An Inexpensive, Software-Defined IF Modulator

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6.1 radio Namespace Reference

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

Classes

- class Filter
- class Gain
- class Modulator
- class PlTone
- class Sinusoid

Enumerations

- 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

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

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

Author

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Bug both FM modulations don't work

clicking on the filtered SSB

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())

Enumerator

OLD

NEW

Definition at line 52 of file definitions.hpp.

```
00052 { OLD, NEW };
```

6.1.2.2 enum radio::Argument

Describes the arguments in argv. Never actually used.

Enumerator

FREQ

MODE

PL_TONE

Definition at line 62 of file definitions.hpp.

```
00062 { FREQ = 1, MODE, PL_TONE };
```

6.1.2.3 enum radio::Fractional

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

Enumerator

NUM

DEN

Definition at line 57 of file definitions.hpp.

```
00057 { NUM, DEN };
```

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 67 of file definitions.hpp.

```
00067                               { DSB_LC, DSB_SC, USB_FILTERED,
      USB_HILBERT,
00068         LSB_FILTERED, LSB_HILBERT, FM_NARROW,
      FM_WIDE };
```

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.

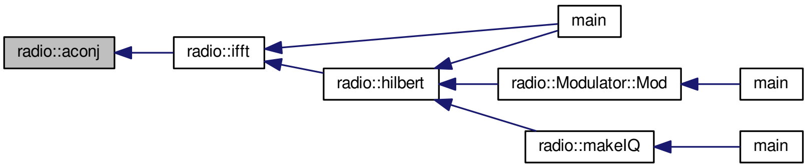
Parameters

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.

```
00084                                          {
00085         for(int i = 0; i < size; i++) {
00086             data[i] = std::conj(data[i]);
00087         }
00088     }
```

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.

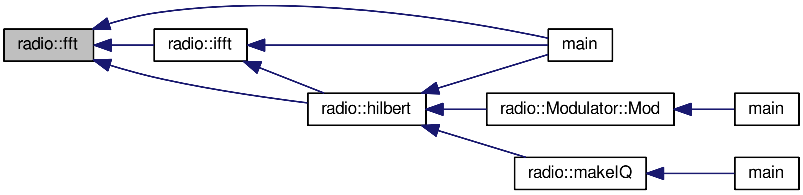
Parameters

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.

```
00090                                            {
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     }
```

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.

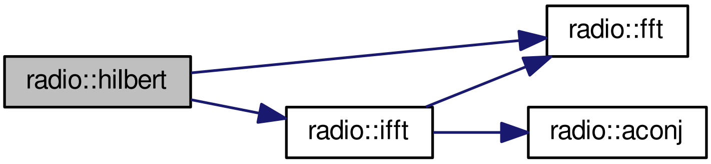
Parameters

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

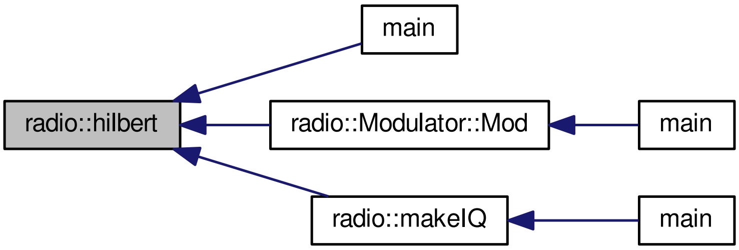
Definition at line 138 of file zdomain.hpp.

```
00138                                                             {
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     }
```

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.

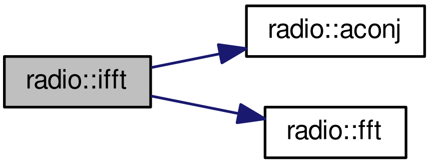
Parameters

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

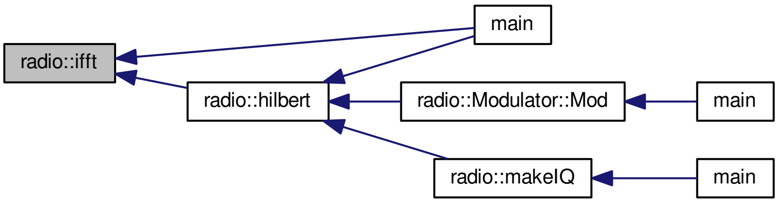
Definition at line 161 of file zdomain.hpp.

```
00161                                        {
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     }
```

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

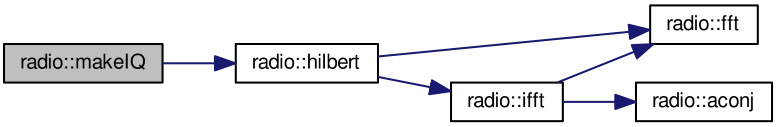
Parameters

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)

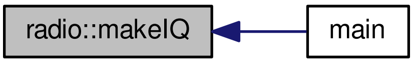
Definition at line 171 of file zdomain.hpp.

```
00171                                                           {
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     }
```

Here is the call graph for this function:



Here is the caller graph for this function:



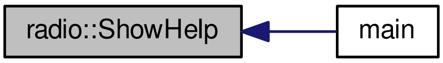
6.1.3.6 void radio::ShowHelp ( )

Displays the help information.

Definition at line 22 of file auxiliary.hpp.

```
00022                   {
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     }
```

Here is the caller graph for this function:



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

Converts float32 samples to sint32 samples. Rounds conversion to nearest integer.

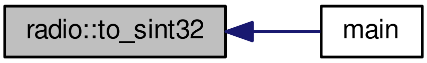
Parameters

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.

```
00062                                                {
00063         for(uint32 i = 0; i < size; i++) {
00064             ((sint32*)data)[i] = (sint32)(data[i] * INT_MAX + 0.5);
00065         }
00066     }
```

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 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

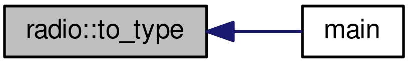
Returns

enum value of the type of modulation

Definition at line 80 of file auxiliary.hpp.

```
00080                                           {
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     }
```

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 19 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 38 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 69 of file fvectors.hpp.

6.1.4.4 const uint32 radio::FREQ_INTERMEDIATE = 20000

The default intermediate carrier frequency

Definition at line 28 of file Modulator.hpp.

6.1.4.5 const uint32 radio::SAMPLING_RATE = 48000

The default sampling rate (frequency)

Definition at line 33 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 already be 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 sequentially 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), 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 80 of file Filter.hpp.

```
00080                                                       {
00081         this->data = data;
00082         this->size = size;
00083         this->diffEq = diffEq;
00084         eqLength = this->diffEq[DEN].size();
00085     }
```

7.1.3 Member Function Documentation

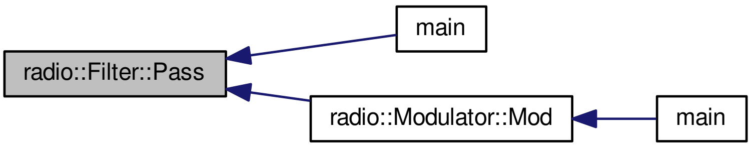
7.1.3.1 void radio::Filter::Pass ( )

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.

```
00087                       {
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     }
```

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 data array that should 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.

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

Applies a gain to 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.

```
00061                                                          {
00062         this->data = data;
00063         this->size = size;
00064         gainCoeff = pow(10, gaindB / 20);
00065     }
```

7.2.3 Member Function Documentation

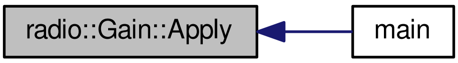
7.2.3.1 void radio::Gain::Apply ( )

Applies the gain to the signal contained in the data array

Definition at line 67 of file Gain.hpp.

```
00067                     {
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     }
```

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, while not intended to be called directly, is a superclass for the classes of the modulation forms used in this project.

Definition at line 39 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. Intended to be called only by subclasses.

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 data
type	form of modulation to use

Definition at line 103 of file Modulator.hpp.

```
00104                                             {
00105         freqCarrier = freqInter;
00106         this->rate = rate;
00107         this->data = data;
00108         this->size = size;
00109         this->type = type;
00110 
00111         if(type == ModulationType::USB_HILBERT
00112                 || type == ModulationType::LSB_HILBERT) {
00113             hilData = (float32*)malloc(size*sizeof(float32));
00114         }
00115     }
```

7.3.2.2 radio::Modulator::∼Modulator ( )

Definition at line 117 of file Modulator.hpp.

```
00117                           {
00118         if(hilData != nullptr) free(hilData);
00119     }
```

7.3.3 Member Function Documentation

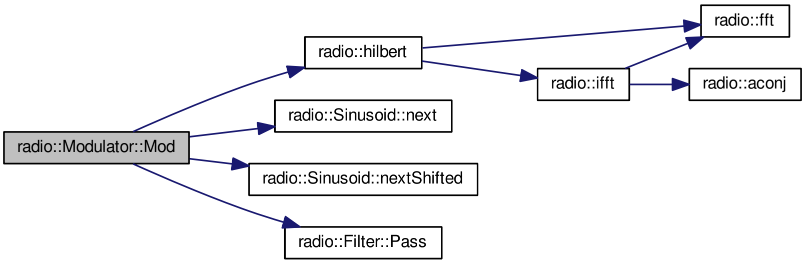
7.3.3.1 void radio::Modulator::Mod ( )

Modulates the audio currently in the data array.

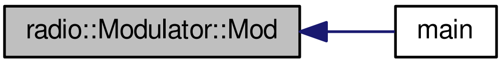
Definition at line 121 of file Modulator.hpp.

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

Here is the call graph for this function:



Here is the caller graph for this function:



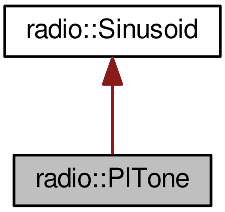
The documentation for this class was generated from the following file:

- src/Modulator.hpp

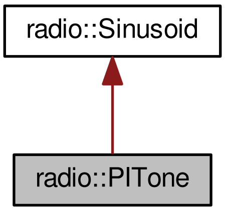
7.4 radio::PlTone Class Reference

```
#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)
- void Add ()

7.4.1 Detailed Description

This class creates a CTCSS subcarrier (PL 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*)

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.

```
        : Sinusoid(frequency, samplingRate) {
        this->data = data;
        this->amplitude = amplitude;
        this->size = size;

        for(uint32 i = 0; i < samplingRate; i++) {
            sinusoid[i] *= amplitude;
        }
    }
```

7.4.3 Member Function Documentation

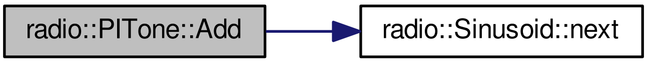
7.4.3.1 void radio::PITone::Add ( )

Adds the CTCSS tone to the baseband signal.

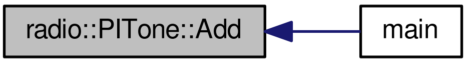
Definition at line 75 of file PITone.hpp.

```
00075                 {
00076         for(uint32 i = 0; i < size; i++) {
00077             data[i] += amplitude * next();
00078             data[i] /= (1 + amplitude);  // ensures value <= 1
00079         }
00080     }
```

Here is the call graph for this function:



Here is the caller graph for this function:



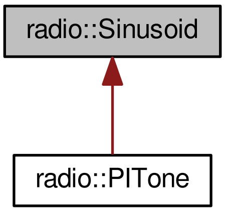
The documentation for this class was generated from the following file:

- src/PITone.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 sinusoid that will preserve its phase throughout its lifespan. Essentially, it is a ring buffer.

Definition at line 20 of file Sinusoid.hpp.

7.5.2 Constructor & Destructor Documentation

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

Creates a ring-buffer sinusoid.

Definition at line 77 of file Sinusoid.hpp.

```
00077                                                             {
00078         this->frequency = frequency;
00079         this->samplingRate = samplingRate;
00080         sinusoid = (float32*)std::malloc(samplingRate * sizeof(
      float32));
00081         sinusoidShift90 = (float32*)std::malloc(
      samplingRate * sizeof(float32));
00082 
00083         float32 arg = 2 * M_PI * frequency / samplingRate;
00084 
00085         for(uint32 i = 0; i < samplingRate; i++) {
00086             // cosine argument evaluates as float due to M_PI and frequency
00087             sinusoid[i] = cos(arg * i);
00088             sinusoidShift90[i] = sin(arg * i);
00089         }
00090     }
```

7.5.2.2 radio::Sinusoid::∼Sinusoid ( )

Free arrays malloc'd in the constructor.

Definition at line 92 of file Sinusoid.hpp.

```
00092                         {
00093         free(sinusoid);
00094         free(sinusoidShift90);
00095     }
```

7.5.3 Member Function Documentation

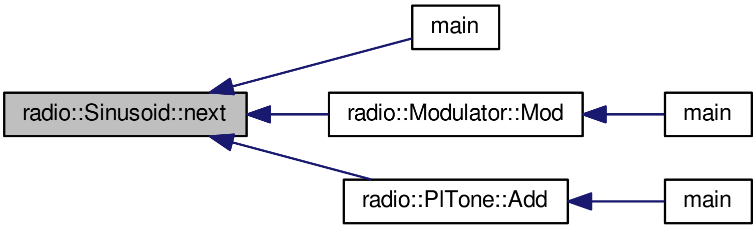
7.5.3.1 float32 radio::Sinusoid::next ( )

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

Definition at line 97 of file Sinusoid.hpp.

```
00097                             {
00098         if(sinIndex >= samplingRate) sinIndex = 0;
00099         return sinusoid[sinIndex++];
00100     }
```

Here is the caller graph for this function:



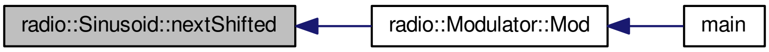
7.5.3.2 float32 radio::Sinusoid::nextShifted ( )

Provides the next value of the sinusoid shifted 90 degrees in a manner consistant with a ring buffer.

Definition at line 102 of file Sinusoid.hpp.

```
00102                                    {
00103         if(sinIndexShifted >= samplingRate)
      sinIndexShifted = 0;
00104         return sinusoidShift90[sinIndexShifted++];
00105     }
```

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 48 of file Sinusoid.hpp.

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

The sampling rate

Definition at line 63 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 53 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 58 of file Sinusoid.hpp.

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

Initialized as an array of the sinusoid values

Definition at line 68 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 74 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

```
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

```
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

```
OPTIONS="-c 2 -r 48000 -t raw -f S32_LE -q"
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

```
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

```
OPTIONS="-c 2 -r 48000 -t raw -f S32_LE"
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

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

```
OPTIONS="-c 2 -r 48000 -t raw -f S32_LE"
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

```
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

```
PROJECT_NAME = "An Inexpensive, Software-Defined IF Modulator"

INPUT = makefile src/ etc/doxygen.config bin/bbftest bin/modtest bin/msintest bin/lsbftest bin/pltest bin/radio bin/sintest bin/usbftest
OUTPUT_DIRECTORY = doc/

GENERATE_HTML = YES
GENERATE_RTF = YES
```

```
GENERATE_LATEX = YES
GENERATE_MAN = YES
GENERATE_XML = NO
GENERATE_DOCBOOK = NO

USE_PDF_LATEX = YES
USE_PDF_HYPERLINKS = YES

RECURSIVE = YES
SOURCE_BROWSER = YES
SOURCE_TOOLTIPS = YES
EXTRACT_ALL = YES
#USE_MDFILE_AS_MAINPAGE = README.md
LATEX_SOURCE_CODE = YES
STRIP_CODE_COMMENTS = YES
INLINE_SOURCES = YES
DISABLE_INDEX = NO
GENERATE_TREEVIEW = YES
SEARCHENGINE = YES
SERVER_BASED_SEARCH = NO

HAVE_DOT = YES
CALL_GRAPH = YES
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

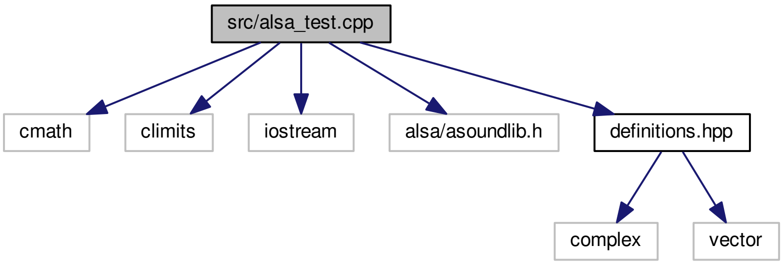
```
GCC = g++ -g -std=gnu++14

alsa-test:
   $(GCC) src/alsa_test.cpp -o bin/alsatest -O0 -lasound

baseband-filter-test:
   $(GCC) src/baseband_filter_test.cpp -o bin/basebandfiltertest

count:
   grep -r "src/" -e "Samuel Andrew Wisner" -l | xargs wc -l

docs:
   rm -r doc/
   doxygen etc/doxygen.config
   cd doc/latex; make pdf;
   git reset
   git add doc/.
   git --no-pager log > etc/log.txt
   git add etc/log.txt
   git commit -m "Updated documentation."
   git push

fft-test:
   $(GCC) src/fft_test.cpp -o bin/fft-test

fft-test2:
   $(GCC) src/fft_test2.cpp -o bin/fft-test2

iq-test:
   $(GCC) src/iq_test.cpp -o bin/iqtest

multi-sinusoid-test:
   $(GCC) src/multi_sinusoid_test.cpp -o bin/multisinusoidtest

modulator-test:
   $(GCC) src/modulator_test.cpp -o bin/modulatortest

lsb-filter-test:
   $(GCC) src/lsb_filter_test.cpp -o bin/lowersidebandftest

pl-tone-test:
   $(GCC) src/pl_tone_test.cpp -o bin/pltonetest

radio:
   $(GCC) src/main.cpp -o bin/sdr

sinusoid-test:
   $(GCC) src/sinusoid_test.cpp -o bin/sinusoidtest

usb-filter-test:
   $(GCC) src/usb_filter_test.cpp -o bin/uppersidebandftest


```

8.21 src/alsa_test.cpp File Reference

Tests sinusoidal tone generation.

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

Include dependency graph for alsa_test.cpp:



Functions

- int main ()

8.21.1 Detailed Description

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 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.

```
00022         {
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 
```

```
    for(int i = 0; i < 100; i++) {
        do {
            ret = snd_pcm_writei(pcm_handle,
                    ptr[i], count);

            if(ret < 0) {
                err = snd_pcm_prepare(pcm_handle);
                cout << "Preparing: " << snd_strerror(err)
                    << endl;
            }
        } while(ret < 0);

        cout << "Writing data: " << ret << endl;
    }
}
```

8.22 alsa_test.cpp

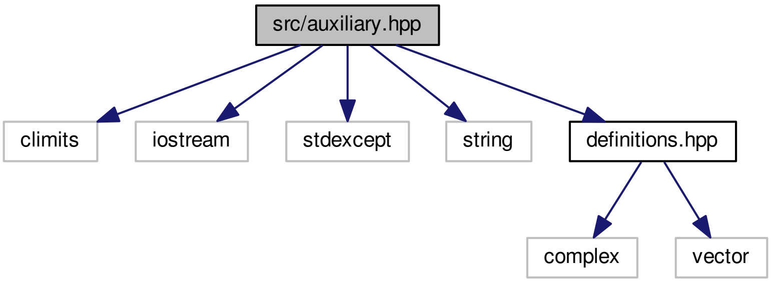
```

#include <cmath>
#include <climits>
#include <iostream>
#include <alsa/asoundlib.h>

#include "definitions.hpp"

using namespace std;

int main() {
    int ret;

    snd_pcm_t* pcm_handle;  // device handle
    snd_pcm_stream_t stream = SND_PCM_STREAM_PLAYBACK;
    snd_pcm_hw_params_t* hwparams;  // hardware information
    char* pcm_name = strdup("plughw:1,0");  // on-board audio jack
    int rate = 48000;

    const uint16 freq = 440;
    long unsigned int bufferSize = 4096*4;  // anything >8192 causes seg fault
    const uint32 len = bufferSize*100;
    const float32 arg = 2 * 3.141592 * freq / rate;
    sint16 vals[len];

    long unsigned int count = 0;

    for(uint32 i = 0; i < len; i = i + 2) {
        vals[i] = (sint16)(SHRT_MAX * cos(arg * i/2) + 0.5);
        vals[i+1] = vals[i];
    }

    ret = snd_pcm_open(&pcm_handle, pcm_name, stream, 0);
    cout << "Opening: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_any(pcm_handle, hwparams);
    cout << "Initializing hwparams structure: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_access(pcm_handle, hwparams,
            SND_PCM_ACCESS_RW_INTERLEAVED);
    cout << "Setting access: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_format(pcm_handle, hwparams,
            SND_PCM_FORMAT_S16_LE);
    cout << "Setting format: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_rate(pcm_handle, hwparams,
            rate, (int)0);
    cout << "Setting rate: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_channels(pcm_handle, hwparams, 2);
    cout << "Setting channels: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_periods(pcm_handle, hwparams, 2, 0);
    cout << "Setting periods: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_buffer_size_near(pcm_handle, hwparams,
            &bufferSize);
    cout << "Setting buffer size: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params(pcm_handle, hwparams);
    cout << "Applying parameters: " << snd_strerror(ret) << endl;

//  ret = snd_pcm_hw_params_get_period_size(hwparams, &count, 0);
    cout << "Actual period size: " << count << endl;
    cout << "Returned: " << snd_strerror(ret) << endl;



    cout << endl << endl;


    const void* ptr[100];

    for(int i = 0; i < 100; i++) {
        ptr[i] = (const void*)&vals + bufferSize*i;
    }

    int err;

    for(int i = 0; i < 100; i++) {
        do {
            ret = snd_pcm_writei(pcm_handle,
                    ptr[i], count);

            if(ret < 0) {
                err = snd_pcm_prepare(pcm_handle);
                cout << "Preparing: " << snd_strerror(err)
                    << endl;
            }
        } while(ret < 0);

        cout << "Writing data: " << ret << endl;
    }
}
```

8.23 src/auxiliary.hpp File Reference

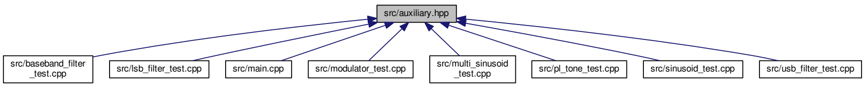
Contains helper-functions for main().

```
#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

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

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

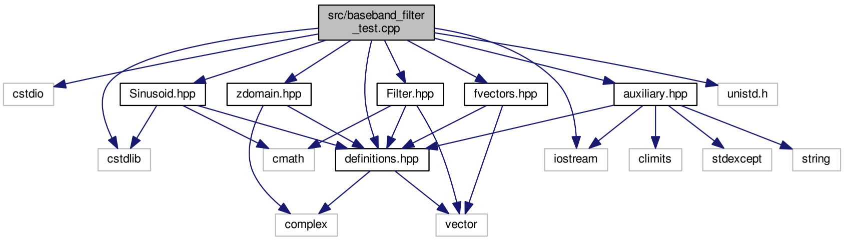
```

#ifndef auxiliary_H
#define auxiliary_H

#include <climits>
#include <iostream>
#include <stdexcept>
#include <string>

#include "definitions.hpp"

namespace radio {

    void ShowHelp() {
        std::cerr << std::endl << "Usage: radio [MODE] [MIC GAIN] "
            "[PL TONE]" << std::endl << std::endl
            << "MODE: one of the following types "
            "of modulation" << std::endl << std::endl;

        std::cerr << "dsblc\t\tDouble sideband, large carrier" << std::endl
            << "am\t\tAlias for dsblc" << std::endl
            << "dsbsc\t\tDouble sideband, suppressed carrier" << std::endl
            << "lsbhil\t\tLower sideband created via Hilbert transform"
            << std::endl
            << "lsbfilt\t\tLower sideband created via digital low-pass filter"
            << std::endl
            << "usbhil\t\tUpper sideband created via Hilbert transform"
            << std::endl
            << "usbfilt\t\tUpper sideband created via digital high-pass filter"
            << std::endl
//          << "nfm\t\tFrequency modulation, 2.5 kHz bandwidth"
            << std::endl;
//          << "wfm\t\tFrequency modulation, 5 kHz bandwidth" << std::endl
//          << "fm\t\talias for wfm" << std::endl << std::endl;

        std::cerr << "MIC GAIN: Microphone power gain expressed in decibels"
        << std::endl << std::endl;

        std::cerr << "PL TONE: Optional specification for CTCSS tone from "
            "60-260 Hz" << std::endl << std::endl;

        std::exit(ERROR);
    }

    void to_sint32(float32* data, uint32 size) {
        for(uint32 i = 0; i < size; i++) {
            ((sint32*)data)[i] = (sint32)(data[i] * INT_MAX + 0.5);
        }
    }

    ModulationType to_type(std::string str) {
        ModulationType type;

        if(str == "dsblc" || str == "am") {
            type = ModulationType::DSB_LC;
        } else if(str == "dsbsc") {
            type = ModulationType::DSB_SC;
        } else if(str == "lsbhil") {
            type = ModulationType::LSB_HILBERT;
        } else if(str == "lsbfilt") {
            type = ModulationType::LSB_FILTERED;
        } else if(str == "usbhil") {
            type = ModulationType::USB_HILBERT;
        } else if(str == "usbfilt") {
            type = ModulationType::USB_FILTERED;
        } else if(str == "wfm" || str == "fm") {
            type = ModulationType::FM_NARROW;
        } else if(str == "nfm") {
            type = ModulationType::FM_WIDE;
        } else {
            throw std::logic_error("The given modulation type is invalid!");
        }

        return type;
    }
}

#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

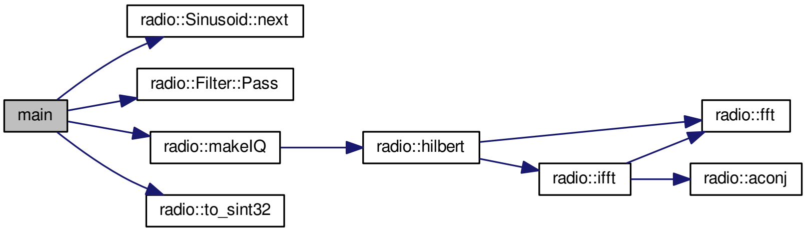
8.25.2.1 int main (int *argc,* char ∗ *argv[]*)

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

Definition at line 25 of file baseband_filter_test.cpp.

```
00025                                     {
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 }
```

Here is the call graph for this function:



8.26 baseband_filter_test.cpp

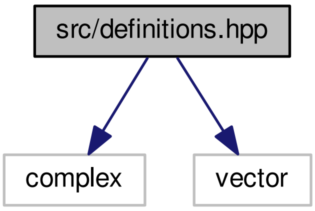
```

#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"

using namespace std;
using namespace radio;

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

    // Constants
    const uint16 BUFFER_SIZE = 48000;

    // Declare primative Variables
    uint8 i = 0;
    uint8 size = 0;
    uint16 delta = 250;
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];

    // create 1 sec of audio
    for(uint16 f = delta; f <= 3000; f += delta, i++) {
        Sinusoid sinusoid(f);

        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] += sinusoid.next();
        }
    }

    size = i;

    // adjust dataBuffer so values are between -1 and 1
    for(uint16 i = 0; i < BUFFER_SIZE; i++) {
        dataBuffer[i] /= size;
    }

    Filter filter(dataBuffer, BUFFER_SIZE, F_BASEBAND);
    filter.Pass();
    makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
    to_sint32(iqBuffer, 2 * BUFFER_SIZE);

    while(true) {
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

8.27 src/definitions.hpp File Reference

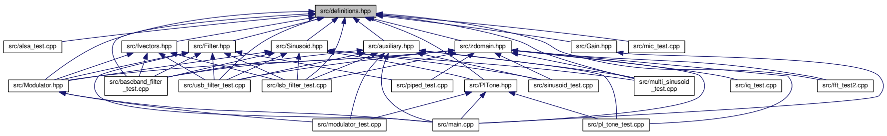
Contains declarations of system-independant (universal size) integers and float types, shortened type names for some commonly used types, and enumerations.

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

Include dependency graph for definitions.hpp:



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



Namespaces

- radio

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

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::F↩
  M_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

Definition at line 15 of file definitions.hpp.

8.27.2.2 #define ERROR -1

Definition at line 16 of file definitions.hpp.

8.27.3 Typedef Documentation

8.27.3.1 typedef unsigned char byte

Definition at line 18 of file definitions.hpp.

8.27.3.2 typedef std::complex<float32> cfloat32

Defines a type for complex float32's.

Definition at line 37 of file definitions.hpp.

8.27.3.3 typedef float float32

Definition at line 31 of file definitions.hpp.

8.27.3.4 typedef double float64

Definition at line 32 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 42 of file definitions.hpp.

8.27.3.6 typedef signed short sint16

Definition at line 23 of file definitions.hpp.

8.27.3.7 typedef signed int sint32

Definition at line 26 of file definitions.hpp.

8.27.3.8 typedef signed long long sint64

Definition at line 29 of file definitions.hpp.

8.27.3.9 typedef signed char sint8

Definition at line 20 of file definitions.hpp.

8.27.3.10 typedef unsigned short uint16

Definition at line 22 of file definitions.hpp.

8.27.3.11 typedef unsigned int uint32

Definition at line 25 of file definitions.hpp.

8.27.3.12 typedef unsigned long long uint64

Definition at line 28 of file definitions.hpp.

8.27.3.13 typedef unsigned char uint8

Definition at line 19 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
00015 #define ENUM signed char
00016 #define ERROR -1
00017
00018 typedef unsigned char byte;
00019 typedef unsigned char uint8;
00020 typedef signed char sint8;
00021
00022 typedef unsigned short uint16;
00023 typedef signed short sint16;
```

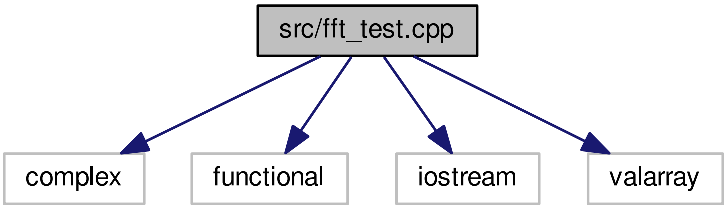
```

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;

namespace radio {
    enum Age { OLD, NEW };

    enum Fractional { NUM, DEN };

    enum Argument { FREQ = 1, MODE, PL_TONE };

    enum class ModulationType { DSB_LC, DSB_SC, USB_FILTERED, USB_HILBERT,
          LSB_FILTERED, LSB_HILBERT, FM_NARROW, FM_WIDE };
}

#endif

// Doxygen descriptions for non-code files

```

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 = 3.141592653589793238460

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*)

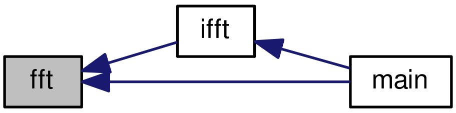
This code was taken from http://rosettacode.org/wiki/Fast_Fourier_transform#C.2B.2B.

Definition at line 23 of file fft_test.cpp.

```
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 }
```

Here is the caller graph for this function:

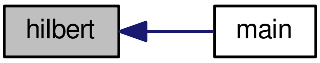


8.29.3.2 std::complex<double> hilbert (std::complex< double > *n*)

Definition at line 87 of file fft_test.cpp.

```
00087                                                  {
00088     return std::complex<double>(-2 * n.imag(), 0);
00089 }
```

Here is the caller graph for this function:

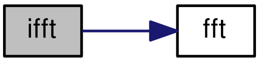


8.29.3.3 void ifft (CArray & *x*)

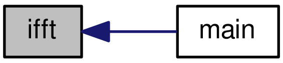
Definition at line 72 of file fft_test.cpp.

```
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 }
```

Here is the call graph for this function:



Here is the caller graph for this function:

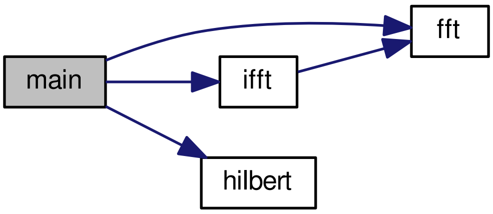


8.29.3.4 int main ( )

Definition at line 91 of file fft_test.cpp.

```
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 }
```

Here is the call graph for this function:



8.29.4 Variable Documentation

8.29.4.1 const double PI = 3.141592653589793238460

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 = 3.141592653589793238460;
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));
```

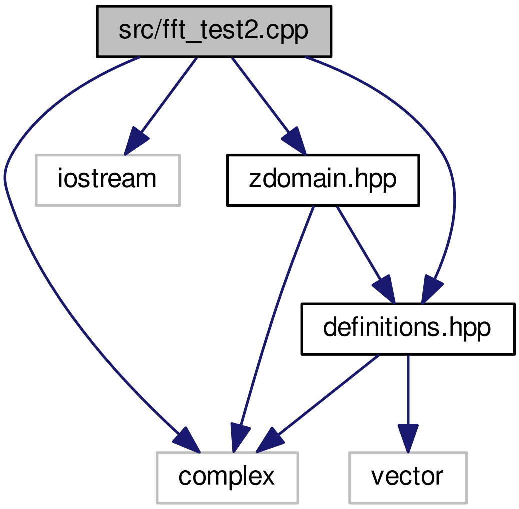
```
        b = ((b >> 16) | (b << 16)) >> (32 - m);
        if (b > a)
        {
            std::complex<double> t = x[a];
            x[a] = x[b];
            x[b] = t;
        }
    }
    //std::complex<double> f = 1.0 / sqrt(N);
    //for (unsigned int i = 0; i < N; i++)
    //  x[i] *= f;
}

// inverse fft (in-place)
void ifft(CArray& x)
{
    // conjugate the complex numbers
    x = x.apply(std::conj);

    // forward fft
    fft( x );

    // conjugate the complex numbers again
    x = x.apply(std::conj);

    // scale the numbers
    x /= x.size();
}

std::complex<double> hilbert(std::complex<double> n) {
    return std::complex<double>(-2 * n.imag(), 0);
}

int main()
{
    const std::complex<double> test[] = { 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16 };
    CArray data(test, 16);

    // forward fft
    fft(data);

    std::cout << "fft" << std::endl;
    for (int i = 0; i < 16; ++i)
    {
    //  std::cout << data[i] << std::endl;
    }

    for(int i = 8; i < 16; i++) {
        data[i] = 0;
    }

    // inverse fft
    ifft(data);
    std::cout << std::endl << "ifft" << std::endl;

    for (int i = 0; i < 16; ++i)
    {
    //  std::cout << data[i] << std::endl;
    }

    data = data.apply(hilbert);

    std::cout << std::endl;

    for(int i = 0; i < 16; i++) {
        std::cout << data[i].real() << std::endl;
    }

    return 0;
}
```

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 ( )

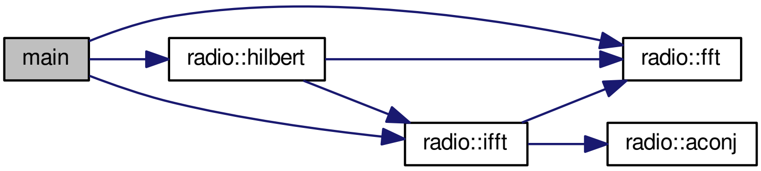
This program tests the fft(), ifft(), and hilbert() functions in the zdomain.hpp file.

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.

```
{
    std::complex<float32> test[] = { 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16 };
    float32 ftest[16];
    float32 dest[16];

    for(int i = 0; i < 16; i++) {
        ftest[i] = test[i].real();
    }

    // forward fft
    fft(test, 16);

    std::cout << "fft" << std::endl;

    for (int i = 0; i < 16; ++i)
    {
    //  std::cout << test[i] << std::endl;
    }

    // inverse fft
    ifft(test, 16);
    std::cout << std::endl << "ifft" << std::endl;

    for (int i = 0; i < 16; ++i)
    {
        std::cout << test[i] << std::endl;
    }

    hilbert(ftest, dest, 16);
    std::cout << std::endl << "hilbert" << std::endl;

    for(int i = 0; i < 16; i++) {
        std::cout << dest[i] << std::endl;
    }

    return 0;
}
```

Here is the call graph for this function:



8.32 fft_test2.cpp

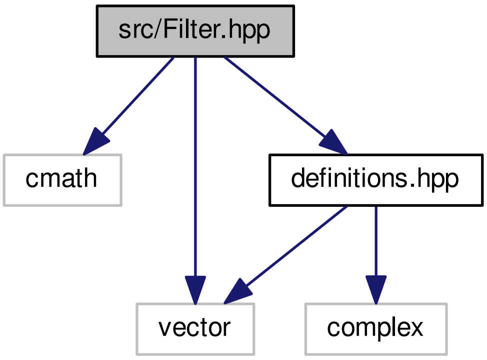
```

#include <complex>
#include <iostream>

#include "definitions.hpp"
#include "zdomain.hpp"

using namespace radio;

int main()
{
    std::complex<float32> test[] = { 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16 };
    float32 ftest[16];
    float32 dest[16];

    for(int i = 0; i < 16; i++) {
        ftest[i] = test[i].real();
    }

    // forward fft
    fft(test, 16);

    std::cout << "fft" << std::endl;

    for (int i = 0; i < 16; ++i)
    {
    //  std::cout << test[i] << std::endl;
    }

    // inverse fft
    ifft(test, 16);
    std::cout << std::endl << "ifft" << std::endl;

    for (int i = 0; i < 16; ++i)
    {
        std::cout << test[i] << std::endl;
    }

    hilbert(ftest, dest, 16);
    std::cout << std::endl << "hilbert" << std::endl;

    for(int i = 0; i < 16; i++) {
        std::cout << dest[i] << std::endl;
    }

    return 0;
}
```

8.33 src/Filter.hpp File Reference

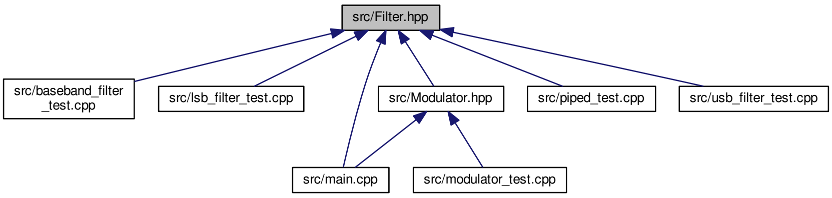
Defines the Filter class.

```
#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

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

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

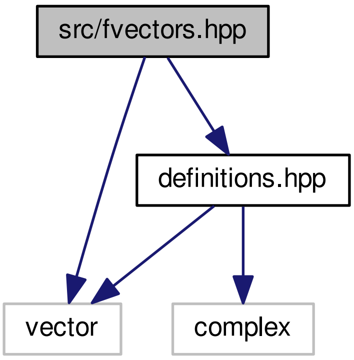
```

#ifndef Filter_H
#define Filter_H

#include <cmath>
#include <vector>

#include "definitions.hpp"

namespace radio {
    class Filter {
        public:
            Filter(float32* data, uint32 size, fparams& diffEq);

            void Pass();

        protected:
            uint8 eqLength;

            uint32 size;

            float32* data;

            fparams diffEq;
    };

    Filter::Filter(float32* data, uint32 size, fparams& diffEq) {
        this->data = data;
        this->size = size;
        this->diffEq = diffEq;
        eqLength = this->diffEq[DEN].size();
    }

    void Filter::Pass() {
        float64 temp[size];

        // create first values in filtered data
        for(int i = 0; i< eqLength; i++) {
            temp[i] = 0;

            for(int j = 0; j < eqLength; j++) {
                temp[i] += diffEq[NUM][j] * (j > i ? 0 : data[i - j]);
            }

            for(int j = 1; j < eqLength; j++) {
                temp[i] -= diffEq[DEN][j] * (j > i ? 0 : temp[i - j]);
            }
        }

        // create the REST of the values in filtered data
        for(int i = eqLength; i < size; i++) {
            temp[i] = 0;

            for(int j = 0; j < eqLength; j++) {
                temp[i] += diffEq[NUM][j] * data[i - j];
            }

            for(int j = 1; j < eqLength; j++) {
                temp[i] -= diffEq[DEN][j] * temp[i - j];
            }
        }

        // save final values of data and filtered data
    for(int i = 0; i < size; i++) {
            data[i] = temp[i];
        }
    }
}

#endif
```

8.35 src/fvectors.hpp File Reference

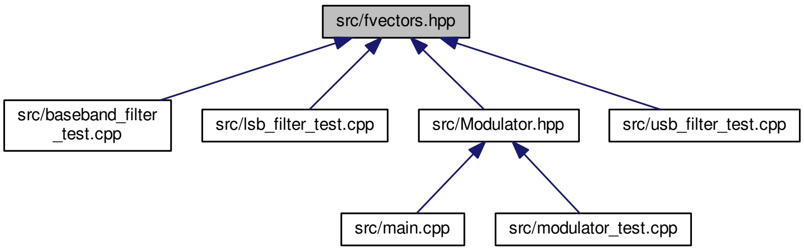
Defines the transfer function coefficients used in the instances of the Filter class in this program.

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

Include dependency graph for fvectors.hpp:



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



Namespaces

- radio

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

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.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file fvectors.hpp.

8.36 fvectors.hpp

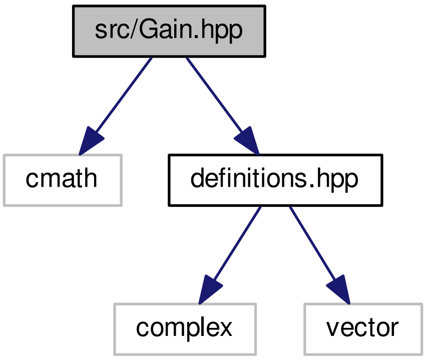
```
#ifndef fvectors_H
#define fvectors_H

#include <vector>

#include "definitions.hpp"

namespace radio {
    fparams F_BASEBAND = { 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
    } };

    fparams F_LOWERSIDEBAND = { 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
    } };

    fparams F_UPPERSIDEBAND = { 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
    } };


}

#endif
```

8.37 src/Gain.hpp File Reference

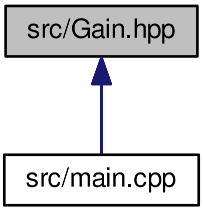
Contains the Gain class.

```
#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

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

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

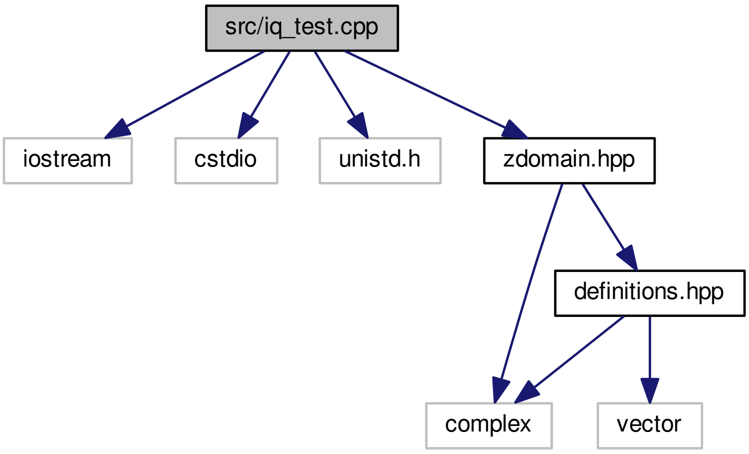
```
#ifndef Gain_H
#define Gain_H

#include <cmath>

#include "definitions.hpp"

namespace radio {
    class Gain {
        public:
            Gain(float32* data, uint32 size, float32 gaindB);

            void Apply();

        private:
            float32* data;

            float32 gainCoeff;

            bool hasClipped = false;

            uint32 size;

    };

    Gain::Gain(float32* data, uint32 size, float32 gaindB) {
        this->data = data;
        this->size = size;
        gainCoeff = pow(10, gaindB / 20);
    }

    void Gain::Apply() {
        for(uint32 i = 0; i < size; i++) {
            data[i] *= gainCoeff;

            if((data[i] > 1 || data[i] < -1) && !hasClipped) {
                hasClipped = true;
                std::cerr << "Baseband clipping has occurred!"
                    << std::endl;
            }
        }
    }
}

#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

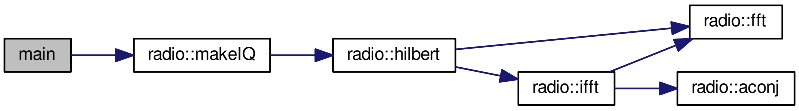
8.39.2.1 int main ( )

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

Definition at line 20 of file iq_test.cpp.

```
00020           {
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 }
```

Here is the call graph for this function:



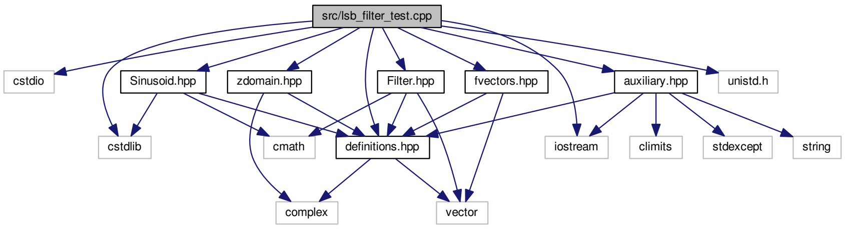
8.40 iq_test.cpp

```

#include <iostream>
#include <cstdio>
#include <unistd.h>

#include "zdomain.hpp"

using namespace std;
using namespace radio;

int main() {
    const uint16 len = 16384;
    float32 data[len];
    float32 iqData[2*len];

    for(int i = 0; i < len; i++) {
        data[i] = sin(2*3.141592*170*i/len);
    }

    while(true) {
        read(STDIN_FILENO, &data, len * sizeof(float32));
        makeIQ(data, iqData, len);
        write(STDOUT_FILENO, &iqData,  2 * len * sizeof(float32));
    }
}
```

8.41 src/lsb_filter_test.cpp File Reference

```
#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 Function Documentation

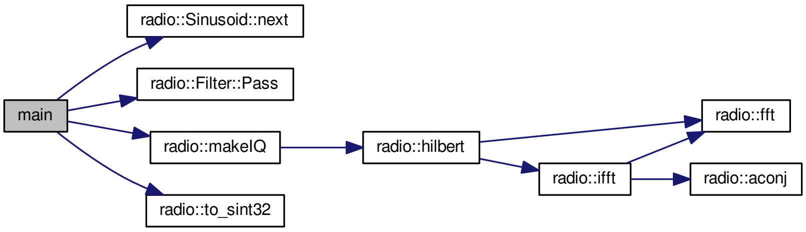
8.41.1.1 int main (int *argc,* char ∗ *argv[ ]*)

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

Definition at line 25 of file lsb_filter_test.cpp.

```
00025                                   {
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 = 17000; f <= 23000; 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_LOWERSIDEBAND);
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 }
```

Here is the call graph for this function:



8.42 lsb_filter_test.cpp

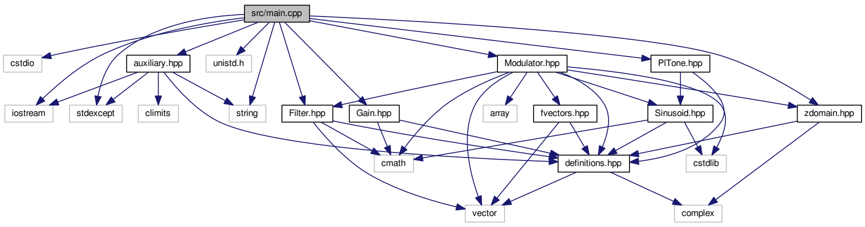
```

#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"

using namespace std;
using namespace radio;

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

    // Constants
    const uint16 BUFFER_SIZE = 48000;

    // Declare primative Variables
    uint8 i = 0;
    uint8 size = 0;
    uint16 delta = 250;
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];

    // create 1 sec of audio
    for(uint16 f = 17000; f <= 23000; f += delta, i++) {
        Sinusoid sinusoid(f);

        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] += sinusoid.next();
        }
    }

    size = i;

    // adjust dataBuffer so values are between -1 and 1
    for(uint16 i = 0; i < BUFFER_SIZE; i++) {
        dataBuffer[i] /= size;
    }

    Filter filter(dataBuffer, BUFFER_SIZE, F_LOWERSIDEBAND);
    filter.Pass();
    makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
    to_sint32(iqBuffer, 2 * BUFFER_SIZE);

    while(true) {
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

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[]*)

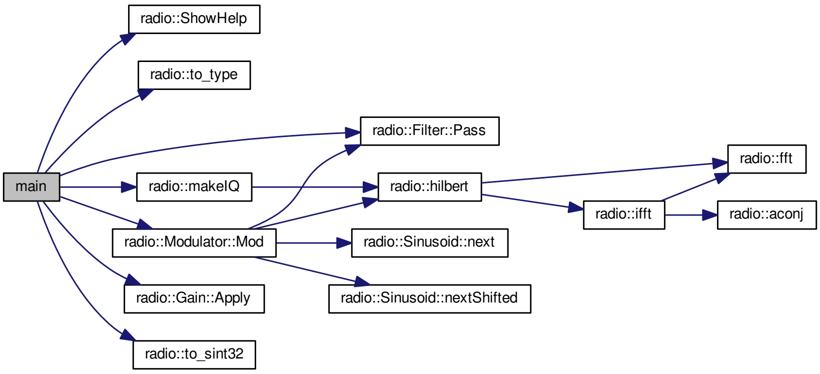
Final result of the entire project. Completes all goals and more!

Definition at line 26 of file main.cpp.

```
00026                                   {
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;
```

```
    // Ensure 1 or 2 arguments given
    if(argc > 4) {
        std::cerr << "Error: too many arguments!" << std::endl;
        ShowHelp();
        return ERROR;
    } else if(argc < 2) {
        std::cerr << "Error: too few arguments!" << std::endl;
        ShowHelp();
        return ERROR;
    }

    // Declare primative Variables
    float32 micGain = 0;
    float32 toneFreq = 0;
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[IQ_BUFFER_SIZE];
    ModulationType type;

    // validate modulation type
    try{
        type = to_type(string(argv[1]));
    } catch(std::exception ex) {
        std::cerr << "The given modulation type is invalid!" << std::endl;
        ShowHelp();
    }

    // process mic gain
    if(argc >= 3) {
        try {
            micGain = std::stof(argv[2]);
        } catch(std::invalid_argument ex) {
            std::cerr << "The specified microphone gain is not a number."
                << std::endl;
            ShowHelp();
        }
    }

    // validate CTCSS tone
    if(argc == 4) {
        try {
            toneFreq = std::stof(argv[3]);

            if(toneFreq < 60 || toneFreq > 260) {
                throw std::out_of_range("");
            }
        } catch(std::out_of_range ex) {
            std::cerr << "The specified CTCSS frequency is outside of the "
                "standard PL tone range." << std::endl;
            ShowHelp();
        } catch(std::invalid_argument ex) {
            std::cerr << "The specified CTCSS frequency is not a number."
                << std::endl;
            ShowHelp();
        }
    }

    // Declare objects
    Filter baseFilter(dataBuffer, BUFFER_SIZE, F_BASEBAND);
    Gain gain(dataBuffer, BUFFER_SIZE, micGain);
    PlTone pltone(0.15, dataBuffer, BUFFER_SIZE, toneFreq, SAMPLING_RATE);
    Modulator modulator(dataBuffer, BUFFER_SIZE, type, 20000);

    // SDR guts of the program
    while(true) {
        // get next samples
        read(STDIN_FILENO, &dataBuffer, BUFFER_BYTE_COUNT);

        // process/modulate samples
        baseFilter.Pass();
//      pltone.Add();
        gain.Apply();
        modulator.Mod();
        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, IQ_BUFFER_SIZE);

        // write samples
        write(STDOUT_FILENO, &iqBuffer, IQ_BUFFER_BYTE_COUNT);
    }
}
```

Here is the call graph for this function:



8.44 main.cpp

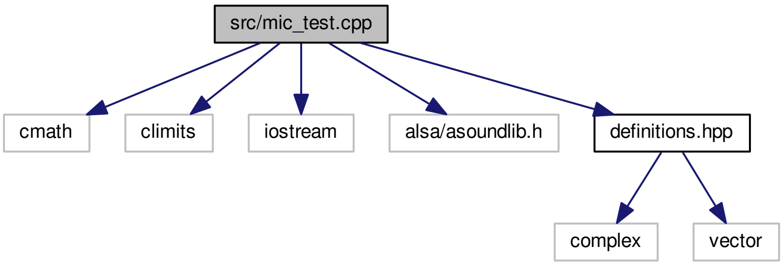
```

#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"

using namespace std;
using namespace radio;

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

    // Constants
    const uint8 NUM_TYPES = 8;
    const uint16 BUFFER_SIZE = 16384;
    const uint32 BUFFER_BYTE_COUNT = BUFFER_SIZE * sizeof(sint32);
    const uint32 IQ_BUFFER_SIZE = 2 * BUFFER_SIZE;
    const uint32 IQ_BUFFER_BYTE_COUNT = BUFFER_BYTE_COUNT * 2;
    const uint32 SAMPLING_RATE = 48000;

    // Ensure 1 or 2 arguments given
    if(argc > 4) {
        std::cerr << "Error: too many arguments!" << std::endl;
        ShowHelp();
        return ERROR;
    } else if(argc < 2) {
        std::cerr << "Error: too few arguments!" << std::endl;
        ShowHelp();
        return ERROR;
    }

    // Declare primative Variables
    float32 micGain = 0;
    float32 toneFreq = 0;
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[IQ_BUFFER_SIZE];
    ModulationType type;

    // validate modulation type
    try{
        type = to_type(string(argv[1]));
    } catch(std::exception ex) {
        std::cerr << "The given modulation type is invalid!" << std::endl;
        ShowHelp();
    }

    // process mic gain
    if(argc >= 3) {
        try {
            micGain = std::stof(argv[2]);
        } catch(std::invalid_argument ex) {
            std::cerr << "The specified microphone gain is not a number."
                << std::endl;
            ShowHelp();
        }
    }

    // validate CTCSS tone
    if(argc == 4) {
        try {
            toneFreq = std::stof(argv[3]);

            if(toneFreq < 60 || toneFreq > 260) {
                throw std::out_of_range("");
            }
        } catch(std::out_of_range ex) {
            std::cerr << "The specified CTCSS frequency is outside of the "
                "standard PL tone range." << std::endl;
            ShowHelp();
        } catch(std::invalid_argument ex) {
            std::cerr << "The specified CTCSS frequency is not a number."
                << std::endl;
            ShowHelp();
        }
    }

    // Declare objects
    Filter baseFilter(dataBuffer, BUFFER_SIZE, F_BASEBAND);
    Gain gain(dataBuffer, BUFFER_SIZE, micGain);
    PlTone pltone(0.15, dataBuffer, BUFFER_SIZE, toneFreq, SAMPLING_RATE);
    Modulator modulator(dataBuffer, BUFFER_SIZE, type, 20000);

    // SDR guts of the program
    while(true) {
        // get next samples
        read(STDIN_FILENO, &dataBuffer, BUFFER_BYTE_COUNT);

        // process/modulate samples
        baseFilter.Pass();
//      pltone.Add();
        gain.Apply();
        modulator.Mod();
        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, IQ_BUFFER_SIZE);

        // write samples
        write(STDOUT_FILENO, &iqBuffer, IQ_BUFFER_BYTE_COUNT);
    }
}
```

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.

```
00021           {
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;
```

```
        if(last > 2 * M_PI) last -= 2 * M_PI;

        test = 32000 * sin(last);

        if(abs(sin(last)) < 0.01 && lastWas) count++;

        vals[i] = (sint16)(test + 0.5);
        vals[i+1] = vals[i];
    }

    cout << "COUNT: " << count << endl;
    snd_pcm_hw_params_alloca(&hwparams);

    ret = snd_pcm_open(&pcm_handle, pcm_name, stream, 0);
    cout << "Opening: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_any(pcm_handle, hwparams);
    cout << "Initializing hwparams structure: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_access(pcm_handle, hwparams,
            SND_PCM_ACCESS_RW_INTERLEAVED);
    cout << "Setting access: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_format(pcm_handle, hwparams,
            SND_PCM_FORMAT_S16_LE);
    cout << "Setting format: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_rate(pcm_handle, hwparams,
            rate, (int)0);
    cout << "Setting rate: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_channels(pcm_handle, hwparams, 2);
    cout << "Setting channels: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_periods(pcm_handle, hwparams, 2, 0);
    cout << "Setting periods: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_buffer_size_near(pcm_handle, hwparams,
            &bufferSize);
    cout << "Setting buffer size: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params(pcm_handle, hwparams);
    cout << "Applying parameters: " << snd_strerror(ret) << endl;

/*  ret = snd_pcm_hw_params_get_period_size(hwparams, &count, &count2);
    cout << "Actual period size: " << count << endl;
    cout << "Returned: " << snd_strerror(ret) << endl;*/



    cout << endl << endl;


    //const void* ptr = (const void*)&vals;
    void* ptr = (void*)&vals;
    int err;

    for(int i = 0; i < 100; i++) {
        do {
            ret = snd_pcm_readi(pcm_handle,
                    ptr, bufferSize);

            if(ret < 0) {
                err = snd_pcm_prepare(pcm_handle);
                cout << "Preparing: " << snd_strerror(err)
                    << endl;
            }
        } while(ret < 0);

        cout << "Writing data: " << ret << endl;
    }
}
```

8.46 mic_test.cpp

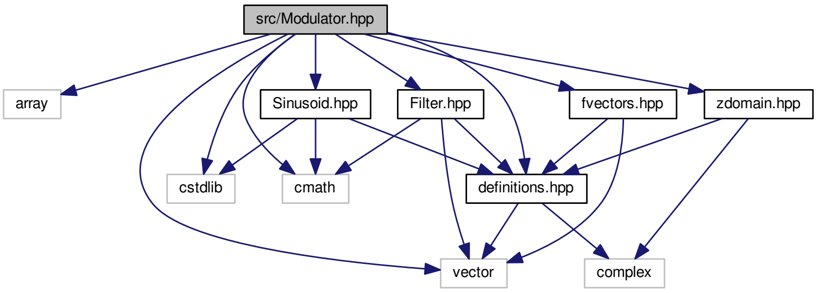
```

#include <cmath>
#include <climits>
#include <iostream>
#include <alsa/asoundlib.h>

#include "definitions.hpp"

```

```
using namespace std;

int main() {
    int ret;

    snd_pcm_t* pcm_handle;  // device handle
//  snd_pcm_stream_t stream = SND_PCM_STREAM_PLAYBACK;
    snd_pcm_stream_t stream = SND_PCM_STREAM_CAPTURE;
    snd_pcm_hw_params_t* hwparams;  // hardware information
    char* pcm_name = strdup("plughw:1,0");  // on-board audio jack
    //char* pcm_name = strdup("plughw:0,0");  // on-board audio jack
    int rate = 48000;

    const uint16 freq = 440;
    long unsigned int bufferSize = 8192*4;
    const uint32 len = bufferSize*100;
    const float32 arg = 2 * 3.141592 * freq / rate;
    sint16 vals[len];

    float test;
    float last = 0;
    long unsigned int count = 0;
    int count2 = 0;

    for(int i = 0; i < len; i = i + 2) {
        bool lastWas = abs(sin(last)) < 0.01;

        last += arg;
        if(last > 2 * M_PI) last -= 2 * M_PI;

        test = 32000 * sin(last);

        if(abs(sin(last)) < 0.01 && lastWas) count++;

        vals[i] = (sint16)(test + 0.5);
        vals[i+1] = vals[i];
    }

    cout << "COUNT: " << count << endl;
    snd_pcm_hw_params_alloca(&hwparams);

    ret = snd_pcm_open(&pcm_handle, pcm_name, stream, 0);
    cout << "Opening: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_any(pcm_handle, hwparams);
    cout << "Initializing hwparams structure: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_access(pcm_handle, hwparams,
            SND_PCM_ACCESS_RW_INTERLEAVED);
    cout << "Setting access: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_format(pcm_handle, hwparams,
            SND_PCM_FORMAT_S16_LE);
    cout << "Setting format: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_rate(pcm_handle, hwparams,
            rate, (int)0);
    cout << "Setting rate: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_channels(pcm_handle, hwparams, 2);
    cout << "Setting channels: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_periods(pcm_handle, hwparams, 2, 0);
    cout << "Setting periods: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params_set_buffer_size_near(pcm_handle, hwparams,
            &bufferSize);
    cout << "Setting buffer size: " << snd_strerror(ret) << endl;

    ret = snd_pcm_hw_params(pcm_handle, hwparams);
    cout << "Applying parameters: " << snd_strerror(ret) << endl;

/*  ret = snd_pcm_hw_params_get_period_size(hwparams, &count, &count2);
    cout << "Actual period size: " << count << endl;
    cout << "Returned: " << snd_strerror(ret) << endl;*/



    cout << endl << endl;


    //const void* ptr = (const void*)&vals;
    void* ptr = (void*)&vals;
    int err;

    for(int i = 0; i < 100; i++) {
        do {
            ret = snd_pcm_readi(pcm_handle,
                    ptr, bufferSize);

            if(ret < 0) {
                err = snd_pcm_prepare(pcm_handle);
                cout << "Preparing: " << snd_strerror(err)
                    << endl;
            }
        } while(ret < 0);

        cout << "Writing data: " << ret << endl;
    }
}
```

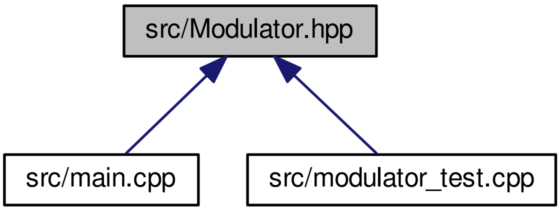
8.47 src/Modulator.hpp File Reference

```
#include <array>
#include <cmath>
#include <cstdlib>
#include <vector>
#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

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

Variables

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

8.48 Modulator.hpp

```

#ifndef modulation_H
#define modulation_H

#include <array>
#include <cmath>
#include <cstdlib>
#include <vector>

#include "definitions.hpp"
#include "Filter.hpp"
#include "fvectors.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"

namespace radio {

    const uint32 FREQ_INTERMEDIATE = 20000;

    const uint32 SAMPLING_RATE = 48000;

    class Modulator {
        public:
            Modulator(float32 data[], uint32 size, ModulationType type,
                    float32 freqInter = FREQ_INTERMEDIATE,
                    uint32 rate = SAMPLING_RATE);

            ~Modulator();

            void Mod();

        private:
            float32* data;

            float32 freqCarrier;


            float32* hilData = nullptr;

            float32 rate;

            uint32 size;

            ModulationType type;
    };

    Modulator::Modulator(float32 data[], uint32 size, ModulationType type,
            float32 freqInter, uint32 rate) {
        freqCarrier = freqInter;
        this->rate = rate;
        this->data = data;
        this->size = size;
        this->type = type;

        if(type == ModulationType::USB_HILBERT
                || type == ModulationType::LSB_HILBERT) {
```

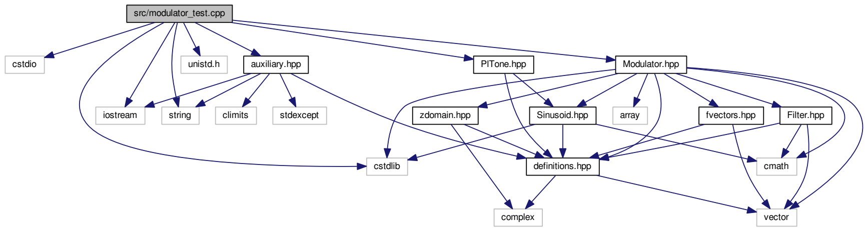
```
            hilData = (float32*)malloc(size*sizeof(float32));
        }
    }

    Modulator::~Modulator() {
        if(hilData != nullptr) free(hilData);
    }

    void Modulator::Mod() {
        // these variables should only ever be created once
        static float32 fmArg = 2 * M_PI * freqCarrier / (float32)rate;
        static float32 fmK = 2 * M_PI / rate;
        static float32 fmSum = 0;  // cummulative sum used in FM modulation
        static Filter lsbFilter(data, size, F_LOWERSIDEBAND);
        static Sinusoid sinusoid(freqCarrier, rate);  // IF carrier sinusoid
        static Filter usbFilter(data, size, F_UPPERSIDEBAND);

        // take hilbert transform if necessary
        if(type == ModulationType::USB_HILBERT
                || type == ModulationType::LSB_HILBERT) {
            hilbert(data, hilData, size);
        } else if(type == ModulationType::FM_NARROW) {
            fmK *= 2.5;
        } else if(type == ModulationType::FM_WIDE) {
            fmK *= 5;
        }

        // perform main modulation
        for(uint32 i = 0; i < size; i++) {
            switch(type) {
                case ModulationType::DSB_LC:
                    data[i] = ((data[i] + 1) * sinusoid.next()) / 2;
                    break;

                case ModulationType::DSB_SC:
                case ModulationType::USB_FILTERED:
                case ModulationType::LSB_FILTERED:
                    data[i] = data[i] * sinusoid.next();
                    break;

                case ModulationType::USB_HILBERT:
                    data[i] = data[i] * sinusoid.next()
                        - hilData[i] * sinusoid.nextShifted();
                    break;

                case ModulationType::LSB_HILBERT:
                    data[i] = data[i] * sinusoid.next()
                        + hilData[i] * sinusoid.nextShifted();
                    break;

                case ModulationType::FM_NARROW:
                case ModulationType::FM_WIDE:
                    fmSum += fmK * data[i];
                    data[i] = cos(fmArg * i + fmSum);
                    break;
            }
        }

        // filter out a sideband if using filtered SSB modulation
        if(type == ModulationType::LSB_FILTERED) {
            lsbFilter.Pass();
        } else if(type == ModulationType::USB_FILTERED) {
            usbFilter.Pass();
        }
    }
}

#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 "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[]*)

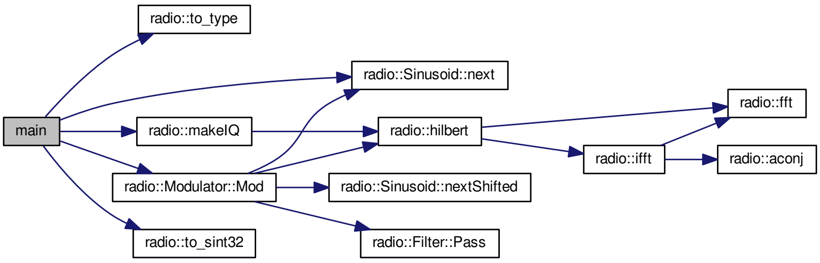
Program to test the Modulator class with a self-generated sinusoidal input.

Definition at line 24 of file modulator_test.cpp.

```
00024                                     {
00025 
00026     // Constants
00027     const uint16 BUFFER_SIZE = 16384;
00028 
00029     // Declare primative Variables
00030     float32 dataBuffer[BUFFER_SIZE];
00031     float32 iqBuffer[2 * BUFFER_SIZE];
00032     ModulationType type;
00033     float32 freq = atof(argv[2]);
00034     float32 tone = 0;
00035 
00036     if(argc >= 4) tone = atof(argv[3]);
00037 
00038     try{
00039         type = to_type(string(argv[1]));
```

```
    } catch(std::exception ex) {
        std::cerr << ex.what() << std::endl << std::endl;
        return ERROR;
    }

    if(freq < 0) {
        cerr << "The given tone was invalid." << endl;
        return ERROR;
    }

    // Declare objects
    Modulator modulator(dataBuffer, BUFFER_SIZE, type, 20000);
    Sinusoid sinusoid(freq);
    PlTone(tone > 0 ? 0.15 : 0, dataBuffer, BUFFER_SIZE, tone, 48000);

    while(true) {
        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] = sinusoid.next();
        }

        modulator.Mod();
        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, 2 * BUFFER_SIZE);
        write(STDOUT_FILENO, &iqBuffer,  2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

Here is the call graph for this function:



8.50 modulator_test.cpp

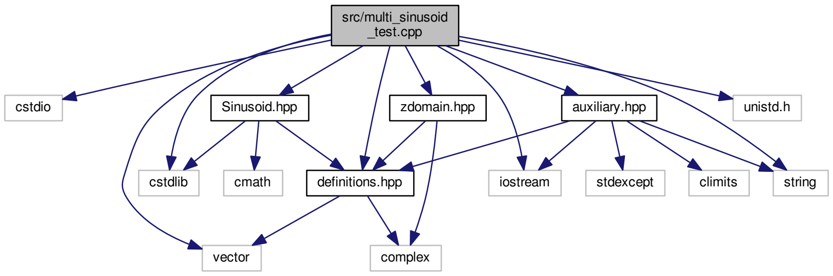
```

#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <string>
#include <unistd.h>

#include "auxiliary.hpp"
#include "Modulator.hpp"
#include "PlTone.hpp"

using namespace std;
using namespace radio;

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

    // Constants
    const uint16 BUFFER_SIZE = 16384;

    // Declare primative Variables
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];
    ModulationType type;
    float32 freq = atof(argv[2]);
    float32 tone = 0;

    if(argc >= 4) tone = atof(argv[3]);

    try{
        type = to_type(string(argv[1]));
    } catch(std::exception ex) {
        std::cerr << ex.what() << std::endl << std::endl;
        return ERROR;
    }

    if(freq < 0) {
        cerr << "The given tone was invalid." << endl;
        return ERROR;
    }

    // Declare objects
    Modulator modulator(dataBuffer, BUFFER_SIZE, type, 20000);
    Sinusoid sinusoid(freq);
    PlTone(tone > 0 ? 0.15 : 0, dataBuffer, BUFFER_SIZE, tone, 48000);

    while(true) {
        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] = sinusoid.next();
        }

        modulator.Mod();
        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, 2 * BUFFER_SIZE);
        write(STDOUT_FILENO, &iqBuffer,  2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

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

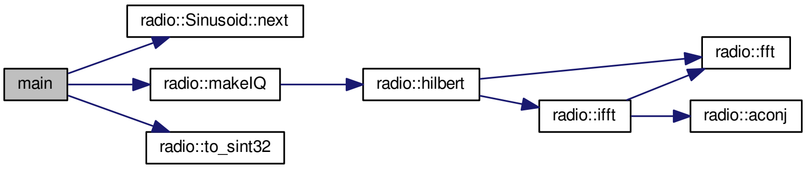
8.51.2.1 int main (int *argc,* char ∗ *argv[]*)

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.

```
00027                                 {
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 }
```

Here is the call graph for this function:



8.52 multi_sinusoid_test.cpp

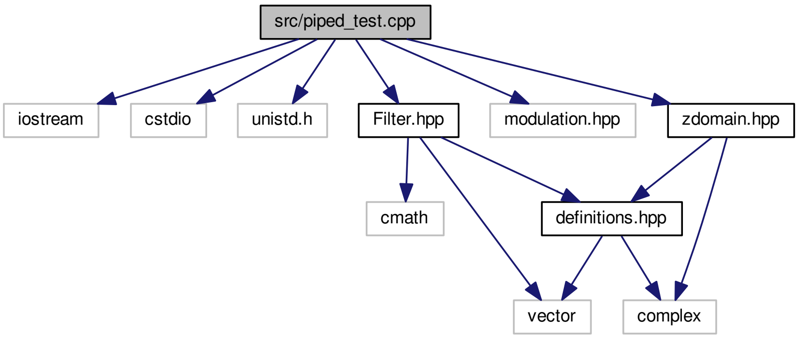
```

#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"

using namespace std;
using namespace radio;

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

    // Constants
    const uint16 BUFFER_SIZE = 48000;

    // Declare primative Variables
    uint8 i = 0;
    uint8 size = 0;
    uint16 delta = 100;
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];

    for(uint16 f = 100; f < 24000; f += delta, i++) {
        Sinusoid sinusoid(f);

        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] += sinusoid.next();
        }

        switch(f) {
            case 500:
                delta = 1000;
                f = 1000;
                break;

            case 2000:
                delta = 2000;
                break;
        }
    }

    size = i;

    for(uint16 i = 0; i < BUFFER_SIZE; i++) {
        dataBuffer[i] /= size;
    }

    makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
    to_sint32(iqBuffer, 2 * BUFFER_SIZE);

    while(true) {
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

8.53 src/piped_test.cpp File Reference

containts the original program used to test the piping-in idea

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

Include dependency graph for piped_test.cpp:



Functions

- int main ()

8.53.1 Detailed Description

containts 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 ( )

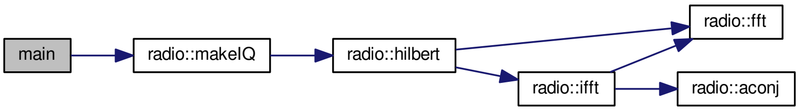
Program originally used to test whether baseband audio could be piped into the program in real time.

Definition at line 22 of file piped_test.cpp.

```
00022           {
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);
```

```
        write(STDOUT_FILENO, &iqData,  2 * len * sizeof(float32));
    }

}
```

Here is the call graph for this function:



8.54 piped_test.cpp

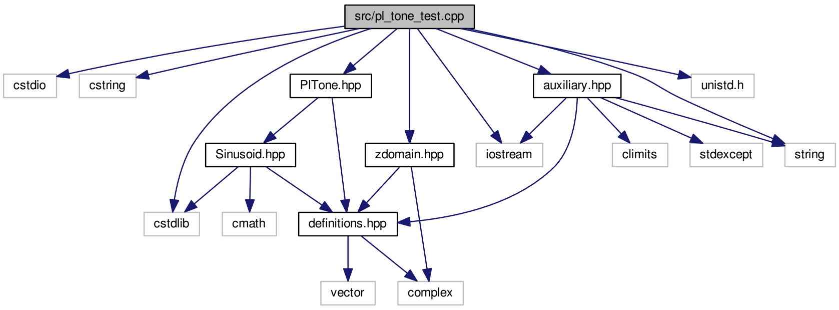
```
#include <iostream>
#include <cstdio>
#include <unistd.h>

#include "Filter.hpp"
#include "modulation.hpp"
#include "zdomain.hpp"

using namespace std;
using namespace lolz;

int main() {
    const uint16 len = 16384;
    float32 data[len];
    float32 iqData[2*len];

    while(true) {
        read(STDIN_FILENO, &data, len * sizeof(float32));
        makeIQ(data, iqData, len);
        write(STDOUT_FILENO, &iqData,  2 * len * sizeof(float32));
    }

}
```

8.55 src/pl_tone_test.cpp File Reference

contains a test program to test the PlTone class

```
#include <cstdio>
#include <cstring>
#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

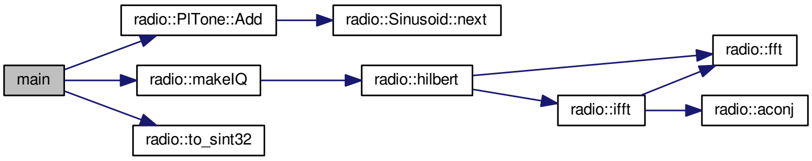
8.55.2.1 int main (int *argc*, char ∗ *argv[]*)

Program to test the PlTone class.

Definition at line 24 of file pl_tone_test.cpp.

```
                                  {
    // Constants
    const uint16 BUFFER_SIZE = 16384;

    // Declare primative Variables
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];
    float32 freq = atof(argv[1]);

    if(freq < 0) {
        cerr << "The given tone was invalid." << endl;
        return ERROR;
    }

    PlTone tone(0.15, dataBuffer, BUFFER_SIZE, freq, 48000);

    while(true) {
        for(uint16 i = 0; i < BUFFER_SIZE; i ++) {
            dataBuffer[i] = 1;
        }

        tone.Add();
        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, 2 * BUFFER_SIZE);
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

Here is the call graph for this function:



8.56 pl_tone_test.cpp

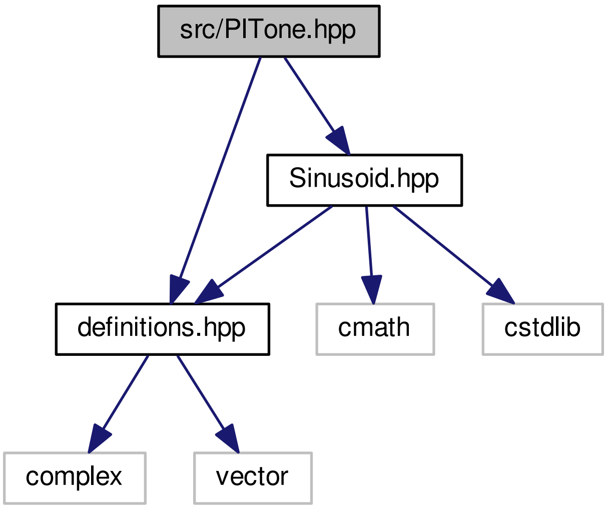
```

#include <cstdio>
#include <cstring>
#include <cstdlib>
#include <iostream>
#include <string>
#include <unistd.h>

#include "auxiliary.hpp"
#include "PlTone.hpp"
#include "zdomain.hpp"

using namespace std;
using namespace radio;

int main(int argc, char* argv[]) {
    // Constants
    const uint16 BUFFER_SIZE = 16384;

    // Declare primative Variables
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];
    float32 freq = atof(argv[1]);

    if(freq < 0) {
        cerr << "The given tone was invalid." << endl;
        return ERROR;
    }

    PlTone tone(0.15, dataBuffer, BUFFER_SIZE, freq, 48000);

    while(true) {
        for(uint16 i = 0; i < BUFFER_SIZE; i ++) {
            dataBuffer[i] = 1;
        }

        tone.Add();
        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, 2 * BUFFER_SIZE);
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

8.57 src/PlTone.hpp File Reference

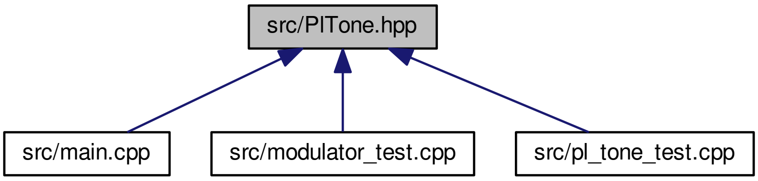
contains the PlTone class

```
#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

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

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

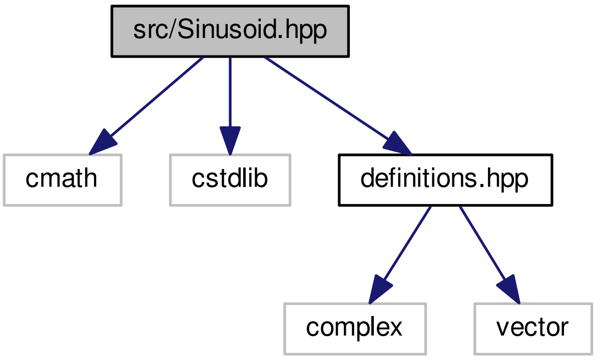
```
#ifndef PlTone_H
#define PlTone_H

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

namespace radio {
    class PlTone : Sinusoid {
        public:
            PlTone(float32 amplitude, float32* data, uint32 size,
                    float32 frequency, uint32 samplingRate);

            void Add();

        private:
            float32 amplitude;

            float32* data;

            uint32 size;
    };

    PlTone::PlTone(float32 amplitude, float32* data,
            uint32 size, float32 frequency, uint32 samplingRate)
        : Sinusoid(frequency, samplingRate) {
        this->data = data;
        this->amplitude = amplitude;
        this->size = size;

        for(uint32 i = 0; i < samplingRate; i++) {
            sinusoid[i] *= amplitude;
        }
    }

    void PlTone::Add() {
        for(uint32 i = 0; i < size; i++) {
            data[i] += amplitude * next();
            data[i] /= (1 + amplitude);  // ensures value <= 1
        }
    }
}

#endif
```

8.59 src/Sinusoid.hpp File Reference

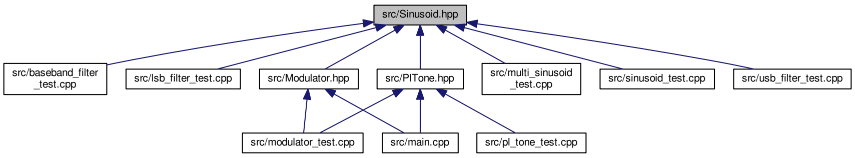
contains the Sinusoid class

```
#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

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

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
```

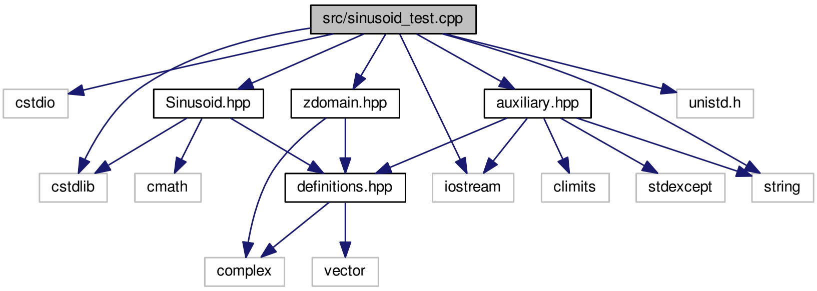
```
#ifndef Sinusoid_H
#define Sinusoid_H

#include <cmath>
#include <cstdlib>

#include "definitions.hpp"

namespace radio {
    class Sinusoid {
        public:
            Sinusoid(float32 frequency, uint32 samplingRate = 48000);

            ~Sinusoid();

            float32 next();

            float32 nextShifted();

        protected:
            float32 frequency;

            uint32 sinIndex = 0;

            uint32 sinIndexShifted = 0;

            uint32 samplingRate;

            float32* sinusoid;

            float32* sinusoidShift90;
    };

    Sinusoid::Sinusoid(float32 frequency, uint32 samplingRate) {
        this->frequency = frequency;
        this->samplingRate = samplingRate;
        sinusoid = (float32*)std::malloc(samplingRate * sizeof(float32));
        sinusoidShift90 = (float32*)std::malloc(samplingRate * sizeof(float32));

        float32 arg = 2 * M_PI * frequency / samplingRate;

        for(uint32 i = 0; i < samplingRate; i++) {
            // cosine argument evaluates as float due to M_PI and frequency
            sinusoid[i] = cos(arg * i);
            sinusoidShift90[i] = sin(arg * i);
        }
    }

    Sinusoid::~Sinusoid() {
        free(sinusoid);
        free(sinusoidShift90);
    }

    float32 Sinusoid::next() {
        if(sinIndex >= samplingRate) sinIndex = 0;
        return sinusoid[sinIndex++];
    }

    float32 Sinusoid::nextShifted() {
        if(sinIndexShifted >= samplingRate) sinIndexShifted = 0;
        return sinusoidShift90[sinIndexShifted++];
    }
}

#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[]*)

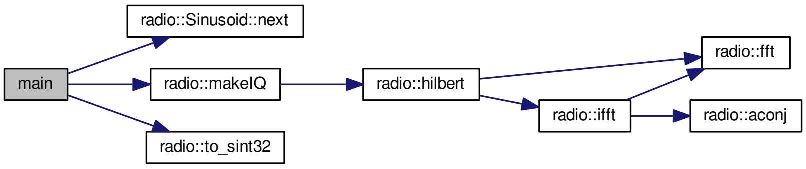
Program to test the Sinusoid class.

Definition at line 23 of file sinusoid_test.cpp.

```
00023                                   {
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     }
```

```

    Sinusoid sinusoid(freq, 48000);

    while(true) {
        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] = sinusoid.next();
        }

        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, 2 * BUFFER_SIZE);
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

Here is the call graph for this function:



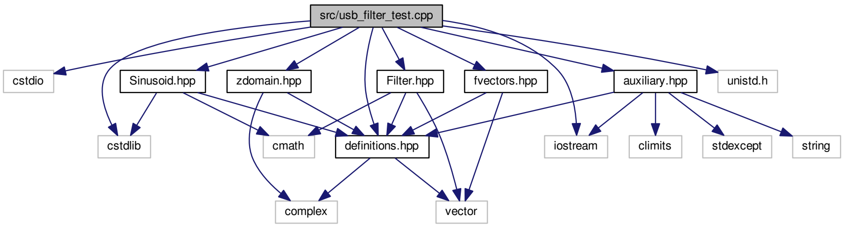
8.62 sinusoid_test.cpp

```

#include <cstdio>
#include <cstdlib>
#include <iostream>
#include <string>
#include <unistd.h>

#include "auxiliary.hpp"
#include "Sinusoid.hpp"
#include "zdomain.hpp"

using namespace std;
using namespace radio;

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

    // Constants
    const uint16 BUFFER_SIZE = 16384;

    // Declare primative Variables
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];
    float32 freq = atof(argv[1]);

    if(freq < 0) {
        cerr << "The given tone was invalid." << endl;
        return ERROR;
    }

    Sinusoid sinusoid(freq, 48000);

    while(true) {
        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] = sinusoid.next();
        }

        makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
        to_sint32(iqBuffer, 2 * BUFFER_SIZE);
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

8.63 src/usb_filter_test.cpp File Reference

```
#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 Function Documentation

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

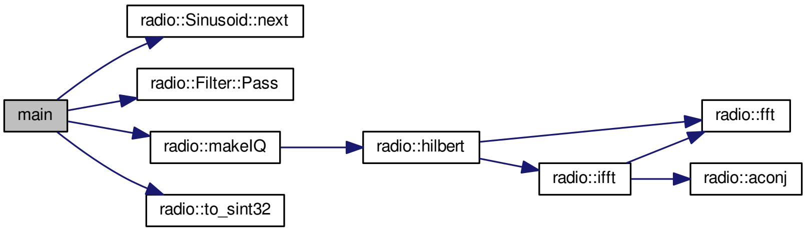
Program to test the Filter class and the USB filter coefficients.

Definition at line 25 of file usb_filter_test.cpp.

```
00025                                     {
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 = 17000; f <= 23000; 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 
```

```
    Filter filter(dataBuffer, BUFFER_SIZE, F_UPPERSIDEBAND);
    filter.Pass();
    makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
    to_sint32(iqBuffer, 2 * BUFFER_SIZE);

    while(true) {
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

Here is the call graph for this function:



8.64 usb_filter_test.cpp

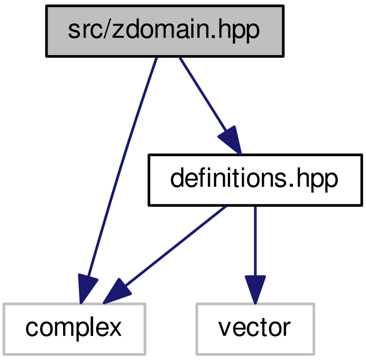
```

#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"

using namespace std;
using namespace radio;

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

    // Constants
    const uint16 BUFFER_SIZE = 48000;

    // Declare primative Variables
    uint8 i = 0;
    uint8 size = 0;
    uint16 delta = 250;
    float32 dataBuffer[BUFFER_SIZE];
    float32 iqBuffer[2 * BUFFER_SIZE];

    // create 1 sec of audio
    for(uint16 f = 17000; f <= 23000; f += delta, i++) {
        Sinusoid sinusoid(f);

        for(uint16 i = 0; i < BUFFER_SIZE; i++) {
            dataBuffer[i] += sinusoid.next();
        }
    }

    size = i;

    // adjust dataBuffer so values are between -1 and 1
    for(uint16 i = 0; i < BUFFER_SIZE; i++) {
        dataBuffer[i] /= size;
    }

    Filter filter(dataBuffer, BUFFER_SIZE, F_UPPERSIDEBAND);
    filter.Pass();
    makeIQ(dataBuffer, iqBuffer, BUFFER_SIZE);
    to_sint32(iqBuffer, 2 * BUFFER_SIZE);
    while(true) {
        write(STDOUT_FILENO, &iqBuffer, 2 * BUFFER_SIZE * sizeof(sint32));
    }
}
```

8.65 src/zdomain.hpp File Reference

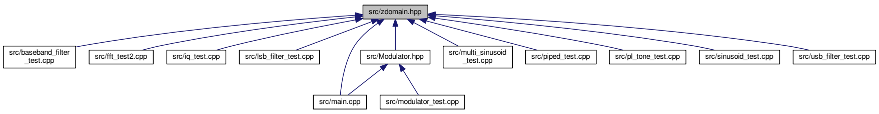
Contains the functions to manipulate sequential data in the frequency (z) domain.

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

Include dependency graph for zdomain.hpp:



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



Namespaces

- radio

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

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

```

#ifndef zdomain_H
#define zdomain_H

#include <complex>

#include "definitions.hpp"

namespace radio {

    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);

    void aconj(cfloat32* data, uint32 size) {
        for(int i = 0; i < size; i++) {
            data[i] = std::conj(data[i]);
        }
    }

    void fft(cfloat32* data, uint32 size) {
        // DFT
        uint32 k = size;
        uint32 n;
        float32 thetaT = M_PI / size;
        cfloat32 phiT(cos(thetaT), sin(thetaT));
        cfloat32 T;

        while(k > 1) {
            n = k;
            k >>= 1;
            phiT = phiT * phiT;
            T = 1.0L;

            for(uint32 l = 0; l < k; l++) {
                for(uint32 a = l; a < size; a += n) {
                    uint32 b = a + k;
                    cfloat32 t = data[a] -data[b];
                    data[a] +=data[b];
                    data[b] = t * T;
                }

                T *= phiT;
            }
        }

        // Decimate
        uint32 m = (uint32)log2(size);

        for(uint32 a = 0; a < size; a++) {
            uint32 b = a;

            // Reverse bits
            b = (((b & 0xaaaaaaaa) >> 1) | ((b & 0x55555555) << 1));
            b = (((b & 0xcccccccc) >> 2) | ((b & 0x33333333) << 2));
            b = (((b & 0xf0f0f0f0) >> 4) | ((b & 0x0f0f0f0f) << 4));
            b = (((b & 0xff00ff00) >> 8) | ((b & 0x00ff00ff) << 8));
            b = ((b >> 16) | (b << 16)) >> (32 - m);

            if (b > a)
            {
                cfloat32 t = data[a];
                data[a] =data[b];
                data[b] = t;
            }
        }
    }

    void hilbert(float32* data, float32* dest, uint32 size) {
        cfloat32* temp = (cfloat32*)std::malloc(sizeof(cfloat32) * size);

        for(int i = 0; i < size; i++) {
            temp[i] = data[i];
        }

        fft(temp, size);

        for(int i = size/2; i < size; i++) {
            temp[i] = 0;
        }

        ifft(temp, size);

        for(int i = 0; i < size; i++) {
            // parentheses around temp prevent free() error
            dest[i] = -2 * (temp[i].imag());
        }

        free(temp);
    }

    void ifft(cfloat32* data, uint32 size) {
        aconj(data, size);
        fft(data, size);
        aconj(data, size);

        for(int i = 0; i < size; i++) {
            data[i] /= size;
        }
    }

    void makeIQ(float32* data, float32* dest, uint32 size) {
        float32 quadData[size];
        hilbert(data, quadData, size);

        for(int i = 0; i < 2 * size; i += 2) {
            dest[i] = quadData[i/2];
            dest[i+1] = data[i/2];
        }
    }
}

#endif
```

Index