

sac-format

0.6.0

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# Chapter 1

## Introduction

sac-format is a single-header statically linked library designed to make working with binary [SAC](#)-files as easy as possible. Written in C++20, it follows a modern and easy to read programming-style while providing the high performance brought by C++.

sac-format's developed on [GitHub](#)!

Download [sac-format](#) from the GitHub release page.

[Download](#) an offline version of the documentation (PDF).

Get [help](#) from the community forum.

### 1.1 Why sac-format

sac-format is Free and Open Source Software (FOSS) released under the MIT license. Anyone can use it, for any purpose (including proprietary software), anywhere in the world. sac-format is operating system agnostic and confirmed working on Windows, macOS, and Linux systems.

#### 1.1.1 Safe

sac-format is **safe** it conforms to a strict set of C++ programming guidelines, chosen to ensure safe code-execution. The guideline conformance list is in [cpp-linter.yml](#) and can be cross-referenced against this [master list](#). Results of conformance checking are [here](#).

Testing is an important part of software development; the sac-format library is extensively tested using the [Catch2](#) testing framework. Everything from low-level binary conversions to high-level `Trace` reading/writing are tested and confirmed working. Check and run the tests yourself. See the [Testing](#) section for more information.

#### 1.1.2 Fast

sac-format is **fast** it's written in C++, carefully optimized, and extensively benchmarked. You can run the benchmarks yourself to find out how sac-format performs on your system. See the [Benchmarking](#) section for more information.

### 1.1.3 Easy

sac-format is **easy** single-header makes integration in any project simple. Installation is easy with our automatic installers. Building is a breeze with [CMake](#), even on different platforms. Object-oriented design makes use easy and intuitive. See the [Quickstart](#) section to get up and running.

### 1.1.4 Small

sac-format is **small** in total (header + implementation; excluding comments) the library is under 2100\* lines of code. Small size opens the door to using on any sort of hardware (old or new) and makes it easy to expand upon.

\* This value includes only the library, excluding all testing/benchmarking and example codes. Including `utests.cpp`, `benchmark.cpp`, `util.hpp`, the example program (`list_sac`), and sac-format totals just over 5100 lines of code.

### 1.1.5 Documented

sac-format is extensively **documented** both online and in the code. Nothing's hidden, nothing's obscured. Curious how something works? Check the documentation and in-code comments.

### 1.1.6 Transparent

sac-format is **transparent** all analysis and coverage information is publicly available online.

- [CodeFactor](#)
- [Codacy](#)
- [CodeCov](#)
- [Coverity Scan](#)

### 1.1.7 Trace Class

sac-format includes the `Trace` class for seismic traces, providing high-level object-oriented abstraction to seismic data. With the `Trace` class, you don't need to worry about manually reading SAC-files word-by-word. It's compatible with `v6` and `v7` SAC-files and can automatically detect the version upon reading. File output defaults to `v7` SAC-files and there is a `legacy_write` function for `v6` output.

### 1.1.8 Low-Level I/O

If you want to roll your own SAC-file processing workflow you can use the low-level I/O functionality built into sac-format. All functions tested and confirmed working they're used to build the `Trace` class!

## Chapter 2

# Installation

The easiest way to use `sac-format` is to install it via the automatic installers. Installers for the latest release are located [here](#). Be sure to check the sha512 checksum of the installer against its correspondingly named `.sha512` file to ensure the file is safe (for example: `sac-format.pkg` corresponds to `sac-format.pkg.sha512`).

### 2.1 Windows

`sac-format` provides a graphical installer on Windows (`sac-format.exe`).

Always check the sha512 checksum value of the installer (`sac-format.exe`; [more info here](#)) against `sac-format.exe.sha512`.

By default, Microsoft Defender will block the installer with a pop-up like that one below:

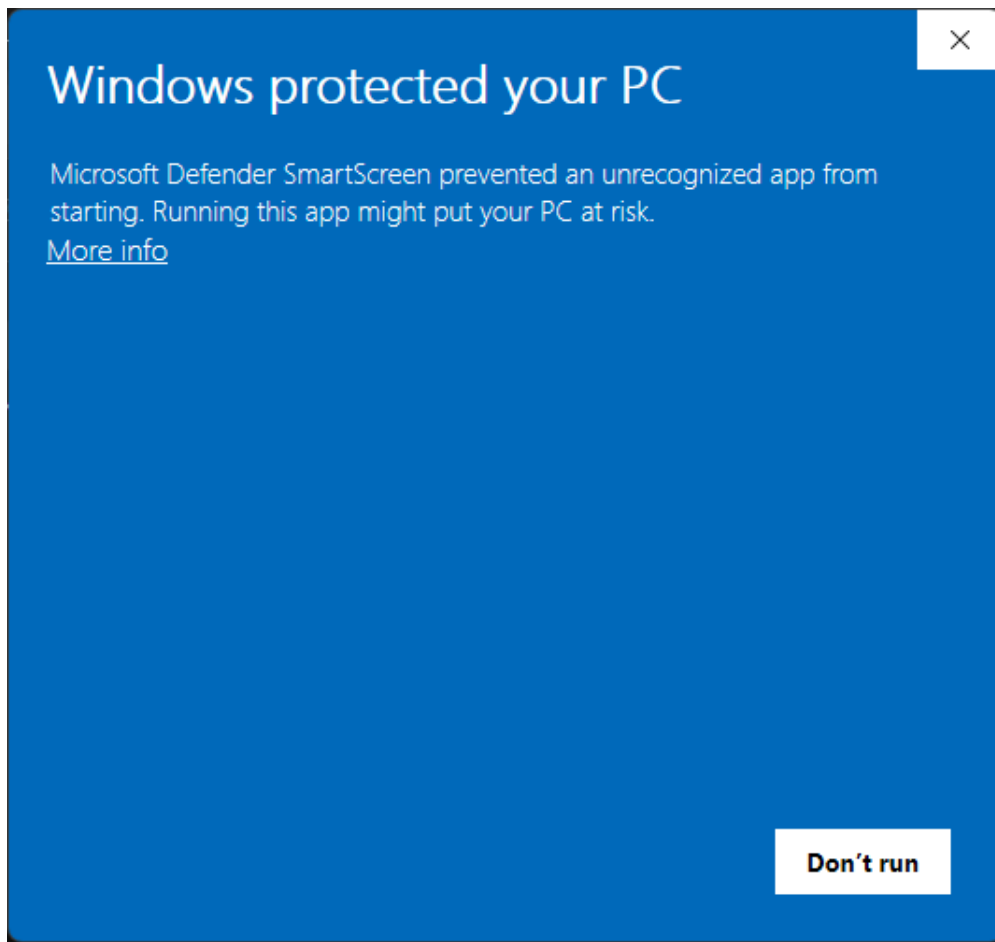


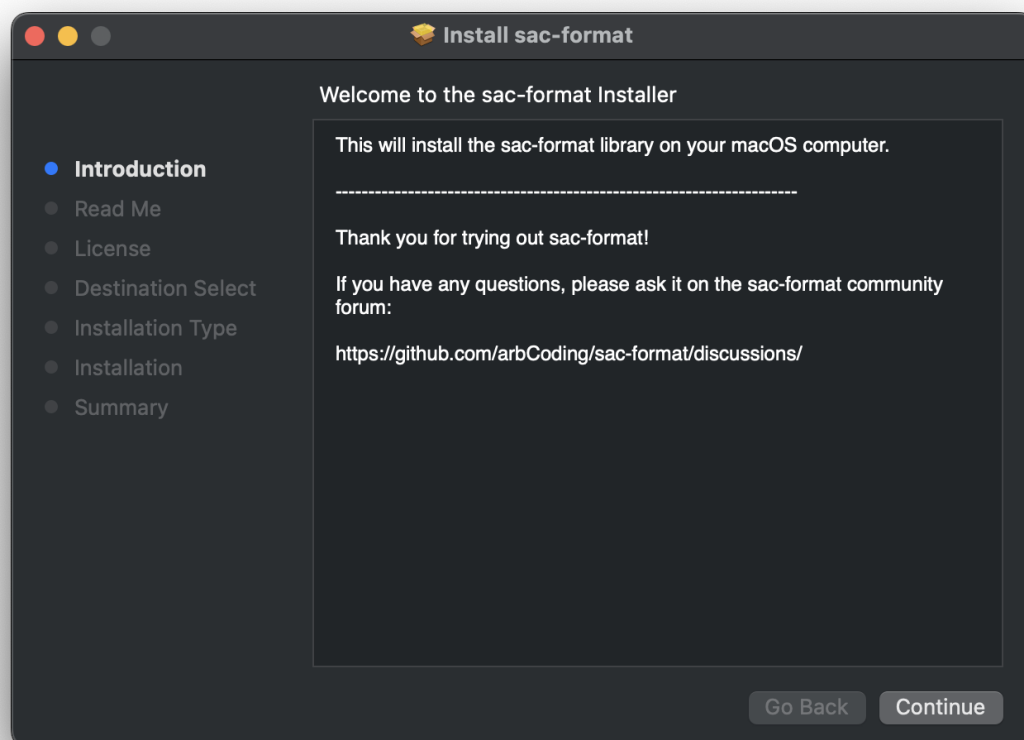
Figure 2.1 Windows Warning 1

To continue the install, click on the "More Info" link and then the "Run anyway" button as seen in the following image:



Figure 2.2 Windows Warning 2

Then the installer will open and present you with the welcome screen:



**Figure 2.3** Windows Intro Install

By default, sac-format installs in `C:/Program Files/sac-format` as seen in the screen below:

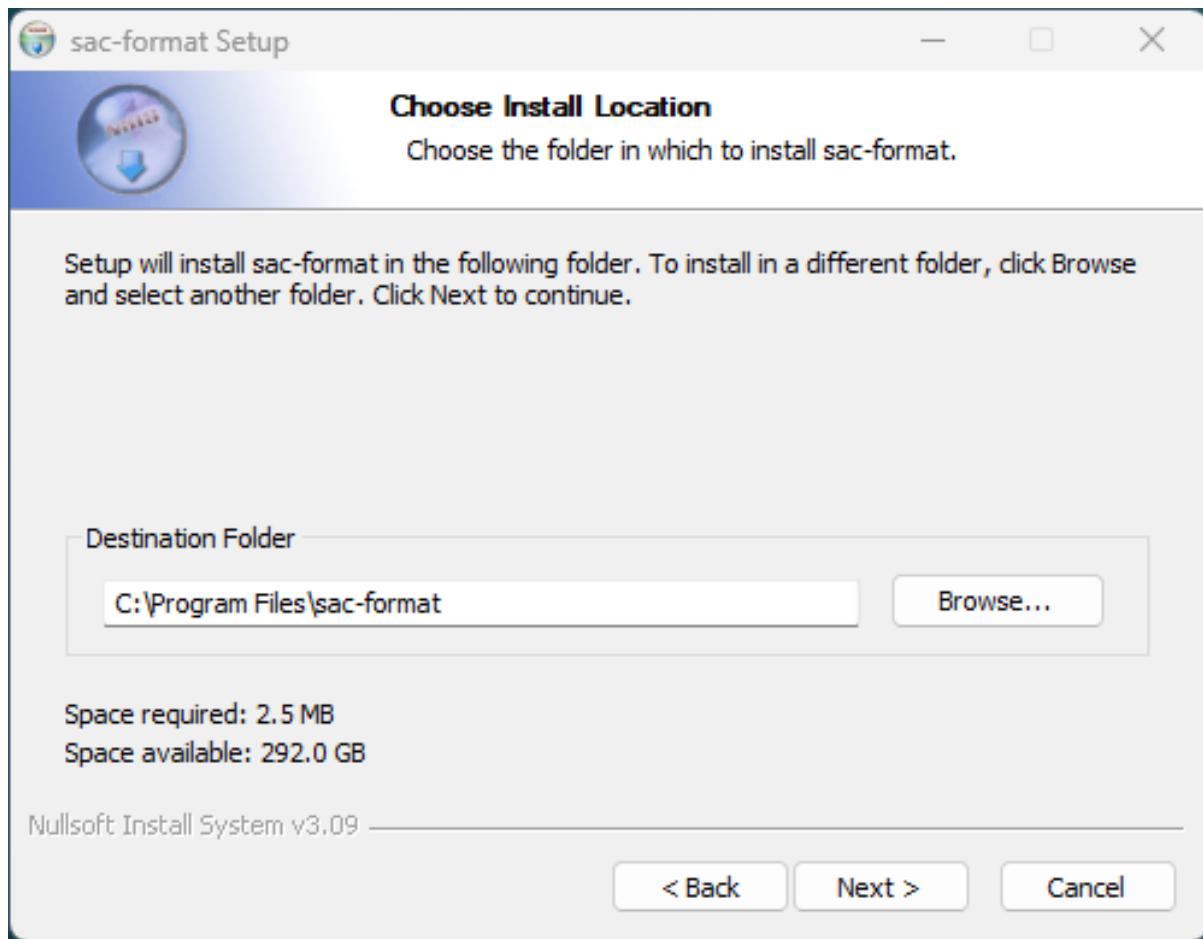


Figure 2.4 Windows Location Install

Because all programs in sac-format are command-line based feel free to disable Start Menu shortcuts:

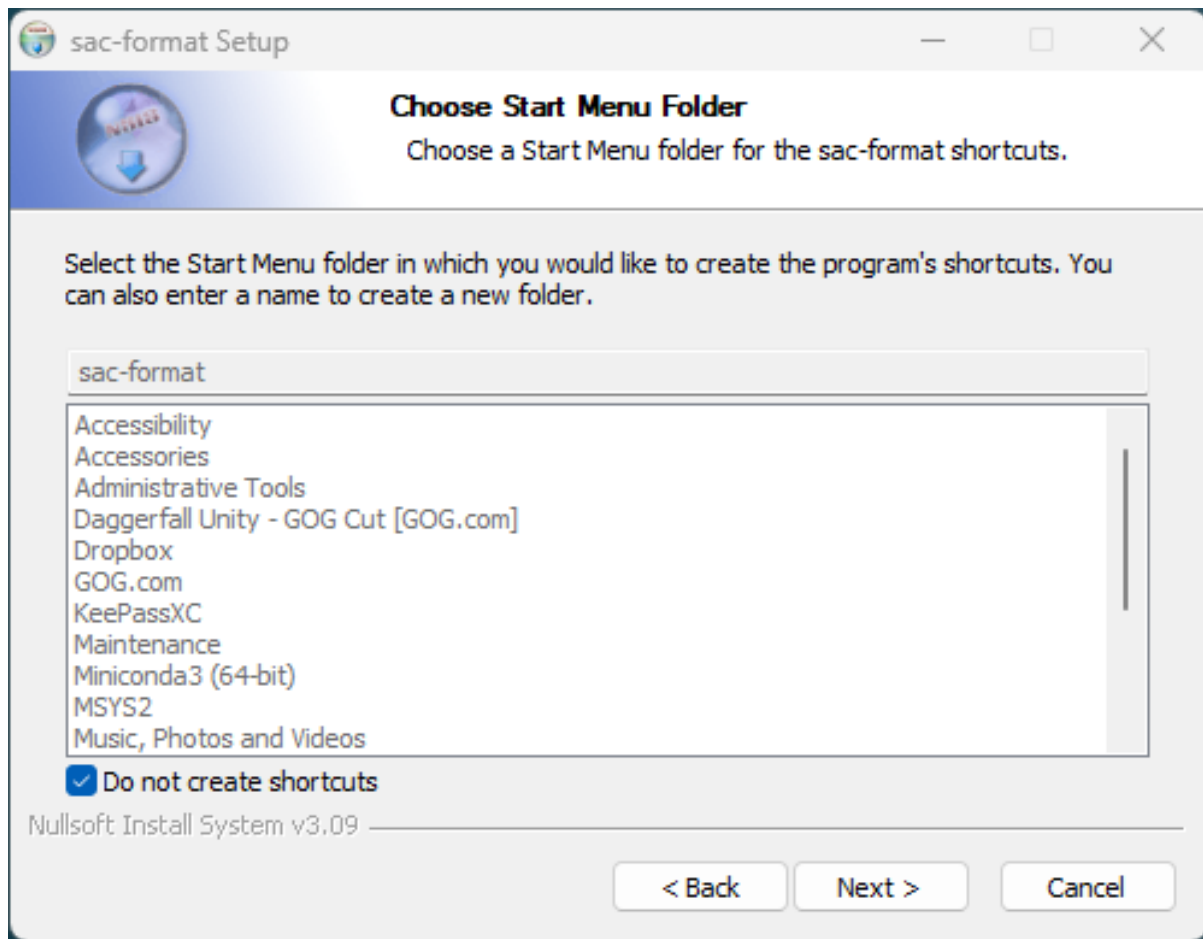


Figure 2.5 Windows No Shortcuts

Upon successful install of sac-format you will see this window:



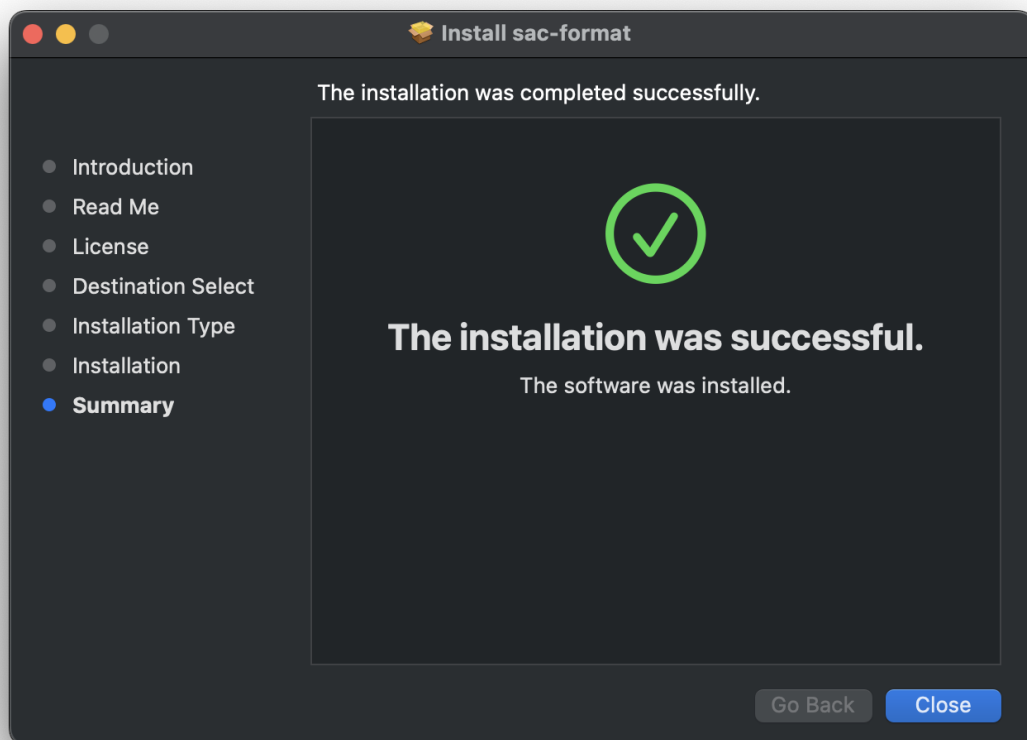


Figure 2.6 Windows Install Success

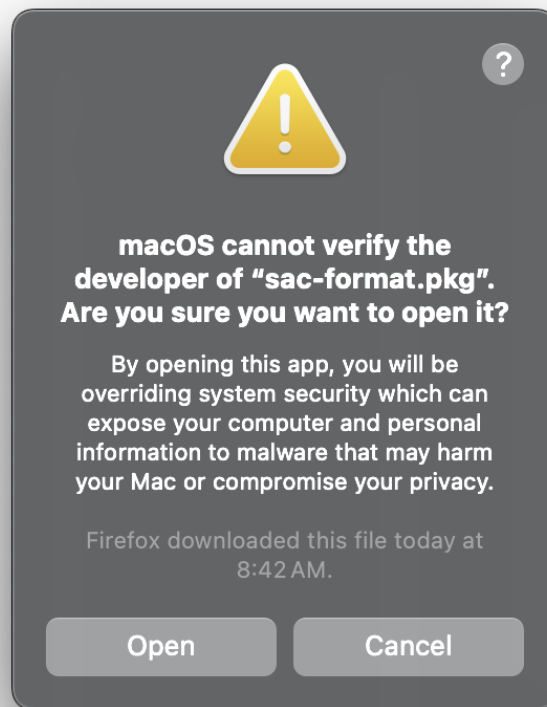
## 2.2 macOS

sac-format provides both command line and graphical installers on macOS.

### 2.2.1 Graphical

The graphical installer is `sac-format.pkg` and will walk you through the installation process. **NOTE:** the default installation location is `/opt/sac-format`.

By default, macOS will block the installer. To install, right-click on `sac-format.pkg` and select open. A warning will pop up that looks like:



**Figure 2.7 macOS Warning**

Simply click "Open" and the installer will begin from the first screen:

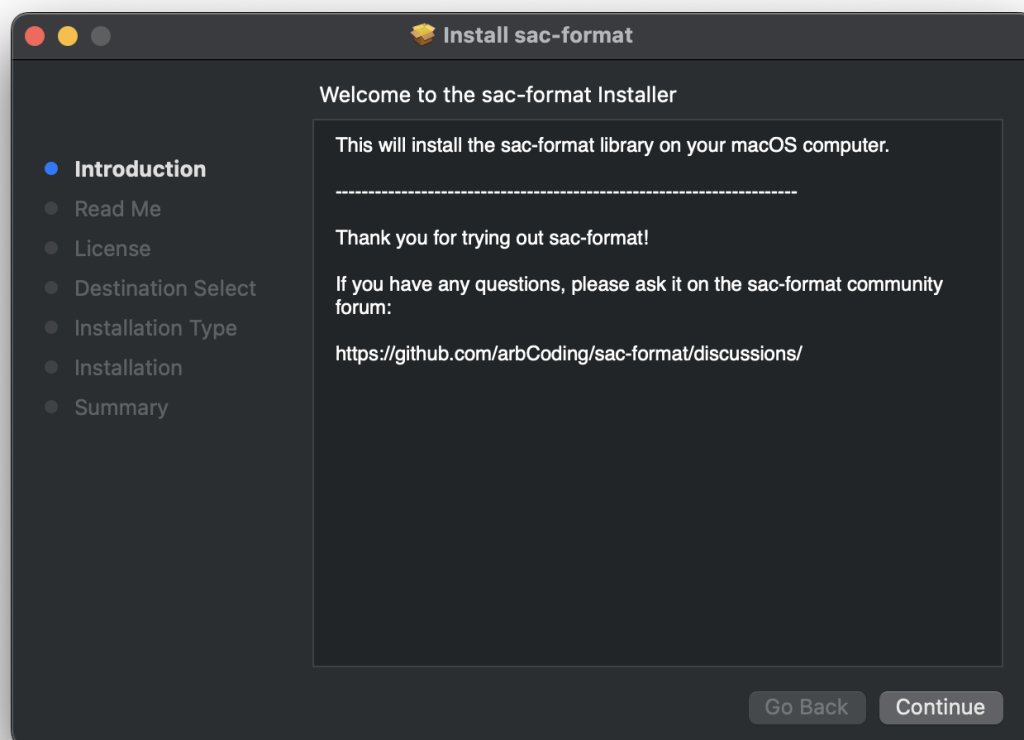


Figure 2.8 macOS Intro Install

Upon successful installation you will see:

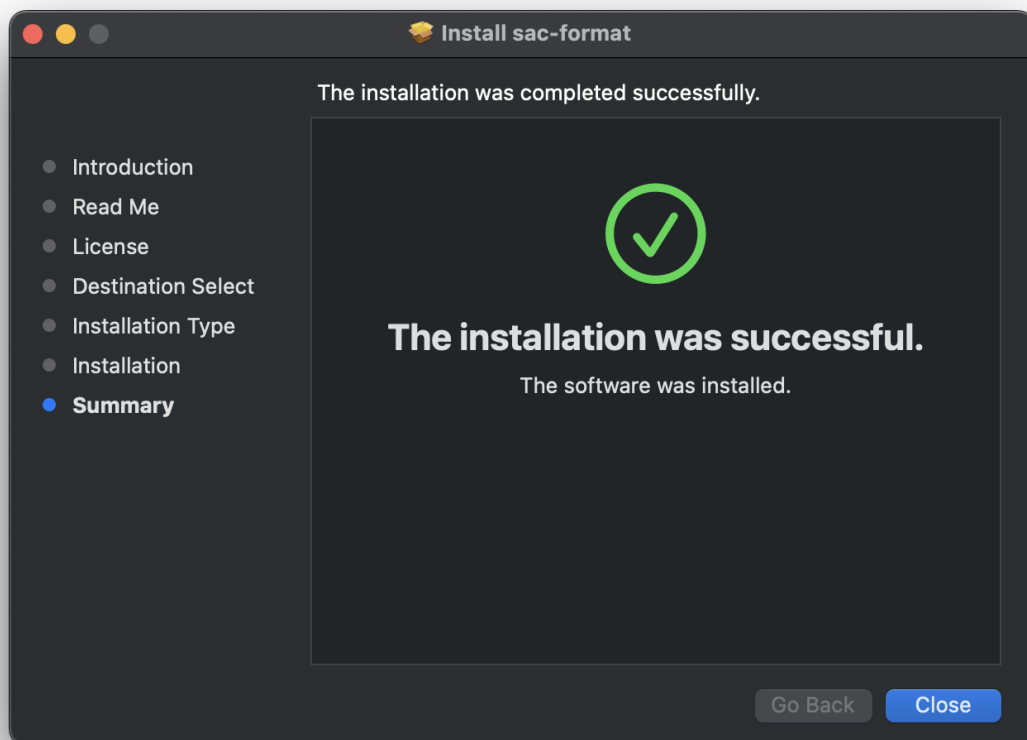


Figure 2.9 macOS Install Success

## 2.2.2 Command line

Command line installation is performed either using the self-extracting archive or by manually extracting the gzipped tar archive.

### 2.2.2.1 Self-Extracting Archive

```
# Check the sha512 checksum
sha512sum -c sac-format-<version>-Darwin-<arch>.sh.sha512
# Run self-extracting archive
bash sac-format-<version>-Darwin-<arch>.sh
```

Be sure to replace `<version>` and `<arch>` with the correct versions and architectures, respectively (for example: `sac-format-0.4.0-Darwin-x86_64.sh`).

### 2.2.2.2 Gzipped Tar Archive

```
# Check the sha512 checksum
sha512sum -c sac-format-<version>-Darwin-<arch>.tar.gz.sha512
# Extract Gzipped tar archive
tar -xzf sac-format-<version>-Darwin-<arch>.tar.gz
```

## 2.3 Linux

sac-format provides four different command line installation methods on Linux.

**Debian** based distributions (for example: Debian, Ubuntu, Linux Mint) can use the Debian Archive.

**RedHat** based distributions (for example: RedHat, Fedora, CentOS) can use the RPM Archive.

All distributions can use the Self-Extracting Archive.

All distributions can use the Gzipped Tar Archive.

### 2.3.1 Debian Archive

```
# Check the sha512 checksum
sha512sum -c sac-format.deb.sha512
# Install using apt
sudo apt install ./sac-format.deb
```

### 2.3.2 RPM Archive

```
# Check the sha512 checksum
sha512sum -c sac-format.rpm.sha512
# Install using rpm
sudo rpm -i sac-format.rpm
```

### 2.3.3 Self-Extrating Archive

```
# Check the sha512 checksum
sha512sum -c sac-format-<version>-Linux-<arch>.sh.sha512
# Run self-extrating archive
bash sac-format-<version>-Linux-<arch>.sh
```

### 2.3.4 Gzipped Tar Archive

```
# Check the sha512 checksum
sha512sum -c sac-format-<version>-Linux-<arch>.tar.gz.sha512
# Extract gzipped tar archive
tar -xzf sac-format-<version>-Linux-<arch>.tar.gz
```



# Chapter 3

## Quickstart

To use link to the library (`libsac-format.a` on Linux/macOS, `sac-format.lib` on Windows) and include `sac_format.hpp`.

### 3.1 Example Programs

#### 3.1.1 `list_sac`

`list_sac` is a command line program that takes a single SAC-file as its input argument. It reads the SAC-file and outputs the header/footer information, as well as the true size of the `data1` and `data2` vectors.

### 3.2 CMake Integration

To integrate `sac-format` into your CMake project, add it to your `CMakeLists.txt`.

```
include(FetchContent)
set(FETCHCONTENT_UPDATES_DISCONNECTED TRUE)
FetchContent_Declare(sac-format
  GIT_REPOSITORY https://github.com/arbCoding/sac-format
  GIT_TAG vX.X.X)
FetchContent_MakeAvailable(sac-format)
include_directories(${sacformat_SOURCE_DIR/src})

project(your_project
  LANGUAGES CXX)

add_executable(your_executable
  your_sources
  sac_format.hpp)

target_link_libraries_library(your_executable
  PRIVATE sac-format)
```

## 3.3 Example

### 3.3.1 Reading and Writing

```
#include <sac_format.hpp>
#include <filesystem>
#include <iostream>

using namespace sacfmt;
namespace fs = std::filesystem;

int main() {
    Trace trace1{};
    // Change header variable
    trace1.kstnm("Station1");
    fs::path file{"/test.SAC"};
    // Write
    trace1.write(file);
    // Read
    Trace trace2{file};
    // Confirm equality
    std::cout << (trace1 == trace2) << '\n';
    fs::remove(file);
    return EXIT_SUCCESS;
}
```



# Chapter 4

## Basic Documentation

### 4.1 Trace class

The `Trace` class provides easy access to SAC-files in C++. Each SAC-file is a `Trace`; therefore, each `Trace` object is a seismic trace (seismogram).

#### 4.1.1 Reading SAC

SAC-files can be read in by using the parameterized constructor with a `std::filesystem::path` (`<filesystem>`) or a `std::string` (`<string>`) variable that corresponds to the location of the SAC-file.

For example:

```
#include <sac_foramt.hpp>
#include <filesystem>

int main() {
    std::filesystem::path my_file{"/home/user/data/ANMO.SAC"};
    sacfmt::Trace anmo{my_file};
    return EXIT_SUCCESS;
}
```

#### 4.1.2 Writing SAC

Writing SAC files can be done using one of two write functions.

##### 4.1.2.1 v7 files

Use `write` (for example `trace.write(filename)`).

##### 4.1.2.2 v6 files

Use `legacy_write` (for example `trace.legacy_write(filename)`).

### 4.1.3 Getters and Setters

Every SAC variable is accessed via getters and setters of the same name.

#### 4.1.3.1 Example Getters

- `trace.npts()`
- `trace.data1()`
- `trace.kstnm()`

#### 4.1.3.2 Example Setters

- `trace.kevnm("Event 1")`
- `trace.evla(32.89)`
- `trace.mag(3.21)`

#### 4.1.3.3 Setter rules

Most of the setters are only constrained by the parameter type (single-precision, double-precision, boolean, etc.). **Some** setters are constrained by additional rules.

##### Required for sanity

Rules here are required because the `sac-format` library assumes them (not strictly required by the SAC format standard). For instance, the geometric functions assume certain bounds on latitudes and longitudes.

`sac-format` automatically imposes these rules.

##### **stla(input)**

Limited to  $[-90, 90]$  degrees, input that is outside that range is reduced using circular symmetry.

##### **stlo(input)**

Limited to  $[-180, 180]$  degrees, input that is outside that range is reduced using circular symmetry.

##### **evla(input)**

Limited to  $[-90, 90]$  degrees, input that is outside that range is reduced using circular symmetry.

**evlo(input)**

Limited to [-180, 180] degrees, input that is outside that range is reduced using circular symmetry.

**Required for safety**

Rules here are required by the SAC format standard. sac-format automatically imposes these rules to prevent the creation of corrupt sac-files.

**npts(input)**

Because `npts` defines the size of the data vectors, changing this value will change the size of `data1` and `data2*`. Increasing `npts` resizes the vectors ( `std::vector::resize`) by placing zeros at the **end** of the vectors. Reducing `npts` resizes the vectors down to the **first npts** values.

Therefore, care must be taken to maintain separate copies of `data1` and `data2*` if you plan to manipulate the original data **after** resizing.

\* `data2` has `npts` only if it is legal, otherwise it is of size 0.

**leven(input)**

Changing the value of `leven` potentially changes the legality of `data2`, it also potentially affects the value of `iftype`.

If `iftype>1`, then `leven` must be `true` (evenly sampled data). Therefore, if `leven` is made `false` in this scenario (unevenly sampled data) then `iftype` becomes `unset*`.

If changing `leven` makes `data2` legal\*\*, then `data2` is qresized to have `npts` zeros.

\* The SAC format defines the unset values for all data-types. For integers (like `iftype`) it is the integer value -12345.

\*\* If `data2` was already legal, then it is unaffected.

**iftype(input)**

Changing the value of `iftype` potentially changes the legality of `data2`, it also potentially affects the value of `leven`.

If `leven` is `false`, then `iftype` must be either 1 or `unset`. Therefore, changing `iftype` to have a value `>1` requires that `leven` becomes `true` (evenly sampled data).

If changing `iftype` makes `data2` legal\*, then `data2` is resized to have `npts` zeros.

\* If `data2` was already legal, then it is unaffected.

**data1(input)**

If the size of `data1` is changed, then `npts` must change to reflect the new size. If `data2` is legal, this adjusts its size to match as well.

## **data2(input)**

If the size of `data2` is changed to be larger than 0 and it is illegal, it is made legal by setting `iftype(2)` (spectral-data).

When the size of `data2` changes, `npts` is updated to the new size and `data1` is resized to match.

If `data2` is made illegal, its size is reduced to 0 while `npts` and `data1` are unaffected.

## **4.1.4 Convenience Methods**

### **4.1.4.1 calc\_geometry**

Calculate `gcArc`, `dist`, `az`, and `baz` assuming spherical Earth.

```
trace.stla(45.3);
trace.stlo(34.5);
trace.evla(18.5);
trace.evlo(-34);
trace.calc_geometry();
std::cout << "GcArc: " << trace.gcArc() << '\n';
std::cout << "Dist: " << trace.dist() << '\n';
std::cout << "Azimuth: " << trace.az() << '\n';
std::cout << "BAzimuth: " << trace.baz() << '\n';
```

### **4.1.4.2 frequency**

Calculate frequency from `delta`.

```
double frequency{trace.frequency()};
```

### **4.1.4.3 date**

Return `std::string` formatted as YYYY-JJJ from `nzyear` and `nzjday`.

```
std::string date{trace.date()};
```

### **4.1.4.4 time**

Return `std::string` formatted as HH:MM:SS.xxx from `nzhour`, `nzmin`, `nzsec`, and `nzmsec`.

```
std::string time{trace.time()};
```

## **4.1.5 Exceptions**

`sac-format` throws exceptions of type `sacfmt::io_error` (inherits `std::exception`) in the event of a failure to read/write a SAC-file.

## **4.2 Convenience Functions**

### **4.2.1 degrees\_to\_radians**

Convert decimal degrees to radians.

```
double radians{sacfmt::degrees_to_radians(degrees)};
```

### 4.2.2 radians\_to\_degrees

Convert radians to decimal degrees.

```
double degrees{sacfmt::radians_to_degrees(radians)};
```

### 4.2.3 gcarc

Calculate great-circle arc distance (spherical planet).

```
double gcarc{sacfmt::gcarc(latitude1, longitude1, latitude2, longitude2)};
```

### 4.2.4 azimuth

Calculate azimuth between two points (spherical planet).

```
double azimuth{sacfmt::azimuth(latitude2, longitude2, latitude1, longitude1)};  
double back_azimuth{sacfmt::azimuth(latitude1, longitude1, latitude2, longitude2)};
```

### 4.2.5 limit\_360

Take arbitrary value of degrees and unwrap to [0, 360].

```
double degrees_limited{sacfmt::limit_360(degrees)};
```

### 4.2.6 limit\_180

Take arbitrary value of degrees and unwrap to [-180, 180]. Useful for longitude.

```
double degrees_limited{sacfmt::limit_180(degrees)};
```

### 4.2.7 limit\_90

Take arbitrary value of degrees and unwrap to [-90, 90]. Useful for latitude.

```
double degrees_limited{sacfmt::limit_90(degrees)};
```

## 4.3 Low-Level I/O

Low-level I/O functions are discussed below.

### 4.3.1 Binary conversion

#### 4.3.1.1 int\_to\_binary and binary\_to\_int

Conversion pair for binary representation of integer values.

```
const int input{10};  
// sacfmt::word_one is alias for std::bitset<32> (one word)  
sacfmt::word_one binary{sacfmt::int_to_binary(input)};  
const int output{sacfmt::binary_to_int(binary)};  
std::cout << (input == output) << '\n';
```

#### 4.3.1.2 float\_to\_binary and binary\_to\_float

Conversion pair for binary representation of floating-point values.

```
const float input{5F};
sacfmt::word_one binary{sacfmt::float_to_binary(input)};
const float output{sacfmt::binary_to_float(binary)};
std::cout << (input == output) << '\n';
```

#### 4.3.1.3 double\_to\_binary and binary\_to\_double

Conversion pair for binary representation of double-precision values.

```
const double input{1e5};
// sacfmt::word_two is alias for std::bitset<64> (two words)
sacfmt::word_two binary{sacfmt::double_to_binary(input)};
const double output{sacfmt::binary_to_double(binary)};
std::cout << (input == output) << '\n';
```

#### 4.3.1.4 string\_to\_binary and binary\_to\_string

Conversion pair for binary representation of two-word (regular) string values.

```
const std::string input{"NmlStrng"};
sacfmt::word_two binary{sacfmt::string_to_binary(input)};
const std::string output{sacfmt::binary_to_string(binary)};
std::cout << (input == output) << '\n';
```

#### 4.3.1.5 long\_string\_to\_binary and binary\_to\_long\_string

Conversion pair for binary representation of four-word (only `kstnm` string values).

```
const std::string input{"The Long String"};
// sacfmt::word_four is alias for std::bitset<128> (four words)
sacfmt::word_four binary{sacfmt::long_string_to_binary(input)};
const std::string output{sacfmt::binary_to_long_string(binary)};
std::cout << (input == output) << '\n';
```

### 4.3.2 Reading/Writing

**NOTE** that care must be taken when using them to ensure that safe input is provided; the `Trace` class ensures safe I/O, low-level I/O functions do not necessarily ensure safety.

#### 4.3.2.1 read\_word, read\_two\_words, read\_four\_words, and read\_data

Functions to read one-, two-, and four-word variables (depending on the header) and an arbitrary amount of binary data (exclusive to `data1` and `data2`).

#### 4.3.2.2 convert\_to\_word, convert\_to\_words, and bool\_to\_word

Takes objects and converts them into `std::vector<char>` (`convert_to_word` and `bool_to_word`) or `std::array<char, N>` (`convert_to_words`, `N = # of words`).

#### 4.3.2.3 write\_words

Writes input words (as `std::vector<char>`) to a binary SAC-file.

### 4.3.3 Utility

#### 4.3.3.1 `concat_words`

Concatenates words taking into account the system endianness.

#### 4.3.3.2 `bits_string` and `string_bits`

Template function that performs conversion of binary strings of arbitrary length to an arbitrary number of words.

#### 4.3.3.3 `remove_leading_spaces` and `remove_trailing_spaces`

Remove leading and trailing blank spaces from strings assuming ASCII convention (space character is integer 32, below that value are control characters that also appear as blank spaces).

#### 4.3.3.4 `string_cleaning`

Ensures string does not contain an internal termination character (`\0`) and removes it if present, then removes blank spaces.

#### 4.3.3.5 `prep_string`

Performs `string_cleaning` followed by string truncation/padding to the necessary length.

#### 4.3.3.6 `equal_within_tolerance`

Floating-point/double-precision equality within a provided tolerance (default is `f_eps`, defined in `sac_format.h` ↔ `hpp`).

## 4.4 Testing

Unit- and integration-tests (using Catch2) are contained in the `tests` folder. They include:

- `binary_conversions.cpp` confirms that conversion to/from binary functions correctly.
- `constants.cpp` confirms constant values (e.g. SAC magic numbers) are correct.
- `datetime.cpp` confirms date and time functions work correctly.
- `geometry.cpp` confirms that geometric calculations are correct (azimuth, greater-circle arc-length, etc.).
- `trace.cpp` confirms that the trace class is functioning correctly (I/O, exceptions, bounded headers, etc.).

The tests compile to the following programs:

- `basic_tests` (binary conversions and constants).
- `datetime_tests`
- `geometry_tests`
- `trace_tests`

Test coverage details are visible on [CodeCov.io](https://codecov.io) and [Codacy.com](https://codacy.com). All tests can be locally-run to ensure full functionality and compliance.

#### 4.4.1 Errors only

By default each test prints out a pass summary, without details unless an error is encountered.

#### 4.4.2 Full output

By passing the `--success` flag you can see the full results of all tests.

#### 4.4.3 Compact output

The full output is verbose, using the compact reporter will condense the test results (`--reporter=compact`).

#### 4.4.4 Additional options

To see additional options, run `-?`.

#### 4.4.5 Using ctest

If you have CMake install, you can run the tests using `ctest`.

### 4.5 Benchmarking

`benchmark.cpp` contains the benchmarks. Running it locally will provide information on how long each function takes; benchmarks start with the low-level I/O function and build up to Trace reading, writing, and equality comparison.

To view available optional flags, run `benchmark -?`.

### 4.6 Source File List

#### 4.6.1 Core

The two core files are split in the standard interface (hpp)/implementation (cpp) format.

##### 4.6.1.1 `sac_format.hpp`

Interface: function declarations and constants.

##### 4.6.1.2 `sac_format.cpp`

Implementation: function details.



## 4.6.2 Testing and Benchmarking

### 4.6.2.1 util.hpp

Utility functions and constants exclusive to testing and benchmarking. Not split into interface/implementation.

### 4.6.2.2 utests.cpp

### 4.6.2.3 benchmark.cpp

## 4.6.3 Example programs

### 4.6.3.1 list\_sac.cpp



## Chapter 5

# SAC-file format

The official and up-to-date documentation for the SAC-file format is available from the EarthScope Consortium (formerly IRIS/UNAVCO) [here](#). The following subsections constitute my notes on the format. Below is a quick guide: all credit for the creation of, and documentation for, the SAC file-format belongs to its developers and maintainers (details [here](#)).

### 5.1 Floating-point (39)

32-bit (1 word, 4 bytes)

#### 5.1.1 depmin

Minimum value of the dependent variable (displacement/velocity/acceleration/volts/counts).

#### 5.1.2 depmen

Mean value of the dependent variable.

#### 5.1.3 depmax

Maximum value of the dependent variable.

#### 5.1.4 odelta

Modified (*observational*) value of `delta`.

#### 5.1.5 resp(0–9)

Instrument response parameters (poles, zeros, and a constant).

**Not used by SAC** they're free for other purposes.

### 5.1.6 stel

Station elevation in meters above sea level (*m.a.s.l.*).

**Not used by SAC** free for other purposes.

### 5.1.7 stdp

Station depth in meters below surface (borehole/buried vault).

**Not used by SAC** free for other purposes.

### 5.1.8 evel

Event elevation *m.a.s.l.*

**Not used by SAC** free for other purposes.

### 5.1.9 evdp

Event depth in kilometers (*previously meters*) below surface.

### 5.1.10 mag

Event magnitude.

### 5.1.11 user(0–9)

Storage for user-defined values.

### 5.1.12 dist

Station-Event distance in kilometers.

### 5.1.13 az

Azimuth (*Event → Station*), decimal degrees from North.

### 5.1.14 baz

Back-azimuth (*Station → Event*), decimal degrees from North.

### 5.1.15 gcarc

Station-Event great circle arc-length, decimal degrees.

### 5.1.16 cmpaz

Instrument measurement azimuth, decimal degrees from North.

Value	Direction
0°	North
90°	East
180°	South
270°	West
Other	1/2/3

### 5.1.17 cmpinc

Instrument measurement incident angle, decimal degrees from upward vertical (incident 0° = dip -90°).

Value	Direction
0°	Up
90°	Horizontal
180°	Down
270°	Horizontal

**NOTE:** SEED/MINISEED use dip angle, decimal degrees down from horizontal (dip 0° = incident 90°).

### 5.1.18 xminimum

Spectral-only equivalent of `depmin` (  $f_0$  or  $\omega_0$  ).

### 5.1.19 xmaximum

Spectral-only equivalent of `depmax` (  $f_{max}$  or  $\omega_{max}$  ).

### 5.1.20 yminimum

Spectral-only equivalent of `b`.

### 5.1.21 ymaximum

Spectral-only equivalent of `e`.

## 5.2 Double (22)

64-bit (2 words, 8 bytes)

**NOTE:** in the header section these are floats; they're doubles in the footer section of  $\nu^7$  SAC-files. In memory they're stored as doubles regardless of the SAC-file version.

### 5.2.1 delta

Increment between evenly spaced samples (  $\Delta t$  for timeseries,  $\Delta f$  or  $\Delta \omega$  for spectra).

### 5.2.2 b

First value (*begin*) of independent variable (  $t_0$  ).

### 5.2.3 e

Final value (*end*) of independent variable (  $t_{max}$  ).

### 5.2.4 o

Event *origin* time, in seconds relative to the reference time.

### 5.2.5 a

Event first *arrival* time, in seconds relative to the reference time.

### 5.2.6 t(0–9)

User defined *time* values, in seconds relative to the reference time.

### 5.2.7 f

Event end (*fin*) time, in seconds relative to the reference time.

### 5.2.8 stla

Station latitude in decimal degrees, N/S - positive/negative.

sac-format automatically enforces  $stla \in [-90, 90]$ .

### 5.2.9 stlo

Station longitude in decimal degrees, E/W - positive/negative.

sac-format automatically enforces  $stlo \in [-180, 180]$ .

### 5.2.10 evla

Event latitude in decimal degrees, N/S - positive/negative.

sac-format automatically enforces  $evla \in [-90, 90]$ .

### 5.2.11 evlo

Event longitude in decimal degrees, E/W - positive/negative.

sac-format automatically enforces  $evlo \in [-180, 180]$ .

### 5.2.12 sb

Original (*saved*) `b` value.

### 5.2.13 sdelta

Original (*saved*) `delta` value.

## 5.3 Integer (26)

32-bit (1 word, 4 bytes)

### 5.3.1 nzyear

Reference time GMT year.

### 5.3.2 nzjday

Reference time GMT day-of-year (often called *Julian Date*) (1–366).

### 5.3.3 nzhour

Reference time GMT hour (0–23).

### 5.3.4 nzmin

Reference time GMT minute (0–59).

### 5.3.5 nzsec

Reference time GMT second (0–59).

### 5.3.6 nzmsec

Reference time GMT Millisecond (0–999).

### 5.3.7 nvhdr

SAC-file version.

Version	Description
v7	Footer (2020+, sac 102.0+)
v6	No footer (pre-2020, sac 101.6a-)

### 5.3.8 norid

Origin ID.

### 5.3.9 nevid

Event ID.

### 5.3.10 npts

*Number of points* in data.

### 5.3.11 nsnpts

Original (*saved*) `npts`.

### 5.3.12 nwfid

Waveform ID.

### 5.3.13 nxsize

Spectral-only equivalent of `npts` (length of spectrum).

### 5.3.14 nysize

Spectral-only, width of spectrum.

### 5.3.15 iftype

File type.

Value	Type	Description
01	ITIME	Time-series
02	IRLIM	Spectral ( <i>real/imaginary</i> )
03	IAMPH	Spectral ( <i>amplitude/phase</i> )
04	IXY	General XY file
??	IXYZ*	General XYZ file



\*Value not listed in the standard.

### 5.3.16 idep

Dependent variable type.

Value	Type	Description
05	IUNKN	Unknown
06	IDISP	Displacement (nm)
07	IVEL	Velocity ( $\frac{\text{nm}}{\text{s}}$ )
08	IACC	Acceleration ( $\frac{\text{nm}}{\text{s}^2}$ )
50	IVOLTS	Velocity (volts)

### 5.3.17 iztype

Reference time equivalent.

Value	Type	Description
05	IUNKN	Unknown
09	IB	Recording start time
10	IDAY	Midnight reference GMT day
11	IO	Event origin time
12	IA	First arrival time
13-22	IT(0-9)	User defined time (t) pick

### 5.3.18 iinst

Recording instrument type.

**Not used by SAC:** free for other purposes.

### 5.3.19 istreg

Station geographic region.

**Not used by SAC:** free for other purposes.

### 5.3.20 ievreg

Event geographic region.

**Not used by SAC:** free for other purposes.

### 5.3.21 ievtyp

Event type.

Value	Type	Description
05	IUNKN	Unknown
11	IO	Other source of known origin
37	INUCL	Nuclear
38	IPREN	Nuclear pre-shot
39	IPOSTN	Nuclear post-shot
40	IQUAKE	Earthquake
41	IPREQ	Foreshock
42	IPOSTQ	Aftershock
43	ICHEM	Chemical explosion
44	IOTHER	Other
72	IQB	Quarry/mine blast: confirmed by quarry/mine
73	IQB1	Quarry/mine blast: designed shot info-ripple fired
74	IQB2	Quarry/mine blast: observed shot info-ripple fired
75	IQBX	Quarry/mine blast: single shot
76	IQMT	Quarry/mining induced events: tremor and rockbursts
77	IEQ	Earthquake
78	IEQ1	Earthquake in a swarm or in an aftershock sequence
79	IEQ2	Felt earthquake
80	IME	Marine explosion
81	IEX	Other explosion
82	INU	Nuclear explosion
83	INC	Nuclear cavity collapse
85	IL	Local event of unknown origin
86	IR	Region event of unknown origin
87	IT	Teleseismic event of unknown origin
88	IU	Undetermined/conflicting information

### 5.3.22 igual

Quality of data.

Value	Type	Description
44	IOTHER	Other
45	IGOOD	Good
46	IGLCH	Glitches
47	IDROP	Dropouts
48	ILOWSN	Low signal-to-noise ratio

**Not used by SAC:** free for other purposes.

### 5.3.23 isynth

Synthetic data flag.

Value	Type	Description
49	IRLDATA	Real data
XX	*	Synthetic

\*Values and types not listed in the standard.

### 5.3.24 imagtyp

Magnitude type.

Value	Type	Description
52	IMB	Body-wave magnitude ( $M_b$ )
53	IMS	Surface-wave magnitude ( $M_s$ )
54	IML	Local magnitude ( $M_l$ )
55	IMW	Moment magnitude ( $M_w$ )
56	IMD	Duration magnitude ( $M_d$ )
57	IMX	User-defined magnitude ( $M_x$ )

### 5.3.25 imagsrc

Source of magnitude information.

Value	Type	Description
58	INEIC	National Earthquake Information Center
61	IPDE	Preliminary Determination of Epicenter
62	IISC	International Seismological Centre
63	IREB	Reviewed Event Bulletin
64	IUSGS	U.S. Geological Survey
65	IBRK	UC Berkeley
66	ICALTECH	California Institute of Technology
67	ILLNL	Lawrence Livermore National Laboratory
68	IEVLOC	Event location (computer program)
69	IJSOP	Joint Seismic Observation Program
70	IUSER	The user
71	IUNKNOWN	Unknown

### 5.3.26 ibody

Body/spheroid definition used to calculate distances.

Value	Type	Name	Semi-major axis (a [m])	Inverse Flattening (f)
-12345	UNDEF	Earth ( <i>Historic</i> )	6378160.0	0.00335293
98	ISUN	Sun	696000000.0	8.189e-6
99	IMERCURY	Mercury	2439700.0	0.0
100	IVENUS	Venus	6051800.0	0.0
101	IEARTH	Earth ( <i>WGS84</i> )	6378137.0	0.0033528106647474805
102	IMOON	Moon	1737400.0	0.0
103	IMARS	Mars	3396190.0	0.005886007555525457

## 5.4 Boolean (4)

32-bit (1 word, 4 bytes) in-file/8-bit (1 byte) in-memory

### 5.4.1 leven

**REQUIRED** Evenly-spaced data flag.

If true, then data is evenly spaced.

### 5.4.2 lpspol

Station polarity flag.

If true, then station has positive-polarity; it follows the left-hand convention (for example, North-East-Up [NEZ]).

### 5.4.3 lovrok

File overwrite flag.

If true, then it's okay to overwrite the file.

### 5.4.4 lcalda

Calculate geometry flag.

If true, then calculate `dist`, `az`, `baz`, and `gcarc` from `stla`, `stlo`, `evla`, and `evlo`.

## 5.5 String (23)

32/64-bit (2/4 words, 8/16 bytes, 8/16 characters)

### 5.5.1 kstnm

Station name.

### 5.5.2 kevnrm

Event name.

\*This is the **only** four word (16 character) string.

### 5.5.3 khole

Nuclear: Hole identifier.

Other: Location identifier (LOCID).

### 5.5.4 ko

Text for `o`.

### 5.5.5 ka

Text for `a`.

### 5.5.6 kt(0–9)

Text for `t` (0–9).

### 5.5.7 kf

Text for `f`.

### 5.5.8 kuser(0–2)

Text for the first three of `user` (0–9).

### 5.5.9 kdatrd

Date the data was read onto a computer.

### 5.5.10 kinst

Text for `inst`.

## 5.6 Data (2)

32-bit (2 words, 8 bytes) in-file/64-bit (4 words, 16 bytes) in-memory

Stored as floating-point (32-bit) values in SAC-files; stored as double-precision in memory.

### 5.6.1 data1

The first data vector—**\*\*always\*\*** present in a SAC-file and begins at word 158.

### 5.6.2 data2

The second data vector—**\*\*conditionally\*\*** present and begins after `data1`.

**Required** if `leven` is false, or if `iftype` is `spectral/XY/XYZ`.



# Chapter 6

## Build Instructions

### 6.1 Dependencies

#### 6.1.1 Automatic (CMake)

`Xoshiro-cpp v1.12.0` (testing and benchmarking).

#### 6.1.2 Manual

`Catch2 v3.4.0` (testing and benchmarking). Note that this is automatic on Windows (not Linux nor macOS).

##### 6.1.2.1 macOS and Linux

```
git clone https://github.com/catchorg/Catch2.git
cd Catch2
git checkout v3.5.2
cmake -Bbuild -S. -DBUILD_TESTING=OFF
sudo cmake --build ./build/ --target install
```

### 6.2 Building

Building is as easy as cloning the repository, running CMake for your preferred build tool, and then building.

#### 6.2.1 GCC

```
git clone https://github.com/arbCoding/sac-format.git
cd sac-format
cmake --preset gcc-hard-release
cmake --build ./build/hard/release/gcc
```

#### 6.2.2 Clang

```
git clone https://github.com/arbCoding/sac-format.git
cd sac-format
cmake --preset clang-hard-release
cmake --build ./build/hard/release/clang
```

#### 6.2.3 MSVC

```
git clone https://github.com/arbCoding/sac-format.git
cd sac-format
cmake -B ./build -DCMAKE_BUILD_TYPE=Release -DCMAKE_CXX_STANDARD=20 -DCMAKE_CXX_STANDARD_REQUIRED=ON
  -DCMAKE_CXX_EXTENSIONS=OFF -DCMAKE_CXX_FLAGS="/O2 /EHsc /Gs /guard:cf"
```





## Chapter 7

# Namespace Index

### 7.1 Namespace List

Here is a list of all namespaces with brief descriptions:

<a href="#">sacfmt</a>	Sac-format namespace . . . . .	<a href="#">47</a>
<a href="#">sacfmt::bitset_type</a>	Bitset type-safety namespace . . . . .	<a href="#">99</a>



## Chapter 8

# Hierarchical Index

### 8.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

std::exception	
sacfmt::io_error . . . . .	101
sacfmt::read_spec . . . . .	103
sacfmt::Trace . . . . .	104
sacfmt::bitset_type::uint< nbits > . . . . .	188
sacfmt::bitset_type::uint< 4 *bits_per_byte > . . . . .	188
sacfmt::bitset_type::uint< bytes *bits_per_byte > . . . . .	188
sacfmt::word_pair< T > . . . . .	189



## Chapter 9

# Class Index

### 9.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

<a href="#">sacfmt::io_error</a>	
Class for generic I/O exceptions . . . . .	101
<a href="#">sacfmt::read_spec</a>	
Struct that specifies parameters for reading . . . . .	103
<a href="#">sacfmt::Trace</a>	
The <a href="#">Trace</a> class . . . . .	104
<a href="#">sacfmt::bitset_type::uint&lt; nbits &gt;</a>	
Ensure type-safety for conversions between floats/doubles and bitsets . . . . .	188
<a href="#">sacfmt::bitset_type::uint&lt; 4 *bits_per_byte &gt;</a>	
One-word (floats) . . . . .	188
<a href="#">sacfmt::bitset_type::uint&lt; bytes *bits_per_byte &gt;</a>	
. . . . .	188
<a href="#">sacfmt::word_pair&lt; T &gt;</a>	
Struct containing a pair of words . . . . .	189



# Chapter 10

## Namespace Documentation

### 10.1 sacfmt Namespace Reference

sac-format namespace

#### Namespaces

- namespace [bitset\\_type](#)  
*bitset type-safety namespace.*

#### Classes

- class [io\\_error](#)  
*Class for generic I/O exceptions.*
- struct [read\\_spec](#)  
*Struct that specifies parameters for reading.*
- class [Trace](#)  
*The [Trace](#) class.*
- struct [word\\_pair](#)  
*Struct containing a pair of words.*

#### Typedefs

- [using char\\_bit](#) = [std::bitset](#)< [bits\\_per\\_byte](#) >  
*One binary character (useful for building strings).*
- [using word\\_one](#) = [std::bitset](#)< [binary\\_word\\_size](#) >  
*One binary word (useful for non-strings).*
- [using word\\_two](#) = [std::bitset](#)< [static\\_cast](#)< [size\\_t](#) >(2) \*[binary\\_word\\_size](#) >  
*Two binary words (useful for strings).*
- [using word\\_four](#) = [std::bitset](#)< [static\\_cast](#)< [size\\_t](#) >(4) \*[binary\\_word\\_size](#) >  
*Four binary words (kEvNm only).*
- [template](#)<[class T](#) >  
[using unsigned\\_int](#) = [typename](#) [bitset\\_type::uint](#)< [sizeof](#)(T) \*[bits\\_per\\_byte](#) >::type  
*Convert variable to unsigned-integer using type-safe conversions.*

## Enumerations

- enum class `name` {  
`depmin` , `depmax` , `odelta` , `resp0` ,  
`resp1` , `resp2` , `resp3` , `resp4` ,  
`resp5` , `resp6` , `resp7` , `resp8` ,  
`resp9` , `stel` , `stdp` , `evel` ,  
`evdp` , `mag` , `user0` , `user1` ,  
`user2` , `user3` , `user4` , `user5` ,  
`user6` , `user7` , `user8` , `user9` ,  
`dist` , `az` , `baz` , `gcarc` ,  
`depmen` , `cmpaz` , `cmpinc` , `xminimum` ,  
`xmaximum` , `yminimum` , `ymaximum` , `delta` ,  
`b` , `e` , `o` , `a` ,  
`t0` , `t1` , `t2` , `t3` ,  
`t4` , `t5` , `t6` , `t7` ,  
`t8` , `t9` , `f` , `stla` ,  
`stlo` , `evla` , `evlo` , `sb` ,  
`sdelta` , `nzyear` , `nzjday` , `nzhour` ,  
`nzmin` , `nzsec` , `nzmsec` , `nvhdr` ,  
`norid` , `nevid` , `npts` , `nsnpts` ,  
`nwfid` , `nxsize` , `nysize` , `iftype` ,  
`idep` , `iztype` , `iinst` , `istreg` ,  
`ievreg` , `ievtyp` , `iqua` , `isynth` ,  
`imagtyp` , `imagsrc` , `ibody` , `leven` ,  
`lpspol` , `lovrok` , `lcalda` , `kstnm` ,  
`kevm` , `khole` , `ko` , `ka` ,  
`kt0` , `kt1` , `kt2` , `kt3` ,  
`kt4` , `kt5` , `kt6` , `kt7` ,  
`kt8` , `kt9` , `kf` , `kuser0` ,  
`kuser1` , `kuser2` , `kcompnm` , `knetwk` ,  
`kdatrd` , `kinst` , `data1` , `data2` }

*Enumeration of all SAC fields.*

## Functions

- `std::streamoff word_position (const size_t word_number) noexcept`  
*Calculates position of word in SAC-file.*
- `word_one uint_to_binary (uint num) noexcept`  
*Convert unsigned integer to 32-bit (one word) binary bitset.*
- `word_one int_to_binary (int num) noexcept`  
*Convert integer to 32-bit (one word) binary bitset.*
- `int binary_to_int (word_one bin) noexcept`  
*Convert 32-bit (one word) binary bitset to integer.*
- `word_one float_to_binary (const float num) noexcept`  
*Convert floating-point value to 32-bit (one word) binary bitset.*
- `float binary_to_float (const word_one &bin) noexcept`  
*Convert 32-bit (one word) binary bitset to a floating-point value.*
- `word_two double_to_binary (const double num) noexcept`  
*Convert double-precision value to 64-bit (two words) binary bitset.*
- `double binary_to_double (const word_two &bin) noexcept`  
*Convert 64-bit (two words) binary bitset to double-precision value.*
- `void remove_leading_spaces (std::string *str) noexcept`  
*Remove all leading spaces from a string.*



- `void remove_trailing_spaces (std::string *str) noexcept`  
*Remove all trailing spaces from a string.*
- `std::string string_cleaning (const std::string &str) noexcept`  
*Remove leading/trailing spaces and control characters from a string.*
- `void prep_string (std::string *str, const size_t str_size) noexcept`  
*Cleans string and then truncates/pads as necessary.*
- `template<typename T >`  
`void string_bits (T *bits, const std::string &str, const size_t str_size) noexcept`  
*Template function to convert string into binary bitset.*
- `template<typename T >`  
`std::string bits_string (const T &bits, const size_t num_words) noexcept`  
*Template function to convert binary bitset to string.*
- `word_two string_to_binary (std::string str) noexcept`  
*Convert string to a 64-bit (two word) binary bitset.*
- `std::string binary_to_string (const word_two &str) noexcept`  
*Convert a 64-bit (two word) binary bitset to a string.*
- `word_four long_string_to_binary (std::string str) noexcept`  
*Convert a string to a 128-bit (four word) binary bitset.*
- `std::string binary_to_long_string (const word_four &str) noexcept`  
*Convert a 128-bit (four word) binary bitset to a string.*
- `word_one bool_to_binary (const bool flag) noexcept`  
*Convert a boolean to a 32-bit (one word) binary bitset.*
- `bool binary_to_bool (const word_one &flag) noexcept`  
*Convert a 32-bit (one word) binary bitset to a boolean.*
- `word_two concat_words (const word_pair< word_one > &pair_words) noexcept`  
*Concatenate two `word_one` binary strings into a single `word_two` string.*
- `word_four concat_words (const word_pair< word_two > &pair_words) noexcept`  
*Concatenate two `word_two` binary strings into a single `word_four` string.*
- `bool nwords_after_current (std::ifstream *sac, const read_spec &spec) noexcept`  
*Determine if the SAC-file has enough remaining data to read the requested amount of data.*
- `void safe_to_read_header (std::ifstream *sac)`  
*Determine if the SAC-file is large enough to contain a complete header.*
- `void safe_to_read_footer (std::ifstream *sac)`  
*Determines if the SAC-file has enough space remaining to contain a complete footer.*
- `void safe_to_read_data (std::ifstream *sac, const size_t n_words, const bool data2)`  
*Determines if the SAC-file has enough space remaining to contain a complete data vector.*
- `void safe_to_finish_reading (std::ifstream *sac)`  
*Determines if the SAC-file is finished.*
- `word_one read_word (std::ifstream *sac)`  
*Read one word (32 bits, useful for non-strings) from a binary SAC-File.*
- `word_two read_two_words (std::ifstream *sac)`  
*Read two words (64 bits, useful for most strings) from a binary SAC-file.*
- `word_four read_four_words (std::ifstream *sac)`  
*Read four words (128 bits, kEvNm only) from a binary SAC-file.*
- `std::vector< double > read_data (std::ifstream *sac, const read_spec &spec)`  
*Reader arbitrary number of words (useful for vectors) from a binary SAC-file.*
- `void write_words (std::ofstream *sac_file, const std::vector< char > &input)`  
*Write arbitrary number of words (useful for vectors) to a binary SAC-file.*
- `template<typename T >`  
`std::vector< char > convert_to_word (const T input) noexcept`  
*Template function to convert input value into a `std::vector<char>` for writing.*

- `std::vector< char > convert_to_word (const double input) noexcept`  
*Convert double value into a std::vector<char> for writing.*
- `template<size_t N>`  
`std::array< char, N > convert_to_words (const std::string &str, int n_words) noexcept`  
*Template function to convert input string value into a std::array<char> for writing.*
- `std::vector< char > bool_to_word (const bool flag) noexcept`  
*Convert boolean to a word for writing.*
- `bool equal_within_tolerance (const std::vector< double > &vector1, const std::vector< double > &vector2, const double tolerance) noexcept`  
*Check if two std::vector<double> are equal within a tolerance limit.*
- `bool equal_within_tolerance (const double val1, const double val2, const double tolerance) noexcept`  
*Check if two double values are equal within a tolerance limit.*
- `double degrees_to_radians (const double degrees) noexcept`  
*Convert decimal degrees to radians.*
- `double radians_to_degrees (const double radians) noexcept`  
*Convert radians to decimal degrees.*
- `double gcarc (const double latitude1, const double longitude1, const double latitude2, const double longitude2) noexcept`  
*Calculate great circle arc distance in decimal degrees between two points.*
- `double azimuth (const double latitude1, const double longitude1, const double latitude2, const double longitude2) noexcept`  
*Calculate azimuth between two points.*
- `double limit_360 (const double degrees) noexcept`  
*Takes a decimal degree value and constrains it to full circle using symmetry.*
- `double limit_180 (const double degrees) noexcept`  
*Takes a decimal degree value and constrains it to a half circle using symmetry.*
- `double limit_90 (const double degrees) noexcept`  
*Takes a decimal degree value and constrains it to a quarter circle using symmetry.*
- `template std::vector< char > convert_to_word (const float input) noexcept`
- `template std::vector< char > convert_to_word (const int x) noexcept`
- `template std::array< char, word_length > convert_to_words (const std::string &str, const int n_words) noexcept`

## Variables

- `constexpr size_t word_length {4}`  
*Size (bytes) of fundamental data-chunk.*
- `constexpr size_t bits_per_byte {8}`  
*Size (bits) of binary character.*
- `constexpr size_t binary_word_size {word_length * bits_per_byte}`  
*Size (bits) of fundamental data-chunk.*
- `constexpr std::streamoff data_word {158}`  
*First word of (first) data-section (stream offset).*
- `constexpr int unset_int {-12345}`  
*Integer unset value (SAC Magic).*
- `constexpr float unset_float {-12345.0F}`  
*Float-point unset value (SAC Magic).*
- `constexpr double unset_double {-12345.0}`  
*Double-precision unset value (SAC Magic).*
- `constexpr bool unset_bool {false}`  
*Boolean unset value (SAC Magic).*

- `const std::string unset_word {"-12345"}`  
*String unset value (SAC Magic).*
- `constexpr float f_eps {2.75e-6F}`  
*Accuracy precision expected of SAC floating-point values.*
- `constexpr int ascii_space {32}`  
*ASCII-code of 'space' character.*
- `constexpr int num_float {39}`  
*Number of float-point header values in SAC format.*
- `constexpr int num_double {22}`  
*Number of double-precision header values in SAC format.*
- `constexpr int num_int {26}`  
*Number of integer header values in SAC format.*
- `constexpr int num_bool {4}`  
*Number of boolean header values in SAC format.*
- `constexpr int num_string {23}`  
*Number of string header values in SAC format.*
- `constexpr int num_data {2}`  
*Number of data arrays in SAC format.*
- `constexpr int num_footer {22}`  
*Number of double-precision footer values in SAC format (version 7).*
- `constexpr int modern_hdr_version {7}`  
*nVHdr value for newest SAC format (2020+).*
- `constexpr int old_hdr_version {6}`  
*nVHdr value for historic SAC format (pre-2020).*
- `constexpr int common_skip_num {7}`  
*Extremely common number of 'internal use' headers in SAC format.*
- `constexpr double rad_per_deg {std::numbers::pi_v<double> / 180.0}`  
*Radians per degree.*
- `constexpr double deg_per_rad {1.0 / rad_per_deg}`  
*Degrees per radian.*
- `constexpr double circle_deg {360.0}`  
*Degrees in a circle.*
- `constexpr double earth_radius {6378.14}`  
*Average radius of Earth (kilometers).*
- `const std::unordered_map< name, const size_t > sac_map`  
*Lookup table for variable locations.*

### 10.1.1 Detailed Description

sac-format namespace

### 10.1.2 Typedef Documentation

#### 10.1.2.1 char\_bit

```
using sacfmt::char_bit = typedef std::bitset<bits_per_byte>
```

One binary character (useful for building strings).

### 10.1.2.2 unsigned\_int

```
template<class T >
using sacfmt::unsigned_int = typedef typename bitset_type::uint<sizeof(T) * bits_per_byte>←
::type
```

Convert variable to unsigned-integer using type-safe conversions.

### 10.1.2.3 word\_four

```
using sacfmt::word_four = typedef std::bitset<static_cast<size_t>(4) * binary_word_size>
```

Four binary words (kEvNm only).

### 10.1.2.4 word\_one

```
using sacfmt::word_one = typedef std::bitset<binary_word_size>
```

One binary word (useful for non-strings).

### 10.1.2.5 word\_two

```
using sacfmt::word_two = typedef std::bitset<static_cast<size_t>(2) * binary_word_size>
```

Two binary words (useful for strings).

## 10.1.3 Enumeration Type Documentation

### 10.1.3.1 name

```
enum class sacfmt::name [strong]
```

Enumeration of all SAC fields.

Additional information can be found at [SAC-file format](#)

#### Enumerator

depmin	Float Minimum value of the dependent variable (displacement/velocity/acceleration/volts/counts).
depmax	Float Maximum value of the dependent variable.
odelta	Float Modified (observational) value of delta.
resp0	Float Instrument response parameter (poles, zeros, and a constant). Not used by SAC - free for other purposes.
resp1	See resp0.
resp2	See resp0.

## Enumerator

resp3	See resp0.
resp4	See resp0.
resp5	See resp0.
resp6	See resp0.
resp7	See resp0.
resp8	See resp0.
resp9	See resp0.
stel	Float Station elevation in meters above sea level (m.a.s.l.). Not used by SAC - free for other purposes.
stdp	Float Station depth in meters below surface (borehole/buried vault). Not used by SAC - free for other purposes.
evel	Float Event elevation m.a.s.l. Not used by SAC - free for other purposes.
evdp	Float Event depth in kilometers (previous meters) below surface.
mag	Float Event magnitude.
user0	Float Storage for user-defined values.
user1	See user0.
user2	See user0.
user3	See user0.
user4	See user0.
user5	See user0.
user6	See user0.
user7	See user0.
user8	See user0.
user9	See user0.
dist	Float Station-Event distance in kilometers.
az	Float Azimuth <i>Station</i> → <i>Event</i> in decimal degrees from North.
baz	Float Back-Azimuth <i>Event</i> → <i>Station</i> in decimal degrees from North.
gcarc	Float Great-circle arc-distance between station and event in decimal degrees.
depmen	Float Mean value of dependent variable.
cmpaz	Float Instrument measurement azimuth, decimal degrees from North.
cmpinc	Float Instrument measurement incidence angle, decimal degrees from upward vertical (incident 0 = dip -90). Note: SEED/MINISEED use dip angle, decimal degrees from horizontal (dip 0 = incident 90).
xminimum	Float Spectral-only equivalent of depmin ( $f_0$ or $\omega_0$ ).
xmaximum	Float Spectral-only equivalent of depman ( $f_{max}$ or $\omega_{max}$ ).

## Enumerator

yminimum	Float Spectral-only equivalent of b.
ymaximum	Float Spectral-only equivalent of e.
delta	Double Increment between evenly-spaced samples ( $\Delta t$ for timeseries, $\Delta f$ or $\Delta \omega$ for spectral).
b	Double First value (beginning) of independent variable ( $t_0$ ).
e	Double Final value (ending) of the independent variable ( $t_{max}$ ).
o	Double Event origin time, in seconds relative to the reference time.
a	Double Event first arrival time, in seconds relative to the reference time.
t0	Double User defined time value, in seconds relative to the reference time.
t1	See t0.
t2	See t0.
t3	See t0.
t4	See t0.
t5	See t0.
t6	See t0.
t7	See t0.
t8	See t0.
t9	See t0.
f	Double Event end (fini) time, in seconds relative to the reference time.
stla	Double Station latitude in decimal degrees, N/S is positive/negative. sac-format automatically enforces $\phi \in [-90, 90]$ .
stlo	Double Station longitude in decimal degrees, E/W is positive/negative. sac-format automatically enforces $\lambda \in [-180, 180]$ .
evla	Double Event latitude in decimal degrees, N/S is positive/negative. sac-format automatically enforces $\phi \in [-90, 90]$ .
evlo	Double Event longitude in decimal degrees, E/W is positive/negative. sac-format automatically enforces $\lambda \in [-180, 180]$ .
sb	Double Original (saved) value of b (beginning).
sdelta	Double Original (saved) value of delta (sample-spacing).
nzyear	Integer Reference time GMT year.
nzjday	Integer Reference time GMT day-of-year (often called Julian Date). 1-366 Not enforced.
nzhour	Integer Reference time GMT hour. 00-23 Not enforced.

## Enumerator

nzmin	Integer Reference time GMT minute. 00-59 Not enforced.
nzsec	Integer Reference time GMT second. 00-59 Not enforced.
nzmsc	Integer Reference time GMT millisecond. 0-999 not enforced.
nvhdr	Integer SAC-file version. 7 = 2020+, sac 102.0+, has a Footer. 6 = pre-2020, sac 101.6a-, no Footer.
norid	Integer Origin ID.
nevid	Integer Event ID.
npts	Integer Number of points in data.
nsnpts	Integer Original (saved) npts.
nwfid	Integer Waveform ID.
nxsize	Integer Spectral-only equivalent of npts (length of spectrum).
nysize	Integer Spectral-only; width of spectrum.
iftype	Integer File type.
idep	Integer Dependent variable type.
iztype	Integer Reference time equivalent.
iinst	Integer Recording instrument type. Not used by SAC - free for other purposes.
istreg	Integer Station geographic region. Not used by SAC - free for other purposes.
ievreg	Integer Event geographic region. Not used by SAC - free for other purposes.
ievtyp	Integer Event type. Not used by SAC - free for other purposes.
iqua	Integer Quality of data. Not used by SAC - free for other purposes.
isynth	Integer Synthetic data flag. Not used by SAC - free for other purposes.
imagtyp	Integer Magnitude type.

## Enumerator

imagsrc	Integer Magnitude information source.
ibody	Integer Body/spheroid definition used to calculate distances. Not currently-used by sac-format (SAC does use it).
leven	Boolean REQUIRED Evenly-spaced data flag. True = even.
lpspol	Boolean Station polarity flag. True = positive (left-handed, e.g. North-East-Up).
lovrok	Boolean File overwrite flag. If true, okay to overwrite file. Not used by sac-format.
lcalda	Boolean Calculate geometry flag. Not used by sac-format.
kstnm	String (2 words) Station name.
kevnrm	String (4 words) Event name.
khole	String (2 words) Nuclear-Hole identifier. Other-Location identifier (LOCID).
ko	String (2 words) Text for o.
ka	String (2 words) Text for a.
kt0	String (2 words) Text for t0
kt1	See kt0.
kt2	See kt0.
kt3	See kt0.
kt4	See kt0.
kt5	See kt0.
kt6	See kt0.
kt7	See kt0.
kt8	See kt0.
kt9	See kt0.
kf	String (2 words) Text for f.
kuser0	String (2 words) Text for user0.
kuser1	See kuser0.
kuser2	See kuser0.
kcmpnm	String (2 words) Component name.
knetwk	String (2 words) Network name.
kdatrd	String (2 words) Date the data was read onto a computer.



## Enumerator

kinst	String (2 words) Instrument name.
data1	std::vector<double> First data vector. ALWAYS present, ALWAYS begins at word 158.
data2	std::vector<double> Second data vector. CONDITIONAL present. IF PRESENT, begins at end of data1. Required if leven is false (uneven sampling), or if iftype is spectral/XY/XYZ.

```

00280
00281 // Floats
00288 depmin,
00294 depmax,
00300 odelta,
00308 resp0,
00310 resp1,
00312 resp2,
00314 resp3,
00316 resp4,
00318 resp5,
00320 resp6,
00322 resp7,
00324 resp8,
00326 resp9,
00334 stel,
00342 stdp,
00350 evel,
00356 evdp,
00362 mag,
00368 user0,
00370 user1,
00372 user2,
00374 user3,
00376 user4,
00378 user5,
00380 user6,
00382 user7,
00384 user8,
00386 user9,
00392 dist,
00399 az,
00406 baz,
00412 gcarc,
00418 depmen,
00424 cmpaz,
00434 cmpinc,
00441 xminimum,
00448 xmaximum,
00454 yminimum,
00460 ymaximum,
00461 // Doubles
00470 delta,
00476 b,
00483 e,
00489 o,
00495 a,
00501 t0,
00503 t1,
00505 t2,
00507 t3,
00509 t4,
00511 t5,
00513 t6,
00515 t7,
00517 t8,
00519 t9,
00525 f,
00533 stla,
00541 stlo,
00549 evla,
00557 evlo,
00563 sb,
00569 sdelta,
00570 // Ints
00576 nzyear,
00584 nzjday,
00592 nzhour,
00600 nzmin,
00608 nzsec,
00616 nzmsec,
00625 nvhdr,

```

```

00631     norid,
00637     nevid,
00643     npts,
00649     nsnpts,
00655     nwfid,
00661     nxsize,
00667     nysize,
00673     iftype,
00679     idep,
00685     iztype,
00693     iinst,
00701     istreg,
00709     ievreg,
00717     ievtyp,
00725     igual,
00733     isynth,
00739     imagtyp,
00745     imagsrc,
00753     ibody,
00754     // Bools
00762     leven,
00770     lspol,
00780     lovrok,
00788     lcalda,
00789     // Strings
00795     kstnm,
00801     kevnrm,
00809     khole,
00815     ko,
00821     ka,
00827     kt0,
00829     kt1,
00831     kt2,
00833     kt3,
00835     kt4,
00837     kt5,
00839     kt6,
00841     kt7,
00843     kt8,
00845     kt9,
00851     kf,
00857     kuser0,
00859     kuser1,
00861     kuser2,
00867     kcmpnm, // missing in org documentation
00873     knetwk, // missing in org documentation
00879     kdatrd,
00885     kinst,
00886     // Data
00892     data1,
00901     data2
00902 };

```

## 10.1.4 Function Documentation

### 10.1.4.1 azimuth()

```

double sacfmt::azimuth (
    const double latitude1,
    const double longitude1,
    const double latitude2,
    const double longitude2 ) [noexcept]

```

Calculate azimuth between two points.

Assumes spherical Earth (in future may update to solve on a more general body).

$\phi$  is latitude.  $\lambda$  is longitude.  $\theta$  is azimuth.

$$\theta = \tan^{-1} \left( \frac{\sin(\delta\lambda)\cos(\phi_2)}{\cos(\phi_1)\sin(\phi_2) - \sin(\phi_1)\cos(\phi_2)\cos(\delta\lambda)} \right)$$

## Parameters

in	<i>latitude1</i>	Latitude of first location in decimal degrees.
in	<i>longitude1</i>	Longitude of first location in decimal degrees.
in	<i>latitude2</i>	Latitude of second location in decimal degrees.
in	<i>longitude2</i>	Longitude of second location in decimal degrees.

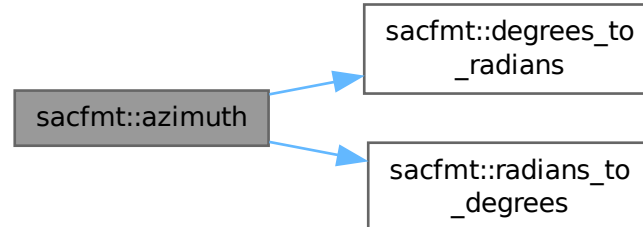
## Returns

double The azimuth from the first location to the second location.

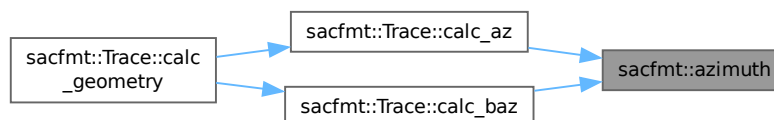
```

00739                                     {
00740     const double lat1{degrees_to_radians(latitude1)};
00741     const double lon1{degrees_to_radians(longitude1)};
00742     const double lat2{degrees_to_radians(latitude2)};
00743     const double lon2{degrees_to_radians(longitude2)};
00744     const double dlon{lon2 - lon1};
00745     const double numerator{std::sin(dlon) * std::cos(lat2)};
00746     const double denominator{(std::cos(lat1) * std::sin(lat2)) -
00747                               (std::sin(lat1) * std::cos(lat2) * std::cos(dlon))};
00748     double result{radians_to_degrees(std::atan2(numerator, denominator))};
00749     while (result < 0.0) {
00750         result += circle_deg;
00751     }
00752     return result;
00753 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.2 `binary_to_bool()`

```
bool sacfmt::binary_to_bool (
    const word_one & flag ) [noexcept]
```

Convert a 32-bit (one word) binary bitset to a boolean.

## Parameters

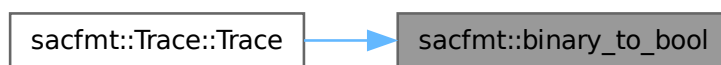
in	<i>flag</i>	<a href="#">word_one</a> binary bitset to be converted (takes zeroth element).
----	-------------	--

## Returns

boolean Converted boolean value.

```
00357 { return flag[0]; }
```

Here is the caller graph for this function:



## 10.1.4.3 binary\_to\_double()

```
double sacfmt::binary_to_double (
    const word_two & bin ) [noexcept]
```

Convert 64-bit (two words) binary bitset to double-precision value.

Converts bitset to unsigned long long then to double.

## Parameters

in	<i>bin</i>	<a href="#">word_two</a> Binary value to be converted.
----	------------	--

## Returns

double Converted value.

```
00159                                     {
00160     const auto val = bin.to_ullong();
00161     double result{};
00162     // flawfinder: ignore
00163     memcpy(&result, &val, sizeof(double));
00164     return result;
00165 }
```

Here is the caller graph for this function:



#### 10.1.4.4 `binary_to_float()`

```
float sacfmt::binary_to_float (
    const word_one & bin ) [noexcept]
```

Convert 32-bit (one word) binary bitset to a floating-point value.

Converts bitset to unsigned long then to float.

##### Parameters

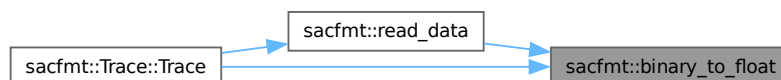
in	<i>bin</i>	<code>word_one</code> Binary value to be converted.
----	------------	---

##### Returns

float Converted value.

```
00127                                     {
00128     const auto val = bin.to_ulong();
00129     float result{};
00130     // flawfinder: ignore
00131     memcpy(&result, &val, sizeof(float));
00132     return result;
00133 }
```

Here is the caller graph for this function:



#### 10.1.4.5 `binary_to_int()`

```
int sacfmt::binary_to_int (
    word_one bin ) [noexcept]
```

Convert 32-bit (one word) binary bitset to integer.

Uses two's complement to convert a binary value into an integer.

## Parameters

in	<i>bin</i>	Binary value to be converted.
----	------------	-------------------------------

## Returns

int Converted value.

```

00088                                     {
00089     int result{};
00090     if (bin.test(binary_word_size - 1)) {
00091         // Complement
00092         bin.flip();
00093         result = static_cast<int>(bin.to_ulong());
00094         result += 1;
00095         // Change sign to make it negative
00096         result *= -1;
00097     } else {
00098         result = static_cast<int>(bin.to_ulong());
00099     }
00100     return result;
00101 }
```

Here is the caller graph for this function:



## 10.1.4.6 binary\_to\_long\_string()

```

std::string sacfmt::binary_to_long_string (
    const word_four & str ) [noexcept]
```

Convert a 128-bit (four word) binary bitset to a string.

Exclusively used to work with the kEvNm header.

## Parameters

in	<i>str</i>	<i>word_four</i> to be converted to a string.
----	------------	---

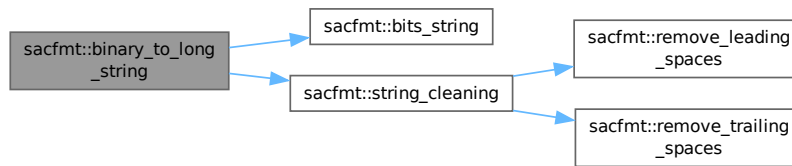
## Returns

std::string Converted string.

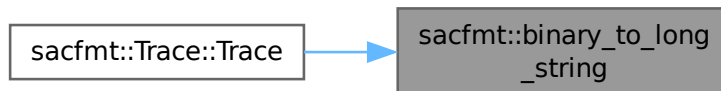
```

00332                                     {
00333     std::string result{bits_string(str, 4)};
00334     return string_cleaning(result);
00335 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.7 binary\_to\_string()

```
std::string sacfmt::binary_to_string (
    const word_two & str ) [noexcept]
```

Convert a 64-bit (two word) binary bitset to a string.

##### Parameters

in	str	word_two to be converted to a string.
----	-----	---------------------------------------



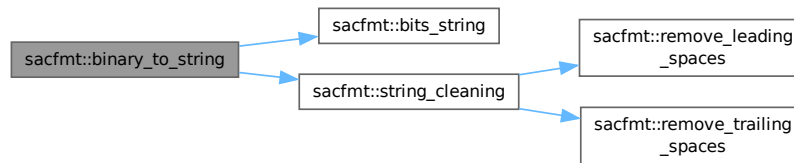
**Returns**

std::string Converted string.

```

00298                                     {
00299     std::string result{bits_string(str, 2)};
00300     return string_cleaning(result);
00301 }
```

Here is the call graph for this function:



Here is the caller graph for this function:

**10.1.4.8 bits\_string()**

```

template<typename T >
std::string sacfmt::bits_string (
    const T & bits,
    const size_t num_words ) [noexcept]
```

Template function to convert binary bitset to string.

**Parameters**

in	<i>bits</i>	Source bitset for the string.
in	<i>num_words</i>	Length of string in words (4 chars = 1 word)

**Returns**

std::string String converted from bitset.

```

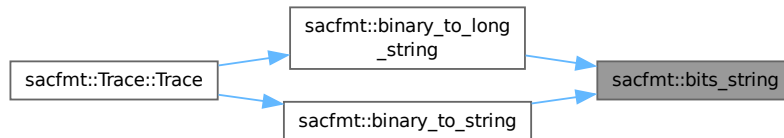
00258                                     {
00259     std::string result{};
00260     result.reserve(num_words * word_length);
00261     constexpr size_t char_size{bits_per_byte};
```

```

00262     char_bit byte{};
00263     for (size_t i{0}; i < num_words * binary_word_size; i += char_size) {
00264         for (size_t j{0}; j < char_size; ++j) [[likely]] {
00265             byte[j] = bits[i + j];
00266         }
00267         result.push_back(static_cast<char>(byte.to_ulong()));
00268     }
00269     return result;
00270 }

```

Here is the caller graph for this function:



#### 10.1.4.9 bool\_to\_binary()

```

word_one sacfmt::bool_to_binary (
    const bool flag ) [noexcept]

```

Convert a boolean to a 32-bit (one word) binary bitset.

##### Parameters

in	flag	Boolean value to be converted to a bitset (sets zeroth element).
----	------	--

##### Returns

**word\_one** Converted binary bitset.

```

00344                                     {
00345     word_one result{};
00346     result[0] = flag;
00347     return result;
00348 }

```

#### 10.1.4.10 bool\_to\_word()

```

std::vector< char > sacfmt::bool_to_word (
    const bool flag ) [noexcept]

```

Convert boolean to a word for writing.

##### Parameters

in	flag	Boolean to be converted.
----	------	--------------------------

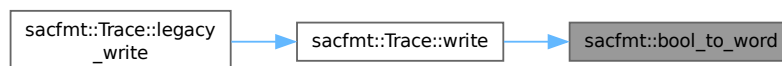
**Returns**

`std::vector<char>` Prepared value for writing.

```

00598                                     {
00599     std::vector<char> result;
00600     result.resize(word_length);
00601     result[0] = static_cast<char>(flag ? 1 : 0);
00602     for (size_t i{1}; i < word_length; ++i) {
00603         result[i] = 0;
00604     }
00605     return result;
00606 }
```

Here is the caller graph for this function:

**10.1.4.11 concat\_words() [1/2]**

```

word_two sacfmt::concat_words (
    const word_pair< word_one > & pair_words ) [noexcept]
```

Concatenate two `word_one` binary strings into a single `word_two` string.

Useful for reading strings from SAC-files.

**Parameters**

in	<code>pair_words</code>	<code>word_pair</code> Words to be concatenated.
----	-------------------------	--

**Returns**

`word_two` Concatenated words.

```

00368                                     {
00369     word_two result{};
00370     for (size_t i{0}; i < binary_word_size; ++i) [[likely]] {
00371         result[i] = pair_words.first[i];
00372         result[i + binary_word_size] = pair_words.second[i];
00373     }
00374     return result;
00375 }
```

Here is the caller graph for this function:



**10.1.4.12 concat\_words()** [2/2]

```
word_four sacfmt::concat_words (
    const word_pair< word_two > & pair_words ) [noexcept]
```

Concatenate two `word_two` binary strings into a single `word_four` string.

Exclusively used to read kEvNm header from SAC-file.

**Parameters**

in	<i>pair_words</i>	<code>word_pair</code> Words to be concatenated.
----	-------------------	--

**Returns**

`word_four` Concatenated words.

```
00386
00387     word_four result{};
00388     constexpr size_t two_words(2 * binary_word_size);
00389     for (size_t i{0}; i < two_words; ++i) [[likely]] {
00390         result[i] = pair_words.first[i];
00391         result[i + two_words] = pair_words.second[i];
00392     }
00393     return result;
00394 }
```

**10.1.4.13 convert\_to\_word()** [1/4]

```
std::vector< char > sacfmt::convert_to_word (
    const double input ) [noexcept]
```

Convert double value into a `std::vector<char>` for writing.

**Parameters**

in	<i>input</i>	Input value to convert (double).
----	--------------	----------------------------------

**Returns**

`std::vector<char>` Prepared for writing to binary SAC-file.

```
00550
00551     std::array<char, static_cast<size_t>(2) * word_length> tmp{};
00552     // Copy bytes from input into the tmp array
00553     // flawfinder: ignore
00554     std::memcpy(tmp.data(), &input, static_cast<size_t>(2) * word_length);
00555     std::vector<char> word{};
00556     word.resize(static_cast<size_t>(2) * word_length);
00557     for (size_t i{0}; i < 2 * word_length; ++i) {
00558         word[i] = tmp[i];
00559     }
00560     return word;
00561 }
```

**10.1.4.14 convert\_to\_word()** [2/4]

```
template std::vector< char > sacfmt::convert_to_word (
    const float input ) [noexcept]
```

## 10.1.4.15 convert\_to\_word() [3/4]

```
template std::vector< char > sacfmt::convert_to_word (
    const int x ) [noexcept]
```

## 10.1.4.16 convert\_to\_word() [4/4]

```
template<typename T >
std::vector< char > sacfmt::convert_to_word (
    const T input ) [noexcept]
```

Template function to convert input value into a std::vector<char> for writing.

## Parameters

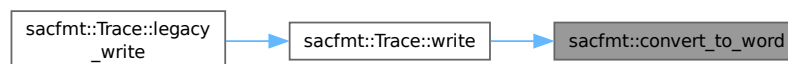
in	input	Input value (float or int) to convert.
----	-------	--

## Returns

std::vector<char> Prepared for writing to binary SAC-file.

```
00527                                     {
00528     std::array<char, word_length> tmp{};
00529     // Copy bytes from input into the tmp array
00530     // flawfinder: ignore
00531     std::memcpy(tmp.data(), &input, word_length);
00532     std::vector<char> word{};
00533     word.resize(word_length);
00534     for (size_t i{0}; i < word_length; ++i) [[likely]] {
00535         word[i] = tmp[i];
00536     }
00537     return word;
00538 }
```

Here is the caller graph for this function:



## 10.1.4.17 convert\_to\_words() [1/2]

```
template std::array< char, word_length > sacfmt::convert_to_words (
    const std::string & str,
    const int n_words ) [noexcept]
```

## 10.1.4.18 convert\_to\_words() [2/2]

```
template<size_t N>
template std::array< char, 4 *word_length > sacfmt::convert_to_words (
    const std::string & str,
    int n_words ) [noexcept]
```

Template function to convert input string value into a std::array<char> for writing.

## Parameters

in	<i>str</i>	Input string to convert.
in	<i>n_words</i>	Number of words

## Returns

`std::array<char, N>` Prepared for writing to a binary SAC-file.

```

00574                                     {
00575     std::array<char, N> all_words{};
00576     // String to null-terminated character array
00577     const char *c_str = str.c_str();
00578     for (size_t i{0}; i < static_cast<size_t>(n_words) * word_length; ++i) {
00579         all_words[i] = c_str[i];
00580     }
00581     return all_words;
00582 }
```

## 10.1.4.19 degrees\_to\_radians()

```

double sacfmt::degrees_to_radians (
    const double degrees ) [noexcept]
```

Convert decimal degrees to radians.

$$r = d \cdot \frac{\pi}{180^\circ}$$

## Parameters

in	<i>degrees</i>	Angle in decimal degrees to be converted.
----	----------------	---

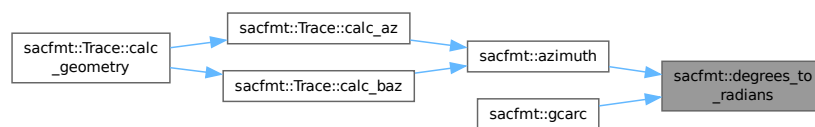
## Returns

double Angle in radians.

```

00661                                     {
00662     return rad_per_deg * degrees;
00663 }
```

Here is the caller graph for this function:



#### 10.1.4.20 double\_to\_binary()

```
word_two sacfmt::double_to_binary (
    const double num ) [noexcept]
```

Convert double-precision value to 64-bit (two words) binary bitset.

Converts double to unsigned-integer of same size for storage in bitset.

##### Parameters

in	<i>num</i>	Double value to be converted.
----	------------	-------------------------------

##### Returns

**word\_two** Converted value.

```
00143                                     {
00144     unsigned_int<double> num_as_uint{0};
00145     // flawfinder: ignore
00146     std::memcpy(&num_as_uint, &num, sizeof(double));
00147     word_two result{num_as_uint};
00148     return result;
00149 }
```

#### 10.1.4.21 equal\_within\_tolerance() [1/2]

```
bool sacfmt::equal_within_tolerance (
    const double val1,
    const double val2,
    const double tolerance ) [noexcept]
```

Check if two double values are equal within a tolerance limit.

Default tolerance is `f_eps`.

##### Parameters

in	<i>val1</i>	First double in comparison.
in	<i>val2</i>	Second double in comparison.
in	<i>tolerance</i>	Numerical equality tolerance (default <code>f_eps</code> ).

##### Returns

**bool** Boolean equality value.

```
00647                                     {
00648     return (std::abs(val1 - val2) < tolerance);
00649 }
```

#### 10.1.4.22 equal\_within\_tolerance() [2/2]

```
bool sacfmt::equal_within_tolerance (
    const std::vector< double > & vector1,
```

```
const std::vector< double > & vector2,
const double tolerance ) [noexcept]
```

Check if two `std::vector<double>` are equal within a tolerance limit.

Default tolerance is `f_eps`.

#### Parameters

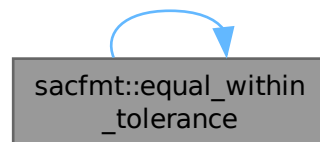
in	<i>vector1</i>	First data vector in comparison.
in	<i>vector2</i>	Second data vector in comparison.
in	<i>tolerance</i>	Numerical equality tolerance (default <code>f_eps</code> ).

#### Returns

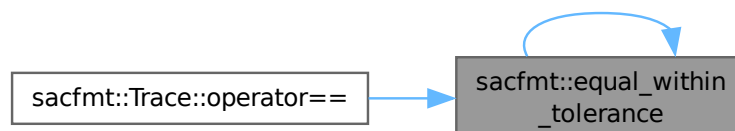
bool Boolean equality value.

```
00624                                     {
00625     if (vector1.size() != vector2.size()) {
00626         return false;
00627     }
00628     for (size_t i{0}; i < vector1.size(); ++i) [[likely]] {
00629         if (!equal_within_tolerance(vector1[i], vector2[i], tolerance)) {
00630             return false;
00631         }
00632     }
00633     return true;
00634 }
```

Here is the call graph for this function:



Here is the caller graph for this function:





## 10.1.4.23 float\_to\_binary()

```
word_one sacfmt::float_to_binary (
    const float num ) [noexcept]
```

Convert floating-point value to 32-bit (one word) binary bitset.

Converts float to unsigned-integer of same size for storage in bitset.

## Parameters

in	<i>num</i>	Float value to be converted.
----	------------	------------------------------

## Returns

*word\_one* Converted value.

```
00111 {
00112     unsigned_int<float> num_as_uint{0};
00113     // flawfinder: ignore
00114     std::memcpy(&num_as_uint, &num, sizeof(float));
00115     word_one result{num_as_uint};
00116     return result;
00117 }
```

## 10.1.4.24 gcarc()

```
double sacfmt::gcarc (
    const double latitude1,
    const double longitude1,
    const double latitude2,
    const double longitude2 ) [noexcept]
```

Calculate great circle arc distance in decimal degrees between two points.

Assumes spherical Earth (in future will include flattenning and adjustable radius for other bodies/greater accuracy).

$\phi$  is latitude.  $\lambda$  is longitude.  $\Delta$  is great circle arc distance (gcarc).

$$\Delta = \cos^{-1}(\sin(\phi_1)\sin(\phi_2) + \cos(\phi_1)\cos(\phi_2)\cos(\lambda_2 - \lambda_1))$$

## Parameters

in	<i>latitude1</i>	Latitude of first location in decimal degrees.
in	<i>longitude1</i>	Longitude of first location in decimal degrees.
in	<i>latitude2</i>	Latitude of second location in decimal degrees.
in	<i>longitude2</i>	Longitude of second location in decimal degrees.

## Returns

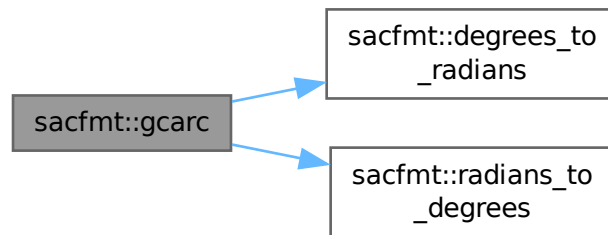
double The great circle arc distance in decimal degrees.

```

00704                                     {
00705     const double lat1{degrees_to_radians(latitude1)};
00706     const double lon1{degrees_to_radians(longitude1)};
00707     const double lat2{degrees_to_radians(latitude2)};
00708     const double lon2{degrees_to_radians(longitude2)};
00709     double result{radians_to_degrees(
00710         std::acos(std::sin(lat1) * std::sin(lat2) +
00711             std::cos(lat1) * std::cos(lat2) * std::cos(lon2 - lon1))});
00712     return result;
00713 }

```

Here is the call graph for this function:



#### 10.1.4.25 int\_to\_binary()

```

word_one sacfmt::int_to_binary (
    int num ) [noexcept]

```

Convert integer to 32-bit (one word) binary bitset.

Uses two's complement to convert an integer into a binary value.

##### Parameters

in	<i>num</i>	Number to be converted.
----	------------	-------------------------

##### Returns

**word\_one** Converted value.

```

00067                                     {
00068     word_one bits{};
00069     if (num >= 0) {
00070         bits = uint_to_binary(static_cast<uint>(num));
00071     } else {
00072         bits = uint_to_binary(static_cast<uint>(-num));
00073         // Complement
00074         bits.flip();
00075         bits = bits.to_ulong() + 1;
00076     }
00077     return bits;
00078 }

```

Here is the call graph for this function:



#### 10.1.4.26 limit\_180()

```
double sacfmt::limit_180 (
    const double degrees ) [noexcept]
```

Takes a decimal degree value and constrains it to a half circle using symmetry.

$$[-\infty, \infty] \rightarrow (-180, 180]$$

##### Parameters

in	<i>degrees</i>	Decimal degrees to be constrained.
----	----------------	------------------------------------

##### Returns

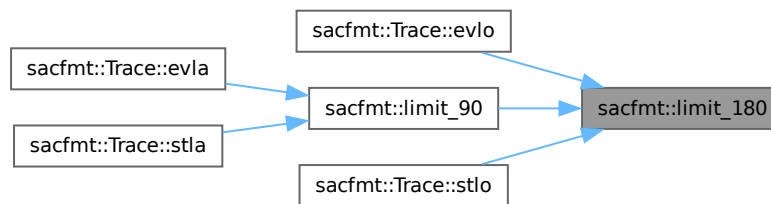
double Value within limits.

```
00792 {
00793     double result{limit_360(degrees)};
00794     constexpr double hemi{180.0};
00795     if (result > hemi) {
00796         result = result - circle_deg;
00797     }
00798     return result;
00799 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.27 limit\_360()

```
double sacfmt::limit_360 (
    const double degrees ) [noexcept]
```

Takes a decimal degree value and constrains it to full circle using symmetry.

$$[-\infty, \infty] \rightarrow [0, 360]$$

##### Parameters

in	<i>degrees</i>	Decimal degrees to be constrained.
----	----------------	------------------------------------

##### Returns

double Value within limits.

```

00766                                     {
00767     double result(degrees);
00768     while (std::abs(result) > circle_deg) {
00769         if (result > circle_deg) {
00770             result -= circle_deg;
00771         } else {
00772             result += circle_deg;
00773         }
00774     }
00775     if (result < 0) {
00776         result += circle_deg;
00777     }
00778     return result;
00779 }
```

Here is the caller graph for this function:



## 10.1.4.28 limit\_90()

```
double sacfmt::limit_90 (
    const double degrees ) [noexcept]
```

Takes a decimal degree value and constrains it to a quarter circle using symmetry.

$$[-\infty, \infty] \rightarrow [-90, 90]$$

## Parameters

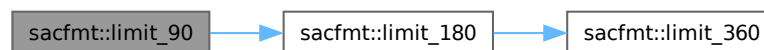
in	<i>degrees</i>	Decimal degrees to be constrained.
----	----------------	------------------------------------

## Returns

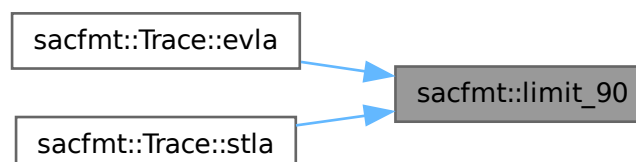
double Value within limits.

```
00812 {
00813     double result{limit_180(degrees)};
00814     constexpr double quarter{90.0};
00815     if (result > quarter) {
00816         result = (2 * quarter) - result;
00817     } else if (result < -quarter) {
00818         result = (-2 * quarter) - result;
00819     }
00820     return result;
00821 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.29 long\_string\_to\_binary()

```
word_four sacfmt::long_string_to_binary (
    std::string str ) [noexcept]
```

Convert a string to a 128-bit (four word) binary bitset.

If the string is longer than 16 characters, then only the first 16 characters are kept. If the string is less than 16 characters long, it is right-padded with spaces.

Exclusively used to work with the kEvNm header.

##### Parameters

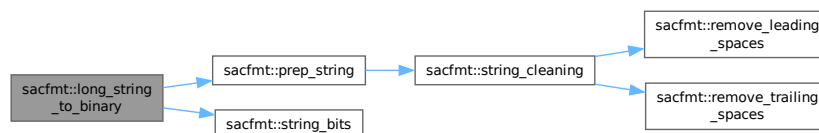
in	<i>str</i>	String to be converted to a bitset.
----	------------	-------------------------------------

##### Returns

**word\_four** Converted binary bitset.

```
00315
00316 constexpr size_t string_size{4 * word_length};
00317 prep_string(&str, string_size);
00318 // Four words (16 characters)
00319 word_four bits{};
00320 string_bits(&bits, str, string_size);
00321 return bits;
00322 }
```

Here is the call graph for this function:



#### 10.1.4.30 nwords\_after\_current()

```
bool sacfmt::nwords_after_current (
    std::ifstream * sac,
    const read_spec & spec ) [noexcept]
```

Determine if the SAC-file has enough remaining data to read the requested amount of data.

##### Parameters

in	<i>sac</i>	std::ifstream* SAC-file to read.
in	<i>spec</i>	<a href="#">read_spec</a> reading specification.

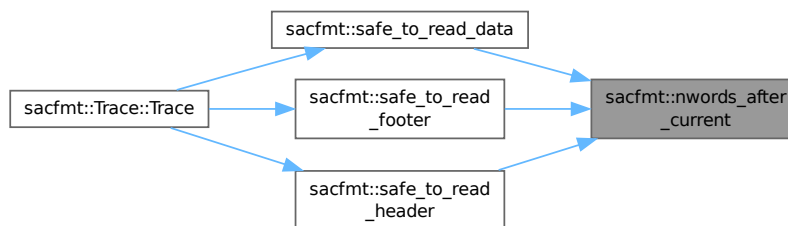
## Returns

bool Truth value (true = safe to read).

```

01637                                     {
01638     bool result{false};
01639     if (sac->good()) {
01640         sac->seekg(0, std::ios::end);
01641         const std::size_t final_pos{static_cast<size_t>(sac->tellg())};
01642         // Doesn't like size_t since it wants to allow
01643         // the possibility of negative offsets (not how I use it)
01644         sac->seekg(static_cast<std::streamoff>(spec.start_word));
01645         const std::size_t diff{final_pos - spec.start_word};
01646         result = (diff >= (spec.num_words * word_length));
01647     }
01648     return result;
01649 }
```

Here is the caller graph for this function:



## 10.1.4.31 prep\_string()

```

void sacfmt::prep_string (
    std::string * str,
    const size_t str_size ) [noexcept]
```

Cleans string and then truncates/pads as necessary.

This edits the string in-place.

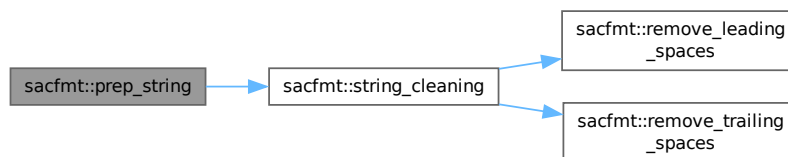
## Parameters

in, out	<i>str</i>	std::string* String to be prepared.
in	<i>str_size</i>	Desired string length.

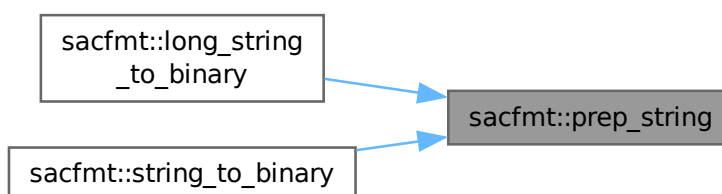
```

00218                                     {
00219     *str = string_cleaning(*str);
00220     if (str->length() > str_size) {
00221         str->resize(str_size);
00222     } else if (str->length() < str_size) {
00223         *str = str->append(str_size - str->length(), ' ');
00224     }
00225 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.32 radians\_to\_degrees()

```
double sacfmt::radians_to_degrees (
    const double radians ) [noexcept]
```

Convert radians to decimal degrees.

$$d = r \cdot \frac{180^\circ}{\pi}$$

##### Parameters

in	<i>radians</i>	Angle in radians to be converted.
----	----------------	-----------------------------------

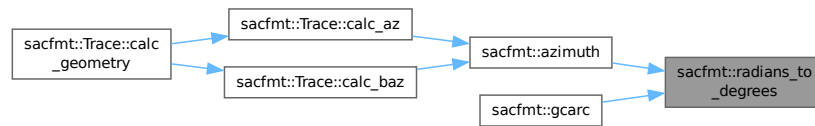
##### Returns

double Angle in decimal degrees.

```
00675                                     {
00676     return deg_per_rad * radians;
00677 }
```



Here is the caller graph for this function:



#### 10.1.4.33 read\_data()

```

std::vector< double > sacfmt::read_data (
    std::ifstream * sac,
    const read_spec & spec )

```

Reader arbitrary number of words (useful for vectors) from a binary SAC-file.

Note that this modifies the position of the reader within the stream (to the end of the read words).

##### Parameters

in, out	sac	std::ifstream* Input binary SAC-file.
in	spec	read_spec Reading specification.

##### Returns

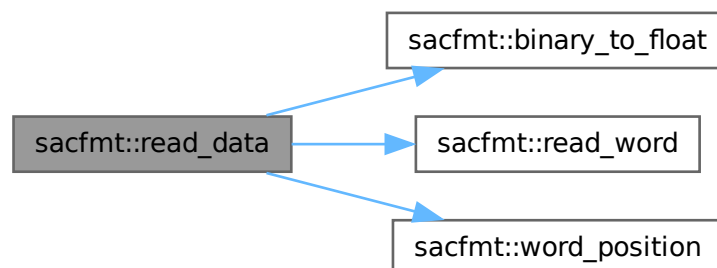
std::vector<double> Data vector read in.

```

00487                                     {
00488     sac->seekg(word_position(spec.start_word));
00489     std::vector<double> result{};
00490     result.resize(spec.num_words);
00491     for (size_t i{0}; i < spec.num_words; ++i) [[likely]] {
00492         result[i] = static_cast<double>(binary_to_float(read_word(sac)));
00493     }
00494     return result;
00495 }

```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.34 read\_four\_words()

```
word_four sacfmt::read_four_words (
    std::ifstream * sac )
```

Read four words (128 bits, kEvNm only) from a binary SAC-file.

Note that this modifies the position of the reader within the stream (to the end of the read words).

##### Parameters

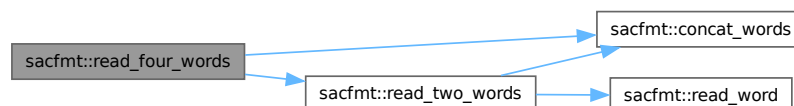
in, out	sac	std::ifstream* Input binary SAC-file.
---------	-----	---------------------------------------

##### Returns

**word\_four** Binary bitset representation of four words.

```
00462 {
00463     const word_two first_words{read_two_words(sac)};
00464     const word_two second_words{read_two_words(sac)};
00465     word_pair<word_two> pair_words{};
00466     if constexpr (std::endian::native == std::endian::little) {
00467         pair_words.first = first_words;
00468         pair_words.second = second_words;
00469     } else {
00470         pair_words.first = second_words;
00471         pair_words.second = first_words;
00472     }
00473     return concat_words(pair_words);
00474 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.35 read\_two\_words()

```
word_two sacfmt::read_two_words (
    std::ifstream * sac )
```

Read two words (64 bits, useful for most strings) from a binary SAC-file.

Note that this modifies the position of the reader within the stream (to the end of the read words).

##### Parameters

<code>in, out</code>	<code>sac</code>	<code>std::ifstream*</code> Input binary SAC-file.
----------------------	------------------	--

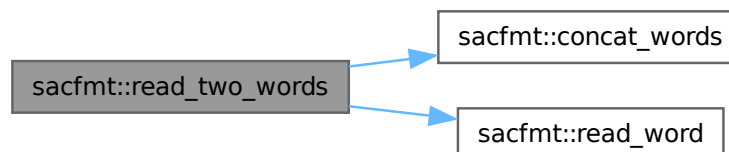
##### Returns

`word_two` Binary bitset representation of two words.

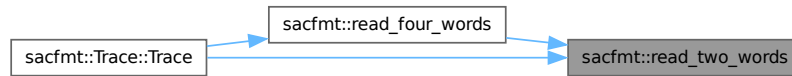
```

00439 {
00440     const word_one first_word{read_word(sac)};
00441     const word_one second_word{read_word(sac)};
00442     word_pair<word_one> pair_words{};
00443     if constexpr (std::endian::native == std::endian::little) {
00444         pair_words.first = first_word;
00445         pair_words.second = second_word;
00446     } else {
00447         pair_words.first = second_word;
00448         pair_words.second = first_word;
00449     }
00450     return concat_words(pair_words);
00451 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.36 read\_word()

```
word_one sacfmt::read_word (
    std::ifstream * sac )
```

Read one word (32 bits, useful for non-strings) from a binary SAC-File.

Note that this modifies the position of the reader within the stream (to the end of the read word).

##### Parameters

in, out	sac	std::ifstream* Input binary SAC-file.
---------	-----	---------------------------------------

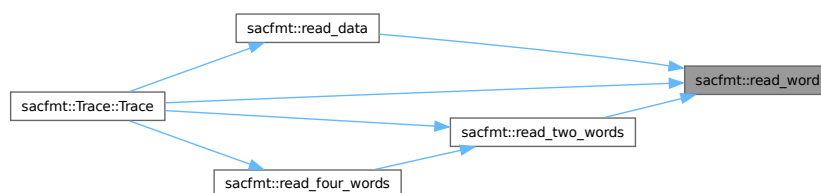
##### Returns

**word\_one** Binary bitset representation of single word.

```

00407                                     {
00408     word_one bits{};
00409     constexpr size_t char_size{bits_per_byte};
00410     // Where we will store the characters
00411     std::array<char, word_length> word{};
00412     // Read to our character array
00413     // This can always hold the source due to careful typing/sizing
00414     // flawfinder: ignore
00415     if (sac->read(word.data(), word_length)) {
00416         // Take each character
00417         for (size_t i{0}; i < word_length; ++i) [[likely]] {
00418             uint character{static_cast<uint>(word[i])};
00419             char_bit byte{character};
00420             // bit-by-bit
00421             for (size_t j{0}; j < char_size; ++j) [[likely]] {
00422                 bits[(i * char_size) + j] = byte[j];
00423             }
00424         }
00425     }
00426     return bits;
00427 }
```

Here is the caller graph for this function:



## 10.1.4.37 remove\_leading\_spaces()

```
void sacfmt::remove_leading_spaces (
    std::string * str ) [noexcept]
```

Remove all leading spaces from a string.

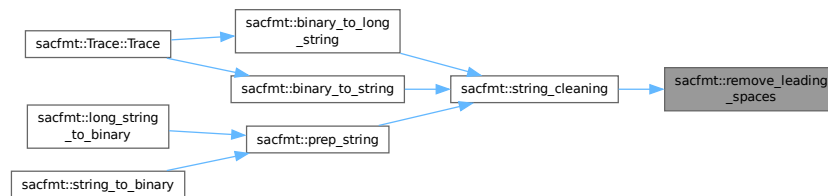
This edits the string in-place.

## Parameters

in, out	str	std::string* String to have spaces removed.
---------	-----	---

```
00174                                     {
00175     while ((static_cast<int>(str->front()) <= ascii_space) && (!str->empty())) {
00176         str->erase(0, 1);
00177     }
00178 }
```

Here is the caller graph for this function:



## 10.1.4.38 remove\_trailing\_spaces()

```
void sacfmt::remove_trailing_spaces (
    std::string * str ) [noexcept]
```

Remove all trailing spaces from a string.

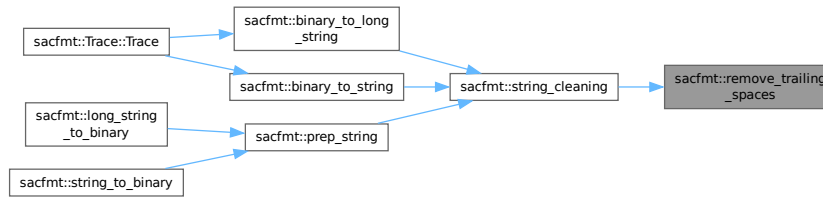
This edits the string in-place.

## Parameters

in, out	str	std::string* String to have spaces removed.
---------	-----	---

```
00187                                     {
00188     while ((static_cast<int>(str->back()) <= ascii_space) && (!str->empty())) {
00189         str->pop_back();
00190     }
00191 }
```

Here is the caller graph for this function:



#### 10.1.4.39 safe\_to\_finish\_reading()

```
void sacfmt::safe_to_finish_reading (
    std::ifstream * sac )
```

Determines if the SAC-file is finished.

This must run after reading the header, data vector(s), and footer (if applicable). This checks to ensure there is no additional data in the SAC-file (there shouldn't be, and out of safety it throws an [io\\_error](#) to inform the user if there are shenanigans).

##### Parameters

in	sac	std::ifstream* SAC-file to be checked.
----	-----	--

##### Exceptions

<a href="#">io_error</a>	If the file is not finished.
--------------------------	------------------------------

```

01717 {
01718     const std::streamoff current_pos{sac->tellg()};
01719     sac->seekg(0, std::ios::end);
01720     const std::streamoff end_pos{sac->tellg()};
01721     sac->seekg(current_pos, std::ios::beg);
01722     // How far are we from the end of the file?
01723     const std::streamoff diff{end_pos - current_pos};
01724     // If there is more, something weird happened...
01725     if (diff != 0) {
01726         std::ostringstream oss{};
01727         oss << "Filesize exceeds data specification with ";
01728         oss << diff;
01729         oss << " bytes excess. Data corruption suspected.";
01730         throw io_error(oss.str());
01731     }
01732 }
```

Here is the caller graph for this function:



#### 10.1.4.40 safe\_to\_read\_data()

```

void sacfmt::safe_to_read_data (
    std::ifstream * sac,
    const size_t n_words,
    const bool data2 )
  
```

Determines if the SAC-file has enough space remaining to contain a complete data vector.

This must be run after reading the header (and first data vector if applicable) and before the footer (if applicable).

##### Parameters

in	<i>sac</i>	std::ifstream* SAC-file to read.
in	<i>n_words</i>	Number of values in data vector.
in	<i>data2</i>	bool True if reading data2, false (default) if reading data1.

##### Exceptions

<i>io_error</i>	If unsafe to read.
-----------------	--------------------

```

01698
01699     const std::string data{data2 ? "data2" : "data1"};
01700     const read_spec spec{n_words, static_cast<size_t>(sac->tellg())};
01701     if (!nwords_after_current(sac, spec)) {
01702         throw io_error("Insufficient filesize for " + data + '.');
01703     }
01704 }
  
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.41 safe\_to\_read\_footer()

```
void sacfmt::safe_to_read_footer (
    std::ifstream * sac )
```

Determines if the SAC-file has enough space remaining to contain a complete footer.

This must be run after reading the header and data vector(s), not before.

##### Parameters

in	sac	std::ifstream* SAC-file to read.
----	-----	----------------------------------

##### Exceptions

<a href="#">io_error</a>	If unsafe to read.
--------------------------	--------------------

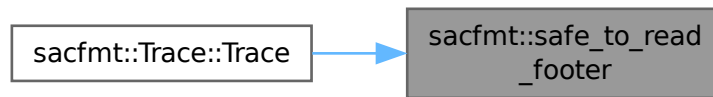
```
01676                                     {
01677     // doubles are two words long
01678     const read_spec spec{static_cast<size_t>(num_footer) * 2,
01679                          static_cast<size_t>(sac->tellg())};
01680     if (!nwords_after_current(sac, spec)) {
01681         throw io_error("Insufficient filesize for footer.");
01682     }
01683 }
```

Here is the call graph for this function:





Here is the caller graph for this function:



#### 10.1.4.42 safe\_to\_read\_header()

```
void sacfmt::safe_to_read_header (
    std::ifstream * sac )
```

Determine if the SAC-file is large enough to contain a complete header.

This must be run prior to reading the data vector(s) and footer (if applicable), not after.

##### Parameters

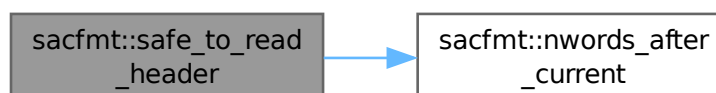
in	sac	std::ifstream* SAC-file to read.
----	-----	----------------------------------

##### Exceptions

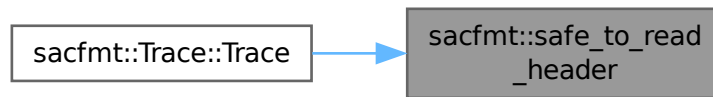
<i>io_error</i>	If unsafe to read.
-----------------	--------------------

```
01660                                     {
01661     const read_spec spec{data_word, 0};
01662     if (!nwords_after_current(sac, spec)) {
01663         throw io_error("Insufficient filesize for header.");
01664     }
01665 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.43 string\_bits()

```

template<typename T >
void sacfmt::string_bits (
    T * bits,
    const std::string & str,
    const size_t str_size ) [noexcept]
  
```

Template function to convert string into binary bitset.

Note that this edits the bitset in place.

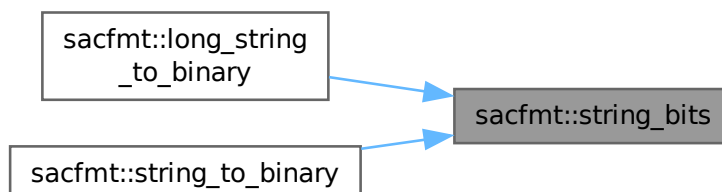
##### Parameters

out	<i>bits</i>	Destintation bitset for the string (result).
in	<i>str</i>	String to undergo conversion.
in	<i>str_size</i>	Desired string size in words (4 chars = 1 word).

```

00238                                     {
00239     constexpr size_t char_size{bits_per_byte};
00240     char_bit byte{};
00241     for (size_t i{0}; i < str_size; ++i) {
00242         size_t character{static_cast<size_t>(str[i])};
00243         byte = char_bit(character);
00244         for (size_t j{0}; j < char_size; ++j) {
00245             (*bits)[(i * char_size) + j] = byte[j];
00246         }
00247     }
00248 }
  
```

Here is the caller graph for this function:



#### 10.1.4.44 string\_cleaning()

```
std::string sacfmt::string_cleaning (
    const std::string & str ) [noexcept]
```

Remove leading/trailing spaces and control characters from a string.

##### Parameters

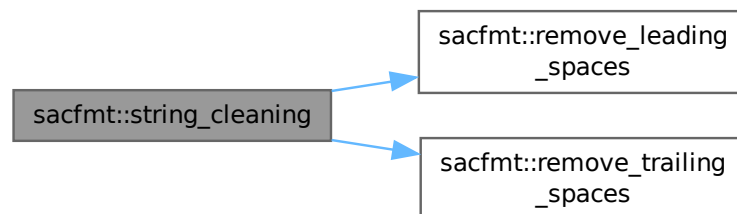
in	str	std::string String to be cleaned.
----	-----	-----------------------------------

##### Returns

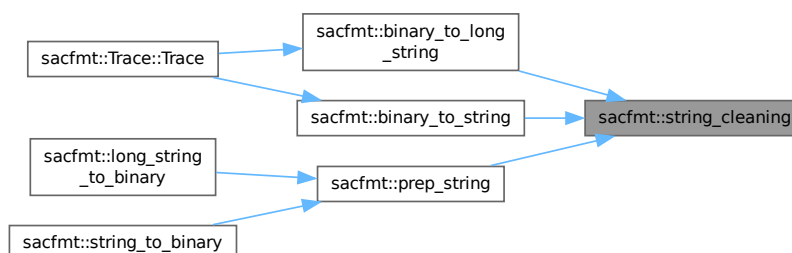
std::string Cleaned string.

```
00199                                     {
00200     std::string result{str};
00201     size_t null_position{str.find('\0')};
00202     if (null_position != std::string::npos) {
00203         result.erase(null_position);
00204     }
00205     remove_leading_spaces(&result);
00206     remove_trailing_spaces(&result);
00207     return result;
00208 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 10.1.4.45 string\_to\_binary()

```
word_two sacfmt::string_to_binary (
    std::string str ) [noexcept]
```

Convert string to a 64-bit (two word) binary bitset.

If the string is longer than 8 characters, then only the first 8 characters are kept. If the string is less than 8 characters long, it is right-padded with spaces.

##### Parameters

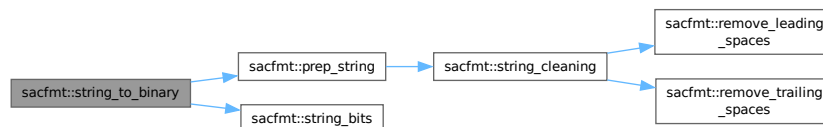
in	<i>str</i>	String to be converted to a bitset.
----	------------	-------------------------------------

##### Returns

**word\_two** Converted binary bitset.

```
00282
00283     constexpr size_t string_size{2 * word_length}; {
00284     // 1 byte per character
00285     prep_string(&str, string_size);
00286     // Two words (8 characters)
00287     word_two bits{};
00288     string_bits(&bits, str, string_size);
00289     return bits;
00290 }
```

Here is the call graph for this function:



#### 10.1.4.46 uint\_to\_binary()

```
word_one sacfmt::uint_to_binary (
    uint num ) [noexcept]
```

Convert unsigned integer to 32-bit (one word) binary bitset.

This sets the current bit using bitwise and, updates the bit to manipulate and performs a right-shift (division by 2) until the number is zero.

##### Parameters

in	<i>num</i>	Number to be converted.
----	------------	-------------------------

## Returns

`word_one` Converted value.

```

00044                                     {
00045     word_one bits{};
00046     for (size_t pos{0}; pos < bits.size(); ++pos) {
00047         if (num > 0) {
00048             // Bitwise and to set flag.
00049             bits.set(pos, static_cast<bool>(num & 1));
00050             // Right-shift bits by 1, same as division by 2
00051             num >>= 1;
00052         } else {
00053             break;
00054         }
00055     }
00056     return bits;
00057 }

```

Here is the caller graph for this function:



## 10.1.4.47 word\_position()

```

std::streamoff sacfmt::word_position (
    const size_t word_number ) [noexcept]

```

Calculates position of word in SAC-file.

Multiplies given word number by the word-length in bytes (defined by the SAC format.)

## Parameters

in	<code>word_number</code>	Number of desired word in file stream.
----	--------------------------	--

## Returns

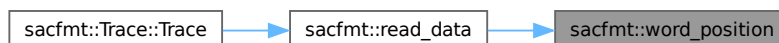
`std::streamoff` Position in SAC-file of desired word (in bytes).

```

00031                                     {
00032     return static_cast<std::streamoff>(word_number * word_length);
00033 }

```

Here is the caller graph for this function:



#### 10.1.4.48 write\_words()

```
void sacfmt::write_words (
    std::ofstream * sac_file,
    const std::vector< char > & input )
```

Write arbitrary number of words (useful for vectors) to a binary SAC-file.

Note that this modifies the position of the writer within the stream (to the end of the written words).

##### Parameters

in, out	sac_file	std::ofstream* Output binary SAC-file.
in	input	std::vector<char> Character vector representation of data for writing.

```
00510                                     {
00511     std::ofstream &sac = *sac_file;
00512     if (sac.is_open()) {
00513         for (char character : input) [[likely]] {
00514             sac.write(&character, sizeof(char));
00515         }
00516     }
00517 }
```

Here is the caller graph for this function:



### 10.1.5 Variable Documentation

#### 10.1.5.1 ascii\_space

```
constexpr int sacfmt::ascii_space {32} [constexpr]
```

ASCII-code of 'space' character.

```
00090 {32};
```

#### 10.1.5.2 binary\_word\_size

```
constexpr size_t sacfmt::binary_word_size {word_length * bits_per_byte} [constexpr]
```

Size (bits) of funamental data-chunk.

```
00066 {word_length * bits_per_byte};
```

#### 10.1.5.3 bits\_per\_byte

```
constexpr size_t sacfmt::bits_per_byte {8} [constexpr]
```

Size (bits) of binary character.

```
00064 {8};
```

#### 10.1.5.4 circle\_deg

```
constexpr double sacfmt::circle_deg {360.0} [constexpr]
```

Degrees in a circle.

```
00116 {360.0};
```

#### 10.1.5.5 common\_skip\_num

```
constexpr int sacfmt::common_skip_num {7} [constexpr]
```

Extremely common number of 'internal use' headers in SAC format.

```
00110 {7};
```

#### 10.1.5.6 data\_word

```
constexpr std::streamoff sacfmt::data_word {158} [constexpr]
```

First word of (first) data-section (stream offset).

```
00068 {158};
```

#### 10.1.5.7 deg\_per\_rad

```
constexpr double sacfmt::deg_per_rad {1.0 / rad_per_deg} [constexpr]
```

Degrees per radian.

```
00114 {1.0 / rad_per_deg};
```

#### 10.1.5.8 earth\_radius

```
constexpr double sacfmt::earth_radius {6378.14} [constexpr]
```

Average radius of Earth (kilometers).

```
00118 {6378.14};
```

#### 10.1.5.9 f\_eps

```
constexpr float sacfmt::f_eps {2.75e-6F} [constexpr]
```

Accuracy precision expected of SAC floating-point values.

```
00080 {2.75e-6F};
```

#### 10.1.5.10 modern\_hdr\_version

```
constexpr int sacfmt::modern_hdr_version {7} [constexpr]
```

nVHdr value for newest SAC format (2020+).

```
00106 {7};
```

#### 10.1.5.11 num\_bool

```
constexpr int sacfmt::num_bool {4} [constexpr]
```

Number of boolean header values in SAC format.

```
00098 {4};
```

#### 10.1.5.12 num\_data

```
constexpr int sacfmt::num_data {2} [constexpr]
```

Number of data arrays in SAC format.

```
00102 {2};
```

#### 10.1.5.13 num\_double

```
constexpr int sacfmt::num_double {22} [constexpr]
```

Number of double-precision header values in SAC format.

```
00094 {22};
```

#### 10.1.5.14 num\_float

```
constexpr int sacfmt::num_float {39} [constexpr]
```

Number of float-precision header values in SAC format.

```
00092 {39};
```

#### 10.1.5.15 num\_footer

```
constexpr int sacfmt::num_footer {22} [constexpr]
```

Number of double-precision footer values in SAC format (version 7).

```
00104 {22};
```

#### 10.1.5.16 num\_int

```
constexpr int sacfmt::num_int {26} [constexpr]
```

Number of integer header values in SAC format.

```
00096 {26};
```

#### 10.1.5.17 num\_string

```
constexpr int sacfmt::num_string {23} [constexpr]
```

Number of string header values in SAC format.

```
00100 {23};
```



### 10.1.5.18 old\_hdr\_version

```
constexpr int sacfmt::old_hdr_version {6} [constexpr]
```

nVHdr value for historic SAC format (pre-2020).

```
00108 {6};
```

### 10.1.5.19 rad\_per\_deg

```
constexpr double sacfmt::rad_per_deg {std::numbers::pi_v<double> / 180.0} [constexpr]
```

Radians per degree.

```
00112 {std::numbers::pi_v<double> / 180.0};
```

### 10.1.5.20 sac\_map

```
const std::unordered_map<name, const size_t> sacfmt::sac_map
```

Lookup table for variable locations.

Maps SAC variables (headers and data) to their internal locations in the [Trace](#) class.

```
00910 {
00911     // Floats
00912     {name::depmin, 0},
00913     {name::depmax, 1},
00914     {name::odelta, 2},
00915     {name::resp0, 3},
00916     {name::resp1, 4},
00917     {name::resp2, 5},
00918     {name::resp3, 6},
00919     {name::resp4, 7},
00920     {name::resp5, 8},
00921     {name::resp6, 9},
00922     {name::resp7, 10},
00923     {name::resp8, 11},
00924     {name::resp9, 12},
00925     {name::stel, 13},
00926     {name::stdp, 14},
00927     {name::evel, 15},
00928     {name::evdp, 16},
00929     {name::mag, 17},
00930     {name::user0, 18},
00931     {name::user1, 19},
00932     {name::user2, 20},
00933     {name::user3, 21},
00934     {name::user4, 22},
00935     {name::user5, 23},
00936     {name::user6, 24},
00937     {name::user7, 25},
00938     {name::user8, 26},
00939     {name::user9, 27},
00940     {name::dist, 28},
00941     {name::az, 29},
00942     {name::baz, 30},
00943     {name::gcarc, 31},
00944     {name::depmen, 32},
00945     {name::cmpaz, 33},
00946     {name::cmpinc, 34},
00947     {name::xminimum, 35},
00948     {name::xmaximum, 36},
00949     {name::yminimum, 37},
00950     {name::ymaximum, 38},
00951     // Doubles
00952     {name::delta, 0},
00953     {name::b, 1},
00954     {name::e, 2},
00955     {name::o, 3},
00956     {name::a, 4},
00957     {name::t0, 5},
00958     {name::t1, 6},
00959     {name::t2, 7},
00960     {name::t3, 8},
```

```

00961     {name::t4, 9},
00962     {name::t5, 10},
00963     {name::t6, 11},
00964     {name::t7, 12},
00965     {name::t8, 13},
00966     {name::t9, 14},
00967     {name::f, 15},
00968     {name::stla, 16},
00969     {name::stlo, 17},
00970     {name::evla, 18},
00971     {name::evlo, 19},
00972     {name::sb, 20},
00973     {name::sdelta, 21},
00974     // Ints
00975     {name::nzyear, 0},
00976     {name::nzjday, 1},
00977     {name::nzhour, 2},
00978     {name::nzmin, 3},
00979     {name::nzsec, 4},
00980     {name::nzmsec, 5},
00981     {name::nvhdr, 6},
00982     {name::norid, 7},
00983     {name::nevid, 8},
00984     {name::npts, 9},
00985     {name::nsnpts, 10},
00986     {name::nwfid, 11},
00987     {name::nxsize, 12},
00988     {name::nysize, 13},
00989     {name::iftyp, 14},
00990     {name::idep, 15},
00991     {name::iztyp, 16},
00992     {name::iinst, 17},
00993     {name::istreg, 18},
00994     {name::ievreg, 19},
00995     {name::ievtyp, 20},
00996     {name::iqual, 21},
00997     {name::isynth, 22},
00998     {name::imagtyp, 23},
00999     {name::imagsrc, 24},
01000     {name::ibody, 25},
01001     // Bools
01002     {name::leven, 0},
01003     {name::lpspol, 1},
01004     {name::lovrok, 2},
01005     {name::lcalda, 3},
01006     // Strings
01007     {name::kstnm, 0},
01008     {name::kevn, 1},
01009     {name::khole, 2},
01010     {name::ko, 3},
01011     {name::ka, 4},
01012     {name::kt0, 5},
01013     {name::kt1, 6},
01014     {name::kt2, 7},
01015     {name::kt3, 8},
01016     {name::kt4, 9},
01017     {name::kt5, 10},
01018     {name::kt6, 11},
01019     {name::kt7, 12},
01020     {name::kt8, 13},
01021     {name::kt9, 14},
01022     {name::kf, 15},
01023     {name::kuser0, 16},
01024     {name::kuser1, 17},
01025     {name::kuser2, 18},
01026     {name::kcmpnm, 19},
01027     {name::knetwk, 20},
01028     {name::kdatrd, 21},
01029     {name::kinst, 22},
01030     // Data
01031     {name::data1, 0},
01032     {name::data2, 1}};

```

### 10.1.5.21 unset\_bool

```
constexpr bool sacfmt::unset_bool {false} [constexpr]
```

Boolean unset value (SAC Magic).

```
00076 {false};
```

### 10.1.5.22 unset\_double

```
constexpr double sacfmt::unset_double {-12345.0} [constexpr]
```

Double-precision unset value (SAC Magic).

```
00074 {-12345.0};
```

### 10.1.5.23 unset\_float

```
constexpr float sacfmt::unset_float {-12345.0F} [constexpr]
```

Float-point unset value (SAC Magic).

```
00072 {-12345.0F};
```

### 10.1.5.24 unset\_int

```
constexpr int sacfmt::unset_int {-12345} [constexpr]
```

Integer unset value (SAC Magic).

```
00070 {-12345};
```

### 10.1.5.25 unset\_word

```
const std::string sacfmt::unset_word {"-12345"}
```

String unset value (SAC Magic).

```
00078 {"-12345"};
```

### 10.1.5.26 word\_length

```
constexpr size_t sacfmt::word_length {4} [constexpr]
```

Size (bytes) of fundamental data-chunk.

```
00062 {4};
```

## 10.2 sacfmt::bitset\_type Namespace Reference

bitset type-safety namespace.

### Classes

- struct [uint](#)  
*Ensure type-safety for conversions between floats/doubles and bitsets.*
- struct [uint< 4 \\*bits\\_per\\_byte >](#)  
*One-word (floats).*
- struct [uint< bytes \\*bits\\_per\\_byte >](#)

## Variables

- `constexpr int bytes {8}`  
*Two-words (doubles)*

### 10.2.1 Detailed Description

bitset type-safety namespace.

### 10.2.2 Variable Documentation

#### 10.2.2.1 bytes

```
constexpr int sacfmt::bitset_type::bytes {8} [constexpr]
```

Two-words (doubles)  
`00139 {8};`

## Chapter 11

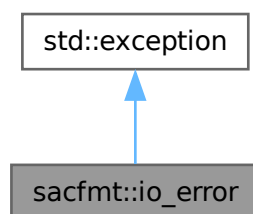
# Class Documentation

### 11.1 sacfmt::io\_error Class Reference

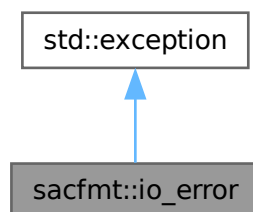
Class for generic I/O exceptions.

```
#include <sac_format.hpp>
```

Inheritance diagram for sacfmt::io\_error:



Collaboration diagram for sacfmt::io\_error:



## Public Member Functions

- [io\\_error](#) (std::string *msg*)  
*io\_error* Constructor
- [const char \\* what \(\) const noexcept override](#)  
*Error message delivery.*

## Private Attributes

- [const std::string message {}](#)  
*Error message.*

### 11.1.1 Detailed Description

Class for generic I/O exceptions.

These errors occur due to bad path, bad permissions, or otherwise corrupt SAC-files.

I/O operations may raise other exceptions (disk failure, out of space, etc.), but those are difficult to emulate for testing purposes (therefore I am unable to reliably cover them); they also arise due to conditions that would render how sac-format handles them moot.

### 11.1.2 Constructor & Destructor Documentation

#### 11.1.2.1 io\_error()

```
sacfmt::io_error::io_error (
    std::string msg ) [inline], [explicit]
```

[io\\_error](#) Constructor

#### Parameters

<i>in</i>	<i>msg</i>	std::string Error message.
-----------	------------	----------------------------

```
01352 : message (std::move (msg)) {}
```

### 11.1.3 Member Function Documentation

#### 11.1.3.1 what()

```
const char \* sacfmt::io_error::what ( ) const [inline], [override], [noexcept]
```

Error message delivery.

#### Returns

*what* char\* Error message.

```
01358                                     {
01359     return message.c_str();
01360 }
```

### 11.1.4 Member Data Documentation

#### 11.1.4.1 message

```
const std::string sacfmt::io_error::message {} [private]
```

Error message.

```
01344 {};
```

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

- include/sac-format/sac\_format.hpp

## 11.2 sacfmt::read\_spec Struct Reference

Struct that specifies parameters for reading.

```
#include <sac_format.hpp>
```

### Public Attributes

- [size\\_t num\\_words](#) {}  
*Number of words to read.*
- [size\\_t start\\_word](#) {}  
*Word to start reading from.*

### 11.2.1 Detailed Description

Struct that specifies parameters for reading.

Prevents bug-prone number-swapping in functions that use a reading specification.

### 11.2.2 Member Data Documentation

#### 11.2.2.1 num\_words

```
size_t sacfmt::read_spec::num_words {}
```

Number of words to read.

```
00211 {};
```

#### 11.2.2.2 start\_word

```
size_t sacfmt::read_spec::start_word {}
```

Word to start reading from.

```
00213 {};
```

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

- include/sac-format/sac\_format.hpp

## 11.3 sacfmt::Trace Class Reference

The [Trace](#) class.

```
#include <sac_format.hpp>
```

### Public Member Functions

- [Trace \(\) noexcept](#)  
*Trace default constructor.*
- [Trace \(const std::filesystem::path &path\)](#)  
*Binary SAC-file reader.*
- [void write \(const std::filesystem::path &path, bool legacy=false\) const](#)  
*Binary SAC-file writer.*
- [void legacy\\_write \(const std::filesystem::path &path\) const](#)  
*Binary SAC-file legacy-write convenience function.*
- [bool operator== \(const Trace &other\) const noexcept](#)  
*Trace equality operator.*
- [void calc\\_geometry \(\) noexcept](#)  
*Calculates gcarc, dist, az, and baz from stla, stlo, evla, and evlo.*
- [double frequency \(\) const noexcept](#)  
*Calculate frequency from delta.*
- [std::string date \(\) const noexcept](#)  
*Get date string.*
- [std::string time \(\) const noexcept](#)  
*Get time string.*
- [float depmin \(\) const noexcept](#)
- [float depmax \(\) const noexcept](#)
- [float odelta \(\) const noexcept](#)
- [float resp0 \(\) const noexcept](#)
- [float resp1 \(\) const noexcept](#)
- [float resp2 \(\) const noexcept](#)
- [float resp3 \(\) const noexcept](#)
- [float resp4 \(\) const noexcept](#)
- [float resp5 \(\) const noexcept](#)
- [float resp6 \(\) const noexcept](#)
- [float resp7 \(\) const noexcept](#)
- [float resp8 \(\) const noexcept](#)
- [float resp9 \(\) const noexcept](#)
- [float stel \(\) const noexcept](#)
- [float stdp \(\) const noexcept](#)
- [float evel \(\) const noexcept](#)
- [float evdp \(\) const noexcept](#)
- [float mag \(\) const noexcept](#)
- [float user0 \(\) const noexcept](#)
- [float user1 \(\) const noexcept](#)
- [float user2 \(\) const noexcept](#)
- [float user3 \(\) const noexcept](#)
- [float user4 \(\) const noexcept](#)
- [float user5 \(\) const noexcept](#)
- [float user6 \(\) const noexcept](#)
- [float user7 \(\) const noexcept](#)



- `float user8 () const noexcept`
- `float user9 () const noexcept`
- `float dist () const noexcept`
- `float az () const noexcept`
- `float baz () const noexcept`
- `float gcarc () const noexcept`
- `float depmen () const noexcept`
- `float cmpaz () const noexcept`
- `float cmpinc () const noexcept`
- `float xminimum () const noexcept`
- `float xmaximum () const noexcept`
- `float yminimum () const noexcept`
- `float ymaximum () const noexcept`
- `double delta () const noexcept`
- `double b () const noexcept`
- `double e () const noexcept`
- `double o () const noexcept`
- `double a () const noexcept`
- `double t0 () const noexcept`
- `double t1 () const noexcept`
- `double t2 () const noexcept`
- `double t3 () const noexcept`
- `double t4 () const noexcept`
- `double t5 () const noexcept`
- `double t6 () const noexcept`
- `double t7 () const noexcept`
- `double t8 () const noexcept`
- `double t9 () const noexcept`
- `double f () const noexcept`
- `double stla () const noexcept`
- `double stlo () const noexcept`
- `double evla () const noexcept`
- `double evlo () const noexcept`
- `double sb () const noexcept`
- `double sdelta () const noexcept`
- `int nzyear () const noexcept`
- `int nzjday () const noexcept`
- `int nzhour () const noexcept`
- `int nzmin () const noexcept`
- `int nzsec () const noexcept`
- `int nzmsec () const noexcept`
- `int nvhdr () const noexcept`
- `int norid () const noexcept`
- `int nevid () const noexcept`
- `int npts () const noexcept`
- `int nsnpts () const noexcept`
- `int nwfid () const noexcept`
- `int nxsize () const noexcept`
- `int nysize () const noexcept`
- `int iftype () const noexcept`
- `int idep () const noexcept`
- `int iztype () const noexcept`
- `int iinst () const noexcept`
- `int istreg () const noexcept`
- `int ievreg () const noexcept`

- `int ievtyp () const noexcept`
- `int igual () const noexcept`
- `int isynth () const noexcept`
- `int imagtyp () const noexcept`
- `int imagsrc () const noexcept`
- `int ibody () const noexcept`
- `bool leven () const noexcept`
- `bool lpspol () const noexcept`
- `bool lovrok () const noexcept`
- `bool lcalda () const noexcept`
- `std::string kstnm () const noexcept`
- `std::string kevnrm () const noexcept`
- `std::string khole () const noexcept`
- `std::string ko () const noexcept`
- `std::string ka () const noexcept`
- `std::string kt0 () const noexcept`
- `std::string kt1 () const noexcept`
- `std::string kt2 () const noexcept`
- `std::string kt3 () const noexcept`
- `std::string kt4 () const noexcept`
- `std::string kt5 () const noexcept`
- `std::string kt6 () const noexcept`
- `std::string kt7 () const noexcept`
- `std::string kt8 () const noexcept`
- `std::string kt9 () const noexcept`
- `std::string kf () const noexcept`
- `std::string kuser0 () const noexcept`
- `std::string kuser1 () const noexcept`
- `std::string kuser2 () const noexcept`
- `std::string kcmpnm () const noexcept`
- `std::string knetwk () const noexcept`
- `std::string kdatrd () const noexcept`
- `std::string kinst () const noexcept`
- `std::vector< double > data1 () const noexcept`
- `std::vector< double > data2 () const noexcept`
- `void depmin (float input) noexcept`
- `void depmax (float input) noexcept`
- `void odelta (float input) noexcept`
- `void resp0 (float input) noexcept`
- `void resp1 (float input) noexcept`
- `void resp2 (float input) noexcept`
- `void resp3 (float input) noexcept`
- `void resp4 (float input) noexcept`
- `void resp5 (float input) noexcept`
- `void resp6 (float input) noexcept`
- `void resp7 (float input) noexcept`
- `void resp8 (float input) noexcept`
- `void resp9 (float input) noexcept`
- `void stel (float input) noexcept`
- `void stdp (float input) noexcept`
- `void evel (float input) noexcept`
- `void evdp (float input) noexcept`
- `void mag (float input) noexcept`
- `void user0 (float input) noexcept`
- `void user1 (float input) noexcept`

- void user2 (float input) noexcept
- void user3 (float input) noexcept
- void user4 (float input) noexcept
- void user5 (float input) noexcept
- void user6 (float input) noexcept
- void user7 (float input) noexcept
- void user8 (float input) noexcept
- void user9 (float input) noexcept
- void dist (float input) noexcept
- void az (float input) noexcept
- void baz (float input) noexcept
- void gcarc (float input) noexcept
- void depmen (float input) noexcept
- void cmpaz (float input) noexcept
- void cmpinc (float input) noexcept
- void xminimum (float input) noexcept
- void xmaximum (float input) noexcept
- void yminimum (float input) noexcept
- void ymaximum (float input) noexcept
- void delta (double input) noexcept
- void b (double input) noexcept
- void e (double input) noexcept
- void o (double input) noexcept
- void a (double input) noexcept
- void t0 (double input) noexcept
- void t1 (double input) noexcept
- void t2 (double input) noexcept
- void t3 (double input) noexcept
- void t4 (double input) noexcept
- void t5 (double input) noexcept
- void t6 (double input) noexcept
- void t7 (double input) noexcept
- void t8 (double input) noexcept
- void t9 (double input) noexcept
- void f (double input) noexcept
- void stla (double input) noexcept
- void stlo (double input) noexcept
- void evla (double input) noexcept
- void evlo (double input) noexcept
- void sb (double input) noexcept
- void sdelta (double input) noexcept
- void nzyear (int input) noexcept
- void nzjday (int input) noexcept
- void nzhour (int input) noexcept
- void nzmin (int input) noexcept
- void nzsec (int input) noexcept
- void nzmsec (int input) noexcept
- void nvhdr (int input) noexcept
- void norid (int input) noexcept
- void nevid (int input) noexcept
- void npts (int input) noexcept
- void nsnpts (int input) noexcept
- void nwfid (int input) noexcept
- void nxsize (int input) noexcept
- void nysize (int input) noexcept

- [void iftype \(int input\) noexcept](#)
- [void idep \(int input\) noexcept](#)
- [void iztype \(int input\) noexcept](#)
- [void iinst \(int input\) noexcept](#)
- [void istreg \(int input\) noexcept](#)
- [void ievreg \(int input\) noexcept](#)
- [void ievtyp \(int input\) noexcept](#)
- [void igual \(int input\) noexcept](#)
- [void isynth \(int input\) noexcept](#)
- [void imagtyp \(int input\) noexcept](#)
- [void imagsrc \(int input\) noexcept](#)
- [void ibody \(int input\) noexcept](#)
- [void leven \(bool input\) noexcept](#)
- [void lpspol \(bool input\) noexcept](#)
- [void lovrok \(bool input\) noexcept](#)
- [void lcalda \(bool input\) noexcept](#)
- [void kstnm \(const std::string &input\) noexcept](#)
- [void kevnrm \(const std::string &input\) noexcept](#)
- [void khole \(const std::string &input\) noexcept](#)
- [void ko \(const std::string &input\) noexcept](#)
- [void ka \(const std::string &input\) noexcept](#)
- [void kt0 \(const std::string &input\) noexcept](#)
- [void kt1 \(const std::string &input\) noexcept](#)
- [void kt2 \(const std::string &input\) noexcept](#)
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- [void kt4 \(const std::string &input\) noexcept](#)
- [void kt5 \(const std::string &input\) noexcept](#)
- [void kt6 \(const std::string &input\) noexcept](#)
- [void kt7 \(const std::string &input\) noexcept](#)
- [void kt8 \(const std::string &input\) noexcept](#)
- [void kt9 \(const std::string &input\) noexcept](#)
- [void kf \(const std::string &input\) noexcept](#)
- [void kuser0 \(const std::string &input\) noexcept](#)
- [void kuser1 \(const std::string &input\) noexcept](#)
- [void kuser2 \(const std::string &input\) noexcept](#)
- [void kcmpnm \(const std::string &input\) noexcept](#)
- [void knetwk \(const std::string &input\) noexcept](#)
- [void kdatrd \(const std::string &input\) noexcept](#)
- [void kinst \(const std::string &input\) noexcept](#)
- [void data1 \(const std::vector< double > &input\) noexcept](#)
- [void data2 \(const std::vector< double > &input\) noexcept](#)

### Private Member Functions

- [void calc\\_gcrc \(\) noexcept](#)  
*Calculate great-circle arc-distance (gcrc).*
- [void calc\\_dist \(\) noexcept](#)  
*Calculate distance (using gcrc).*
- [void calc\\_az \(\) noexcept](#)  
*Calculate azimuth.*
- [void calc\\_baz \(\) noexcept](#)  
*Calculate back-azimuth.*
- [bool geometry\\_set \(\) const noexcept](#)

*Determine if locations are set for geometry calculation.*

- `void resize_data1 (size_t size) noexcept`
- `void resize_data2 (size_t size) noexcept`
- `void resize_data (size_t size) noexcept`

*Resize data vectors (only if eligible).*

### Private Attributes

- `std::array< float, num_float > floats {}`  
*Float storage array.*
- `std::array< double, num_double > doubles {}`  
*Double storage array.*
- `std::array< int, num_int > ints {}`  
*Integer storage array.*
- `std::array< bool, num_bool > bools {}`  
*Boolean storage array.*
- `std::array< std::string, num_string > strings {}`  
*String storage array.*
- `std::array< std::vector< double >, num_data > data {}`  
*std::vector<double> storage array.*

## 11.3.1 Detailed Description

The [Trace](#) class.

This class is the recommended way for reading/writing SAC-files.

It safely reads all data, provides automatic write support based upon the nVHdr header value (determine if a footer should be included or not).

It provides getters and setters for all SAC headers and the data.

## 11.3.2 Constructor & Destructor Documentation

### 11.3.2.1 Trace() [1/2]

```
sacfmt::Trace::Trace ( ) [noexcept]
```

[Trace](#) default constructor.

Fills all values with their default (unset) values. Data vectors are of size zero.

#### Returns

Default created [Trace](#) object.

```
00833     {
00834     std::ranges::fill(floats.begin(), floats.end(), unset_float);
00835     std::ranges::fill(doubles.begin(), doubles.end(), unset_double);
00836     std::ranges::fill(ints.begin(), ints.end(), unset_int);
00837     std::ranges::fill(bools.begin(), bools.end(), unset_bool);
00838     std::ranges::fill(strings.begin(), strings.end(), unset_word);
00839 }
```

### 11.3.2.2 Trace() [2/2]

```
sacfmt::Trace::Trace (
    const std::filesystem::path & path ) [explicit]
```

Binary SAC-file reader.

## Parameters

in	<i>path</i>	std::filesystem::path SAC-file to be read.
----	-------------	--

## Returns

[Trace](#) read in-file.

## Exceptions

<i>io_error</i>	If the file is not safe to read for whatever reason.
<i>std::exception</i>	(disk failure).

```

01742                                     {
01743     std::ifstream file(path, std::ifstream::binary);
01744     if (!file) {
01745         throw io_error(path.string() + " cannot be opened to read.");
01746     }
01747     safe_to_read_header(&file); // throws io_error if not safe
01748     //-----
01749     // Header
01750     delta(binary_to_float(read_word(&file)));
01751     depmin(binary_to_float(read_word(&file)));
01752     depmax(binary_to_float(read_word(&file)));
01753     // Skip 'unused'
01754     read_word(&file);
01755     odelta(binary_to_float(read_word(&file)));
01756     b(binary_to_float(read_word(&file)));
01757     e(binary_to_float(read_word(&file)));
01758     o(binary_to_float(read_word(&file)));
01759     a(binary_to_float(read_word(&file)));
01760     // Skip 'internal'
01761     read_word(&file);
01762     // T# pick headers
01763     t0(binary_to_float(read_word(&file)));
01764     t1(binary_to_float(read_word(&file)));
01765     t2(binary_to_float(read_word(&file)));
01766     t3(binary_to_float(read_word(&file)));
01767     t4(binary_to_float(read_word(&file)));
01768     t5(binary_to_float(read_word(&file)));
01769     t6(binary_to_float(read_word(&file)));
01770     t7(binary_to_float(read_word(&file)));
01771     t8(binary_to_float(read_word(&file)));
01772     t9(binary_to_float(read_word(&file)));
01773     f(binary_to_float(read_word(&file)));
01774     // Response headers
01775     resp0(binary_to_float(read_word(&file)));
01776     resp1(binary_to_float(read_word(&file)));
01777     resp2(binary_to_float(read_word(&file)));
01778     resp3(binary_to_float(read_word(&file)));
01779     resp4(binary_to_float(read_word(&file)));
01780     resp5(binary_to_float(read_word(&file)));
01781     resp6(binary_to_float(read_word(&file)));
01782     resp7(binary_to_float(read_word(&file)));
01783     resp8(binary_to_float(read_word(&file)));
01784     resp9(binary_to_float(read_word(&file)));
01785     // Station headers
01786     stla(binary_to_float(read_word(&file)));
01787     stlo(binary_to_float(read_word(&file)));
01788     stel(binary_to_float(read_word(&file)));
01789     stdp(binary_to_float(read_word(&file)));
01790     // Event headers
01791     evla(binary_to_float(read_word(&file)));
01792     evlo(binary_to_float(read_word(&file)));
01793     evel(binary_to_float(read_word(&file)));
01794     evdp(binary_to_float(read_word(&file)));
01795     mag(binary_to_float(read_word(&file)));
01796     // User misc headers
01797     user0(binary_to_float(read_word(&file)));
01798     user1(binary_to_float(read_word(&file)));
01799     user2(binary_to_float(read_word(&file)));
01800     user3(binary_to_float(read_word(&file)));
01801     user4(binary_to_float(read_word(&file)));
01802     user5(binary_to_float(read_word(&file)));
01803     user6(binary_to_float(read_word(&file)));
01804     user7(binary_to_float(read_word(&file)));
01805     user8(binary_to_float(read_word(&file)));
01806     user9(binary_to_float(read_word(&file)));

```

```

01807 // Geometry headers
01808 dist(binary_to_float(read_word(&file)));
01809 az(binary_to_float(read_word(&file)));
01810 baz(binary_to_float(read_word(&file)));
01811 gcArc(binary_to_float(read_word(&file)));
01812 // Metadata headers
01813 sb(binary_to_float(read_word(&file)));
01814 sdelta(binary_to_float(read_word(&file)));
01815 depmen(binary_to_float(read_word(&file)));
01816 cmpaz(binary_to_float(read_word(&file)));
01817 cmpinc(binary_to_float(read_word(&file)));
01818 xminimum(binary_to_float(read_word(&file)));
01819 xmaximum(binary_to_float(read_word(&file)));
01820 yminimum(binary_to_float(read_word(&file)));
01821 ymaximum(binary_to_float(read_word(&file)));
01822 // Skip 'unused' (xcommon_skip_num)
01823 for (int i{0}; i < common_skip_num; ++i) {
01824     read_word(&file);
01825 }
01826 // Date/time headers
01827 nzyear(binary_to_int(read_word(&file)));
01828 nzjday(binary_to_int(read_word(&file)));
01829 nzhour(binary_to_int(read_word(&file)));
01830 nzmin(binary_to_int(read_word(&file)));
01831 nzsec(binary_to_int(read_word(&file)));
01832 nzmsec(binary_to_int(read_word(&file)));
01833 // More metadata headers
01834 nvhdr(binary_to_int(read_word(&file)));
01835 norid(binary_to_int(read_word(&file)));
01836 nevid(binary_to_int(read_word(&file)));
01837 npts(binary_to_int(read_word(&file)));
01838 nsnpts(binary_to_int(read_word(&file)));
01839 nwfid(binary_to_int(read_word(&file)));
01840 nxsize(binary_to_int(read_word(&file)));
01841 nysize(binary_to_int(read_word(&file)));
01842 // Skip 'unused'
01843 read_word(&file);
01844 iftype(binary_to_int(read_word(&file)));
01845 idep(binary_to_int(read_word(&file)));
01846 iztype(binary_to_int(read_word(&file)));
01847 // Skip 'unused'
01848 read_word(&file);
01849 iinst(binary_to_int(read_word(&file)));
01850 istreg(binary_to_int(read_word(&file)));
01851 ievreg(binary_to_int(read_word(&file)));
01852 ievtyp(binary_to_int(read_word(&file)));
01853 igual(binary_to_int(read_word(&file)));
01854 isynth(binary_to_int(read_word(&file)));
01855 imagtyp(binary_to_int(read_word(&file)));
01856 imagsrc(binary_to_int(read_word(&file)));
01857 ibody(binary_to_int(read_word(&file)));
01858 // Skip 'unused' (xcommon_skip_num)
01859 for (int i{0}; i < common_skip_num; ++i) {
01860     read_word(&file);
01861 }
01862 // Logical headers
01863 leven(binary_to_bool(read_word(&file)));
01864 lspol(binary_to_bool(read_word(&file)));
01865 lovrok(binary_to_bool(read_word(&file)));
01866 lcalda(binary_to_bool(read_word(&file)));
01867 // Skip 'unused'
01868 read_word(&file);
01869 // KSTNM is 2 words (normal)
01870 kstnm(binary_to_string(read_two_words(&file)));
01871 // KEVNM is 4 words long (unique!)
01872 kevnrm(binary_to_long_string(read_four_words(&file)));
01873 // All other 'K' headers are 2 words
01874 khole(binary_to_string(read_two_words(&file)));
01875 ko(binary_to_string(read_two_words(&file)));
01876 ka(binary_to_string(read_two_words(&file)));
01877 kt0(binary_to_string(read_two_words(&file)));
01878 kt1(binary_to_string(read_two_words(&file)));
01879 kt2(binary_to_string(read_two_words(&file)));
01880 kt3(binary_to_string(read_two_words(&file)));
01881 kt4(binary_to_string(read_two_words(&file)));
01882 kt5(binary_to_string(read_two_words(&file)));
01883 kt6(binary_to_string(read_two_words(&file)));
01884 kt7(binary_to_string(read_two_words(&file)));
01885 kt8(binary_to_string(read_two_words(&file)));
01886 kt9(binary_to_string(read_two_words(&file)));
01887 kf(binary_to_string(read_two_words(&file)));
01888 kuser0(binary_to_string(read_two_words(&file)));
01889 kuser1(binary_to_string(read_two_words(&file)));
01890 kuser2(binary_to_string(read_two_words(&file)));
01891 kcmpnm(binary_to_string(read_two_words(&file)));
01892 knetwk(binary_to_string(read_two_words(&file)));
01893 kdatrd(binary_to_string(read_two_words(&file)));

```

```

01894     kinst(binary_to_string(read_two_words(&file)));
01895     //-----
01896     // DATA
01897     const bool is_data{npts() != unset_int};
01898     // data1
01899     const size_t n_words{static_cast<size_t>(npts())};
01900     if (is_data) {
01901         // false flags for data1
01902         safe_to_read_data(&file, n_words, false); // throws io_error if unsafe
01903         const read_spec spec{n_words, data_word};
01904         // Originally floats, read as doubles
01905         data1(read_data(&file, spec));
01906     }
01907     // data2 (uneven or spectral data)
01908     if (is_data && (!leven() || (iftype() > 1))) {
01909         // true flags for data2
01910         safe_to_read_data(&file, n_words, true); // throws io_error if unsafe
01911         const read_spec spec{n_words, data_word + static_cast<size_t>(npts())};
01912         data2(read_data(&file, spec));
01913     }
01914     //-----
01915     // Footer
01916     if (nvhdr() == modern_hdr_version) {
01917         safe_to_read_footer(&file); // throws io_error if not safe
01918         delta(binary_to_double(read_two_words(&file)));
01919         b(binary_to_double(read_two_words(&file)));
01920         e(binary_to_double(read_two_words(&file)));
01921         o(binary_to_double(read_two_words(&file)));
01922         a(binary_to_double(read_two_words(&file)));
01923         t0(binary_to_double(read_two_words(&file)));
01924         t1(binary_to_double(read_two_words(&file)));
01925         t2(binary_to_double(read_two_words(&file)));
01926         t3(binary_to_double(read_two_words(&file)));
01927         t4(binary_to_double(read_two_words(&file)));
01928         t5(binary_to_double(read_two_words(&file)));
01929         t6(binary_to_double(read_two_words(&file)));
01930         t7(binary_to_double(read_two_words(&file)));
01931         t8(binary_to_double(read_two_words(&file)));
01932         t9(binary_to_double(read_two_words(&file)));
01933         f(binary_to_double(read_two_words(&file)));
01934         evlo(binary_to_double(read_two_words(&file)));
01935         evla(binary_to_double(read_two_words(&file)));
01936         stlo(binary_to_double(read_two_words(&file)));
01937         stla(binary_to_double(read_two_words(&file)));
01938         sb(binary_to_double(read_two_words(&file)));
01939         sdelta(binary_to_double(read_two_words(&file)));
01940     }
01941     safe_to_finish_reading(&file); // throws io_error if the file isn't finished
01942     file.close();
01943 }

```

### 11.3.3 Member Function Documentation

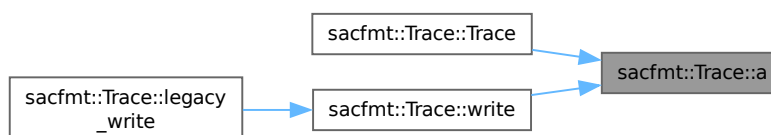
#### 11.3.3.1 a() [1/2]

```

double sacfmt::Trace::a ( ) const [noexcept]
01063 { return doubles[sac_map.at(name::a)]; }

```

Here is the caller graph for this function:





**11.3.3.2 a()** [2/2]

```

void sacfmt::Trace::a (
    double input ) [noexcept]
01318     {
01319     doubles[sac_map.at(name::a)] = input;
01320     }

```

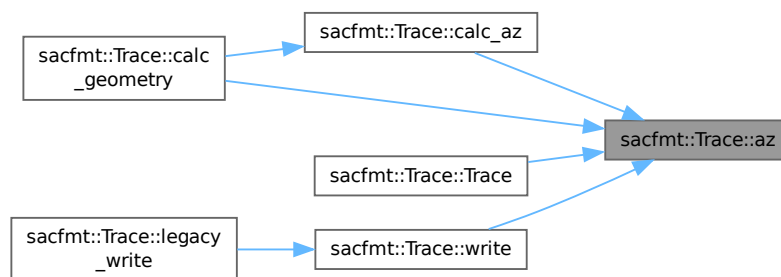
**11.3.3.3 az()** [1/2]

```

float sacfmt::Trace::az ( ) const [noexcept]
01034 { return floats[sac_map.at(name::az)]; }

```

Here is the caller graph for this function:

**11.3.3.4 az()** [2/2]

```

void sacfmt::Trace::az (
    float input ) [noexcept]
01275     {
01276     floats[sac_map.at(name::az)] = input;
01277     }

```

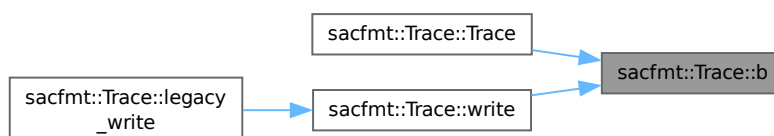
**11.3.3.5 b()** [1/2]

```

double sacfmt::Trace::b ( ) const [noexcept]
01060 { return doubles[sac_map.at(name::b)]; }

```

Here is the caller graph for this function:



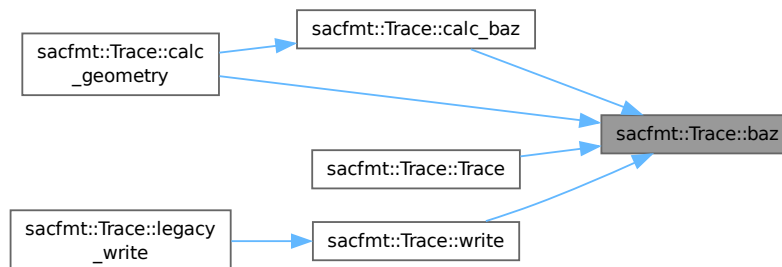
### 11.3.3.6 b() [2/2]

```
void sacfmt::Trace::b (
    double input ) [noexcept]
01309     {
01310     doubles[sac_map.at(name::b)] = input;
01311 }
```

### 11.3.3.7 baz() [1/2]

```
float sacfmt::Trace::baz ( ) const [noexcept]
01035 { return floats[sac_map.at(name::baz)]; }
```

Here is the caller graph for this function:



### 11.3.3.8 baz() [2/2]

```
void sacfmt::Trace::baz (
    float input ) [noexcept]
01278     {
01279     floats[sac_map.at(name::baz)] = input;
01280 }
```

### 11.3.3.9 calc\_az()

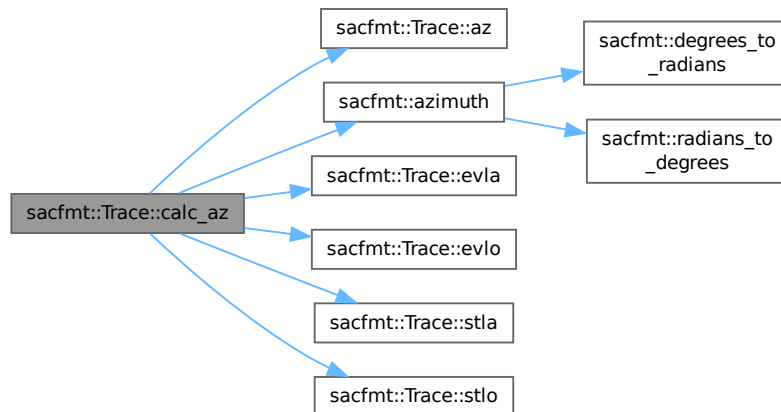
```
void sacfmt::Trace::calc_az ( ) [private], [noexcept]
```

Calculate azimuth.

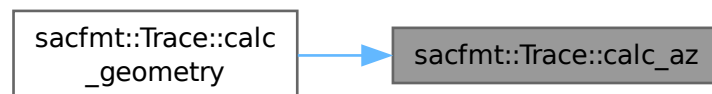
*Station → Event*

```
00943     {
00944     az(static_cast<float>(azimuth(evla(), evlo(), stla(), stlo())));
00945 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



#### 11.3.3.10 calc\_baz()

```
void sacfmt::Trace::calc_baz ( ) [private], [noexcept]
```

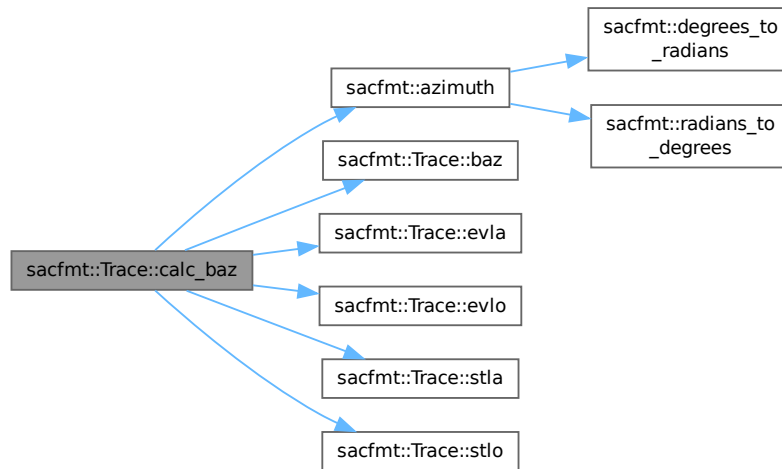
Calculate back-azimuth.

*Event → Station*

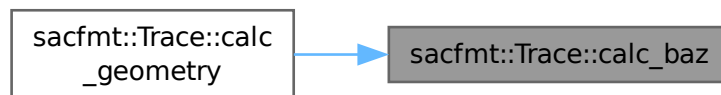
```

00954         {
00955     baz(static_cast<float>(azimuth(stla(), stlo(), evla(), evlo())));
00956 }
  
```

Here is the call graph for this function:



Here is the caller graph for this function:



### 11.3.3.11 calc\_dist()

```
void sacfmt::Trace::calc_dist ( ) [private], [noexcept]
```

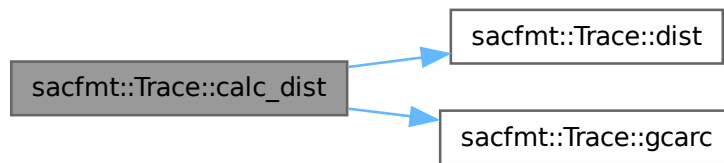
Calculate distance (using `gcarc`).

Assumes spherical Earth (in future may update to include flattening and different planetary bodies).

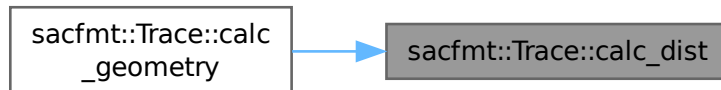
$$d = r_E \cdot \Delta$$

```
00932         {
00933     dist (static_cast<float>(earth_radius * rad_per_deg * gcarc()));
00934 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



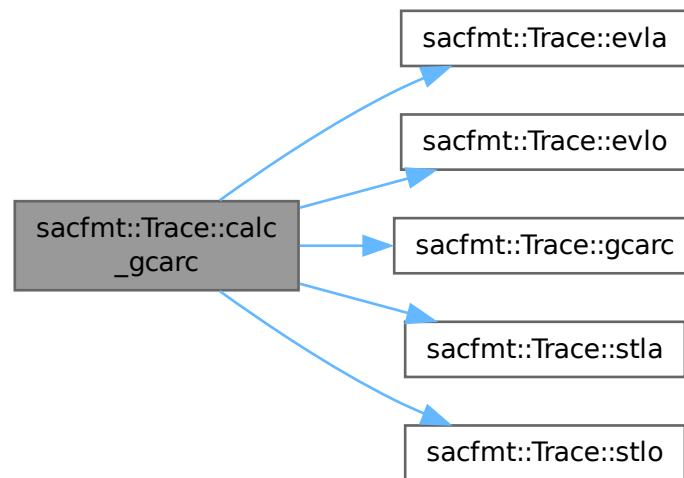
#### 11.3.3.12 calc\_gcarc()

```
void sacfmt::Trace::calc_gcarc ( ) [private], [noexcept]
```

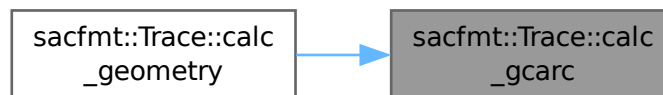
Calculate great-circle arc-distance (gcarc).

```
00917     {  
00918     Trace::gcarc(  
00919         static_cast<float>(sacfmt::gcarc(stla(), stlo(), evla(), evlo())));  
00920 }
```

Here is the call graph for this function:



Here is the caller graph for this function:



### 11.3.3.13 calc\_geometry()

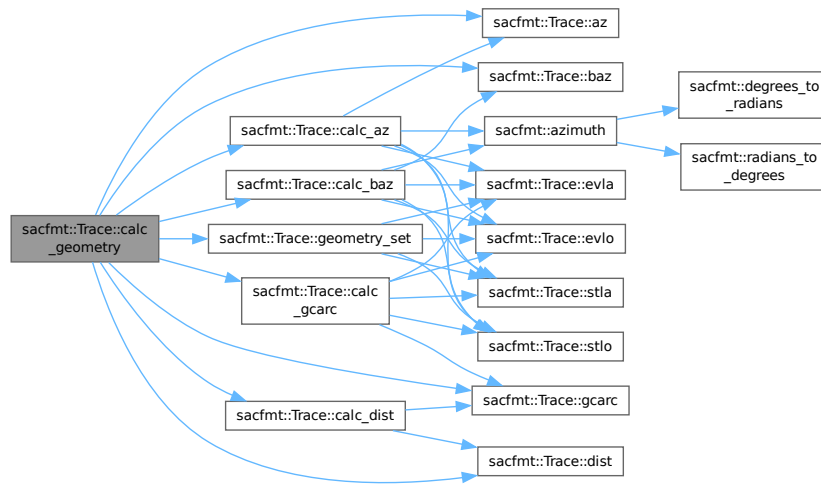
```
void sacfmt::Trace::calc_geometry ( ) [noexcept]
```

Calculates `gcarc`, `dist`, `az`, and `baz` from `stla`, `stlo`, `evla`, and `evlo`.

```

00873     {
00874     if (geometry_set()) {
00875         calc_gcarc();
00876         calc_dist();
00877         calc_az();
00878         calc_baz();
00879     } else {
00880         gcarc(unset_double);
00881         dist(unset_double);
00882         az(unset_double);
00883         baz(unset_double);
00884     }
00885 }
```

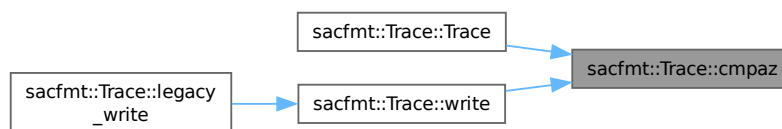
Here is the call graph for this function:



#### 11.3.3.14 cmpaz() [1/2]

```
float sacfmt::Trace::cmpaz ( ) const [noexcept]
01040 { return floats[sac_map.at(name::cmpaz)]; }
```

Here is the caller graph for this function:



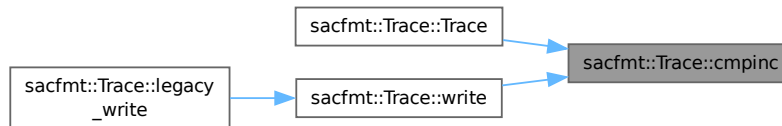
#### 11.3.3.15 cmpaz() [2/2]

```
void sacfmt::Trace::cmpaz (
    float input ) [noexcept]
01287 {
01288     floats[sac_map.at(name::cmpaz)] = input;
01289 }
```

### 11.3.3.16 cmpinc() [1/2]

```
float sacfmt::Trace::cmpinc ( ) const [noexcept]
01041     {
01042     return floats[sac_map.at(name::cmpinc)];
01043 }
```

Here is the caller graph for this function:



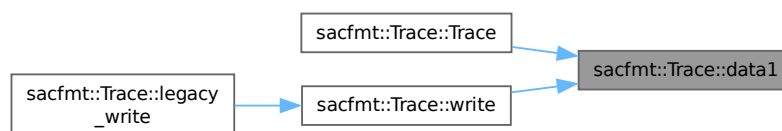
### 11.3.3.17 cmpinc() [2/2]

```
void sacfmt::Trace::cmpinc (
    float input ) [noexcept]
01290     {
01291     floats[sac_map.at(name::cmpinc)] = input;
01292 }
```

### 11.3.3.18 data1() [1/2]

```
std::vector< double > sacfmt::Trace::data1 ( ) const [noexcept]
01180     {
01181     return data[sac_map.at(name::data1)];
01182 }
```

Here is the caller graph for this function:



### 11.3.3.19 data1() [2/2]

```
void sacfmt::Trace::data1 (
    const std::vector< double > & input ) [noexcept]
01564     {
01565     data[sac_map.at(name::data1)] = input;
01566     // Propagate change as needed
01567     int size{static_cast<int>(data1().size())};
01568     size = (((size == 0) && (npts() == unset_int)) ? unset_int : size);
01569     if (size != npts()) {
01570         npts(size);
01571     }
01572 }
```



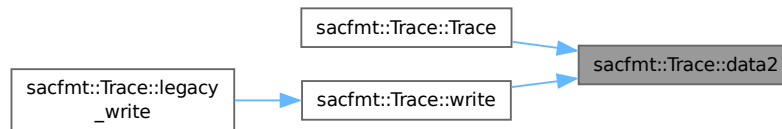
## 11.3.3.20 data2() [1/2]

```

std::vector< double > sacfmt::Trace::data2 ( ) const [noexcept]
01183     {
01184     return data[sac_map.at(name::data2)];
01185     }

```

Here is the caller graph for this function:



## 11.3.3.21 data2() [2/2]

```

void sacfmt::Trace::data2 (
    const std::vector< double > & input ) [noexcept]
01574     {
01575     data[sac_map.at(name::data2)] = input;
01576     // Proagate change as needed
01577     int size{static_cast<int>(data2().size())};
01578     size = (((size == 0) && (npts() == unset_int)) ? unset_int : size);
01579     // Need to make sure this is legal
01580     // If positive size and not-legal, make spectral
01581     if (size > 0) {
01582         // If not legal, make spectral
01583         if (leven() && (iftype() <= 1)) {
01584             iftype(2);
01585         }
01586         // If legal and different from npts, update npts
01587         if ((!leven() || (iftype() > 1)) && (size != npts())) {
01588             npts(size);
01589         }
01590     }
01591 }

```

## 11.3.3.22 date()

```
std::string sacfmt::Trace::date ( ) const [noexcept]
```

Get date string.

## Returns

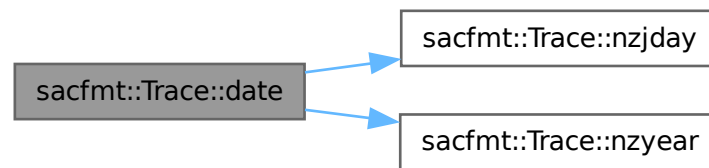
std::string Date (YYYY-JJJ).

```

00963     {
00964     // Require all to be set
00965     if ((nzyear() == unset_int) || (nzjday() == unset_int)) {
00966         return unset_word;
00967     }
00968     std::ostringstream oss{};
00969     oss << nzyear();
00970     oss << '-';
00971     oss << nzjday();
00972     return oss.str();
00973 }

```

Here is the call graph for this function:

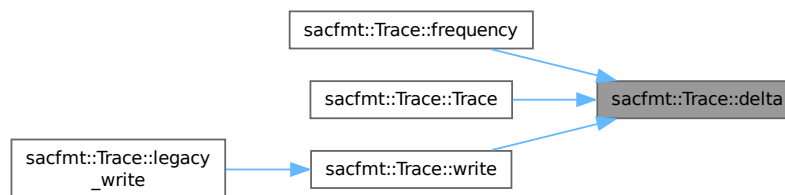


### 11.3.3.23 `delta()` [1/2]

```

double sacfmt::Trace::delta ( ) const [noexcept]
01057 {
01058     return doubles[sac_map.at(name::delta)];
01059 }
  
```

Here is the caller graph for this function:



### 11.3.3.24 `delta()` [2/2]

```

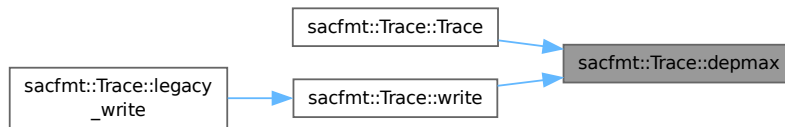
void sacfmt::Trace::delta (
    double input ) [noexcept]
01306 {
01307     doubles[sac_map.at(name::delta)] = input;
01308 }
  
```

### 11.3.3.25 `depmax()` [1/2]

```

float sacfmt::Trace::depmax ( ) const [noexcept]
01002 {
01003     return floats[sac_map.at(name::depmax)];
01004 }
  
```

Here is the caller graph for this function:



#### 11.3.3.26 depmax() [2/2]

```

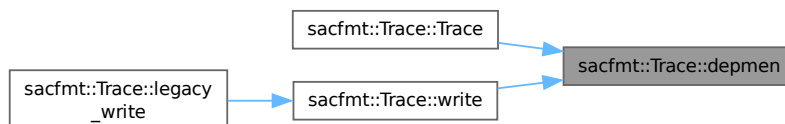
void sacfmt::Trace::depmax (
    float input ) [noexcept]
01191     {
01192     floats[sac_map.at(name::depmax)] = input;
01193     }
  
```

#### 11.3.3.27 depmen() [1/2]

```

float sacfmt::Trace::depmen ( ) const [noexcept]
01037     {
01038     return floats[sac_map.at(name::depmen)];
01039     }
  
```

Here is the caller graph for this function:



#### 11.3.3.28 depmen() [2/2]

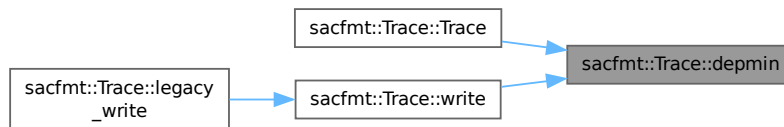
```

void sacfmt::Trace::depmen (
    float input ) [noexcept]
01284     {
01285     floats[sac_map.at(name::depmen)] = input;
01286     }
  
```

### 11.3.3.29 depmin() [1/2]

```
float sacfmt::Trace::depmin ( ) const [noexcept]
00999 {
01000     return floats[sac_map.at(name::depmin)];
01001 }
```

Here is the caller graph for this function:



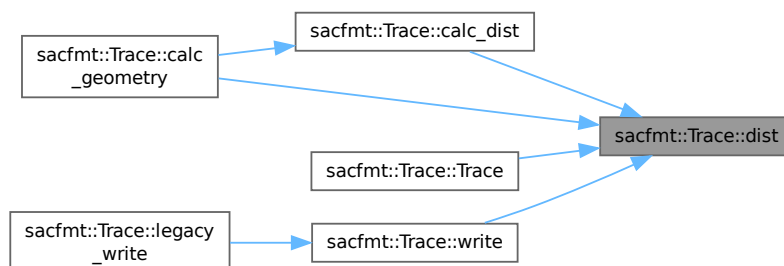
### 11.3.3.30 depmin() [2/2]

```
void sacfmt::Trace::depmin (
    float input ) [noexcept]
01188 {
01189     floats[sac_map.at(name::depmin)] = input;
01190 }
```

### 11.3.3.31 dist() [1/2]

```
float sacfmt::Trace::dist ( ) const [noexcept]
01033 { return floats[sac_map.at(name::dist)]; }
```

Here is the caller graph for this function:



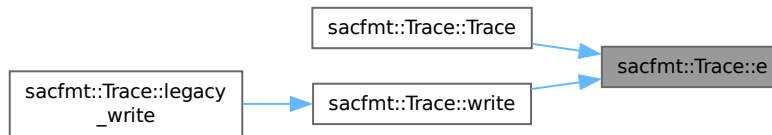
### 11.3.3.32 dist() [2/2]

```
void sacfmt::Trace::dist (
    float input ) [noexcept]
01272 {
01273     floats[sac_map.at(name::dist)] = input;
01274 }
```

**11.3.3.33 e()** [1/2]

```
double sacfmt::Trace::e ( ) const [noexcept]
01061 { return doubles[sac_map.at(name::e)]; }
```

Here is the caller graph for this function:

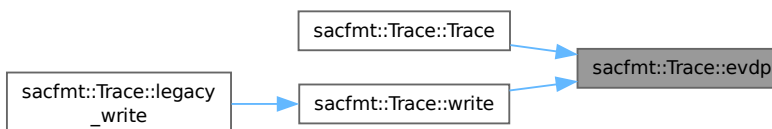
**11.3.3.34 e()** [2/2]

```
void sacfmt::Trace::e (
    double input ) [noexcept]
01312 {
01313     doubles[sac_map.at(name::e)] = input;
01314 }
```

**11.3.3.35 evdp()** [1/2]

```
float sacfmt::Trace::evdp ( ) const [noexcept]
01021 { return floats[sac_map.at(name::evdp)]; }
```

Here is the caller graph for this function:

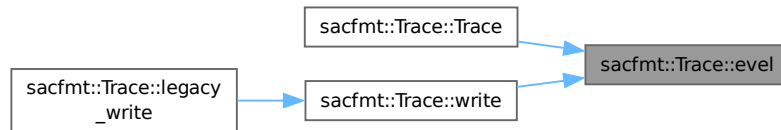
**11.3.3.36 evdp()** [2/2]

```
void sacfmt::Trace::evdp (
    float input ) [noexcept]
01236 {
01237     floats[sac_map.at(name::evdp)] = input;
01238 }
```

**11.3.3.37 evel()** [1/2]

```
float sacfmt::Trace::evel ( ) const [noexcept]
01020 { return floats[sac_map.at(name::evel)]; }
```

Here is the caller graph for this function:

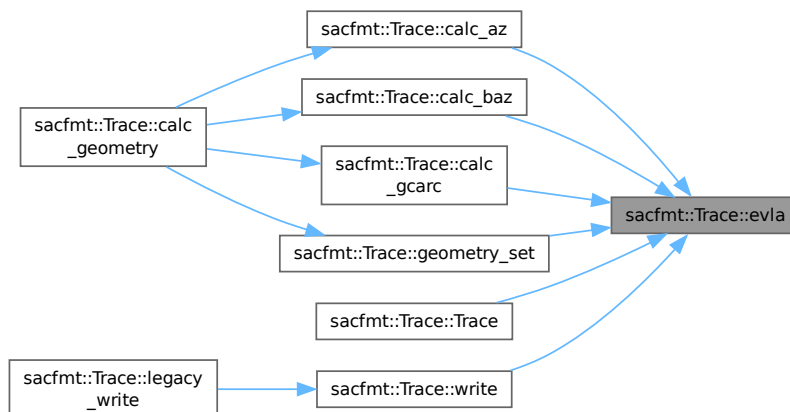
**11.3.3.38 evel()** [2/2]

```
void sacfmt::Trace::evel (
    float input ) [noexcept]
01233 {
01234     floats[sac_map.at(name::evel)] = input;
01235 }
```

**11.3.3.39 evla()** [1/2]

```
double sacfmt::Trace::evla ( ) const [noexcept]
01077 { return doubles[sac_map.at(name::evla)]; }
```

Here is the caller graph for this function:



## 11.3.3.40 evla() [2/2]

```

void sacfmt::Trace::evla (
    double input ) [noexcept]
01366     {
01367     if (input != unset_double) {
01368         input = limit_90(input);
01369     }
01370     doubles[sac_map.at(name::evla)] = input;
01371 }

```

Here is the call graph for this function:



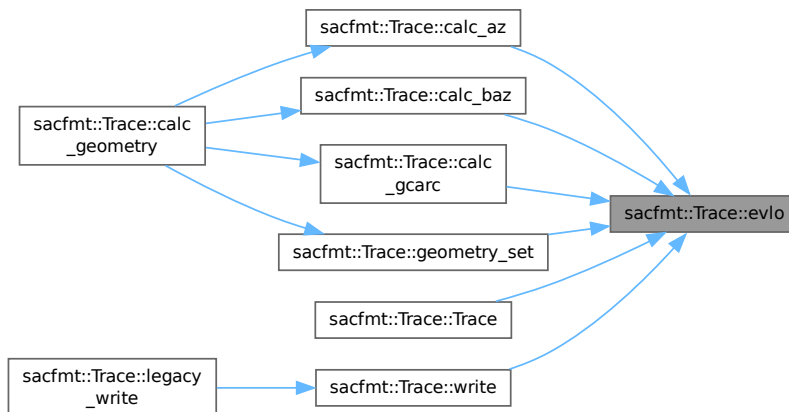
## 11.3.3.41 evlo() [1/2]

```

double sacfmt::Trace::evlo ( ) const [noexcept]
01078 { return doubles[sac_map.at(name::evlo)]; }

```

Here is the caller graph for this function:



## 11.3.3.42 evlo() [2/2]

```

void sacfmt::Trace::evlo (
    double input ) [noexcept]
01372     {
01373     if (input != unset_double) {
01374         input = limit_180(input);
01375     }
01376     doubles[sac_map.at(name::evlo)] = input;
01377 }

```

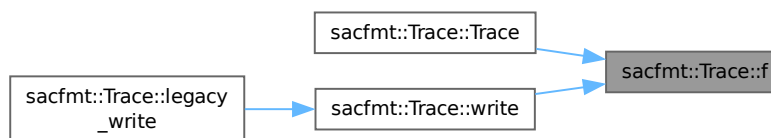
Here is the call graph for this function:



#### 11.3.3.43 f() [1/2]

```
double sacfmt::Trace::f ( ) const [noexcept]
01074 { return doubles[sac_map.at(name::f)]; }
```

Here is the caller graph for this function:



#### 11.3.3.44 f() [2/2]

```
void sacfmt::Trace::f (
    double input ) [noexcept]
01351 {
01352     doubles[sac_map.at(name::f)] = input;
01353 }
```

#### 11.3.3.45 frequency()

```
double sacfmt::Trace::frequency ( ) const [noexcept]
```

Calculate frequency from delta.

$$f = \frac{1}{\delta}$$



## Returns

double Frequency.

```

00896                                     {
00897     const double delta_val{delta()};
00898     if ((delta_val == unset_double) || (delta_val <= 0)) {
00899         return unset_double;
00900     }
00901     return 1.0 / delta_val;
00902 }
```

Here is the call graph for this function:

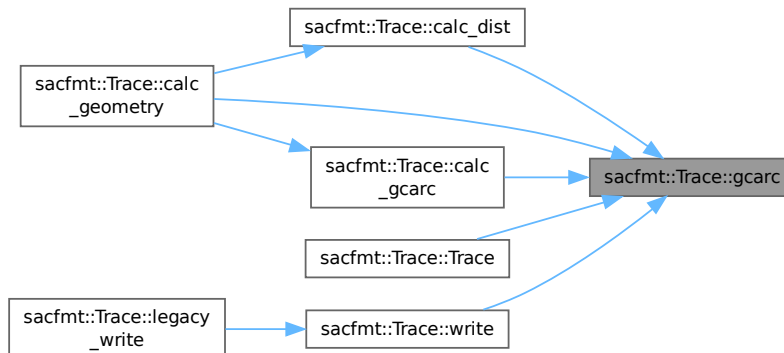


## 11.3.3.46 gcarc() [1/2]

```

float sacfmt::Trace::gcarc ( ) const [noexcept]
01036 { return floats[sac_map.at(name::gcarc)]; }
```

Here is the caller graph for this function:



## 11.3.3.47 gcarc() [2/2]

```

void sacfmt::Trace::gcarc (
    float input ) [noexcept]
01281                                     {
01282     floats[sac_map.at(name::gcarc)] = input;
01283 }
```

### 11.3.3.48 geometry\_set()

```
bool sacfmt::Trace::geometry_set ( ) const [private], [noexcept]
```

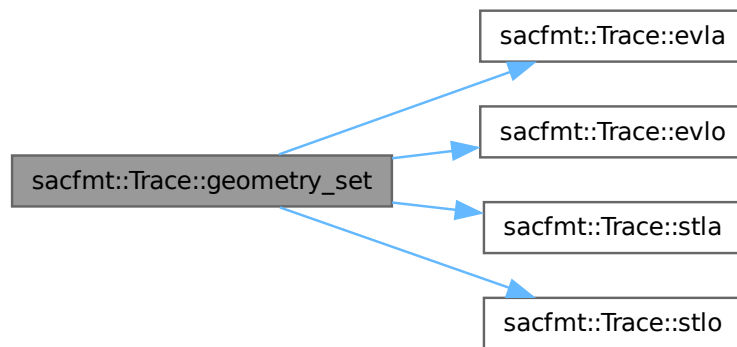
Determine if locations are set for geometry calculation.

#### Returns

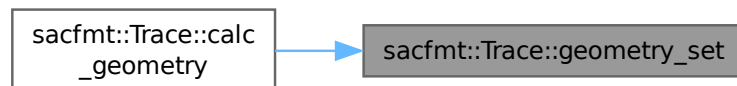
bool True if able to calculate geometry.

```
00909 {
00910     return ((stla() != unset_double) && (stlo() != unset_double) &&
00911            (evla() != unset_double) && (evlo() != unset_double));
00912 }
```

Here is the call graph for this function:



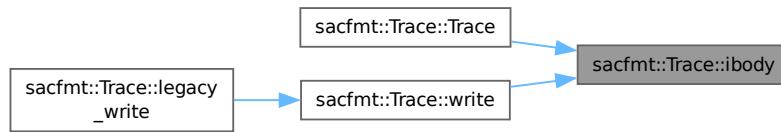
Here is the caller graph for this function:



### 11.3.3.49 ibody() [1/2]

```
int sacfmt::Trace::ibody ( ) const [noexcept]
01109 { return ints[sac_map.at(name::ibody)]; }
```

Here is the caller graph for this function:



#### 11.3.3.50 ibody() [2/2]

```

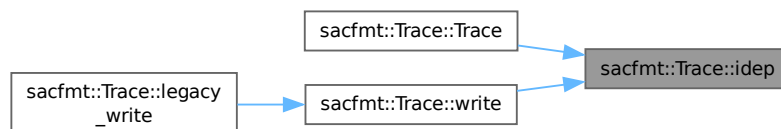
void sacfmt::Trace::ibody (
    int input ) [noexcept]
{
01470     ints[sac_map.at(name::ibody)] = input;
01471 }
01472
  
```

#### 11.3.3.51 idep() [1/2]

```

int sacfmt::Trace::idep ( ) const [noexcept]
01099 { return ints[sac_map.at(name::idep)]; }
  
```

Here is the caller graph for this function:



#### 11.3.3.52 idep() [2/2]

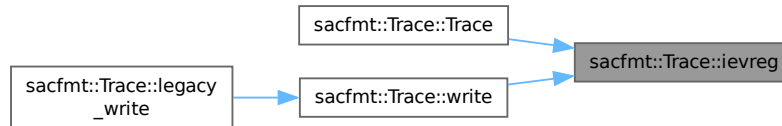
```

void sacfmt::Trace::idep (
    int input ) [noexcept]
{
01440     ints[sac_map.at(name::idep)] = input;
01441 }
01442
  
```

### 11.3.3.53 ievreg() [1/2]

```
int sacfmt::Trace::ievreg ( ) const [noexcept]
01103 { return ints[sac_map.at(name::ievreg)]; }
```

Here is the caller graph for this function:



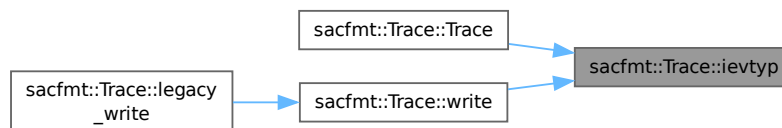
### 11.3.3.54 ievreg() [2/2]

```
void sacfmt::Trace::ievreg (
    int input ) [noexcept]
01452 {
01453     ints[sac_map.at(name::ievreg)] = input;
01454 }
```

### 11.3.3.55 ievtyp() [1/2]

```
int sacfmt::Trace::ievtyp ( ) const [noexcept]
01104 { return ints[sac_map.at(name::ievtyp)]; }
```

Here is the caller graph for this function:



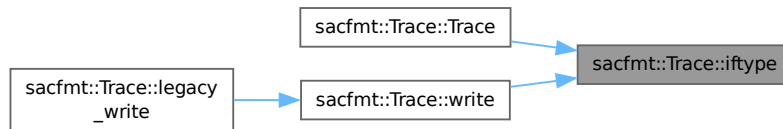
### 11.3.3.56 ievtyp() [2/2]

```
void sacfmt::Trace::ievtyp (
    int input ) [noexcept]
01455 {
01456     ints[sac_map.at(name::ievtyp)] = input;
01457 }
```

## 11.3.3.57 iftype() [1/2]

```
int sacfmt::Trace::ifetime ( ) const [noexcept]
01098 { return ints[sac_map.at(name::ifetime)]; }
```

Here is the caller graph for this function:



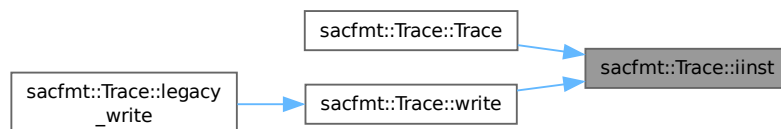
## 11.3.3.58 iftype() [2/2]

```
void sacfmt::Trace::ifetime (
    int input ) [noexcept]
01431
01432     ints[sac_map.at(name::ifetime)] = input; {
01433     const size_t size{npts()} >= 0 ? static_cast<size_t>(npts()) : 0;
01434     // Uneven 2D data not supported as not in specification
01435     if ((input > 1) && !leven()) {
01436         leven(true);
01437     }
01438     resize_data2(size);
01439 }
```

## 11.3.3.59 iinst() [1/2]

```
int sacfmt::Trace::iinst ( ) const [noexcept]
01101 { return ints[sac_map.at(name::iinst)]; }
```

Here is the caller graph for this function:



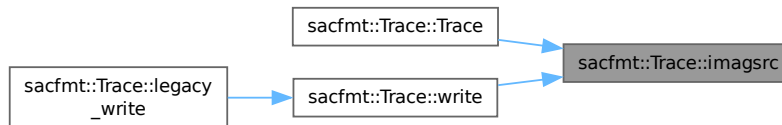
## 11.3.3.60 iinst() [2/2]

```
void sacfmt::Trace::iinst (
    int input ) [noexcept]
01446
01447     ints[sac_map.at(name::iinst)] = input; {
01448 }
```

### 11.3.3.61 `imgsrc()` [1/2]

```
int sacfmt::Trace::imgsrc ( ) const [noexcept]
01108 { return ints[sac_map.at(name::imgsrc)]; }
```

Here is the caller graph for this function:



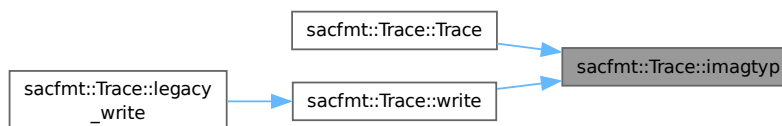
### 11.3.3.62 `imgsrc()` [2/2]

```
void sacfmt::Trace::imgsrc (
    int input ) [noexcept]
01467 {
01468     ints[sac_map.at(name::imgsrc)] = input;
01469 }
```

### 11.3.3.63 `imagtyp()` [1/2]

```
int sacfmt::Trace::imagtyp ( ) const [noexcept]
01107 { return ints[sac_map.at(name::imagtyp)]; }
```

Here is the caller graph for this function:



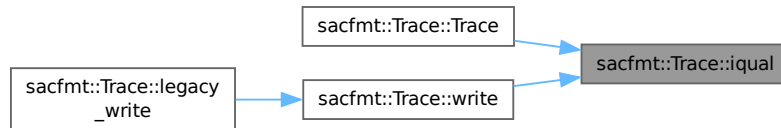
### 11.3.3.64 `imagtyp()` [2/2]

```
void sacfmt::Trace::imagtyp (
    int input ) [noexcept]
01464 {
01465     ints[sac_map.at(name::imagtyp)] = input;
01466 }
```

11.3.3.65 `equal()` [1/2]

```
int sacfmt::Trace::equal ( ) const [noexcept]
01105 { return ints[sac_map.at(name::equal)]; }
```

Here is the caller graph for this function:

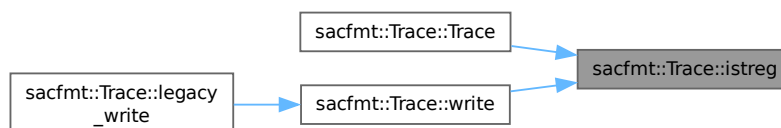
11.3.3.66 `equal()` [2/2]

```
void sacfmt::Trace::equal (
    int input ) [noexcept]
01458 {
01459     ints[sac_map.at(name::equal)] = input;
01460 }
```

11.3.3.67 `istreg()` [1/2]

```
int sacfmt::Trace::istreg ( ) const [noexcept]
01102 { return ints[sac_map.at(name::istreg)]; }
```

Here is the caller graph for this function:

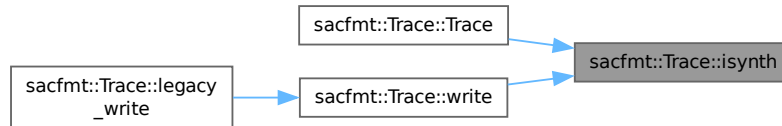
11.3.3.68 `istreg()` [2/2]

```
void sacfmt::Trace::istreg (
    int input ) [noexcept]
01449 {
01450     ints[sac_map.at(name::istreg)] = input;
01451 }
```

### 11.3.3.69 isynth() [1/2]

```
int sacfmt::Trace::isynt ( ) const [noexcept]
01106 { return ints[sac_map.at(name::isynt)]; }
```

Here is the caller graph for this function:



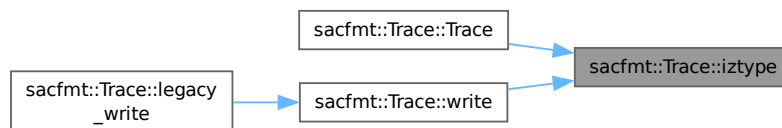
### 11.3.3.70 isynth() [2/2]

```
void sacfmt::Trace::isynt (
    int input ) [noexcept]
01461 {
01462     ints[sac_map.at(name::isynt)] = input;
01463 }
```

### 11.3.3.71 iztype() [1/2]

```
int sacfmt::Trace::iztype ( ) const [noexcept]
01100 { return ints[sac_map.at(name::iztype)]; }
```

Here is the caller graph for this function:



### 11.3.3.72 iztype() [2/2]

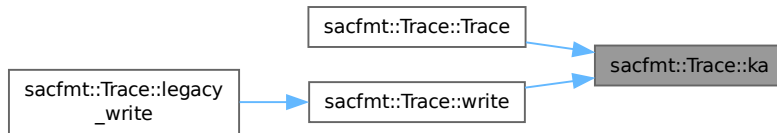
```
void sacfmt::Trace::iztype (
    int input ) [noexcept]
01443 {
01444     ints[sac_map.at(name::iztype)] = input;
01445 }
```



**11.3.3.73 ka()** [1/2]

```
std::string sacfmt::Trace::ka ( ) const [noexcept]
01126 { return strings[sac_map.at(name::ka)]; }
```

Here is the caller graph for this function:

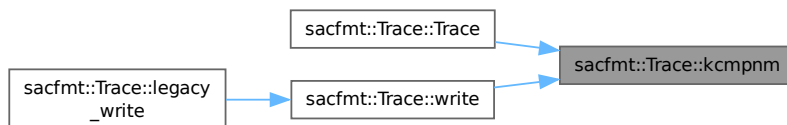
**11.3.3.74 ka()** [2/2]

```
void sacfmt::Trace::ka (
    const std::string & input ) [noexcept]
01505 {
01506     strings[sac_map.at(name::ka)] = input;
01507 }
```

**11.3.3.75 kcmpnm()** [1/2]

```
std::string sacfmt::Trace::kcmpnm ( ) const [noexcept]
01167 {
01168     return strings[sac_map.at(name::kcmpnm)];
01169 }
```

Here is the caller graph for this function:

**11.3.3.76 kcmpnm()** [2/2]

```
void sacfmt::Trace::kcmpnm (
    const std::string & input ) [noexcept]
01550 {
01551     strings[sac_map.at(name::kcmpnm)] = input;
01552 }
```

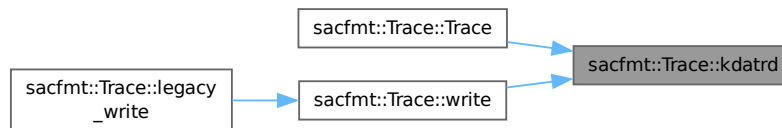
**11.3.3.77 kdatrd()** [1/2]

```

std::string sacfmt::Trace::kdatrd ( ) const [noexcept]
01173     {
01174     return strings[sac_map.at(name::kdatrd)];
01175     }

```

Here is the caller graph for this function:

**11.3.3.78 kdatrd()** [2/2]

```

void sacfmt::Trace::kdatrd (
    const std::string & input ) [noexcept]
01556     {
01557     strings[sac_map.at(name::kdatrd)] = input;
01558     }

```

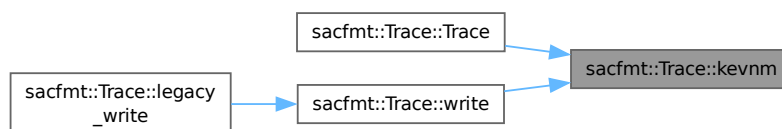
**11.3.3.79 kevnm()** [1/2]

```

std::string sacfmt::Trace::kevnm ( ) const [noexcept]
01119     {
01120     return strings[sac_map.at(name::kevn)];
01121     }

```

Here is the caller graph for this function:

**11.3.3.80 kevnm()** [2/2]

```

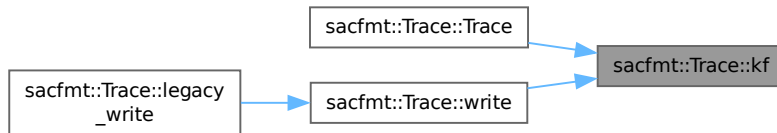
void sacfmt::Trace::kevn (
    const std::string & input ) [noexcept]
01496     {
01497     strings[sac_map.at(name::kevn)] = input;
01498     }

```

**11.3.3.81 kf()** [1/2]

```
std::string sacfmt::Trace::kf ( ) const [noexcept]
01157 { return strings[sac_map.at(name::kf)]; }
```

Here is the caller graph for this function:

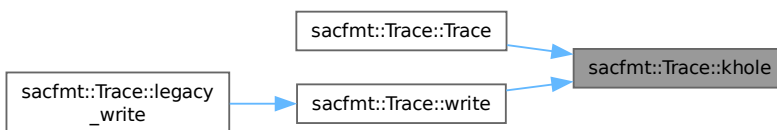
**11.3.3.82 kf()** [2/2]

```
void sacfmt::Trace::kf (
    const std::string & input ) [noexcept]
01538 {
01539     strings[sac_map.at(name::kf)] = input;
01540 }
```

**11.3.3.83 khole()** [1/2]

```
std::string sacfmt::Trace::khole ( ) const [noexcept]
01122 {
01123     return strings[sac_map.at(name::khole)];
01124 }
```

Here is the caller graph for this function:

**11.3.3.84 khole()** [2/2]

```
void sacfmt::Trace::khole (
    const std::string & input ) [noexcept]
01499 {
01500     strings[sac_map.at(name::khole)] = input;
01501 }
```

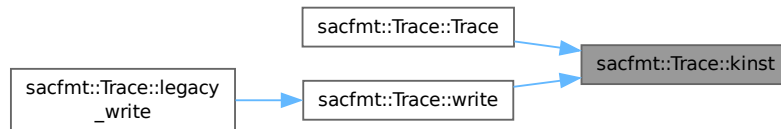
**11.3.3.85 kinst()** [1/2]

```

std::string sacfmt::Trace::kinst ( ) const [noexcept]
01176     {
01177     return strings[sac_map.at(name::kinst)];
01178     }

```

Here is the caller graph for this function:

**11.3.3.86 kinst()** [2/2]

```

void sacfmt::Trace::kinst (
    const std::string & input ) [noexcept]
01559     {
01560     strings[sac_map.at(name::kinst)] = input;
01561     }

```

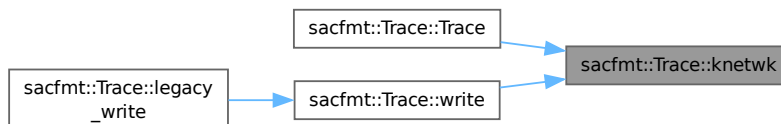
**11.3.3.87 knetwk()** [1/2]

```

std::string sacfmt::Trace::knetwk ( ) const [noexcept]
01170     {
01171     return strings[sac_map.at(name::knetwk)];
01172     }

```

Here is the caller graph for this function:

**11.3.3.88 knetwk()** [2/2]

```

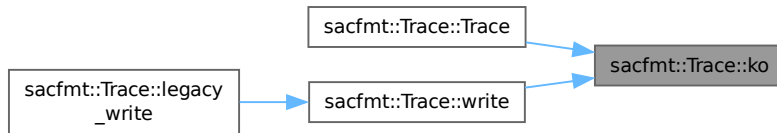
void sacfmt::Trace::knetwk (
    const std::string & input ) [noexcept]
01553     {
01554     strings[sac_map.at(name::knetwk)] = input;
01555     }

```

**11.3.3.89 ko() [1/2]**

```
std::string sacfmt::Trace::ko ( ) const [noexcept]
01125 { return strings[sac_map.at(name::ko)]; }
```

Here is the caller graph for this function:

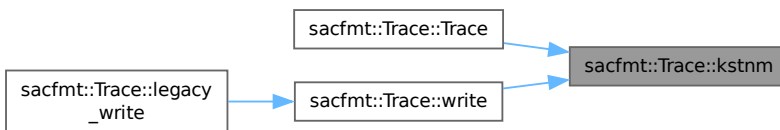
**11.3.3.90 ko() [2/2]**

```
void sacfmt::Trace::ko (
    const std::string & input ) [noexcept]
01502 {
01503     strings[sac_map.at(name::ko)] = input;
01504 }
```

**11.3.3.91 kstnm() [1/2]**

```
std::string sacfmt::Trace::kstnm ( ) const [noexcept]
01116 {
01117     return strings[sac_map.at(name::kstnm)];
01118 }
```

Here is the caller graph for this function:

**11.3.3.92 kstnm() [2/2]**

```
void sacfmt::Trace::kstnm (
    const std::string & input ) [noexcept]
01493 {
01494     strings[sac_map.at(name::kstnm)] = input;
01495 }
```

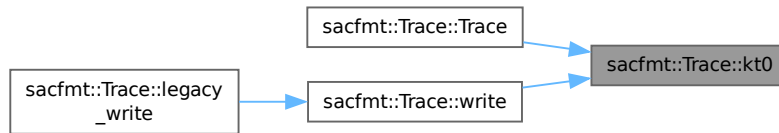
**11.3.3.93 kt0()** [1/2]

```

std::string sacfmt::Trace::kt0 ( ) const [noexcept]
01127     {
01128     return strings[sac_map.at(name::kt0)];
01129     }

```

Here is the caller graph for this function:

**11.3.3.94 kt0()** [2/2]

```

void sacfmt::Trace::kt0 (
    const std::string & input ) [noexcept]
01508     {
01509     strings[sac_map.at(name::kt0)] = input;
01510     }

```

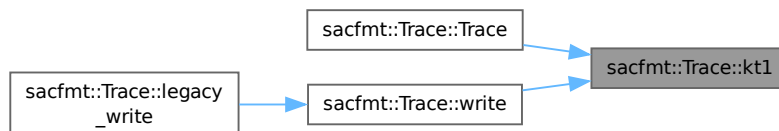
**11.3.3.95 kt1()** [1/2]

```

std::string sacfmt::Trace::kt1 ( ) const [noexcept]
01130     {
01131     return strings[sac_map.at(name::kt1)];
01132     }

```

Here is the caller graph for this function:

**11.3.3.96 kt1()** [2/2]

```

void sacfmt::Trace::kt1 (
    const std::string & input ) [noexcept]
01511     {
01512     strings[sac_map.at(name::kt1)] = input;
01513     }

```

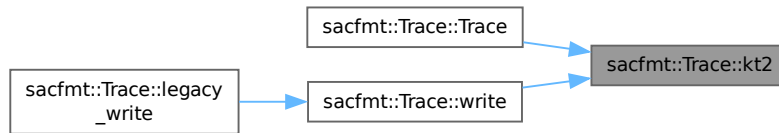
**11.3.3.97 kt2()** [1/2]

```

std::string sacfmt::Trace::kt2 ( ) const [noexcept]
01133     {
01134     return strings[sac_map.at(name::kt2)];
01135     }

```

Here is the caller graph for this function:

**11.3.3.98 kt2()** [2/2]

```

void sacfmt::Trace::kt2 (
    const std::string & input ) [noexcept]
01514     {
01515     strings[sac_map.at(name::kt2)] = input;
01516     }

```

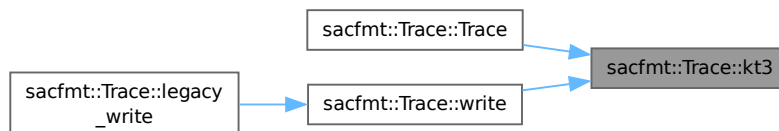
**11.3.3.99 kt3()** [1/2]

```

std::string sacfmt::Trace::kt3 ( ) const [noexcept]
01136     {
01137     return strings[sac_map.at(name::kt3)];
01138     }

```

Here is the caller graph for this function:

**11.3.3.100 kt3()** [2/2]

```

void sacfmt::Trace::kt3 (
    const std::string & input ) [noexcept]
01517     {
01518     strings[sac_map.at(name::kt3)] = input;
01519     }

```

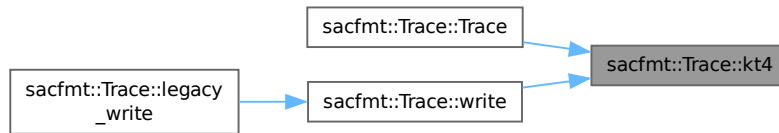
**11.3.3.101 kt4()** [1/2]

```

std::string sacfmt::Trace::kt4 ( ) const [noexcept]
01139     {
01140     return strings[sac_map.at(name::kt4)];
01141     }

```

Here is the caller graph for this function:

**11.3.3.102 kt4()** [2/2]

```

void sacfmt::Trace::kt4 (
    const std::string & input ) [noexcept]
01520     {
01521     strings[sac_map.at(name::kt4)] = input;
01522     }

```

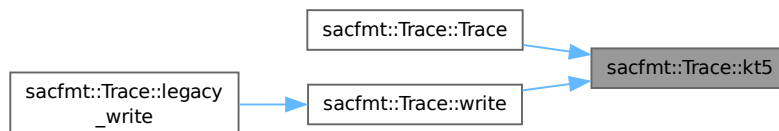
**11.3.3.103 kt5()** [1/2]

```

std::string sacfmt::Trace::kt5 ( ) const [noexcept]
01142     {
01143     return strings[sac_map.at(name::kt5)];
01144     }

```

Here is the caller graph for this function:

**11.3.3.104 kt5()** [2/2]

```

void sacfmt::Trace::kt5 (
    const std::string & input ) [noexcept]
01523     {
01524     strings[sac_map.at(name::kt5)] = input;
01525     }

```



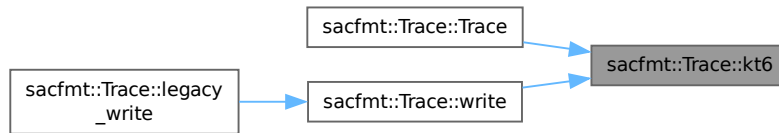
**11.3.3.105 kt6()** [1/2]

```

std::string sacfmt::Trace::kt6 ( ) const [noexcept]
01145     {
01146     return strings[sac_map.at(name::kt6)];
01147     }

```

Here is the caller graph for this function:

**11.3.3.106 kt6()** [2/2]

```

void sacfmt::Trace::kt6 (
    const std::string & input ) [noexcept]
01526     {
01527     strings[sac_map.at(name::kt6)] = input;
01528     }

```

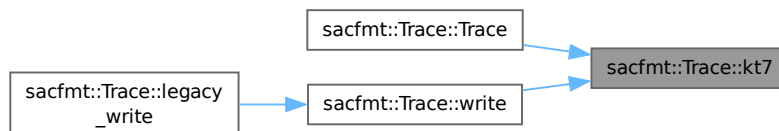
**11.3.3.107 kt7()** [1/2]

```

std::string sacfmt::Trace::kt7 ( ) const [noexcept]
01148     {
01149     return strings[sac_map.at(name::kt7)];
01150     }

```

Here is the caller graph for this function:

**11.3.3.108 kt7()** [2/2]

```

void sacfmt::Trace::kt7 (
    const std::string & input ) [noexcept]
01529     {
01530     strings[sac_map.at(name::kt7)] = input;
01531     }

```

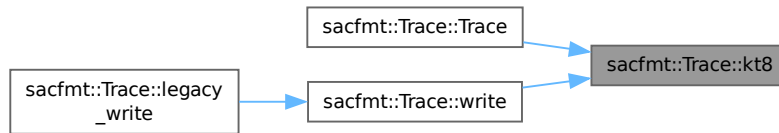
**11.3.3.109 kt8()** [1/2]

```

std::string sacfmt::Trace::kt8 ( ) const [noexcept]
01151     {
01152     return strings[sac_map.at(name::kt8)];
01153     }

```

Here is the caller graph for this function:

**11.3.3.110 kt8()** [2/2]

```

void sacfmt::Trace::kt8 (
    const std::string & input ) [noexcept]
01532     {
01533     strings[sac_map.at(name::kt8)] = input;
01534     }

```

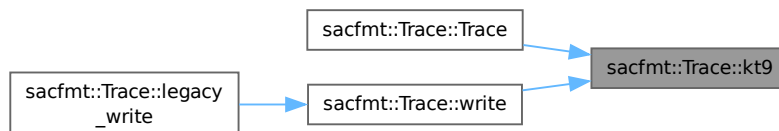
**11.3.3.111 kt9()** [1/2]

```

std::string sacfmt::Trace::kt9 ( ) const [noexcept]
01154     {
01155     return strings[sac_map.at(name::kt9)];
01156     }

```

Here is the caller graph for this function:

**11.3.3.112 kt9()** [2/2]

```

void sacfmt::Trace::kt9 (
    const std::string & input ) [noexcept]
01535     {
01536     strings[sac_map.at(name::kt9)] = input;
01537     }

```

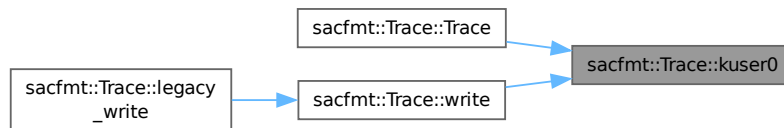
**11.3.3.113 kuser0() [1/2]**

```

std::string sacfmt::Trace::kuser0 ( ) const [noexcept]
01158     {
01159     return strings[sac_map.at(name::kuser0)];
01160     }

```

Here is the caller graph for this function:

**11.3.3.114 kuser0() [2/2]**

```

void sacfmt::Trace::kuser0 (
    const std::string & input ) [noexcept]
01541     {
01542     strings[sac_map.at(name::kuser0)] = input;
01543     }

```

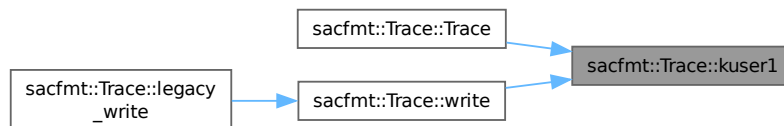
**11.3.3.115 kuser1() [1/2]**

```

std::string sacfmt::Trace::kuser1 ( ) const [noexcept]
01161     {
01162     return strings[sac_map.at(name::kuser1)];
01163     }

```

Here is the caller graph for this function:

**11.3.3.116 kuser1() [2/2]**

```

void sacfmt::Trace::kuser1 (
    const std::string & input ) [noexcept]
01544     {
01545     strings[sac_map.at(name::kuser1)] = input;
01546     }

```

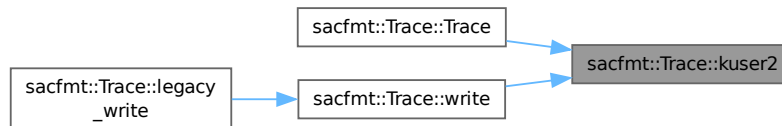
**11.3.3.117 kuser2() [1/2]**

```

std::string sacfmt::Trace::kuser2 ( ) const [noexcept]
01164 {
01165     return strings[sac_map.at(name::kuser2)];
01166 }

```

Here is the caller graph for this function:

**11.3.3.118 kuser2() [2/2]**

```

void sacfmt::Trace::kuser2 (
    const std::string & input ) [noexcept]
01547 {
01548     strings[sac_map.at(name::kuser2)] = input;
01549 }

```

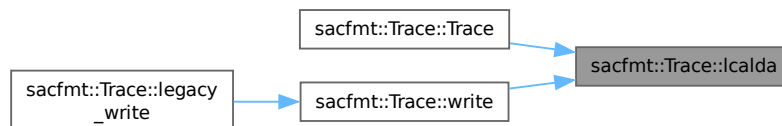
**11.3.3.119 lcalda() [1/2]**

```

bool sacfmt::Trace::lcalda ( ) const [noexcept]
01114 { return bools[sac_map.at(name::lcalda)]; }

```

Here is the caller graph for this function:

**11.3.3.120 lcalda() [2/2]**

```

void sacfmt::Trace::lcalda (
    bool input ) [noexcept]
01489 {
01490     bools[sac_map.at(name::lcalda)] = input;
01491 }

```

**11.3.3.121 legacy\_write()**

```

void sacfmt::Trace::legacy_write (
    const std::filesystem::path & path ) const

```

Binary SAC-file legacy-write convenience function.

## Parameters

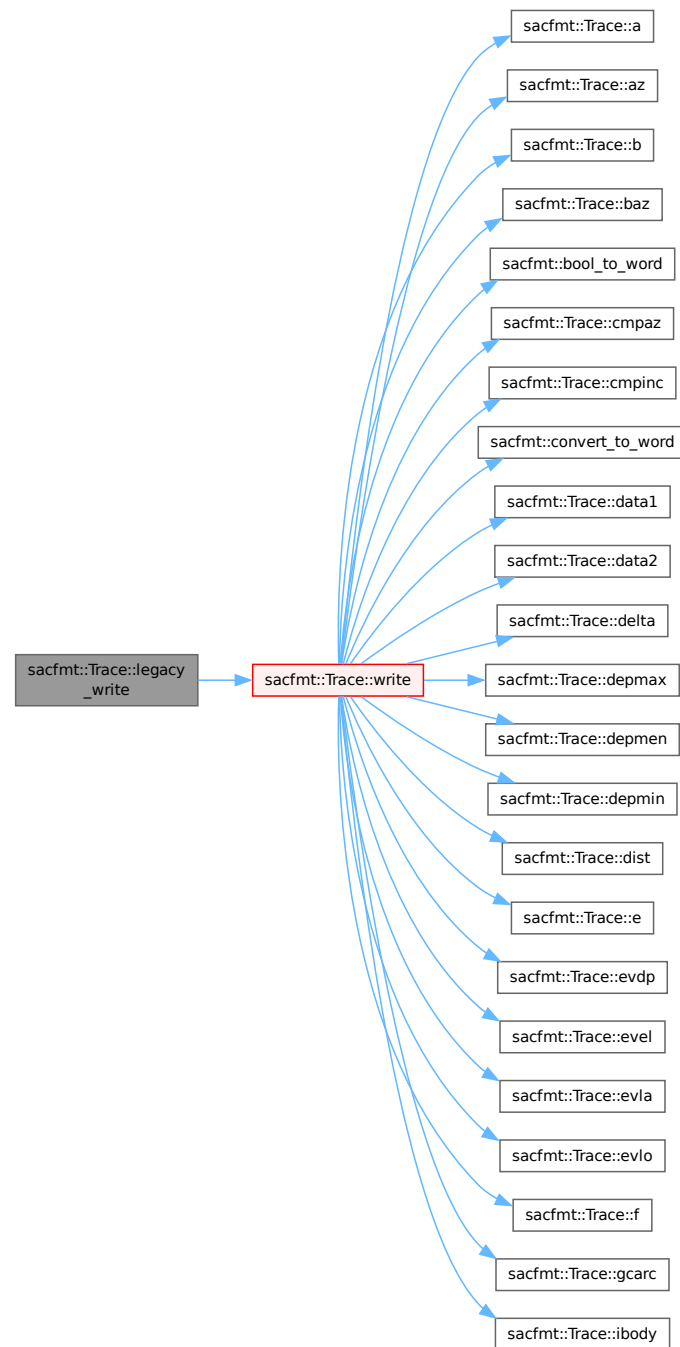
<code>in</code>	<code>path</code>	std::filesystem::path SAC-file to be written.
-----------------	-------------------	---

## Exceptions

<code>io_error</code>	If the file cannot be written (bad path or bad permissions).
<code>std::exception</code>	Other unwritable issues (not enough space, disk failure, etc.).

```
02187                                     {
02188     write(path, true);
02189 }
```

Here is the call graph for this function:



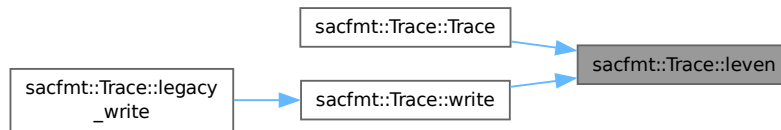
### 11.3.3.122 leven() [1/2]

```

bool sacfmt::Trace::leven ( ) const [noexcept]
01111 { return bools[sac_map.at(name::leven)]; }

```

Here is the caller graph for this function:



### 11.3.3.123 `leven()` [2/2]

```

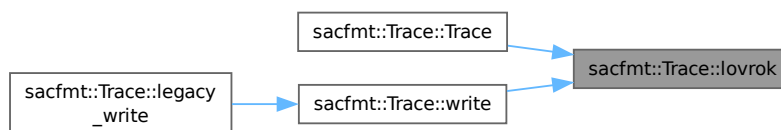
void sacfmt::Trace::leven (
    bool input ) [noexcept]
{
01474     bools[sac_map.at(name::leven)] = input;
01475     const size_t size{npts() >= 0 ? static_cast<size_t>(npts()) : 0};
01476     // Uneven 2D data not supported since not in specification
01477     if (!input && (iftype() > 1)) {
01478         iftype(unset_int);
01479     }
01480     resize_data2(size);
01481 }
01482 }
  
```

### 11.3.3.124 `lovrok()` [1/2]

```

bool sacfmt::Trace::lovrok ( ) const [noexcept]
01113 { return bools[sac_map.at(name::lovrok)]; }
  
```

Here is the caller graph for this function:



### 11.3.3.125 `lovrok()` [2/2]

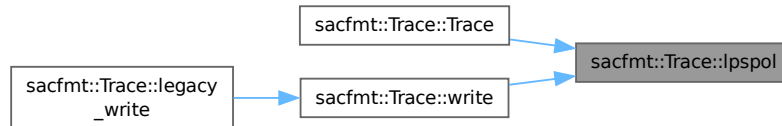
```

void sacfmt::Trace::lovrok (
    bool input ) [noexcept]
{
01486     bools[sac_map.at(name::lovrok)] = input;
01487 }
01488 }
  
```

**11.3.3.126 lpspol()** [1/2]

```
bool sacfmt::Trace::lpspol ( ) const [noexcept]
01112 { return bools[sac_map.at(name::lpspol)]; }
```

Here is the caller graph for this function:

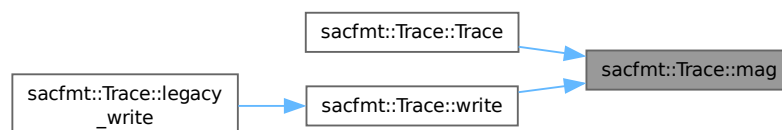
**11.3.3.127 lpspol()** [2/2]

```
void sacfmt::Trace::lpspol (
    bool input ) [noexcept]
01483 {
01484     bools[sac_map.at(name::lpspol)] = input;
01485 }
```

**11.3.3.128 mag()** [1/2]

```
float sacfmt::Trace::mag ( ) const [noexcept]
01022 { return floats[sac_map.at(name::mag)]; }
```

Here is the caller graph for this function:

**11.3.3.129 mag()** [2/2]

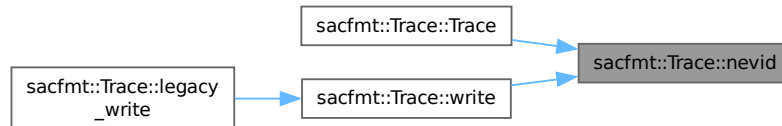
```
void sacfmt::Trace::mag (
    float input ) [noexcept]
01239 {
01240     floats[sac_map.at(name::mag)] = input;
01241 }
```



**11.3.3.130 nevid()** [1/2]

```
int sacfmt::Trace::nevid ( ) const [noexcept]
01092 { return ints[sac_map.at(name::nevid)]; }
```

Here is the caller graph for this function:

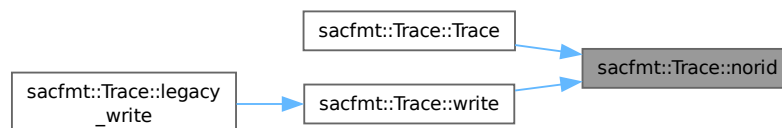
**11.3.3.131 nevid()** [2/2]

```
void sacfmt::Trace::nevid (
    int input ) [noexcept]
01409 {
01410     ints[sac_map.at(name::nevid)] = input;
01411 }
```

**11.3.3.132 norid()** [1/2]

```
int sacfmt::Trace::norid ( ) const [noexcept]
01091 { return ints[sac_map.at(name::norid)]; }
```

Here is the caller graph for this function:

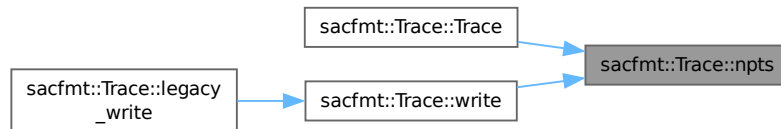
**11.3.3.133 norid()** [2/2]

```
void sacfmt::Trace::norid (
    int input ) [noexcept]
01406 {
01407     ints[sac_map.at(name::norid)] = input;
01408 }
```

**11.3.3.134 npts() [1/2]**

```
int sacfmt::Trace::npts ( ) const [noexcept]
01093 { return ints[sac_map.at(name::npts)]; }
```

Here is the caller graph for this function:

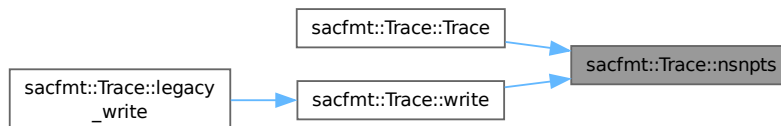
**11.3.3.135 npts() [2/2]**

```
void sacfmt::Trace::npts (
    int input ) [noexcept]
01412 {
01413     if ((input >= 0) || (input == unset_int)) {
01414         ints[sac_map.at(name::npts)] = input;
01415         const size_t size(static_cast<size_t>(input >= 0 ? input : 0));
01416         resize_data(size);
01417     }
01418 }
```

**11.3.3.136 nsnpts() [1/2]**

```
int sacfmt::Trace::nsnpts ( ) const [noexcept]
01094 { return ints[sac_map.at(name::nsnpts)]; }
```

Here is the caller graph for this function:

**11.3.3.137 nsnpts() [2/2]**

```
void sacfmt::Trace::nsnpts (
    int input ) [noexcept]
01419 {
01420     ints[sac_map.at(name::nsnpts)] = input;
01421 }
```

**11.3.3.138 nvhdr()** [1/2]

```
int sacfmt::Trace::nvhdr ( ) const [noexcept]
01090 { return ints[sac_map.at(name::nvhdr)]; }
```

Here is the caller graph for this function:

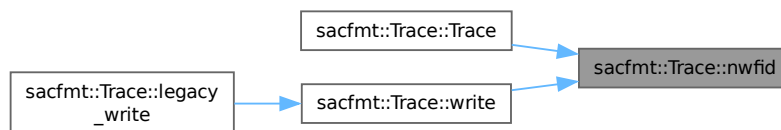
**11.3.3.139 nvhdr()** [2/2]

```
void sacfmt::Trace::nvhdr (
    int input ) [noexcept]
01403 {
01404     ints[sac_map.at(name::nvhdr)] = input;
01405 }
```

**11.3.3.140 nwfid()** [1/2]

```
int sacfmt::Trace::nwfid ( ) const [noexcept]
01095 { return ints[sac_map.at(name::nwfid)]; }
```

Here is the caller graph for this function:

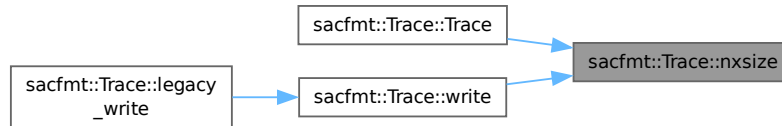
**11.3.3.141 nwfid()** [2/2]

```
void sacfmt::Trace::nwfid (
    int input ) [noexcept]
01422 {
01423     ints[sac_map.at(name::nwfid)] = input;
01424 }
```

**11.3.3.142 nxsize()** [1/2]

```
int sacfmt::Trace::nxsize ( ) const [noexcept]
01096 { return ints[sac_map.at(name:nxsize)]; }
```

Here is the caller graph for this function:

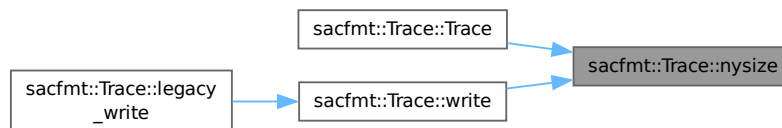
**11.3.3.143 nxsize()** [2/2]

```
void sacfmt::Trace::nxsize (
    int input ) [noexcept]
01425 {
01426     ints[sac_map.at(name:nxsize)] = input;
01427 }
```

**11.3.3.144 nysize()** [1/2]

```
int sacfmt::Trace::nysize ( ) const [noexcept]
01097 { return ints[sac_map.at(name:nysize)]; }
```

Here is the caller graph for this function:

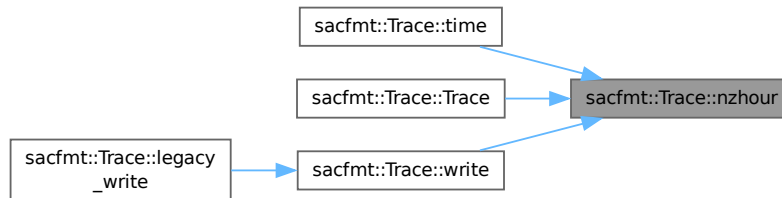
**11.3.3.145 nysize()** [2/2]

```
void sacfmt::Trace::nysize (
    int input ) [noexcept]
01428 {
01429     ints[sac_map.at(name:nysize)] = input;
01430 }
```

**11.3.3.146 nzhour()** [1/2]

```
int sacfmt::Trace::nzhour ( ) const [noexcept]
01086 { return ints[sac_map.at(name:nzhour)]; }
```

Here is the caller graph for this function:

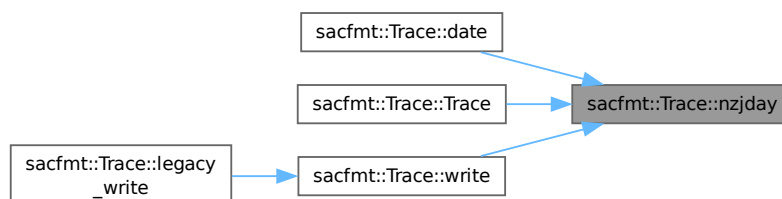
**11.3.3.147 nzhour()** [2/2]

```
void sacfmt::Trace::nzhour (
    int input ) [noexcept]
01391 {
01392     ints[sac_map.at(name:nzhour)] = input;
01393 }
```

**11.3.3.148 nzjday()** [1/2]

```
int sacfmt::Trace::nzjday ( ) const [noexcept]
01085 { return ints[sac_map.at(name:nzjday)]; }
```

Here is the caller graph for this function:

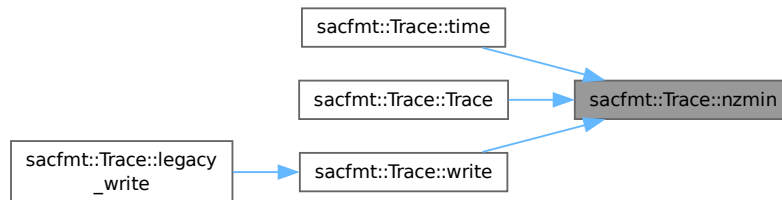
**11.3.3.149 nzjday()** [2/2]

```
void sacfmt::Trace::nzjday (
    int input ) [noexcept]
01388 {
01389     ints[sac_map.at(name:nzjday)] = input;
01390 }
```

**11.3.3.150 nzmin()** [1/2]

```
int sacfmt::Trace::nzmin ( ) const [noexcept]
01087 { return ints[sac_map.at(name:nzmin)]; }
```

Here is the caller graph for this function:

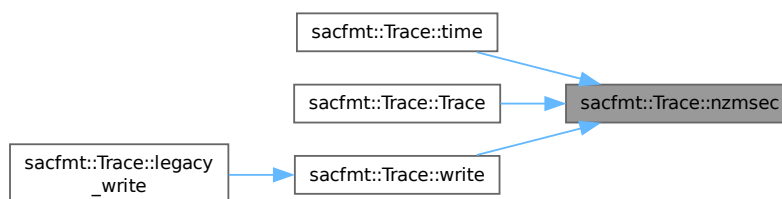
**11.3.3.151 nzmin()** [2/2]

```
void sacfmt::Trace::nzmin (
    int input ) [noexcept]
01394 {
01395     ints[sac_map.at(name:nzmin)] = input;
01396 }
```

**11.3.3.152 nzmsec()** [1/2]

```
int sacfmt::Trace::nzmsec ( ) const [noexcept]
01089 { return ints[sac_map.at(name:nzmsec)]; }
```

Here is the caller graph for this function:

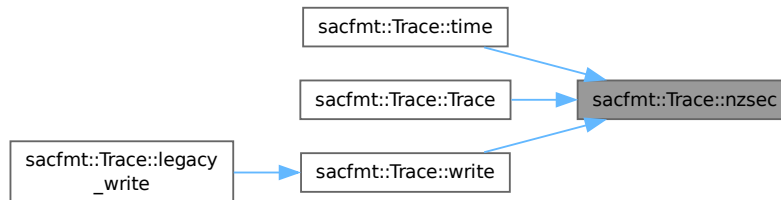
**11.3.3.153 nzmsec()** [2/2]

```
void sacfmt::Trace::nzmsec (
    int input ) [noexcept]
01400 {
01401     ints[sac_map.at(name:nzmsec)] = input;
01402 }
```

**11.3.3.154 nzsec()** [1/2]

```
int sacfmt::Trace::nzsec ( ) const [noexcept]
01088 { return ints[sac_map.at(name:nzsec)]; }
```

Here is the caller graph for this function:

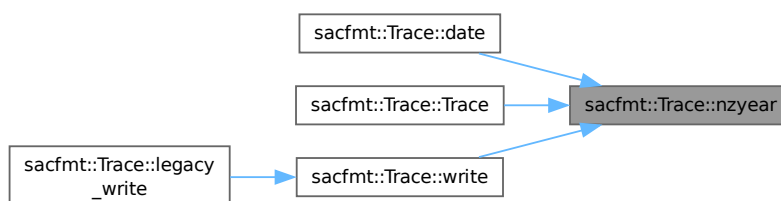
**11.3.3.155 nzsec()** [2/2]

```
void sacfmt::Trace::nzsec (
    int input ) [noexcept]
01397 {
01398     ints[sac_map.at(name:nzsec)] = input;
01399 }
```

**11.3.3.156 nzyear()** [1/2]

```
int sacfmt::Trace::nzyear ( ) const [noexcept]
01084 { return ints[sac_map.at(name:nzyear)]; }
```

Here is the caller graph for this function:

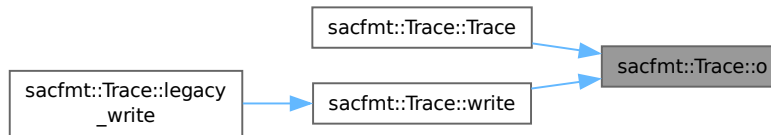
**11.3.3.157 nzyear()** [2/2]

```
void sacfmt::Trace::nzyear (
    int input ) [noexcept]
01385 {
01386     ints[sac_map.at(name:nzyear)] = input;
01387 }
```

**11.3.3.158 o() [1/2]**

```
double sacfmt::Trace::o ( ) const [noexcept]
01062 { return doubles[sac_map.at(name::o)]; }
```

Here is the caller graph for this function:

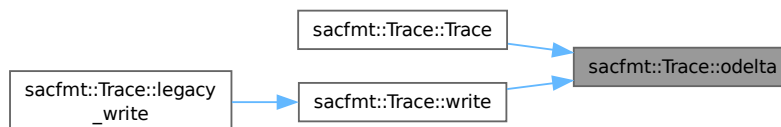
**11.3.3.159 o() [2/2]**

```
void sacfmt::Trace::o (
    double input ) [noexcept]
01315 {
01316     doubles[sac_map.at(name::o)] = input;
01317 }
```

**11.3.3.160 odelta() [1/2]**

```
float sacfmt::Trace::odelta ( ) const [noexcept]
01005 {
01006     return floats[sac_map.at(name::odelta)];
01007 }
```

Here is the caller graph for this function:

**11.3.3.161 odelta() [2/2]**

```
void sacfmt::Trace::odelta (
    float input ) [noexcept]
01194 {
01195     floats[sac_map.at(name::odelta)] = input;
01196 }
```

**11.3.3.162 operator==( )**

```
bool sacfmt::Trace::operator== (
    const Trace & other ) const [noexcept]
```

`Trace` equality operator.



## Parameters

in	<i>this</i>	First <a href="#">Trace</a> in comparison (LHS).
in	<i>other</i>	Second <a href="#">Trace</a> in comparison (RHS).

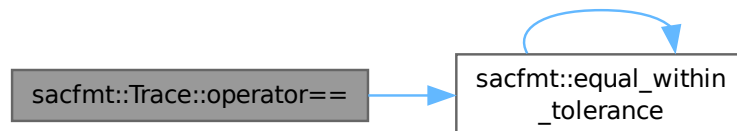
## Returns

bool Truth value of equality.

```

00848                                     {
00849     if (floats != other.floats) {
00850         return false;
00851     }
00852     if (doubles != other.doubles) {
00853         return false;
00854     }
00855     if (ints != other.ints) {
00856         return false;
00857     }
00858     if (strings != other.strings) {
00859         return false;
00860     }
00861     if (!equal_within_tolerance(data[0], other.data[0])) {
00862         return false;
00863     }
00864     if (!equal_within_tolerance(data[1], other.data[1])) {
00865         return false;
00866     }
00867     return true;
00868 }
```

Here is the call graph for this function:

11.3.3.163 `resize_data()`

```

void sacfmt::Trace::resize_data (
    size_t size ) [private], [noexcept]
```

Resize data vectors (only if eligible).

Will always resize data1, data2 only resizes if it can have non-zero size.

```

01622                                     {
01623     resize_data1(size);
01624     resize_data2(size);
01625 }
```

**11.3.3.164** `resize_data1()`

```

void sacfmt::Trace::resize_data1 (
    size_t size ) [private], [noexcept]
01593     {
01594     if (size != data1().size()) {
01595         std::vector<double> new_data1{data1()};
01596         new_data1.resize(size, 0.0);
01597         data1(new_data1);
01598     }
01599 }

```

**11.3.3.165** `resize_data2()`

```

void sacfmt::Trace::resize_data2 (
    size_t size ) [private], [noexcept]
01601     {
01602     // Data2 is legal
01603     if (!leven() || (iftype() > 1)) {
01604         if (size != data2().size()) {
01605             std::vector<double> new_data2{data2()};
01606             new_data2.resize(size, 0.0);
01607             data2(new_data2);
01608         }
01609     } else {
01610         if (!data2().empty()) {
01611             std::vector<double> new_data2{};
01612             data2(new_data2);
01613         }
01614     }
01615 }

```

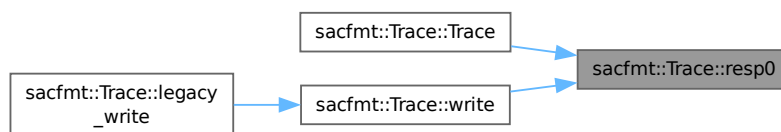
**11.3.3.166** `resp0()` [1/2]

```

float sacfmt::Trace::resp0 ( ) const [noexcept]
01008 { return floats[sac_map.at(name::resp0)]; }

```

Here is the caller graph for this function:

**11.3.3.167** `resp0()` [2/2]

```

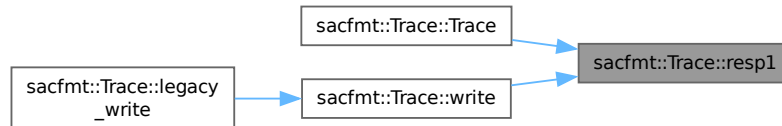
void sacfmt::Trace::resp0 (
    float input ) [noexcept]
01197     {
01198     floats[sac_map.at(name::resp0)] = input;
01199 }

```

**11.3.3.168 resp1()** [1/2]

```
float sacfmt::Trace::resp1 ( ) const [noexcept]
01009 { return floats[sac_map.at(name::resp1)]; }
```

Here is the caller graph for this function:

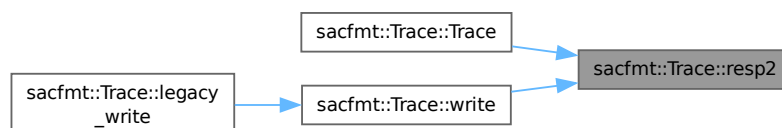
**11.3.3.169 resp1()** [2/2]

```
void sacfmt::Trace::resp1 (
    float input ) [noexcept]
01200 {
01201     floats[sac_map.at(name::resp1)] = input;
01202 }
```

**11.3.3.170 resp2()** [1/2]

```
float sacfmt::Trace::resp2 ( ) const [noexcept]
01010 { return floats[sac_map.at(name::resp2)]; }
```

Here is the caller graph for this function:

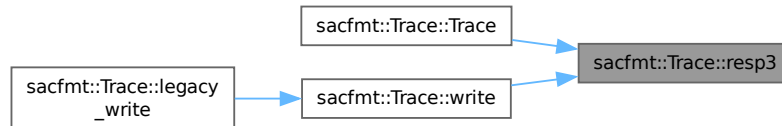
**11.3.3.171 resp2()** [2/2]

```
void sacfmt::Trace::resp2 (
    float input ) [noexcept]
01203 {
01204     floats[sac_map.at(name::resp2)] = input;
01205 }
```

**11.3.3.172 resp3()** [1/2]

```
float sacfmt::Trace::resp3 ( ) const [noexcept]
01011 { return floats[sac_map.at(name::resp3)]; }
```

Here is the caller graph for this function:

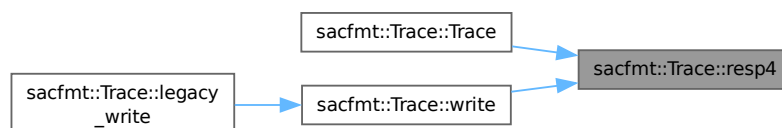
**11.3.3.173 resp3()** [2/2]

```
void sacfmt::Trace::resp3 (
    float input ) [noexcept]
01206     {
01207     floats[sac_map.at(name::resp3)] = input;
01208 }
```

**11.3.3.174 resp4()** [1/2]

```
float sacfmt::Trace::resp4 ( ) const [noexcept]
01012 { return floats[sac_map.at(name::resp4)]; }
```

Here is the caller graph for this function:

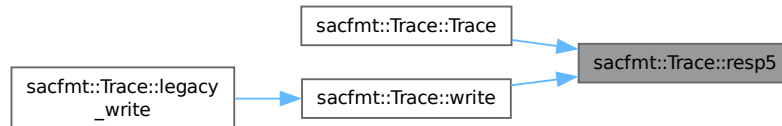
**11.3.3.175 resp4()** [2/2]

```
void sacfmt::Trace::resp4 (
    float input ) [noexcept]
01209     {
01210     floats[sac_map.at(name::resp4)] = input;
01211 }
```

**11.3.3.176 resp5()** [1/2]

```
float sacfmt::Trace::resp5 ( ) const [noexcept]
01013 { return floats[sac_map.at(name::resp5)]; }
```

Here is the caller graph for this function:

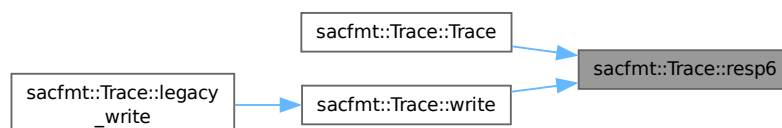
**11.3.3.177 resp5()** [2/2]

```
void sacfmt::Trace::resp5 (
    float input ) [noexcept]
01212 {
01213     floats[sac_map.at(name::resp5)] = input;
01214 }
```

**11.3.3.178 resp6()** [1/2]

```
float sacfmt::Trace::resp6 ( ) const [noexcept]
01014 { return floats[sac_map.at(name::resp6)]; }
```

Here is the caller graph for this function:

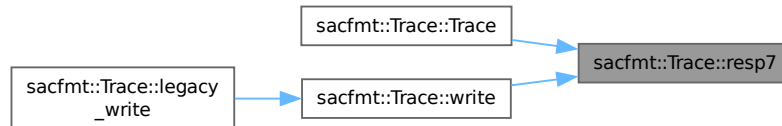
**11.3.3.179 resp6()** [2/2]

```
void sacfmt::Trace::resp6 (
    float input ) [noexcept]
01215 {
01216     floats[sac_map.at(name::resp6)] = input;
01217 }
```

**11.3.3.180 resp7()** [1/2]

```
float sacfmt::Trace::resp7 ( ) const [noexcept]
01015 { return floats[sac_map.at(name::resp7)]; }
```

Here is the caller graph for this function:

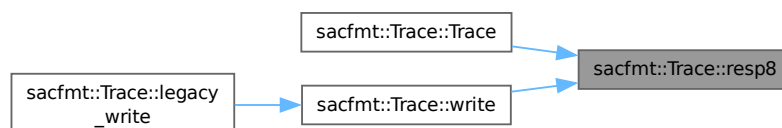
**11.3.3.181 resp7()** [2/2]

```
void sacfmt::Trace::resp7 (
    float input ) [noexcept]
01218 {
01219     floats[sac_map.at(name::resp7)] = input;
01220 }
```

**11.3.3.182 resp8()** [1/2]

```
float sacfmt::Trace::resp8 ( ) const [noexcept]
01016 { return floats[sac_map.at(name::resp8)]; }
```

Here is the caller graph for this function:

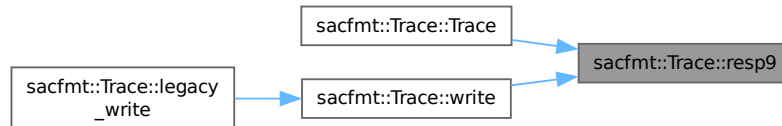
**11.3.3.183 resp8()** [2/2]

```
void sacfmt::Trace::resp8 (
    float input ) [noexcept]
01221 {
01222     floats[sac_map.at(name::resp8)] = input;
01223 }
```

**11.3.3.184 resp9()** [1/2]

```
float sacfmt::Trace::resp9 ( ) const [noexcept]
01017 { return floats[sac_map.at(name::resp9)]; }
```

Here is the caller graph for this function:

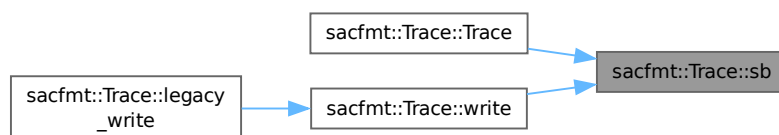
**11.3.3.185 resp9()** [2/2]

```
void sacfmt::Trace::resp9 (
    float input ) [noexcept]
01224 {
01225     floats[sac_map.at(name::resp9)] = input;
01226 }
```

**11.3.3.186 sb()** [1/2]

```
double sacfmt::Trace::sb ( ) const [noexcept]
01079 { return doubles[sac_map.at(name::sb)]; }
```

Here is the caller graph for this function:

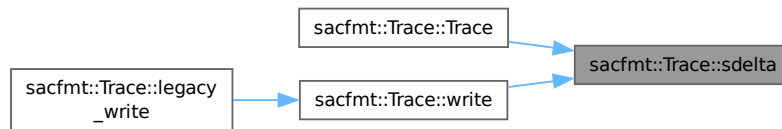
**11.3.3.187 sb()** [2/2]

```
void sacfmt::Trace::sb (
    double input ) [noexcept]
01378 {
01379     doubles[sac_map.at(name::sb)] = input;
01380 }
```

**11.3.3.188 sdelta()** [1/2]

```
double sacfmt::Trace::sdelta ( ) const [noexcept]
01080     {
01081     return doubles[sac_map.at(name::sdelta)];
01082     }
```

Here is the caller graph for this function:

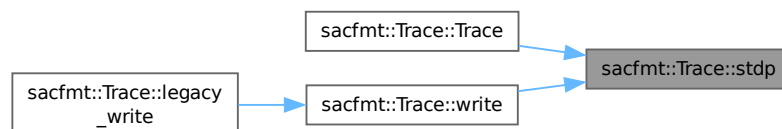
**11.3.3.189 sdelta()** [2/2]

```
void sacfmt::Trace::sdelta (
    double input ) [noexcept]
01381     {
01382     doubles[sac_map.at(name::sdelta)] = input;
01383     }
```

**11.3.3.190 stdp()** [1/2]

```
float sacfmt::Trace::stdp ( ) const [noexcept]
01019 { return floats[sac_map.at(name::stdp)]; }
```

Here is the caller graph for this function:

**11.3.3.191 stdp()** [2/2]

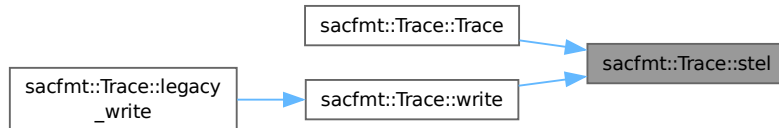
```
void sacfmt::Trace::stdp (
    float input ) [noexcept]
01230     {
01231     floats[sac_map.at(name::stdp)] = input;
01232     }
```



**11.3.3.192 stel()** [1/2]

```
float sacfmt::Trace::stel ( ) const [noexcept]
01018 { return floats[sac_map.at(name::stel)]; }
```

Here is the caller graph for this function:

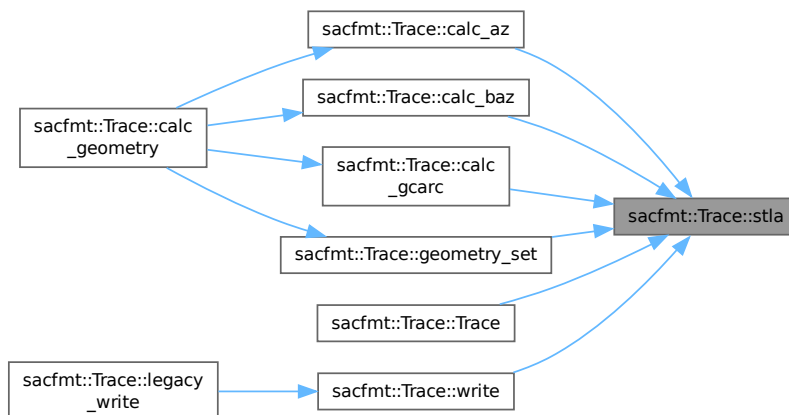
**11.3.3.193 stel()** [2/2]

```
void sacfmt::Trace::stel (
    float input ) [noexcept]
01227 {
01228     floats[sac_map.at(name::stel)] = input;
01229 }
```

**11.3.3.194 stla()** [1/2]

```
double sacfmt::Trace::stla ( ) const [noexcept]
01075 { return doubles[sac_map.at(name::stla)]; }
```

Here is the caller graph for this function:



**11.3.3.195 stla()** [2/2]

```

void sacfmt::Trace::stla (
    double input ) [noexcept]
01354     {
01355     if (input != unset_double) {
01356         input = limit_90(input);
01357     }
01358     doubles[sac_map.at(name::stla)] = input;
01359 }

```

Here is the call graph for this function:

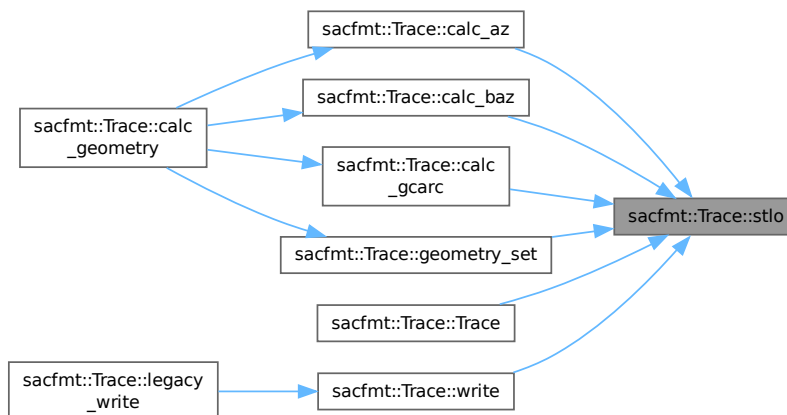
**11.3.3.196 stlo()** [1/2]

```

double sacfmt::Trace::stlo ( ) const [noexcept]
01076 { return doubles[sac_map.at(name::stlo)]; }

```

Here is the caller graph for this function:

**11.3.3.197 stlo()** [2/2]

```

void sacfmt::Trace::stlo (
    double input ) [noexcept]
01360     {
01361     if (input != unset_double) {
01362         input = limit_180(input);
01363     }
01364     doubles[sac_map.at(name::stlo)] = input;
01365 }

```

Here is the call graph for this function:

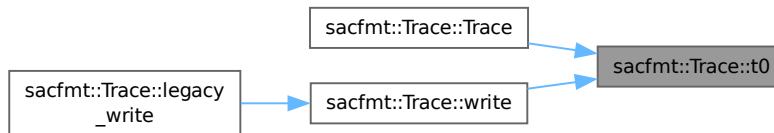


#### 11.3.3.198 t0() [1/2]

```

double sacfmt::Trace::t0 ( ) const [noexcept]
01064 { return doubles[sac_map.at(name::t0)]; }
  
```

Here is the caller graph for this function:



#### 11.3.3.199 t0() [2/2]

```

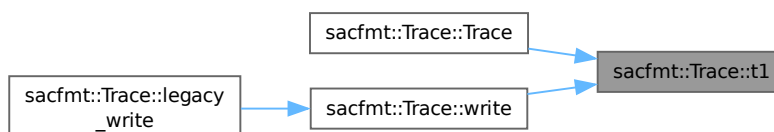
void sacfmt::Trace::t0 (
    double input ) [noexcept]
01321 {
01322     doubles[sac_map.at(name::t0)] = input;
01323 }
  
```

#### 11.3.3.200 t1() [1/2]

```

double sacfmt::Trace::t1 ( ) const [noexcept]
01065 { return doubles[sac_map.at(name::t1)]; }
  
```

Here is the caller graph for this function:



**11.3.3.201 t1()** [2/2]

```

void sacfmt::Trace::t1 (
    double input ) [noexcept]
01324     {
01325     doubles[sac_map.at(name::t1)] = input;
01326     }

```

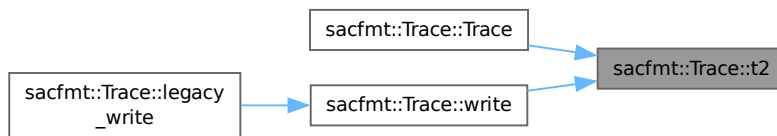
**11.3.3.202 t2()** [1/2]

```

double sacfmt::Trace::t2 ( ) const [noexcept]
01066 { return doubles[sac_map.at(name::t2)]; }

```

Here is the caller graph for this function:

**11.3.3.203 t2()** [2/2]

```

void sacfmt::Trace::t2 (
    double input ) [noexcept]
01327     {
01328     doubles[sac_map.at(name::t2)] = input;
01329     }

```

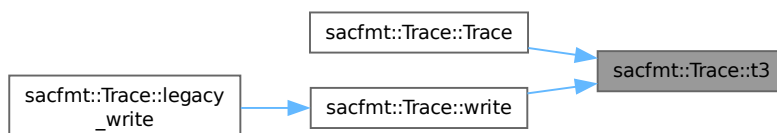
**11.3.3.204 t3()** [1/2]

```

double sacfmt::Trace::t3 ( ) const [noexcept]
01067 { return doubles[sac_map.at(name::t3)]; }

```

Here is the caller graph for this function:



**11.3.3.205 t3()** [2/2]

```

void sacfmt::Trace::t3 (
    double input ) [noexcept]
01330 {
01331     doubles[sac_map.at(name::t3)] = input;
01332 }

```

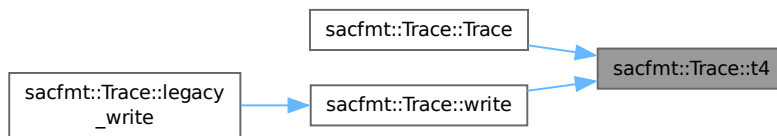
**11.3.3.206 t4()** [1/2]

```

double sacfmt::Trace::t4 ( ) const [noexcept]
01068 { return doubles[sac_map.at(name::t4)]; }

```

Here is the caller graph for this function:

**11.3.3.207 t4()** [2/2]

```

void sacfmt::Trace::t4 (
    double input ) [noexcept]
01333 {
01334     doubles[sac_map.at(name::t4)] = input;
01335 }

```

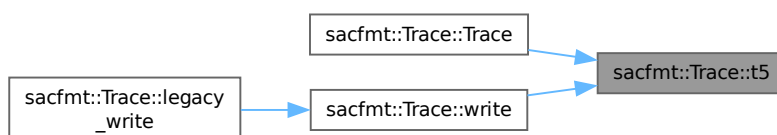
**11.3.3.208 t5()** [1/2]

```

double sacfmt::Trace::t5 ( ) const [noexcept]
01069 { return doubles[sac_map.at(name::t5)]; }

```

Here is the caller graph for this function:



**11.3.3.209 t5()** [2/2]

```

void sacfmt::Trace::t5 (
    double input ) [noexcept]
01336     {
01337     doubles[sac_map.at(name::t5)] = input;
01338     }

```

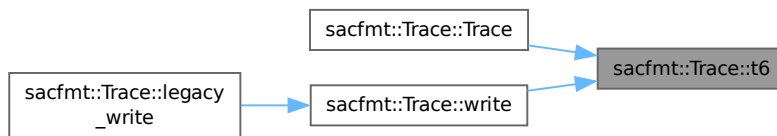
**11.3.3.210 t6()** [1/2]

```

double sacfmt::Trace::t6 ( ) const [noexcept]
01070 { return doubles[sac_map.at(name::t6)]; }

```

Here is the caller graph for this function:

**11.3.3.211 t6()** [2/2]

```

void sacfmt::Trace::t6 (
    double input ) [noexcept]
01339     {
01340     doubles[sac_map.at(name::t6)] = input;
01341     }

```

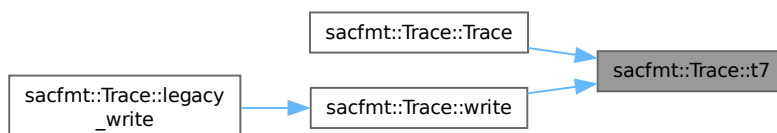
**11.3.3.212 t7()** [1/2]

```

double sacfmt::Trace::t7 ( ) const [noexcept]
01071 { return doubles[sac_map.at(name::t7)]; }

```

Here is the caller graph for this function:



**11.3.3.213 t7()** [2/2]

```

void sacfmt::Trace::t7 (
    double input ) [noexcept]
01342     {
01343     doubles[sac_map.at(name::t7)] = input;
01344     }

```

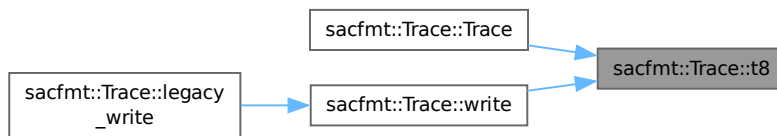
**11.3.3.214 t8()** [1/2]

```

double sacfmt::Trace::t8 ( ) const [noexcept]
01072 { return doubles[sac_map.at(name::t8)]; }

```

Here is the caller graph for this function:

**11.3.3.215 t8()** [2/2]

```

void sacfmt::Trace::t8 (
    double input ) [noexcept]
01345     {
01346     doubles[sac_map.at(name::t8)] = input;
01347     }

```

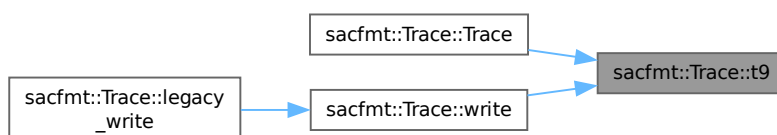
**11.3.3.216 t9()** [1/2]

```

double sacfmt::Trace::t9 ( ) const [noexcept]
01073 { return doubles[sac_map.at(name::t9)]; }

```

Here is the caller graph for this function:



**11.3.3.217 t9()** [2/2]

```

void sacfmt::Trace::t9 (
    double input ) [noexcept]
01348     {
01349     doubles[sac_map.at(name::t9)] = input;
01350 }

```

**11.3.3.218 time()**

```
std::string sacfmt::Trace::time ( ) const [noexcept]
```

Get time string.

**Returns**

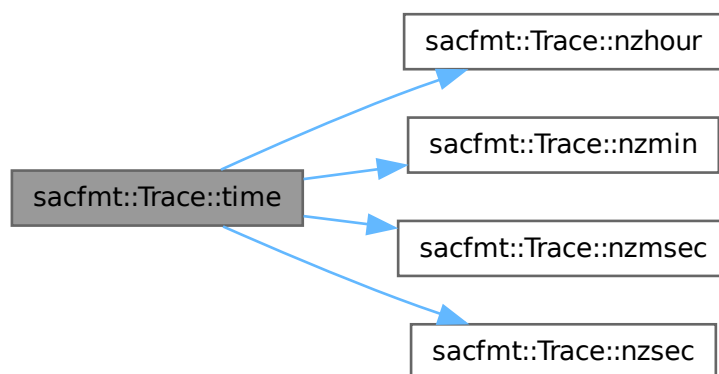
sstd::string Time (HH::MM:SS.sss).

```

00980     {
00981     // Require all to be set
00982     if ((nzhour() == unset_int) || (nzmin() == unset_int) ||
00983         (nzsec() == unset_int) || (nzmsec() == unset_int)) {
00984         return unset_word;
00985     }
00986     std::ostringstream oss{};
00987     oss << nzhour();
00988     oss << ':';
00989     oss << nzmin();
00990     oss << ':';
00991     oss << nzsec();
00992     oss << '.';
00993     oss << nzmsec();
00994     return oss.str();
00995 }

```

Here is the call graph for this function:

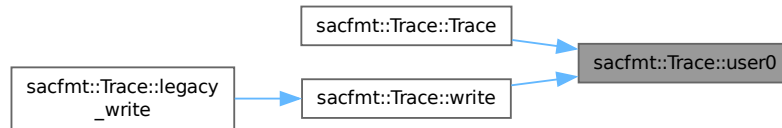




**11.3.3.219 user0() [1/2]**

```
float sacfmt::Trace::user0 ( ) const [noexcept]
01023 { return floats[sac_map.at(name::user0)]; }
```

Here is the caller graph for this function:

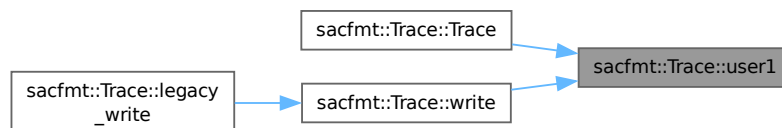
**11.3.3.220 user0() [2/2]**

```
void sacfmt::Trace::user0 (
    float input ) [noexcept]
01242 {
01243     floats[sac_map.at(name::user0)] = input;
01244 }
```

**11.3.3.221 user1() [1/2]**

```
float sacfmt::Trace::user1 ( ) const [noexcept]
01024 { return floats[sac_map.at(name::user1)]; }
```

Here is the caller graph for this function:

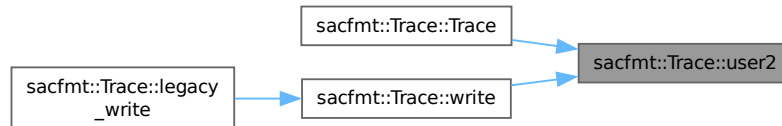
**11.3.3.222 user1() [2/2]**

```
void sacfmt::Trace::user1 (
    float input ) [noexcept]
01245 {
01246     floats[sac_map.at(name::user1)] = input;
01247 }
```

**11.3.3.223 user2()** [1/2]

```
float sacfmt::Trace::user2 ( ) const [noexcept]
01025 { return floats[sac_map.at(name::user2)]; }
```

Here is the caller graph for this function:

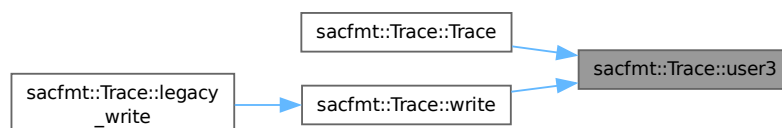
**11.3.3.224 user2()** [2/2]

```
void sacfmt::Trace::user2 (
    float input ) [noexcept]
01248 {
01249     floats[sac_map.at(name::user2)] = input;
01250 }
```

**11.3.3.225 user3()** [1/2]

```
float sacfmt::Trace::user3 ( ) const [noexcept]
01026 { return floats[sac_map.at(name::user3)]; }
```

Here is the caller graph for this function:

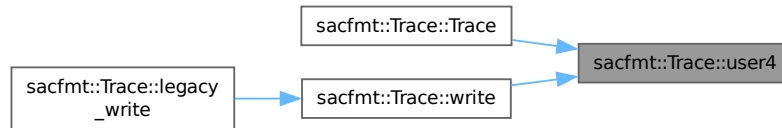
**11.3.3.226 user3()** [2/2]

```
void sacfmt::Trace::user3 (
    float input ) [noexcept]
01251 {
01252     floats[sac_map.at(name::user3)] = input;
01253 }
```

**11.3.3.227 user4() [1/2]**

```
float sacfmt::Trace::user4 ( ) const [noexcept]
01027 { return floats[sac_map.at(name::user4)]; }
```

Here is the caller graph for this function:

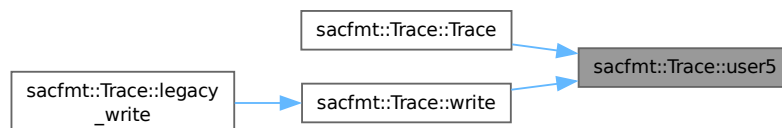
**11.3.3.228 user4() [2/2]**

```
void sacfmt::Trace::user4 (
    float input ) [noexcept]
01254 {
01255     floats[sac_map.at(name::user4)] = input;
01256 }
```

**11.3.3.229 user5() [1/2]**

```
float sacfmt::Trace::user5 ( ) const [noexcept]
01028 { return floats[sac_map.at(name::user5)]; }
```

Here is the caller graph for this function:

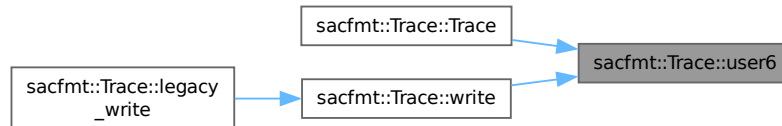
**11.3.3.230 user5() [2/2]**

```
void sacfmt::Trace::user5 (
    float input ) [noexcept]
01257 {
01258     floats[sac_map.at(name::user5)] = input;
01259 }
```

**11.3.3.231 user6()** [1/2]

```
float sacfmt::Trace::user6 ( ) const [noexcept]
01029 { return floats[sac_map.at(name::user6)]; }
```

Here is the caller graph for this function:

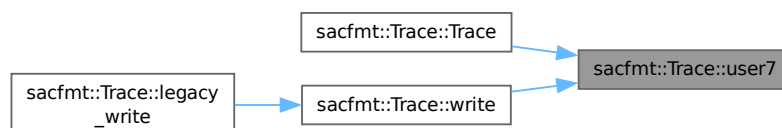
**11.3.3.232 user6()** [2/2]

```
void sacfmt::Trace::user6 (
    float input ) [noexcept]
01260 {
01261     floats[sac_map.at(name::user6)] = input;
01262 }
```

**11.3.3.233 user7()** [1/2]

```
float sacfmt::Trace::user7 ( ) const [noexcept]
01030 { return floats[sac_map.at(name::user7)]; }
```

Here is the caller graph for this function:

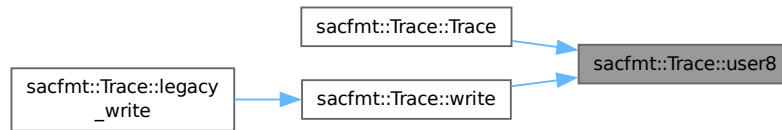
**11.3.3.234 user7()** [2/2]

```
void sacfmt::Trace::user7 (
    float input ) [noexcept]
01263 {
01264     floats[sac_map.at(name::user7)] = input;
01265 }
```

**11.3.3.235 user8() [1/2]**

```
float sacfmt::Trace::user8 ( ) const [noexcept]
01031 { return floats[sac_map.at(name::user8)]; }
```

Here is the caller graph for this function:

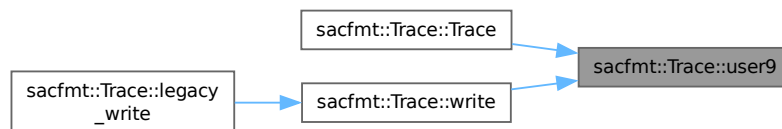
**11.3.3.236 user8() [2/2]**

```
void sacfmt::Trace::user8 (
    float input ) [noexcept]
01266 {
01267     floats[sac_map.at(name::user8)] = input;
01268 }
```

**11.3.3.237 user9() [1/2]**

```
float sacfmt::Trace::user9 ( ) const [noexcept]
01032 { return floats[sac_map.at(name::user9)]; }
```

Here is the caller graph for this function:

**11.3.3.238 user9() [2/2]**

```
void sacfmt::Trace::user9 (
    float input ) [noexcept]
01269 {
01270     floats[sac_map.at(name::user9)] = input;
01271 }
```

**11.3.3.239 write()**

```
void sacfmt::Trace::write (
    const std::filesystem::path & path,
    bool legacy = false ) const
```

Binary SAC-file writer.

## Parameters

in	<i>path</i>	std::filesystem::path SAC-file to write.
in	<i>legacy</i>	bool Legacy-write flag (default false = v7, true = v6).

## Exceptions

<i>io_error</i>	If the file cannot be written (bad path or bad permissions).
<i>std::exception</i>	Other unwritable issues (not enough space, disk failure, etc.).

```

01956
01957     std::ofstream file(path, std::ios::binary | std::ios::out | std::ios::trunc);
01958     if (!file) {
01959         throw io_error(path.string() + " cannot be opened to write.");
01960     }
01961     const int header_version{legacy ? old_hdr_version : modern_hdr_version};
01962     write_words(&file, convert_to_word(static_cast<float>(delta())));
01963     write_words(&file, convert_to_word(depmin()));
01964     write_words(&file, convert_to_word(depmax()));
01965     // Fill 'unused'
01966     write_words(&file, convert_to_word(depmax()));
01967     write_words(&file, convert_to_word(odelta()));
01968     write_words(&file, convert_to_word(static_cast<float>(b())));
01969     write_words(&file, convert_to_word(static_cast<float>(e())));
01970     write_words(&file, convert_to_word(static_cast<float>(o())));
01971     write_words(&file, convert_to_word(static_cast<float>(a())));
01972     // Fill 'internal'
01973     write_words(&file, convert_to_word(depmin()));
01974     write_words(&file, convert_to_word(static_cast<float>(t0())));
01975     write_words(&file, convert_to_word(static_cast<float>(t1())));
01976     write_words(&file, convert_to_word(static_cast<float>(t2())));
01977     write_words(&file, convert_to_word(static_cast<float>(t3())));
01978     write_words(&file, convert_to_word(static_cast<float>(t4())));
01979     write_words(&file, convert_to_word(static_cast<float>(t5())));
01980     write_words(&file, convert_to_word(static_cast<float>(t6())));
01981     write_words(&file, convert_to_word(static_cast<float>(t7())));
01982     write_words(&file, convert_to_word(static_cast<float>(t8())));
01983     write_words(&file, convert_to_word(static_cast<float>(t9())));
01984     write_words(&file, convert_to_word(static_cast<float>(f())));
01985     write_words(&file, convert_to_word(resp0()));
01986     write_words(&file, convert_to_word(resp1()));
01987     write_words(&file, convert_to_word(resp2()));
01988     write_words(&file, convert_to_word(resp3()));
01989     write_words(&file, convert_to_word(resp4()));
01990     write_words(&file, convert_to_word(resp5()));
01991     write_words(&file, convert_to_word(resp6()));
01992     write_words(&file, convert_to_word(resp7()));
01993     write_words(&file, convert_to_word(resp8()));
01994     write_words(&file, convert_to_word(resp9()));
01995     write_words(&file, convert_to_word(static_cast<float>(stla())));
01996     write_words(&file, convert_to_word(static_cast<float>(stlo())));
01997     write_words(&file, convert_to_word(stel()));
01998     write_words(&file, convert_to_word(stdp()));
01999     write_words(&file, convert_to_word(static_cast<float>(evla())));
02000     write_words(&file, convert_to_word(static_cast<float>(evlo())));
02001     write_words(&file, convert_to_word(evel()));
02002     write_words(&file, convert_to_word(evdv()));
02003     write_words(&file, convert_to_word(mag()));
02004     write_words(&file, convert_to_word(user0()));
02005     write_words(&file, convert_to_word(user1()));
02006     write_words(&file, convert_to_word(user2()));
02007     write_words(&file, convert_to_word(user3()));
02008     write_words(&file, convert_to_word(user4()));
02009     write_words(&file, convert_to_word(user5()));
02010     write_words(&file, convert_to_word(user6()));
02011     write_words(&file, convert_to_word(user7()));
02012     write_words(&file, convert_to_word(user8()));
02013     write_words(&file, convert_to_word(user9()));
02014     write_words(&file, convert_to_word(dist()));
02015     write_words(&file, convert_to_word(az()));
02016     write_words(&file, convert_to_word(baz()));
02017     write_words(&file, convert_to_word(gcarc()));
02018     write_words(&file, convert_to_word(static_cast<float>(sb())));
02019     write_words(&file, convert_to_word(static_cast<float>(sdelta())));
02020     write_words(&file, convert_to_word(depmen()));
02021     write_words(&file, convert_to_word(cmpaz()));
02022     write_words(&file, convert_to_word(cmpinc()));
02023     write_words(&file, convert_to_word(xminimum()));
02024     write_words(&file, convert_to_word(xmaximum()));
02025     write_words(&file, convert_to_word(yminimum()));

```

```

02026     write_words(&file, convert_to_word(ymaximum()));
02027     // Fill 'unused' (xcommon_skip_num)
02028     for (int i{0}; i < common_skip_num; ++i) {
02029         write_words(&file, convert_to_word(az()));
02030     }
02031     write_words(&file, convert_to_word(nzyear()));
02032     write_words(&file, convert_to_word(nzjday()));
02033     write_words(&file, convert_to_word(nzhour()));
02034     write_words(&file, convert_to_word(nzmin()));
02035     write_words(&file, convert_to_word(nzsec()));
02036     write_words(&file, convert_to_word(nzmsec()));
02037     write_words(&file, convert_to_word(header_version));
02038     write_words(&file, convert_to_word(norid()));
02039     write_words(&file, convert_to_word(nevid()));
02040     write_words(&file, convert_to_word(npts()));
02041     write_words(&file, convert_to_word(nsnpts()));
02042     write_words(&file, convert_to_word(nwfid()));
02043     write_words(&file, convert_to_word(nxsize()));
02044     write_words(&file, convert_to_word(nysize()));
02045     // Fill 'unused'
02046     write_words(&file, convert_to_word(nysize()));
02047     write_words(&file, convert_to_word(iftyp));
02048     write_words(&file, convert_to_word(idep));
02049     write_words(&file, convert_to_word(iztyp));
02050     // Fill 'unused'
02051     write_words(&file, convert_to_word(iztyp));
02052     write_words(&file, convert_to_word(iinst));
02053     write_words(&file, convert_to_word(istreg));
02054     write_words(&file, convert_to_word(ievreg));
02055     write_words(&file, convert_to_word(ievtyp));
02056     write_words(&file, convert_to_word(igual));
02057     write_words(&file, convert_to_word(isynth));
02058     write_words(&file, convert_to_word(imagtyp));
02059     write_words(&file, convert_to_word(imagsrc));
02060     write_words(&file, convert_to_word(ibody));
02061     // Fill 'unused' (xcommon_skip_num)
02062     for (int i{0}; i < common_skip_num; ++i) {
02063         write_words(&file, convert_to_word(ibody));
02064     }
02065     write_words(&file, bool_to_word(leven));
02066     write_words(&file, bool_to_word(lpspol));
02067     write_words(&file, bool_to_word(lovrok));
02068     write_words(&file, bool_to_word(lcalda));
02069     // Fill 'unused'
02070     write_words(&file, bool_to_word(lcalda));
02071     // Strings are special
02072     std::array<char, static_cast<size_t>(2) * word_length> two_words{
02073         convert_to_words<sizeof(two_words)>(kstnm(), 2)};
02074     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02075
02076     std::array<char, static_cast<size_t>(4) * word_length> four_words{
02077         convert_to_words<sizeof(four_words)>(kevnrm(), 4)};
02078     write_words(&file, std::vector<char>(four_words.begin(), four_words.end()));
02079
02080     two_words = convert_to_words<sizeof(two_words)>(khole(), 2);
02081     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02082
02083     two_words = convert_to_words<sizeof(two_words)>(ko(), 2);
02084     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02085
02086     two_words = convert_to_words<sizeof(two_words)>(ka(), 2);
02087     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02088
02089     two_words = convert_to_words<sizeof(two_words)>(kt0(), 2);
02090     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02091
02092     two_words = convert_to_words<sizeof(two_words)>(kt1(), 2);
02093     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02094
02095     two_words = convert_to_words<sizeof(two_words)>(kt2(), 2);
02096     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02097
02098     two_words = convert_to_words<sizeof(two_words)>(kt3(), 2);
02099     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02100
02101     two_words = convert_to_words<sizeof(two_words)>(kt4(), 2);
02102     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02103
02104     two_words = convert_to_words<sizeof(two_words)>(kt5(), 2);
02105     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02106
02107     two_words = convert_to_words<sizeof(two_words)>(kt6(), 2);
02108     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02109
02110     two_words = convert_to_words<sizeof(two_words)>(kt7(), 2);
02111     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02112

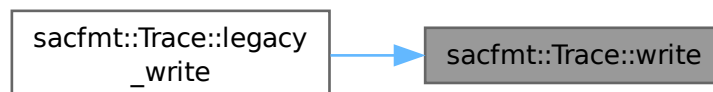
```

```

02113     two_words = convert_to_words<sizeof(two_words)>(kt8(), 2);
02114     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02115
02116     two_words = convert_to_words<sizeof(two_words)>(kt9(), 2);
02117     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02118
02119     two_words = convert_to_words<sizeof(two_words)>(kf(), 2);
02120     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02121
02122     two_words = convert_to_words<sizeof(two_words)>(kuser0(), 2);
02123     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02124
02125     two_words = convert_to_words<sizeof(two_words)>(kuser1(), 2);
02126     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02127
02128     two_words = convert_to_words<sizeof(two_words)>(kuser2(), 2);
02129     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02130
02131     two_words = convert_to_words<sizeof(two_words)>(kcmpnm(), 2);
02132     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02133
02134     two_words = convert_to_words<sizeof(two_words)>(knetwk(), 2);
02135     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02136
02137     two_words = convert_to_words<sizeof(two_words)>(kdatrd(), 2);
02138     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02139
02140     two_words = convert_to_words<sizeof(two_words)>(kinst(), 2);
02141     write_words(&file, std::vector<char>(two_words.begin(), two_words.end()));
02142     // Data
02143     for (double dub : data1()) [[likely]] {
02144         write_words(&file, convert_to_word(static_cast<float>(dub)));
02145     }
02146     if (!leven() || (iftype() > 1)) {
02147         for (double dub : data2()) {
02148             write_words(&file, convert_to_word(static_cast<float>(dub)));
02149         }
02150     }
02151     if (header_version == modern_hdr_version) {
02152         // Write footer
02153         write_words(&file, convert_to_word(delta()));
02154         write_words(&file, convert_to_word(b()));
02155         write_words(&file, convert_to_word(e()));
02156         write_words(&file, convert_to_word(o()));
02157         write_words(&file, convert_to_word(a()));
02158         write_words(&file, convert_to_word(t0()));
02159         write_words(&file, convert_to_word(t1()));
02160         write_words(&file, convert_to_word(t2()));
02161         write_words(&file, convert_to_word(t3()));
02162         write_words(&file, convert_to_word(t4()));
02163         write_words(&file, convert_to_word(t5()));
02164         write_words(&file, convert_to_word(t6()));
02165         write_words(&file, convert_to_word(t7()));
02166         write_words(&file, convert_to_word(t8()));
02167         write_words(&file, convert_to_word(t9()));
02168         write_words(&file, convert_to_word(f()));
02169         write_words(&file, convert_to_word(evlo()));
02170         write_words(&file, convert_to_word(evla()));
02171         write_words(&file, convert_to_word(stlo()));
02172         write_words(&file, convert_to_word(stla()));
02173         write_words(&file, convert_to_word(sb()));
02174         write_words(&file, convert_to_word(sdelta()));
02175     }
02176     file.close();
02177 }

```

Here is the caller graph for this function:

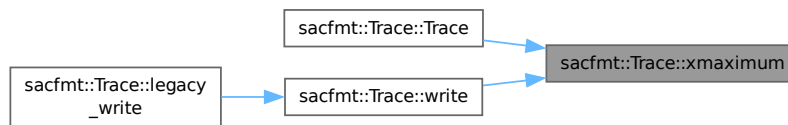




**11.3.3.240 xmaximum() [1/2]**

```
float sacfmt::Trace::xmaximum ( ) const [noexcept]
01047 {
01048     return floats[sac_map.at(name::xmaximum)];
01049 }
```

Here is the caller graph for this function:

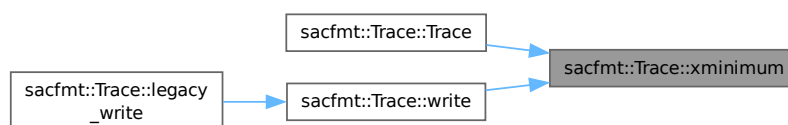
**11.3.3.241 xmaximum() [2/2]**

```
void sacfmt::Trace::xmaximum (
    float input ) [noexcept]
01296 {
01297     floats[sac_map.at(name::xmaximum)] = input;
01298 }
```

**11.3.3.242 xminimum() [1/2]**

```
float sacfmt::Trace::xminimum ( ) const [noexcept]
01044 {
01045     return floats[sac_map.at(name::xminimum)];
01046 }
```

Here is the caller graph for this function:

**11.3.3.243 xminimum() [2/2]**

```
void sacfmt::Trace::xminimum (
    float input ) [noexcept]
01293 {
01294     floats[sac_map.at(name::xminimum)] = input;
01295 }
```

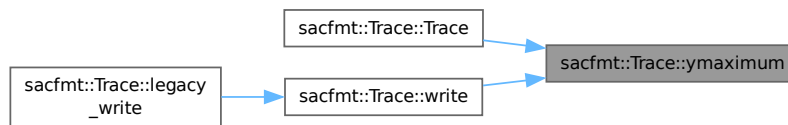
**11.3.3.244 ymaximum() [1/2]**

```

float sacfmt::Trace::ymaximum ( ) const [noexcept]
01053     {
01054     return floats[sac_map.at(name::ymaximum)];
01055     }

```

Here is the caller graph for this function:

**11.3.3.245 ymaximum() [2/2]**

```

void sacfmt::Trace::ymaximum (
    float input ) [noexcept]
01302     {
01303     floats[sac_map.at(name::ymaximum)] = input;
01304     }

```

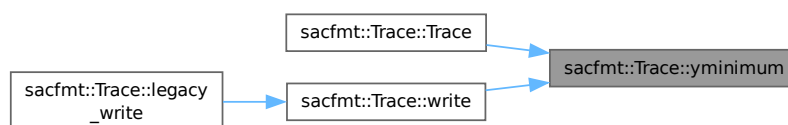
**11.3.3.246 yminimum() [1/2]**

```

float sacfmt::Trace::yminimum ( ) const [noexcept]
01050     {
01051     return floats[sac_map.at(name::yminimum)];
01052     }

```

Here is the caller graph for this function:

**11.3.3.247 yminimum() [2/2]**

```

void sacfmt::Trace::yminimum (
    float input ) [noexcept]
01299     {
01300     floats[sac_map.at(name::yminimum)] = input;
01301     }

```

## 11.3.4 Member Data Documentation

### 11.3.4.1 bools

```
std::array<bool, num_bool> sacfmt::Trace::bools {} [private]
```

Boolean storage array.

```
01323 {};
```

### 11.3.4.2 data

```
std::array<std::vector<double>, num_data> sacfmt::Trace::data {} [private]
```

std::vector<double> storage array.

```
01328 {};
```

### 11.3.4.3 doubles

```
std::array<double, num_double> sacfmt::Trace::doubles {} [private]
```

Double storage array.

```
01319 {};
```

### 11.3.4.4 floats

```
std::array<float, num_float> sacfmt::Trace::floats {} [private]
```

Float storage array.

```
01317 {};
```

### 11.3.4.5 ints

```
std::array<int, num_int> sacfmt::Trace::ints {} [private]
```

Integer storage array.

```
01321 {};
```

### 11.3.4.6 strings

```
std::array<std::string, num_string> sacfmt::Trace::strings {} [private]
```

String storage array.

```
01325 {};
```

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

- include/sac-format/sac\_format.hpp
- src/sac\_format.cpp

## 11.4 sacfmt::bitset\_type::uint< nbits > Struct Template Reference

Ensure type-safety for conversions between floats/doubles and bitsets.

```
#include <sac_format.hpp>
```

### 11.4.1 Detailed Description

```
template<unsigned nbits>
struct sacfmt::bitset_type::uint< nbits >
```

Ensure type-safety for conversions between floats/doubles and bitsets.

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

- include/sac-format/sac\_format.hpp

## 11.5 sacfmt::bitset\_type::uint< 4 \*bits\_per\_byte > Struct Reference

One-word (floats).

```
#include <sac_format.hpp>
```

### Public Types

- `using type = uint32_t`

### 11.5.1 Detailed Description

One-word (floats).

### 11.5.2 Member Typedef Documentation

#### 11.5.2.1 type

```
using sacfmt::bitset_type::uint< 4 *bits_per_byte >::type = uint32_t
```

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

- include/sac-format/sac\_format.hpp

## 11.6 sacfmt::bitset\_type::uint< bytes \*bits\_per\_byte > Struct Reference

```
#include <sac_format.hpp>
```

**Public Types**

- `using type = uint64_t`

**11.6.1 Member Typedef Documentation****11.6.1.1 type**

```
using sacfmt::bitset_type::uint< bytes *bits_per_byte >::type = uint64_t
```

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

- `include/sac-format/sac_format.hpp`

**11.7 sacfmt::word\_pair< T > Struct Template Reference**

Struct containing a pair of words.

```
#include <sac_format.hpp>
```

**Public Attributes**

- `T first {}`  
*First 'word' in the pair.*
- `T second {}`  
*Second 'word' in the pair.*

**11.7.1 Detailed Description**

```
template<typename T>
struct sacfmt::word_pair< T >
```

Struct containing a pair of words.

Prevents bug-prone word-swapping in functions that use a pair of words.

These are not necessarily single words, it could be a pair of `word_one` or a pair of `word_two`.

**11.7.2 Member Data Documentation****11.7.2.1 first**

```
template<typename T >
T sacfmt::word_pair< T >::first {}
```

First 'word' in the pair.  
00192 {};

**11.7.2.2 second**

```
template<typename T >
T sacfmt::word_pair< T >::second {}
```

Second 'word' in the pair.  
00193 {};

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

- `include/sac-format/sac_format.hpp`



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