_FILTERED, radio::ModulationType::LSB_HILBERT, radio::ModulationType::FM_NARROW, radio::ModulationType::FM_WIDE }

8.27.1 Detailed Description

Contains declarations of system-independant (universal size) integers and float types, shortened type names for some commonly used types, and enumerations.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file definitions.hpp.

8.27.2 Macro Definition Documentation

8.27.2.1 #define ENUM signed char

The type used for the enumerations.

Definition at line 18 of file definitions.hpp.

8.27.2.2 #define ERROR -1

A generic error constant.

Definition at line 23 of file definitions.hpp.

8.27.3 Typedef Documentation

8.27.3.1 typedef unsigned char byte

Definition at line 25 of file definitions.hpp.

8.27.3.2 typedef std::complex<float32> cfloat32

Complex float32's.

Definition at line 44 of file definitions.hpp.

8.27.3.3 typedef float float32

Definition at line 38 of file definitions.hpp.

8.27.3.4 typedef double float64

Definition at line 39 of file definitions.hpp.

8.27.3.5 typedef std::vector<std::vector<float64> > fparams

Defines a type for the filter coefficients.

Definition at line 49 of file definitions.hpp.

8.27.3.6 typedef signed short sint16

Definition at line 30 of file definitions.hpp.

8.27.3.7 typedef signed int sint32

Definition at line 33 of file definitions.hpp.

8.27.3.8 typedef signed long long sint64

Definition at line 36 of file definitions.hpp.

8.27.3.9 typedef signed char sint8

Definition at line 27 of file definitions.hpp.

8.27.3.10 typedef unsigned short uint16

Definition at line 29 of file definitions.hpp.

8.27.3.11 typedef unsigned int uint32

Definition at line 32 of file definitions.hpp.

8.27.3.12 typedef unsigned long long uint64

Definition at line 35 of file definitions.hpp.

8.27.3.13 typedef unsigned char uint8

Definition at line 26 of file definitions.hpp.

8.28 definitions.hpp

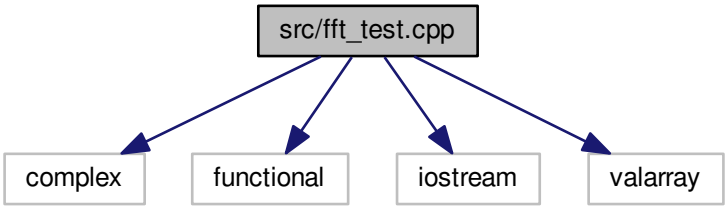
```
00001
00009 #ifndef definitions_H
00010 #define definitions_H
00011
00012 #include <complex>
00013 #include <vector>
00014
00018 #define ENUM signed char
00019
00023 #define ERROR -1
00024
00025 typedef unsigned char byte;
00026 typedef unsigned char uint8;
00027 typedef signed char sint8;
00028
00029 typedef unsigned short uint16;
00030 typedef signed short sint16;
00031
00032 typedef unsigned int uint32;
00033 typedef signed int sint32;
00034
00035 typedef unsigned long long uint64;
00036 typedef signed long long sint64;
00037
00038 typedef float float32;
00039 typedef double float64;
00040
00044 typedef std::complex<float32> cfloat32;
00045
00049 typedef std::vector<std::vector<float64>> fparams;
00050
00055 namespace radio {
00060     enum Age { OLD, NEW };
00061
00065     enum Fractional { NUM, DEN };
00066
00070     enum Argument { FREQ = 1, MODE, PL_TONE };
00071
00075     enum class ModulationType {
00076         DSB_LC, DSB_SC,
00077         USB_FILTERED,
00078         USB_HILBERT,
00079         LSB_FILTERED,
00080         LSB_HILBERT,
00081         FM_NARROW,
00082         FM_WIDE
00083     };
00084 }
00085
00086 #endif
00087
00088 // Doxygen descriptions for non-code files
00089
```

8.29 src/fft_test.cpp File Reference

Tests FFT, IFFT, and Hilbert implementations.

```
#include <complex>
#include <functional>
#include <iostream>
#include <valarray>
```

Include dependency graph for fft_test.cpp:



Typedefs

- typedef std::valarray
  < std::complex< double > > CArray

Functions

- void fft (CArray &x)
- void ifft (CArray &x)
- std::complex< double > hilbert (std::complex< double > n)
- int main ()

Variables

- const double PI = 3.14159265358979323846

8.29.1 Detailed Description

Tests FFT, IFFT, and Hilbert implementations.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file fft_test.cpp.

8.29.2 Typedef Documentation

8.29.2.1 typedef std::valarray<std::complex<double> > CArray

Definition at line 14 of file fft_test.cpp.

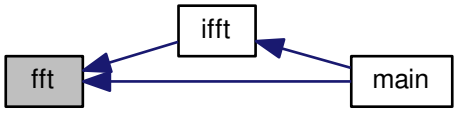
8.29.3 Function Documentation

8.29.3.1 void fft (CArray & *x*)

This code was taken from http://rosettacode.org/wiki/Fast_Fourier_transform#C.2B.2B.

Definition at line 23 of file fft_test.cpp.

Here is the caller graph for this function:



8.29.3.2 std::complex<double> hilbert (std::complex< double > *n*)

Definition at line 87 of file fft_test.cpp.

Here is the caller graph for this function:

8.29.3.3 void ifft (CArray & *x*)

Definition at line 72 of file fft_test.cpp.

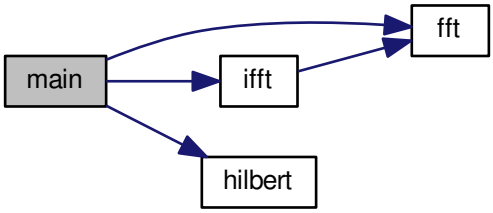
Here is the call graph for this function:

Here is the caller graph for this function:

8.29.3.4 int main ( )

Definition at line 91 of file fft_test.cpp.

Here is the call graph for this function:



8.29.4 Variable Documentation

8.29.4.1 const double PI = 3.14159265358979323846

Definition at line 12 of file fft_test.cpp.

8.30 fft_test.cpp

```
00001
00007 #include <complex>
00008 #include <functional>
00009 #include <iostream>
00010 #include <valarray>
00011
00012 const double PI = 3.14159265358979323846;
00013
00014 typedef std::valarray<std::complex<double>> CArray;
00015
00021 // Cooley-Tukey FFT (in-place, breadth-first, decimation-in-frequency)
00022 // Better optimized but less intuitive
00023 void fft(CArray &x)
00024 {
00025     // DFT
00026     unsigned int N = x.size(), k = N, n;
00027     double thetaT = 3.14159265358979323846264338328L / N;
00028     std::complex<double> phiT(cos(thetaT), sin(thetaT)), T;
00029     while (k > 1)
```

```
00030     {
00031         n = k;
00032         k >>= 1;
00033         phiT = phiT * phiT;
00034         T = 1.0L;
00035         for (unsigned int l = 0; l < k; l++)
00036         {
00037             for (unsigned int a = l; a < N; a += n)
00038             {
00039                 unsigned int b = a + k;
00040                 std::complex<double> t = x[a] - x[b];
00041                 x[a] += x[b];
00042                 x[b] = t * T;
00043             }
00044             T *= phiT;
00045         }
00046     }
00047     // Decimate
00048     unsigned int m = (unsigned int)log2(N);
00049     for (unsigned int a = 0; a < N; a++)
00050     {
00051         unsigned int b = a;
00052         // Reverse bits
00053         b = (((b & 0xaaaaaaaa) >> 1) | ((b & 0x55555555) << 1));
00054         b = (((b & 0xcccccccc) >> 2) | ((b & 0x33333333) << 2));
00055         b = (((b & 0xf0f0f0f0) >> 4) | ((b & 0x0f0f0f0f) << 4));
00056         b = (((b & 0xff00ff00) >> 8) | ((b & 0x00ff00ff) << 8));
00057         b = ((b >> 16) | (b << 16)) >> (32 - m);
00058         if (b > a)
00059         {
00060             std::complex<double> t = x[a];
00061             x[a] = x[b];
00062             x[b] = t;
00063         }
00064     }
00066     //std::complex<double> f = 1.0 / sqrt(N);
00067     //for (unsigned int i = 0; i < N; i++)
00068     //  x[i] *= f;
00069 }
00070
00071 // inverse fft (in-place)
00072 void ifft(CArray& x)
00073 {
00074     // conjugate the complex numbers
00075     x = x.apply(std::conj);
00076
00077     // forward fft
00078     fft( x );
00079
00080     // conjugate the complex numbers again
00081     x = x.apply(std::conj);
00082
00083     // scale the numbers
00084     x /= x.size();
00085 }
00086
00087 std::complex<double> hilbert(std::complex<double> n) {
00088     return std::complex<double>(-2 * n.imag(), 0);
00089 }
00090
00091 int main()
00092 {
00093     const std::complex<double> test[] = { 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16 };
00094     CArray data(test, 16);
00095
00096     // forward fft
00097     fft(data);
00098
00099     std::cout << "fft" << std::endl;
00100     for (int i = 0; i < 16; ++i)
00101     {
00102     //  std::cout << data[i] << std::endl;
00103     }
00104
00105     for(int i = 8; i < 16; i++) {
00106         data[i] = 0;
00107     }
00108
00109     // inverse fft
00110     ifft(data);
00111     std::cout << std::endl << "ifft" << std::endl;
00112
00113     for (int i = 0; i < 16; ++i)
00114     {
00115     //  std::cout << data[i] << std::endl;
00116     }
00117
```

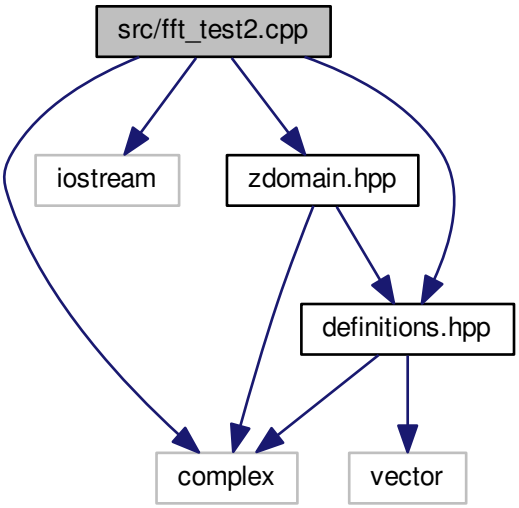
```
00118     data = data.apply(hilbert);
00119
00120     std::cout << std::endl;
00121
00122     for(int i = 0; i < 16; i++) {
00123         std::cout << data[i].real() << std::endl;
00124     }
00125
00126     return 0;
00127 }
```

8.31 src/fft_test2.cpp File Reference

Tests FFT, IFFT, and Hilbert implementations in zdomain.hpp.

```
#include <complex>
#include <iostream>
#include "definitions.hpp"
#include "zdomain.hpp"
```

Include dependency graph for fft_test2.cpp:



Functions

- int main ()

8.31.1 Detailed Description

Tests FFT, IFFT, and Hilbert implementations in zdomain.hpp.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file fft_test2.cpp.

8.31.2 Function Documentation

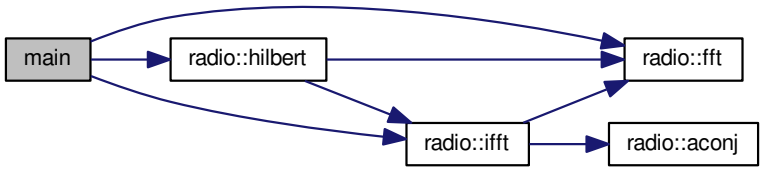
8.31.2.1 int main ( )

This program tests the fft(), ifft(), and hilbert() functions in the zdomain.hpp file.

This code is based on code from http://rosettacode.org/wiki/Fast_Fourier_transform#C.↩2B.2B.

Definition at line 22 of file fft_test2.cpp.

Here is the call graph for this function:



8.32 fft_test2.cpp

```
00001
00007 #include <complex>
00008 #include <iostream>
00009
00010 #include "definitions.hpp"
00011 #include "zdomain.hpp"
00012
00013 using namespace radio;
00014
00022 int main()
00023 {
00024     std::complex<float32> test[] = { 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16 };
00025     float32 ftest[16];
00026     float32 dest[16];
00027
00028     for(int i = 0; i < 16; i++) {
00029         ftest[i] = test[i].real();
00030     }
00031
00032     // forward fft
00033     fft(test, 16);
00034
00035     std::cout << "fft" << std::endl;
00036
00037     for (int i = 0; i < 16; ++i)
00038     {
00039     //  std::cout << test[i] << std::endl;
00040     }
00041
00042     // inverse fft
00043     ifft(test, 16);
00044     std::cout << std::endl << "ifft" << std::endl;
00045
00046     for (int i = 0; i < 16; ++i)
00047     {
00048         std::cout << test[i] << std::endl;
00049     }
00050
00051     hilbert(ftest, dest, 16);
00052     std::cout << std::endl << "hilbert" << std::endl;
00053
00054     for(int i = 0; i < 16; i++) {
00055         std::cout << dest[i] << std::endl;
00056     }
00057
00058     return 0;
```

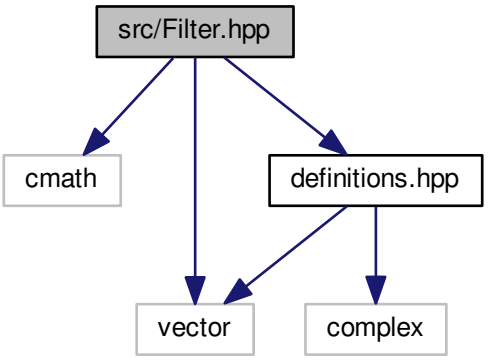
```
00059 }
```

8.33 src/Filter.hpp File Reference

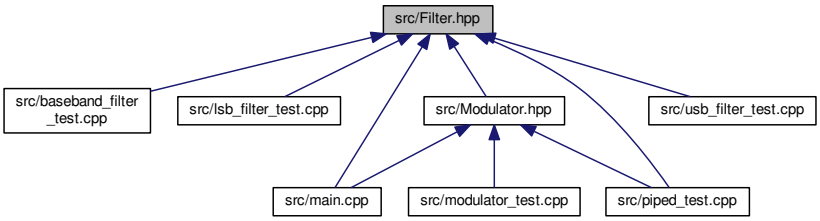
Defines the Filter class.

```
#include <cmath>
#include <vector>
#include "definitions.hpp"
```

Include dependency graph for Filter.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class radio::Filter

Namespaces

- radio

8.33.1 Detailed Description

Defines the Filter class.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Bug Discontinuities created at the beginning of each pass

Definition in file Filter.hpp.

8.34 Filter.hpp

```
00001
00008 #ifndef Filter_H
00009 #define Filter_H
00010
00011 #include <cmath>
00012 #include <vector>
00013
00014 #include "definitions.hpp"
00015
00016 namespace radio {
00028     class Filter {
00029         public:
00044             Filter(float32* data, uint32 size,
      fparams& diffEq);
00045
00051             void Pass();
00052
00053         protected:
00058             uint8 eqLength;
00059
00063             uint32 size;
00064
00069             float32* data;
00070
00077             fparams diffEq;
00078     };
00079
00080     Filter::Filter(float32* data, uint32 size,
      fparams& diffEq) {
00081         this->data = data;
00082         this->size = size;
00083         this->diffEq = diffEq;
00084         eqLength = this->diffEq[DEN].size();
00085     }
00086
00087     void Filter::Pass() {
00088         float64 temp[size];
00089
00090         // create first values in filtered data
00091         for(int i = 0; i< eqLength; i++) {
00092             temp[i] = 0;
00093
00094             for(int j = 0; j < eqLength; j++) {
00095                 temp[i] += diffEq[NUM][j] * (j > i ? 0 : data[i - j]);
00096             }
00097
00098             for(int j = 1; j < eqLength; j++) {
00099                 temp[i] -= diffEq[DEN][j] * (j > i ? 0 : temp[i - j]);
00100             }
00101         }
00102
00103         // create the REST of the values in filtered data
00104         for(int i = eqLength; i < size; i++) {
00105             temp[i] = 0;
00106
00107             for(int j = 0; j < eqLength; j++) {
00108                 temp[i] += diffEq[NUM][j] * data[i - j];
00109             }
00110
00111             for(int j = 1; j < eqLength; j++) {
00112                 temp[i] -= diffEq[DEN][j] * temp[i - j];
00113             }
00114         }
00115
```

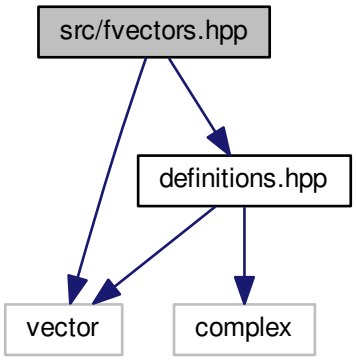
```
00116         // save final values of data and filtered data
00117     for(int i = 0; i < size; i++) {
00118             data[i] = temp[i];
00119         }
00120     }
00121 }
00122
00123 #endif
```

8.35 src/fvectors.hpp File Reference

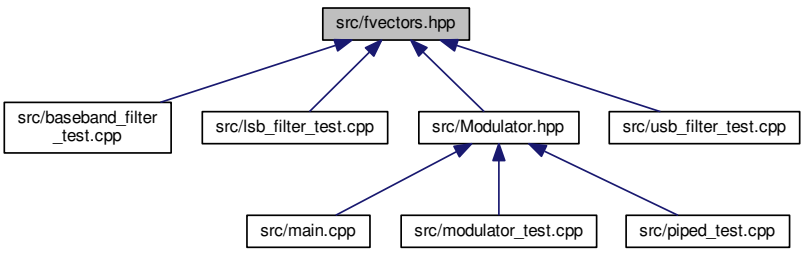
Defines the transfer function coefficients used in the instances of the Filter class in this program. The coefficients are listed by greatest order to least.

```
#include <vector>
#include "definitions.hpp"
```

Include dependency graph for fvectors.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- radio

Variables

- fparams radio::F_BASEBAND
- fparams radio::F_LOWERSIDEBAND
- fparams radio::F_UPPERSIDEBAND

8.35.1 Detailed Description

Defines the transfer function coefficients used in the instances of the Filter class in this program. The coefficients are listed by greatest order to least.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file fvectors.hpp.

8.36 fvectors.hpp

```
00001
00009 #ifndef fvectors_H
00010 #define fvectors_H
00011
00012 #include <vector>
00013
00014 #include "definitions.hpp"
00015
00016 namespace radio {
00020     fparams F_BASEBAND = { std::vector<float64> {
00021         0.0008977019461,
00022             -0.002215694636,
00023             0.001372192986,
00024             0.001372192986,
00025             -0.002215694636,
00026             0.0008977019461
00027     }, std::vector<float64> {
00028         1,
00029             -4.678616047,
00030             8.822912216,
00031             -8.379911423,
00032             4.007629871,
00033             -0.7719064355
00034     } };
00035
00039     fparams F_LOWERSIDEBAND = { std::vector<float64> {
00040         0.2758039069174,
00041             2.763578787693,
00042             12.83915022756,
00043             36.47584850651,
00044             70.37084637368,
00045             96.76893503179,
00046             96.76893503179,
00047             70.37084637368,
00048             36.47584850651,
00049             12.83915022756,
00050             2.763578787693,
00051             0.2758039069174
00052     }, std::vector<float64> {
00053         1,
00054             7.605497780083,
00055             27.34180552438,
00056             60.83375457605,
00057             92.60908886875,
00058             100.8363857,
00059             79.74796574736,
00060             45.4982252145,
00061             18.13566776308,
00062             4.690036472717,
00063             0.6617552879305,
00064             0.0281427334611
00065     } };
00066
00070     fparams F_UPPERSIDEBAND = { std::vector<float64> {
00071         0.001690387681463,
00072             0.01145271586989,
```

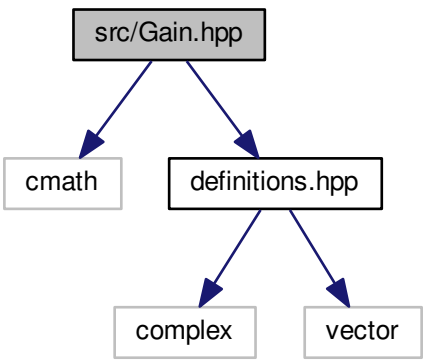
```
00073             0.03591799189724,
00074             0.06576926098562,
00075             0.07119343282702,
00076             0.03156377419766,
00077             -0.03156377419766,
00078             -0.07119343282702,
00079             -0.06576926098562,
00080             -0.03591799189724,
00081             -0.01145271586989,
00082             -0.001690387681463
00083     }, std::vector<float64> {
00084         1,
00085             9.465175013624,
00086             41.62402815905,
00087             112.0971027069,
00088             205.2097686473,
00089             267.9378582311,
00090             254.486805213,
00091             175.7772755115,
00092             86.51619894548,
00093             28.89988093561,
00094             5.89781461091,
00095             0.5572910543053
00096     } };
00097
00098
00099 }
00100
00101 #endif
```

8.37 src/Gain.hpp File Reference

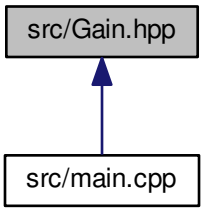
Contains the Gain class.

```
#include <cmath>
#include "definitions.hpp"
```

Include dependency graph for Gain.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class radio::Gain

Namespaces

- radio

8.37.1 Detailed Description

Contains the Gain class.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file Gain.hpp.

8.38 Gain.hpp

```
00001
00007 #ifndef Gain_H
00008 #define Gain_H
00009
00010 #include <cmath>
00011
00012 #include "definitions.hpp"
00013
00014 namespace radio {
00018     class Gain {
00019         public:
00030             Gain(float32* data, uint32 size, float32 gaindB);
00031
00035             void Apply();
00036
00037         private:
00041             float32* data;
00042
00046             float32 gainCoeff;
00047
00052             bool hasClipped = false;
00053
00057             uint32 size;
00058
00059     };
00060
```

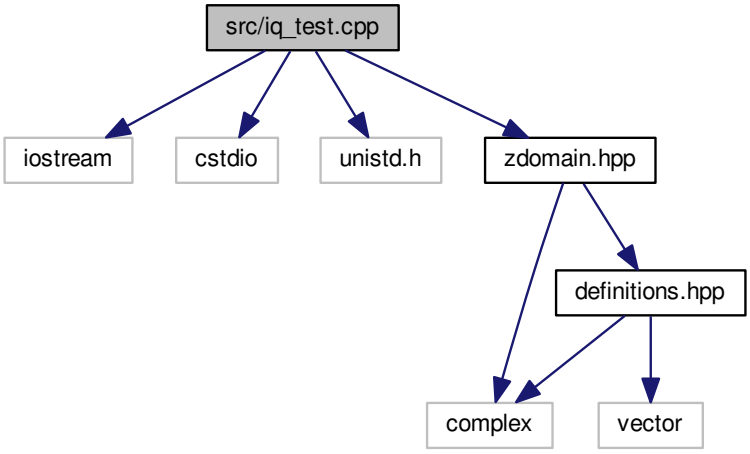
```
00061     Gain::Gain(float32* data, uint32 size, float32 gaindB) {
00062         this->data = data;
00063         this->size = size;
00064         gainCoeff = pow(10, gaindB / 20);
00065     }
00066
00067     void Gain::Apply() {
00068         for(uint32 i = 0; i < size; i++) {
00069             data[i] *= gainCoeff;
00070
00071             if((data[i] > 1 || data[i] < -1) && !hasClipped) {
00072                 hasClipped = true;
00073                 std::cerr << "Baseband clipping has occurred!"
00074                     << std::endl;
00075             }
00076         }
00077     }
00078 }
00079
00080 #endif
```

8.39 src/iq_test.cpp File Reference

Generates test IQ signal.

```
#include <iostream>
#include <cstdio>
#include <unistd.h>
#include "zdomain.hpp"
```

Include dependency graph for iq_test.cpp:



Functions

- int main ()

8.39.1 Detailed Description

Generates test IQ signal.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file iq_test.cpp.

8.39.2 Function Documentation

8.39.2.1 int main ( )

This small program demonstrates the IQ generation abilities of the makeIQ() function.

Definition at line 20 of file iq_test.cpp.

Here is the call graph for this function:

8.40 iq_test.cpp

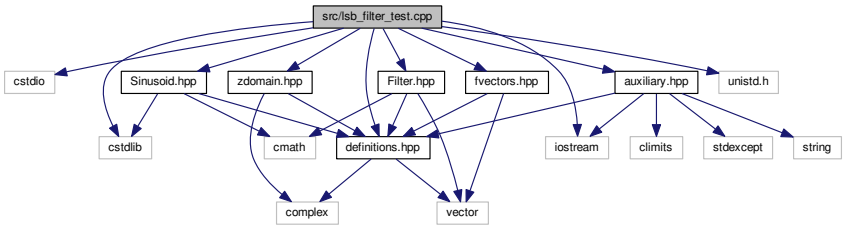
```
00001
00007 #include <iostream>
00008 #include <cstdio>
00009 #include <unistd.h>
00010
00011 #include "zdomain.hpp"
00012
00013 using namespace std;
00014 using namespace radio;
00015
00020 int main() {
00021     const uint16 len = 16384;
00022     float32 data[len];
00023     float32 iqData[2*len];
00024
00025     for(int i = 0; i < len; i++) {
00026         data[i] = sin(2*3.141592*170*i/len);
00027     }
00028
00029     while(true) {
00030         read(STDIN_FILENO, &data, len * sizeof(float32));
00031         makeIQ(data, iqData, len);
00032         write(STDOUT_FILENO, &iqData,  2 * len * sizeof(float32));
00033     }
00034 }
```

8.41 src/lsb_filter_test.cpp File Reference

Contains a program to demonstrate the the LSB/AF filter.

```
#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <unistd.h>
#include "auxiliary.hpp"
#include "definitions.hpp"
#include "Filter.hpp"
#include "fvectors.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"
```

Include dependency graph for lsb_filter_test.cpp:



Functions

- int main (int argc, char ∗argv[])

8.41.1 Detailed Description

Contains a program to demonstrate the the LSB/AF filter.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Bug Clicking occurs at start of each filter pass

Definition in file lsb_filter_test.cpp.

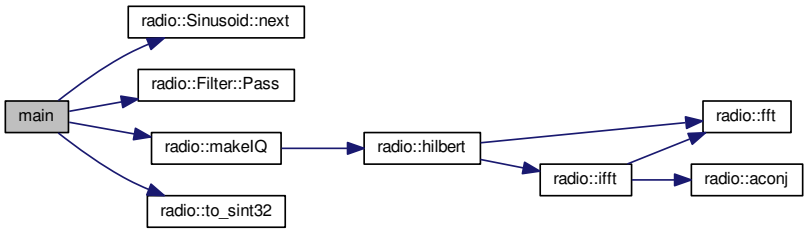
8.41.2 Function Documentation

8.41.2.1 int main (int *argc*, char ∗ *argv[]*)

Program to test the Filter class and the LSB filter coefficients.

Definition at line 26 of file lsb_filter_test.cpp.

Here is the call graph for this function:



8.42 lsb_filter_test.cpp

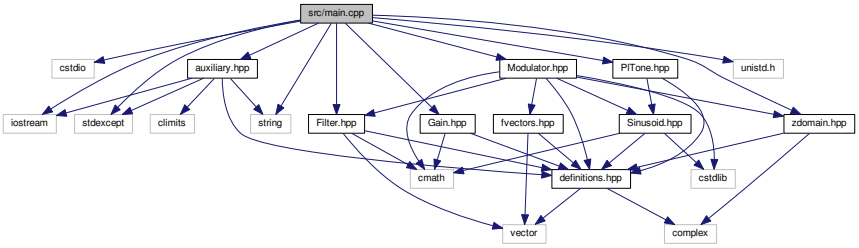
```
00001
00008 #include <cstdio>
00009 #include <cstdlib>
00010 #include <iostream>
00011 #include <unistd.h>
00012
00013 #include "auxiliary.hpp"
00014 #include "definitions.hpp"
00015 #include "Filter.hpp"
00016 #include "fvectors.hpp"
00017 #include "Sinusoid.hpp"
00018 #include "zdomain.hpp"
00019
00020 using namespace std;
00021 using namespace radio;
00022
00026 int main(int argc, char* argv[]) {
00027
00028     // Constants
00029     const uint16 BUFFER_SIZE = 48000;
00030
00031     // Declare primative Variables
00032     uint8 i = 0;
00033     uint8 size = 0;
00034     uint16 delta = 250;
00035     float32 dataBuffer[BUFFER_SIZE];
00036     float32 iqBuffer[2 * BUFFER_SIZE];
00037
00038     // create 1 sec of audio
00039     for(uint16 f = 17000; f <= 23000; f += delta, i++) {
00040         Sinusoid sinusoid(f);
00041
00042         for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00043             dataBuffer[i] += sinusoid.next();
00044         }
00045     }
00046
00047     size = i;
00048
00049     // adjust dataBuffer so values are between -1 and 1
00050     for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00051         dataBuffer[i] /= size;
00052     }
00053
00054     Filter filter(dataBuffer, BUFFER_SIZE, F_LOWERSIDEBAND);
00055     filter.Pass();
00056     makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00057     to_sint32(iqBuffer, 2 * BUFFER_SIZE);
00058
00059     while(true) {
00060         write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
00061     }
00062 }
```

8.43 src/main.cpp File Reference

Contains the "brains" of the entire project.

```
#include <cstdio>
#include <iostream>
#include <stdexcept>
#include <string>
#include <unistd.h>
#include "auxiliary.hpp"
#include "Filter.hpp"
#include "Gain.hpp"
#include "Modulator.hpp"
#include "PlTone.hpp"
#include "zdomain.hpp"
```

Include dependency graph for main.cpp:



Functions

- int main (int argc, char ∗argv[])

8.43.1 Detailed Description

Contains the "brains" of the entire project.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file main.cpp.

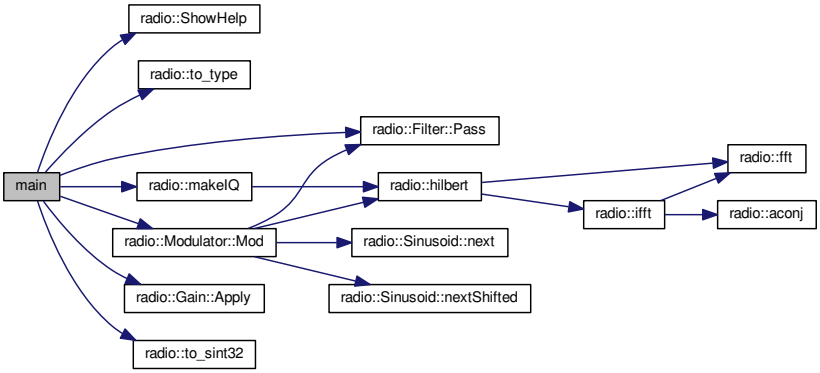
8.43.2 Function Documentation

8.43.2.1 int main (int *argc*, char ∗ *argv[]*)

Final result of the entire project. Completes all goals and more!

Definition at line 26 of file main.cpp.

Here is the call graph for this function:



8.44 main.cpp

```
00001
00007 #include <cstdio>
00008 #include <iostream>
00009 #include <stdexcept>
00010 #include <string>
00011 #include <unistd.h>
00012
00013 #include "auxiliary.hpp"
00014 #include "Filter.hpp"
00015 #include "Gain.hpp"
00016 #include "Modulator.hpp"
00017 #include "PlTone.hpp"
00018 #include "zdomain.hpp"
00019
00020 using namespace std;
00021 using namespace radio;
00022
00026 int main(int argc, char* argv[]) {
00027
00028     // Constants
00029     const uint8 NUM_TYPES = 8;
00030     const uint16 BUFFER_SIZE = 16384;
00031     const uint32 BUFFER_BYTE_COUNT = BUFFER_SIZE * sizeof(sint32);
00032     const uint32 IQ_BUFFER_SIZE = 2 * BUFFER_SIZE;
00033     const uint32 IQ_BUFFER_BYTE_COUNT = BUFFER_BYTE_COUNT * 2;
00034     const uint32 SAMPLING_RATE = 48000;
00035
00036     // Ensure 1 or 2 arguments given
00037     if(argc > 4) {
00038         std::cerr << "Error: too many arguments!" << std::endl;
00039         ShowHelp();
00040         return ERROR;
00041     } else if(argc < 2) {
00042         std::cerr << "Error: too few arguments!" << std::endl;
00043         ShowHelp();
00044         return ERROR;
00045     }
00046
00047     // Declare primative Variables
00048     float32 micGain = 0;
00049     float32 toneFreq = 0;
00050     float32 dataBuffer[BUFFER_SIZE];
00051     float32 iqBuffer[IQ_BUFFER_SIZE];
00052     ModulationType type;
00053
00054     // validate modulation type
00055     try{
00056         type = to_type(string(argv[1]));
00057     } catch(std::exception ex) {
00058         std::cerr << "The given modulation type is invalid!" << std::endl;
00059         ShowHelp();
00060     }
00061
```

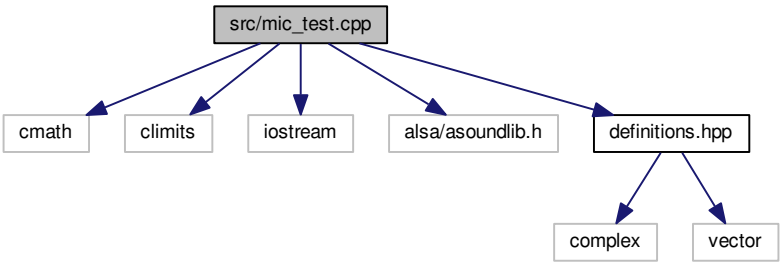
```
00062     // process mic gain
00063     if(argc >= 3) {
00064         try {
00065             micGain = std::stof(argv[2]);
00066         } catch(std::invalid_argument ex) {
00067             std::cerr << "The specified microphone gain is not a number."
00068                 << std::endl;
00069             ShowHelp();
00070         }
00071     }
00072
00073     // validate CTCSS tone
00074     if(argc == 4) {
00075         try {
00076             toneFreq = std::stof(argv[3]);
00077
00078             if(toneFreq < 60 || toneFreq > 260) {
00079                 throw std::out_of_range("");
00080             }
00081         } catch(std::out_of_range ex) {
00082             std::cerr << "The specified CTCSS frequency is outside of the "
00083                 "standard PL tone range." << std::endl;
00084             ShowHelp();
00085         } catch(std::invalid_argument ex) {
00086             std::cerr << "The specified CTCSS frequency is not a number."
00087                 << std::endl;
00088             ShowHelp();
00089         }
00090     }
00091
00092     // Declare objects
00093     Filter baseFilter(dataBuffer, BUFFER_SIZE, F_BASEBAND);
00094     Gain gain(dataBuffer, BUFFER_SIZE, micGain);
00095     PlTone pltone(0.15, dataBuffer, BUFFER_SIZE, toneFreq, SAMPLING_RATE);
00096     Modulator modulator(dataBuffer, BUFFER_SIZE, type, 20000);
00097
00098     // SDR guts of the program
00099     while(true) {
00100         // get next samples
00101         read(STDIN_FILENO, &dataBuffer, BUFFER_BYTE_COUNT);
00102
00103         // process/modulate samples
00104         baseFilter.Pass();
00105 //      pltone.Add();
00106         gain.Apply();
00107         modulator.Mod();
00108         makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00109         to_sint32(iqBuffer, IQ_BUFFER_SIZE);
00110
00111         // write samples
00112         write(STDOUT_FILENO, &iqBuffer, IQ_BUFFER_BYTE_COUNT);
00113     }
00114 }
```

8.45 src/mic_test.cpp File Reference

Tests getting mic input via ALSA. May not even compile at the moment.

```
#include <cmath>
#include <climits>
#include <iostream>
#include <alsa/asoundlib.h>
#include "definitions.hpp"
```

Include dependency graph for mic_test.cpp:



Functions

- int main ()

8.45.1 Detailed Description

Tests getting mic input via ALSA. May not even compile at the moment.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file mic_test.cpp.

8.45.2 Function Documentation

8.45.2.1 int main ( )

This program tests taking information from the microphone via the ALSA API. Not sure if it works.

Definition at line 21 of file mic_test.cpp.

8.46 mic_test.cpp

```
00001
00008 #include <cmath>
00009 #include <climits>
00010 #include <iostream>
00011 #include <alsa/asoundlib.h>
00012
00013 #include "definitions.hpp"
00014
00015 using namespace std;
00016
00021 int main() {
00022     int ret;
00023
00024     snd_pcm_t* pcm_handle;  // device handle
00025 //  snd_pcm_stream_t stream = SND_PCM_STREAM_PLAYBACK;
00026     snd_pcm_stream_t stream = SND_PCM_STREAM_CAPTURE;
00027     snd_pcm_hw_params_t* hwparams;  // hardware information
00028     char* pcm_name = strdup("plughw:1,0");  // on-board audio jack
00029     //char* pcm_name = strdup("plughw:0,0");  // on-board audio jack
00030     int rate = 48000;
00031
```

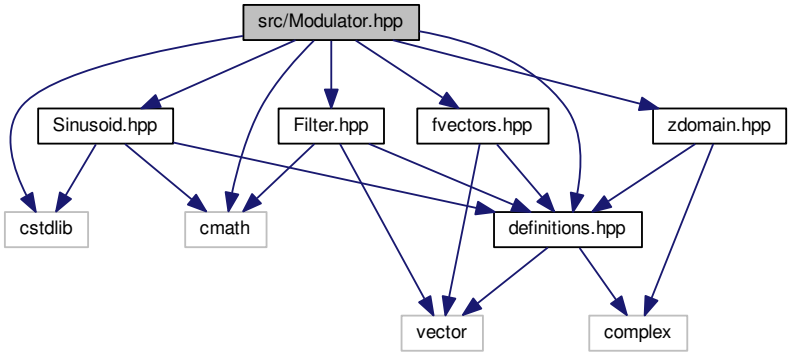
```
00032     const uint16 freq = 440;
00033     long unsigned int bufferSize = 8192*4;
00034     const uint32 len = bufferSize*100;
00035     const float32 arg = 2 * 3.141592 * freq / rate;
00036     sint16 vals[len];
00037
00038     float test;
00039     float last = 0;
00040     long unsigned int count = 0;
00041     int count2 = 0;
00042
00043     for(int i = 0; i < len; i = i + 2) {
00044         bool lastWas = abs(sin(last)) < 0.01;
00045
00046         last += arg;
00047         if(last > 2 * M_PI) last -= 2 * M_PI;
00048
00049         test = 32000 * sin(last);
00050
00051         if(abs(sin(last)) < 0.01 && lastWas) count++;
00052
00053         vals[i] = (sint16)(test + 0.5);
00054         vals[i+1] = vals[i];
00055     }
00056
00057     cout << "COUNT: " << count << endl;
00058     snd_pcm_hw_params_alloca(&hwparams);
00059
00060     ret = snd_pcm_open(&pcm_handle, pcm_name, stream, 0);
00061     cout << "Opening: " << snd_strerror(ret) << endl;
00062
00063     ret = snd_pcm_hw_params_any(pcm_handle, hwparams);
00064     cout << "Initializing hwparams structure: " << snd_strerror(ret) << endl;
00065
00066     ret = snd_pcm_hw_params_set_access(pcm_handle, hwparams,
00067             SND_PCM_ACCESS_RW_INTERLEAVED);
00068     cout << "Setting access: " << snd_strerror(ret) << endl;
00069
00070     ret = snd_pcm_hw_params_set_format(pcm_handle, hwparams,
00071             SND_PCM_FORMAT_S16_LE);
00072     cout << "Setting format: " << snd_strerror(ret) << endl;
00073
00074     ret = snd_pcm_hw_params_set_rate(pcm_handle, hwparams,
00075             rate, (int)0);
00076     cout << "Setting rate: " << snd_strerror(ret) << endl;
00077
00078     ret = snd_pcm_hw_params_set_channels(pcm_handle, hwparams, 2);
00079     cout << "Setting channels: " << snd_strerror(ret) << endl;
00080
00081     ret = snd_pcm_hw_params_set_periods(pcm_handle, hwparams, 2, 0);
00082     cout << "Setting periods: " << snd_strerror(ret) << endl;
00083
00084     ret = snd_pcm_hw_params_set_buffer_size_near(pcm_handle, hwparams,
00085             &bufferSize);
00086     cout << "Setting buffer size: " << snd_strerror(ret) << endl;
00087
00088     ret = snd_pcm_hw_params(pcm_handle, hwparams);
00089     cout << "Applying parameters: " << snd_strerror(ret) << endl;
00090
00091 /*  ret = snd_pcm_hw_params_get_period_size(hwparams, &count, &count2);
00092     cout << "Actual period size: " << count << endl;
00093     cout << "Returned: " << snd_strerror(ret) << endl;*/
00094
00095
00096
00097     cout << endl << endl;
00098
00099
00100     //const void* ptr = (const void*)&vals;
00101     void* ptr = (void*)&vals;
00102     int err;
00103
00104     for(int i = 0; i < 100; i++) {
00105         do {
00106             ret = snd_pcm_readi(pcm_handle,
00107                     ptr, bufferSize);
00108
00109             if(ret < 0) {
00110                 err = snd_pcm_prepare(pcm_handle);
00111                 cout << "Preparing: " << snd_strerror(err)
00112                     << endl;
00113             }
00114         } while(ret < 0);
00115
00116         cout << "Writing data: " << ret << endl;
00117     }
00118 }
```

8.47 src/Modulator.hpp File Reference

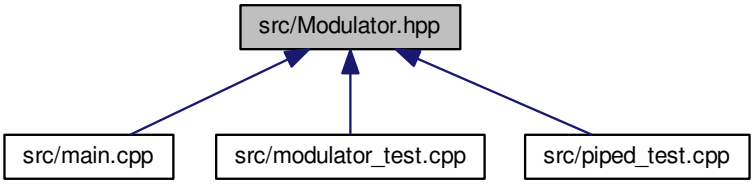
Contains the classes for the various types of modulation supported by the program.

```
#include <cmath>
#include <cstdlib>
#include "definitions.hpp"
#include "Filter.hpp"
#include "fvectors.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"
```

Include dependency graph for Modulator.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class radio::Modulator

Namespaces

- radio

Variables

- const uint32 radio::FREQ_INTERMEDIATE = 20000
- const uint32 radio::SAMPLING_RATE = 48000

8.47.1 Detailed Description

Contains the classes for the various types of modulation supported by the program.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Bug Both FM modulations don't work

Clicking on the filtered SSB

Definition in file Modulator.hpp.

8.48 Modulator.hpp

```
00001
00010 #ifndef modulation_H
00011 #define modulation_H
00012
00013 #include <cmath>
00014 #include <cstdlib>
00015
00016 #include "definitions.hpp"
00017 #include "Filter.hpp"
00018 #include "fvectors.hpp"
00019 #include "Sinusoid.hpp"
00020 #include "zdomain.hpp"
00021
00022 namespace radio {
00023
00027     const uint32 FREQ_INTERMEDIATE = 20000;
00028
00032     const uint32 SAMPLING_RATE = 48000;
00033
00037     class Modulator {
00038         public:
00052             Modulator(float32 data[], uint32 size,
      ModulationType type,
00053                       float32 freqInter = FREQ_INTERMEDIATE,
00054                       uint32 rate = SAMPLING_RATE);
00055
00059             ~Modulator();
00060
00064             void Mod();
00065
00066         private:
00071             float32* data;
00072
00076             float32 freqCarrier;
00077
00078
00082             float32* hilData = nullptr;
00083
00087             float32 rate;
00088
00092             uint32 size;
00093
00097             ModulationType type;
00098     };
00099
00100     Modulator::Modulator(float32 data[], uint32 size,
      ModulationType type,
00101             float32 freqInter, uint32 rate) {
00102         freqCarrier = freqInter;
00103         this->rate = rate;
00104         this->data = data;
00105         this->size = size;
00106         this->type = type;
```

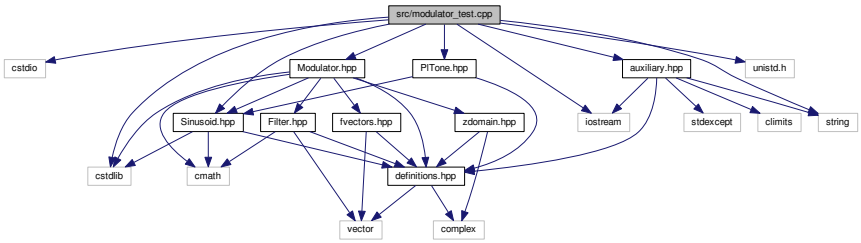
```
00107
00108         if(type == ModulationType::USB_HILBERT
00109                 || type == ModulationType::LSB_HILBERT) {
00110             hilData = (float32*)malloc(size*sizeof(float32));
00111         }
00112     }
00113
00114     Modulator::~Modulator() {
00115         if(hilData != nullptr) free(hilData);
00116     }
00117
00118     void Modulator::Mod() {
00119         // these variables should only ever be created once
00120         static float32 fmArg = 2 * M_PI * freqCarrier / (float32)rate;
00121         static float32 fmK = 2 * M_PI / rate;
00122         static float32 fmSum = 0;  // cummulative sum used in FM modulation
00123         static Filter lsbFilter(data, size, F_LOWERSIDEBAND);
00124         static Sinusoid sinusoid(freqCarrier, rate);  // IF carrier sinusoid
00125         static Filter usbFilter(data, size, F_UPPERSIDEBAND);
00126
00127         // take hilbert transform if necessary
00128         if(type == ModulationType::USB_HILBERT
00129                 || type == ModulationType::LSB_HILBERT) {
00130             hilbert(data, hilData, size);
00131         } else if(type == ModulationType::FM_NARROW) {
00132             fmK *= 2.5;
00133         } else if(type == ModulationType::FM_WIDE) {
00134             fmK *= 5;
00135         }
00136
00137         // perform main modulation
00138         for(uint32 i = 0; i < size; i++) {
00139             switch(type) {
00140                 case ModulationType::DSB_LC:
00141                     data[i] = ((data[i] + 1) * sinusoid.next()) / 2;
00142                     break;
00143
00144                 case ModulationType::DSB_SC:
00145                 case ModulationType::USB_FILTERED:
00146                 case ModulationType::LSB_FILTERED:
00147                     data[i] = data[i] * sinusoid.next();
00148                     break;
00149
00150                 case ModulationType::USB_HILBERT:
00151                     data[i] = data[i] * sinusoid.next()
00152                         - hilData[i] * sinusoid.nextShifted();
00153                     break;
00154
00155                 case ModulationType::LSB_HILBERT:
00156                     data[i] = data[i] * sinusoid.next()
00157                         + hilData[i] * sinusoid.nextShifted();
00158                     break;
00159
00160                 case ModulationType::FM_NARROW:
00161                 case ModulationType::FM_WIDE:
00162                     fmSum += fmK * data[i];
00163                     data[i] = cos(fmArg * i + fmSum);
00164                     break;
00165             }
00166         }
00167
00168         // filter out a sideband if using filtered SSB modulation
00169         if(type == ModulationType::LSB_FILTERED) {
00170             lsbFilter.Pass();
00171         } else if(type == ModulationType::USB_FILTERED) {
00172             usbFilter.Pass();
00173         }
00174     }
00175 }
00176
00177 #endif
```

8.49 src/modulator_test.cpp File Reference

Contains a test program to test the Modulator class.

```
#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <string>
#include <unistd.h>
#include "auxiliary.hpp"
#include "Modulator.hpp"
#include "Sinusoid.hpp"
#include "PlTone.hpp"
```

Include dependency graph for modulator_test.cpp:



Functions

- int main (int argc, char ∗argv[])

8.49.1 Detailed Description

Contains a test program to test the Modulator class.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Bug Filtered SSB clicking

Definition in file modulator_test.cpp.

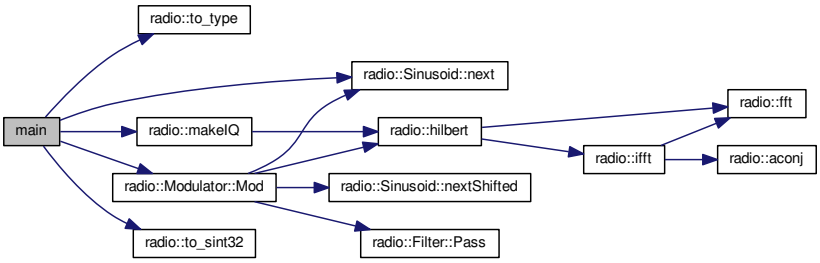
8.49.2 Function Documentation

8.49.2.1 int main (int *argc,* char ∗ *argv[]*)

Program to test the Modulator class.

Definition at line 25 of file modulator_test.cpp.

Here is the call graph for this function:



8.50 modulator_test.cpp

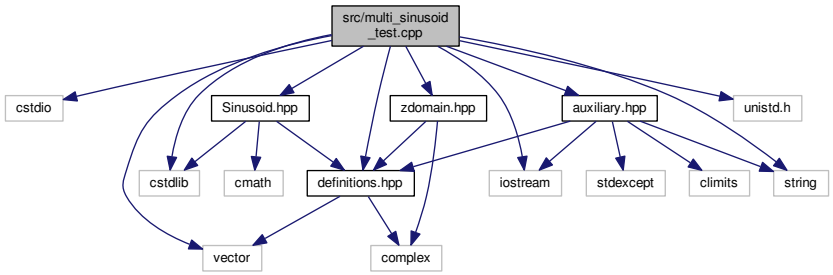
```
00001
00008 #include <cstdio>
00009 #include <cstdlib>
00010 #include <iostream>
00011 #include <string>
00012 #include <unistd.h>
00013
00014 #include "auxiliary.hpp"
00015 #include "Modulator.hpp"
00016 #include "Sinusoid.hpp"
00017 #include "PlTone.hpp"
00018
00019 using namespace std;
00020 using namespace radio;
00021
00025 int main(int argc, char* argv[]) {
00026
00027     // Constants
00028     const uint16 BUFFER_SIZE = 16384;
00029
00030     // Declare primative Variables
00031     float32 dataBuffer[BUFFER_SIZE];
00032     float32 iqBuffer[2 * BUFFER_SIZE];
00033     ModulationType type;
00034     float32 freq = atof(argv[2]);
00035     float32 tone = 0;
00036
00037     if(argc >= 4) tone = atof(argv[3]);
00038
00039     try{
00040         type = to_type(string(argv[1]));
00041     } catch(std::exception ex) {
00042         std::cerr << ex.what() << std::endl << std::endl;
00043         return ERROR;
00044     }
00045
00046     if(freq < 0) {
00047         cerr << "The given tone was invalid." << endl;
00048         return ERROR;
00049     }
00050
00051     // Declare objects
00052     Modulator modulator(dataBuffer, BUFFER_SIZE, type, 20000);
00053     Sinusoid sinusoid(freq);
00054     PlTone(tone > 0 ? 0.15 : 0, dataBuffer, BUFFER_SIZE, tone, 48000);
00055
00056     while(true) {
00057         for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00058             dataBuffer[i] = sinusoid.next();
00059         }
00060
00061         modulator.Mod();
00062         makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00063         to_sint32(iqBuffer, 2 * BUFFER_SIZE);
00064         write(STDOUT_FILENO, &iqBuffer,  2 * BUFFER_SIZE * sizeof(sint32));
00065     }
00066 }
```

8.51 src/multi_sinusoid_test.cpp File Reference

Contains a program to demonstrate the ability of the Sinusoid class and the sound card to generate sinusoids accross the spectrum.

```
#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <string>
#include <unistd.h>
#include <vector>
#include "auxiliary.hpp"
#include "definitions.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"
```

Include dependency graph for multi_sinusoid_test.cpp:



Functions

- int main (int argc, char ∗argv[])

8.51.1 Detailed Description

Contains a program to demonstrate the ability of the Sinusoid class and the sound card to generate sinusoids accross the spectrum.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file multi_sinusoid_test.cpp.

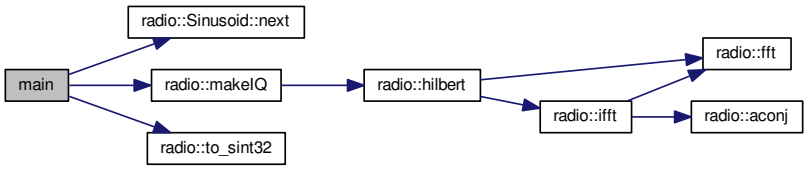
8.51.2 Function Documentation

8.51.2.1 int main (int *argc*, char ∗ *argv[]*)

Program to test the Sinusoid class and demonstrate the frequency range of the sound card.

Definition at line 27 of file multi_sinusoid_test.cpp.

Here is the call graph for this function:



8.52 multi_sinusoid_test.cpp

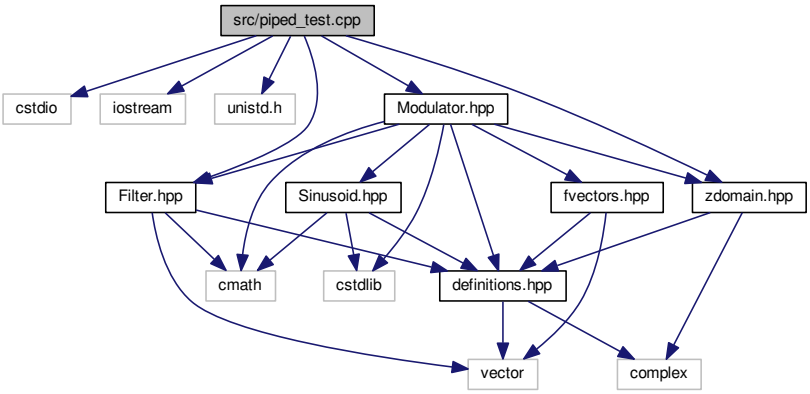
```
00001
00008 #include <cstdio>
00009 #include <cstdlib>
00010 #include <iostream>
00011 #include <string>
00012 #include <unistd.h>
00013 #include <vector>
00014
00015 #include "auxiliary.hpp"
00016 #include "definitions.hpp"
00017 #include "Sinusoid.hpp"
00018 #include "zdomain.hpp"
00019
00020 using namespace std;
00021 using namespace radio;
00022
00027 int main(int argc, char* argv[]) {
00028
00029     // Constants
00030     const uint16 BUFFER_SIZE = 48000;
00031
00032     // Declare primative Variables
00033     uint8 i = 0;
00034     uint8 size = 0;
00035     uint16 delta = 100;
00036     float32 dataBuffer[BUFFER_SIZE];
00037     float32 iqBuffer[2 * BUFFER_SIZE];
00038
00039     for(uint16 f = 100; f < 24000; f += delta, i++) {
00040         Sinusoid sinusoid(f);
00041
00042         for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00043             dataBuffer[i] += sinusoid.next();
00044         }
00045
00046         switch(f) {
00047             case 500:
00048                 delta = 1000;
00049                 f = 1000;
00050                 break;
00051
00052             case 2000:
00053                 delta = 2000;
00054                 break;
00055         }
00056     }
00057
00058     size = i;
00059
00060     for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00061         dataBuffer[i] /= size;
00062     }
00063
00064     makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00065     to_sint32(iqBuffer, 2 * BUFFER_SIZE);
00066
00067     while(true) {
00068         write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
00069     }
00070 }
```

8.53 src/piped_test.cpp File Reference

Contains the original program used to test the piping-in idea.

```
#include <cstdio>
#include <iostream>
#include <unistd.h>
#include "Filter.hpp"
#include "Modulator.hpp"
#include "zdomain.hpp"
```

Include dependency graph for piped_test.cpp:



Functions

- int main ()

8.53.1 Detailed Description

Contains the original program used to test the piping-in idea.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file piped_test.cpp.

8.53.2 Function Documentation

8.53.2.1 int main ( )

Program originally used to test whether baseband audio could be piped into the program in real time.

Definition at line 22 of file piped_test.cpp.

Here is the call graph for this function:

8.54 piped_test.cpp

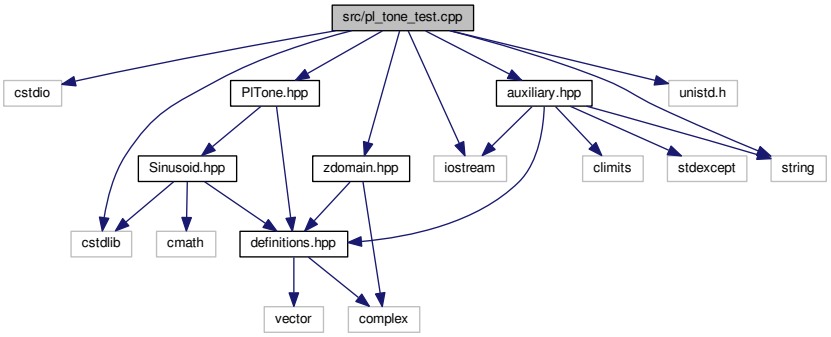
```
00001
00007 #include <cstdio>
00008 #include <iostream>
00009 #include <unistd.h>
00010
00011 #include "Filter.hpp"
00012 #include "Modulator.hpp"
00013 #include "zdomain.hpp"
00014
00015 using namespace std;
00016 using namespace lolz;
00017
00022 int main() {
00023     const uint16 len = 16384;
00024     float32 data[len];
00025     float32 iqData[2*len];
00026
00027     while(true) {
00028         read(STDIN_FILENO, &data, len * sizeof(float32));
00029         makeIQ(data, iqData, len);
00030         write(STDOUT_FILENO, &iqData,  2 * len * sizeof(float32));
00031     }
00032
00033 }
```

8.55 src/pl_tone_test.cpp File Reference

Contains a test program to test the PlTone class.

```
#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <string>
#include <unistd.h>
#include "auxiliary.hpp"
#include "PlTone.hpp"
#include "zdomain.hpp"
```

Include dependency graph for pl_tone_test.cpp:



Functions

- int main (int argc, char ∗argv[])

8.55.1 Detailed Description

Contains a test program to test the PlTone class.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file pl_tone_test.cpp.

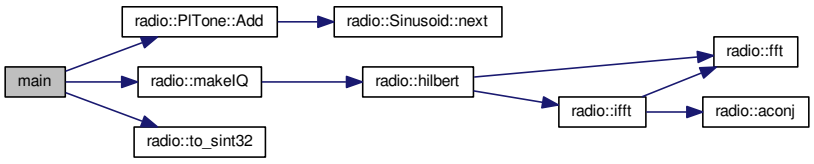
8.55.2 Function Documentation

8.55.2.1 int main (int *argc*, char ∗ *argv[]*)

Program to test the PlTone class.

Definition at line 23 of file pl_tone_test.cpp.

Here is the call graph for this function:



8.56 pl_tone_test.cpp

```
00001
```

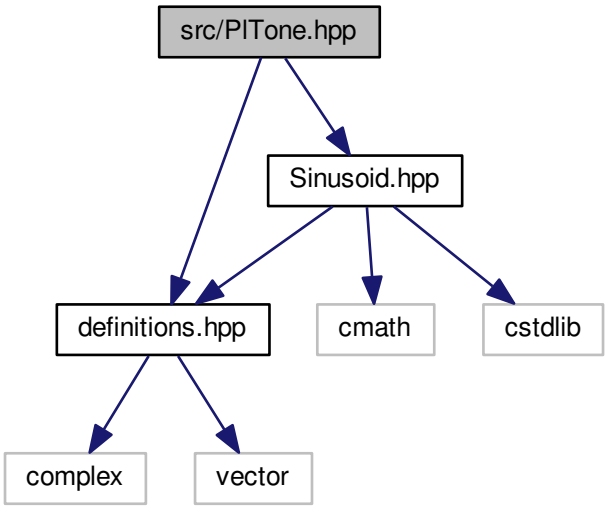
```
00007 #include <cstdio>
00008 #include <cstdlib>
00009 #include <iostream>
00010 #include <string>
00011 #include <unistd.h>
00012
00013 #include "auxiliary.hpp"
00014 #include "PlTone.hpp"
00015 #include "zdomain.hpp"
00016
00017 using namespace std;
00018 using namespace radio;
00019
00023 int main(int argc, char* argv[]) {
00024     // Constants
00025     const uint16 BUFFER_SIZE = 16384;
00026
00027     // Declare primative Variables
00028     float32 dataBuffer[BUFFER_SIZE];
00029     float32 iqBuffer[2 * BUFFER_SIZE];
00030     float32 freq = atof(argv[1]);
00031
00032     if(freq < 0) {
00033         cerr << "The given tone was invalid." << endl;
00034         return ERROR;
00035     }
00036
00037     PlTone tone(0.15, dataBuffer, BUFFER_SIZE, freq, 48000);
00038
00039     while(true) {
00040         for(uint16 i = 0; i < BUFFER_SIZE; i ++) {
00041             dataBuffer[i] = 1;
00042         }
00043
00044         tone.Add();
00045         makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00046         to_sint32(iqBuffer, 2 * BUFFER_SIZE);
00047         write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
00048     }
00049 }
```

8.57 src/PlTone.hpp File Reference

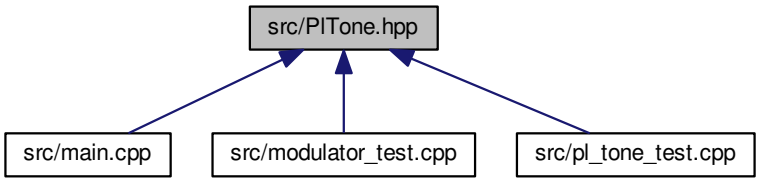
Contains the PlTone class.

```
#include "definitions.hpp"
#include "Sinusoid.hpp"
```

Include dependency graph for PlTone.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class radio::PlTone

Namespaces

- radio

8.57.1 Detailed Description

Contains the PlTone class.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file PlTone.hpp.

8.58 PlTone.hpp

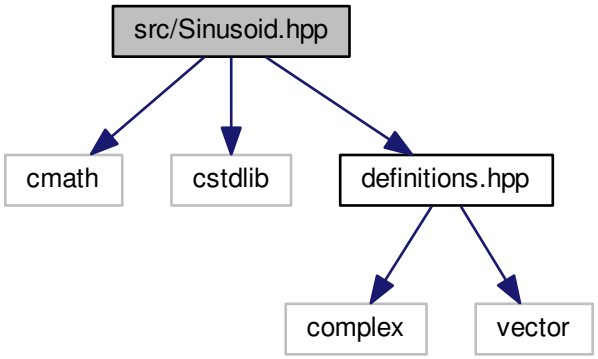
```
00001
00007 #ifndef PlTone_H
00008 #define PlTone_H
00009
00010 #include "definitions.hpp"
00011 #include "Sinusoid.hpp"
00012
00013 namespace radio {
00018     class PlTone : Sinusoid {
00019         public:
00037             PlTone(float32 amplitude, float32* data, uint32 size,
00038                     float32 frequency, uint32 samplingRate = 48000);
00039
00043             void Add();
00044
00045         private:
00050             float32 amplitude;
00051
00055             float32* data;
00056
00060             uint32 size;
00061     };
00062
00063     PlTone::PlTone(float32 amplitude, float32* data,
00064             uint32 size, float32 frequency, uint32 samplingRate)
00065         : Sinusoid(frequency, samplingRate) {
00066         this->data = data;
00067         this->amplitude = amplitude;
00068         this->size = size;
00069
00070         for(uint32 i = 0; i < samplingRate; i++) {
00071             sinusoid[i] *= amplitude;
00072         }
00073     }
00074
00075     void PlTone::Add() {
00076         for(uint32 i = 0; i < size; i++) {
00077             data[i] += amplitude * next();
00078             data[i] /= (1 + amplitude);  // ensures value <= 1
00079         }
00080     }
00081 }
00082
00083 #endif
```

8.59 src/Sinusoid.hpp File Reference

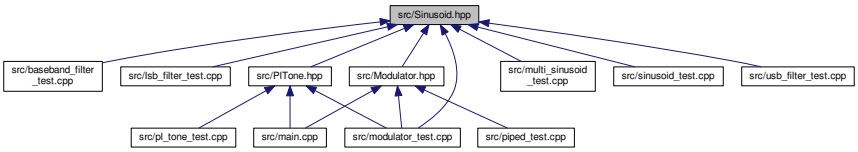
Contains the Sinusoid class.

```
#include <cmath>
#include <cstdlib>
#include "definitions.hpp"
```

Include dependency graph for Sinusoid.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class radio::Sinusoid

Namespaces

- radio

8.59.1 Detailed Description

Contains the Sinusoid class.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file Sinusoid.hpp.

8.60 Sinusoid.hpp

```
00001
00007 #ifndef Sinusoid_H
```

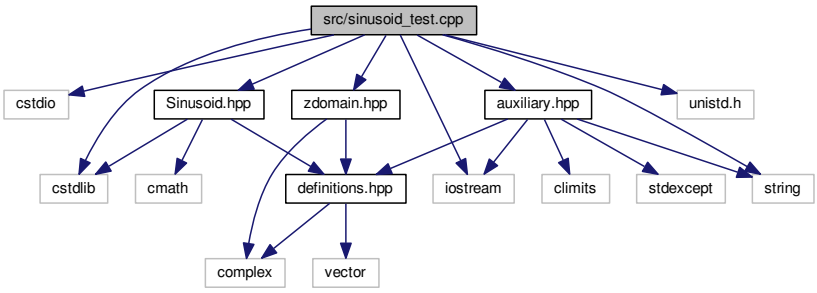
```
00008 #define Sinusoid_H
00009
00010 #include <cmath>
00011 #include <cstdlib>
00012
00013 #include "definitions.hpp"
00014
00015 namespace radio {
00021     class Sinusoid {
00022         public:
00026             Sinusoid(float32 frequency, uint32
      samplingRate = 48000);
00027
00031             ~Sinusoid();
00032
00037             float32 next();
00038
00043             float32 nextShifted();
00044
00045         protected:
00049             float32 frequency;
00050
00054             uint32 sinIndex = 0;
00055
00059             uint32 sinIndexShifted = 0;
00060
00064             uint32 samplingRate;
00065
00069             float32* sinusoid;
00070
00075             float32* sinusoidShift90;
00076     };
00077
00078     Sinusoid::Sinusoid(float32 frequency, uint32 samplingRate) {
00079         this->frequency = frequency;
00080         this->samplingRate = samplingRate;
00081         sinusoid = (float32*)std::malloc(samplingRate * sizeof(
      float32));
00082         sinusoidShift90 = (float32*)std::malloc(samplingRate * sizeof(
      float32));
00083
00084         float32 arg = 2 * M_PI * frequency / samplingRate;
00085
00086         for(uint32 i = 0; i < samplingRate; i++) {
00087             // cosine argument evaluates as float due to M_PI and frequency
00088             sinusoid[i] = cos(arg * i);
00089             sinusoidShift90[i] = sin(arg * i);
00090         }
00091     }
00092
00093     Sinusoid::~Sinusoid() {
00094         free(sinusoid);
00095         free(sinusoidShift90);
00096     }
00097
00098     float32 Sinusoid::next() {
00099         if(sinIndex >= samplingRate) sinIndex = 0;
00100         return sinusoid[sinIndex++];
00101     }
00102
00103     float32 Sinusoid::nextShifted() {
00104         if(sinIndexShifted >= samplingRate)
      sinIndexShifted = 0;
00105         return sinusoidShift90[sinIndexShifted++];
00106     }
00107 }
00108
00109 #endif
```

8.61 src/sinusoid_test.cpp File Reference

Contains a test program to test the Sinusoid class.

```
#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <string>
#include <unistd.h>
#include "auxiliary.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"
```

Include dependency graph for sinusoid_test.cpp:



Functions

- int main (int argc, char ∗argv[])

8.61.1 Detailed Description

Contains a test program to test the Sinusoid class.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file sinusoid_test.cpp.

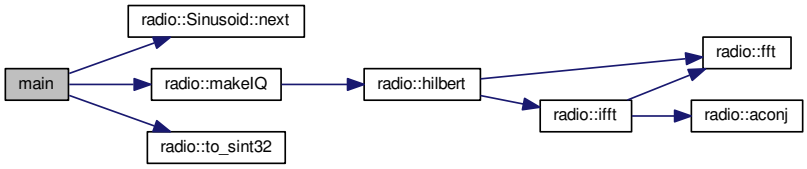
8.61.2 Function Documentation

8.61.2.1 int main (int *argc*, char ∗ *argv[]*)

Program to test the Sinusoid class.

Definition at line 23 of file sinusoid_test.cpp.

Here is the call graph for this function:



8.62 sinusoid_test.cpp

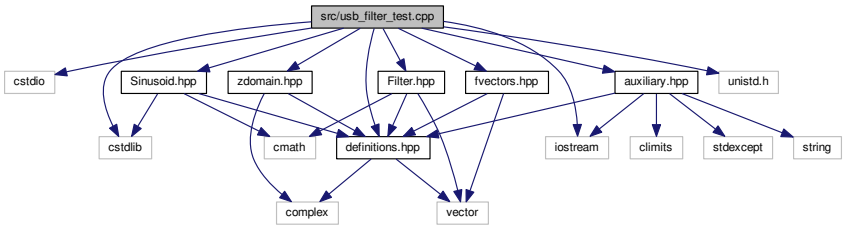
```
00001
00007 #include <cstdio>
00008 #include <cstdlib>
00009 #include <iostream>
00010 #include <string>
00011 #include <unistd.h>
00012
00013 #include "auxiliary.hpp"
00014 #include "Sinusoid.hpp"
00015 #include "zdomain.hpp"
00016
00017 using namespace std;
00018 using namespace radio;
00019
00023 int main(int argc, char* argv[]) {
00024
00025     // Constants
00026     const uint16 BUFFER_SIZE = 16384;
00027
00028     // Declare primative Variables
00029     float32 dataBuffer[BUFFER_SIZE];
00030     float32 iqBuffer[2 * BUFFER_SIZE];
00031     float32 freq = atof(argv[1]);
00032
00033     if(freq < 0) {
00034         cerr << "The given tone was invalid." << endl;
00035         return ERROR;
00036     }
00037
00038     Sinusoid sinusoid(freq, 48000);
00039
00040     while(true) {
00041         for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00042             dataBuffer[i] = sinusoid.next();
00043         }
00044
00045         makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00046         to_sint32(iqBuffer, 2 * BUFFER_SIZE);
00047         write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
00048     }
00049 }
```

8.63 src/usb_filter_test.cpp File Reference

Contains a program to demonstrate the the USB filter.

```
#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <unistd.h>
#include "auxiliary.hpp"
#include "definitions.hpp"
#include "Filter.hpp"
#include "fvectors.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"
```

Include dependency graph for usb_filter_test.cpp:



Functions

- int main (int argc, char ∗argv[])

8.63.1 Detailed Description

Contains a program to demonstrate the the USB filter.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Bug Clicking occurs at start of each filter pass

Definition in file usb_filter_test.cpp.

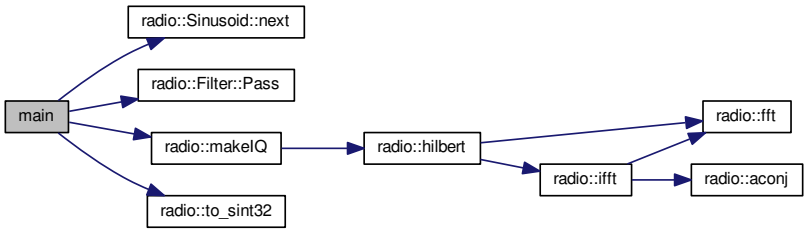
8.63.2 Function Documentation

8.63.2.1 int main (int *argc*, char ∗ *argv[]*)

Program to test the Filter class and the USB filter coefficients.

Definition at line 26 of file usb_filter_test.cpp.

Here is the call graph for this function:



8.64 usb_filter_test.cpp

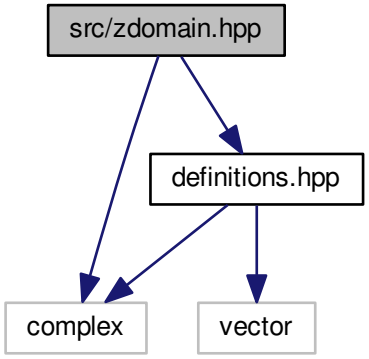
```
00001
00008 #include <cstdio>
00009 #include <cstdlib>
00010 #include <iostream>
00011 #include <unistd.h>
00012
00013 #include "auxiliary.hpp"
00014 #include "definitions.hpp"
00015 #include "Filter.hpp"
00016 #include "fvectors.hpp"
00017 #include "Sinusoid.hpp"
00018 #include "zdomain.hpp"
00019
00020 using namespace std;
00021 using namespace radio;
00022
00026 int main(int argc, char* argv[]) {
00027
00028     // Constants
00029     const uint16 BUFFER_SIZE = 48000;
00030
00031     // Declare primative Variables
00032     uint8 i = 0;
00033     uint8 size = 0;
00034     uint16 delta = 250;
00035     float32 dataBuffer[BUFFER_SIZE];
00036     float32 iqBuffer[2 * BUFFER_SIZE];
00037
00038     // create 1 sec of audio
00039     for(uint16 f = 17000; f <= 23000; f += delta, i++) {
00040         Sinusoid sinusoid(f);
00041
00042         for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00043             dataBuffer[i] += sinusoid.next();
00044         }
00045     }
00046
00047     size = i;
00048
00049     // adjust dataBuffer so values are between -1 and 1
00050     for(uint16 i = 0; i < BUFFER_SIZE; i++) {
00051         dataBuffer[i] /= size;
00052     }
00053
00054     Filter filter(dataBuffer, BUFFER_SIZE, F_UPPERSIDEBAND);
00055     filter.Pass();
00056     makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
00057     to_sint32(iqBuffer, 2 * BUFFER_SIZE);
00058
00059     while(true) {
00060         write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
00061     }
00062 }
```

8.65 src/zdomain.hpp File Reference

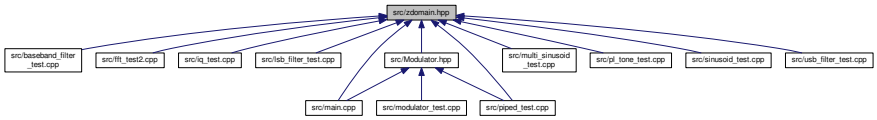
Contains the functions to manipulate sequential data in the frequency (z) domain.

```
#include <complex>
#include "definitions.hpp"
```

Include dependency graph for zdomain.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- radio

Functions

- void radio::aconj (cfloat32 *data, uint32 size)
- void radio::fft (cfloat32 *data, uint32 size)
- void radio::hilbert (float32 *data, float32 *dest, uint32 size)
- void radio::ifft (cfloat32 *data, uint32 size)
- void radio::makeIQ (float32 *data, float32 *dest, uint32 size)

8.65.1 Detailed Description

Contains the functions to manipulate sequential data in the frequency (z) domain.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file zdomain.hpp.

8.66 zdomain.hpp

```
00001
00008 #ifndef zdomain_H
00009 #define zdomain_H
00010
00011 #include <complex>
00012
00013 #include "definitions.hpp"
00014
00015 namespace radio {
00016
00026     void aconj(cfloat32* data, uint32 size);
00027
00039     void fft(cfloat32* data, uint32 size);
00040
00052     void hilbert(float32* data, float32* dest, uint32 size);
00053
00066     void ifft(cfloat32* data, uint32 size);
00067
00082     void makeIQ(float32* data, float32* dest, uint32 size);
00083
00084     void aconj(cfloat32* data, uint32 size) {
00085         for(int i = 0; i < size; i++) {
00086             data[i] = std::conj(data[i]);
00087         }
00088     }
00089
00090     void fft(cfloat32* data, uint32 size) {
00091         // DFT
00092         uint32 k = size;
00093         uint32 n;
00094         float32 thetaT = M_PI / size;
00095         cfloat32 phiT(cos(thetaT), sin(thetaT));
00096         cfloat32 T;
00097
00098         while(k > 1) {
00099             n = k;
00100             k >>= 1;
00101             phiT = phiT * phiT;
00102             T = 1.0L;
00103
00104             for(uint32 l = 0; l < k; l++) {
00105                 for(uint32 a = l; a < size; a += n) {
00106                     uint32 b = a + k;
00107                     cfloat32 t = data[a] -data[b];
00108                     data[a] +=data[b];
00109                     data[b] = t * T;
00110                 }
00111
00112                 T *= phiT;
00113             }
00114         }
00115
00116         // Decimate
00117         uint32 m = (uint32)log2(size);
00118
00119         for(uint32 a = 0; a < size; a++) {
00120             uint32 b = a;
00121
00122             // Reverse bits
00123             b = (((b & 0xaaaaaaaa) >> 1) | ((b & 0x55555555) << 1));
00124             b = (((b & 0xcccccccc) >> 2) | ((b & 0x33333333) << 2));
00125             b = (((b & 0xf0f0f0f0) >> 4) | ((b & 0x0f0f0f0f) << 4));
00126             b = (((b & 0xff00ff00) >> 8) | ((b & 0x00ff00ff) << 8));
00127             b = ((b >> 16) | (b << 16)) >> (32 - m);
00128
00129             if (b > a)
00130             {
00131                 cfloat32 t = data[a];
00132                 data[a] =data[b];
00133                 data[b] = t;
00134             }
00135         }
00136     }
00137
```

```
00138     void hilbert(float32* data, float32* dest, uint32 size) {
00139         cfloat32* temp = (cfloat32*)std::malloc(sizeof(cfloat32) * size);
00140 
00141         for(int i = 0; i < size; i++) {
00142             temp[i] = data[i];
00143         }
00144 
00145         fft(temp, size);
00146 
00147         for(int i = size/2; i < size; i++) {
00148             temp[i] = 0;
00149         }
00150 
00151         ifft(temp, size);
00152 
00153         for(int i = 0; i < size; i++) {
00154             // parentheses around temp prevent free() error
00155             dest[i] = -2 * (temp[i].imag());
00156         }
00157 
00158         free(temp);
00159     }
00160 
00161     void ifft(cfloat32* data, uint32 size) {
00162         aconj(data, size);
00163         fft(data, size);
00164         aconj(data, size);
00165 
00166         for(int i = 0; i < size; i++) {
00167             data[i] /= size;
00168         }
00169     }
00170 
00171     void makeIQ(float32* data, float32* dest, uint32 size) {
00172         float32 quadData[size];
00173         hilbert(data, quadData, size);
00174 
00175         for(int i = 0; i < 2 * size; i += 2) {
00176             dest[i] = quadData[i/2];
00177             dest[i+1] = data[i/2];
00178         }
00179     }
00180 }
00181 
00182 #endif
```

Index