

# Module Interface Specification for FSL

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[The multilined table looks funny when I use makecell to make a cell with multiple lines. I would be thankful if someone could enlighten me with some better ways. —Author]

## 1 Revision History

Date	Version	Notes
Nov. 26, 2019	0.99	First Draft

## 2 Symbols, Abbreviations and Acronyms

See SRS Documentation at <https://github.com/caobo1994/FourierSeries/blob/master/docs/SRS/SRS.pdf>. We also define the following acronyms for the scope of this document

Acronym	Full Text
OOD	Out of range
MC	Mismatched CFS

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### 3 Introduction

The following document details the Module Interface Specifications for Fourier Series Library (FSL).

Complementary documents include the System Requirement Specifications and Module Guide. The full documentation and implementation can be found at <https://github.com/caobo1994/FourierSeries/>.

### 4 Notation

The structure of the MIS for modules comes from Hoffman and Strooper (1995), with the addition that template modules have been adapted from Ghezzi et al. (2003). The mathematical notation comes from Chapter 3 of Hoffman and Strooper (1995). For instance, the symbol  $:=$  is used for a multiple assignment statement and conditional rules follow the form  $(c_1 \Rightarrow r_1 | c_2 \Rightarrow r_2 | \dots | c_n \Rightarrow r_n)$ .

The following table summarizes the primitive data types used by FSL.

Data Type	Notation	Description
character	char	a single symbol or digit
integer	$\mathbb{Z}$	a number without a fractional component in $(-\infty, \infty)$
natural number	$\mathbb{N}$	a number without a fractional component in $[1, \infty)$
real	$\mathbb{R}$	any number in $(-\infty, \infty)$

The specification of FSL uses some derived data types: sequences, strings, and tuples. Sequences are lists filled with elements of the same data type. Strings are sequences of characters. Tuples contain a list of values, potentially of different types. In addition, FSL uses functions, which are defined by the data types of their inputs and outputs. Local functions are described by giving their type signature followed by their specification.

For simplicity, the sequence of type  $T$  will be abbreviated as  $\text{seq}(T)$ , while that with dimensions  $[l_1, \dots, l_n]$  as  $\text{seq}(T, l_1, \dots, l_n)$ . Furthermore, we use both **Var**: **Type** and **Type Var** to indicate that variable **Var** is of type **Type**.

### 5 Module Decomposition

The following table is taken directly from the Module Guide document for this project.

Level 1	Level 2
Hardware-Hiding Module	Infrastructure (hardware-related part, external)
Behaviour-Hiding Module	Data definition module
	Conversion module
	Transformation module
	Basic operations module
	Advanced operations module
Software Decision Module	Linear solver (external or partially external)
	Integral (external or partially external)

Table 1: Module Hierarchy

## 6 MIS of Infrastructure

### 6.1 Module

Infrastructure.

### 6.2 Uses

None.

### 6.3 Syntax

### 6.4 Exported Data Type

`FLOAT` a floating point data type used in the library.

sequence the abstract sequence data type.

## 7 MIS of Data Definition

### 7.1 Module

Data Definition.

### 7.2 Uses

Infrastructure.

### 7.3 Syntax

#### 7.3.1 Exported Constants

None.

#### 7.3.2 Exported Data Type

There is one exported data type, `CFST`, which is the type of a CFS object. (abstract, with one type template `FLOAT`, indicating floating point types)

The structure of `CFST` is

- $n$ : integer
- $\omega$ : `FLOAT`
- $A$ : `seq(FLOAT,  $n$ )`



- $B: \text{seq}(\text{FLOAT}, n + 1)$

The mathematical notation is

$$\text{CFST} := \text{tuple of } (n : \mathbb{N}, \omega : \text{FLOAT}, A : \text{TA}, B : \text{TB})$$

where TA and TB are

$$\text{TA} := \text{seq}(\text{FLOAT}, n)$$

$$\text{TB} := \text{seq}(\text{FLOAT}, n + 1)$$

During implementation, it is recommended that the sequence type used above are random accessible.

### 7.3.3 Exported Access Programs

The exported access programs for this module are mainly getters and setters. For simplicity, we use the following getter and setter rules.

For each variable X, the getters and setters are

Name	In	Out	Exceptions
getX		X: type of X	None.
setX	X: type of X		None.

Furthermore, we design getters and setters for each element of A and B. For each X being A or B, the syntax of the function intended for the element  $X_i$  is

Name	In	Out	Exceptions
getXi	$i \in \mathbb{N}$	V: FLOAT	OOR.
setXi	$i \in \mathbb{N}, V: \text{FLOAT}$		OOR.

For convenience, we may use A(i) and B(i) to represent `getAi(i)` and `getBi(i)`, respectively.

## 7.4 Semantics

### 7.4.1 Assumptions

### 7.4.2 Access Routine Semantics

This part follows the most common rules of getters and setters. For simplicity, we do not elaborate on them.

Note the exceptions of `setXi` and `getXi` are

$$\text{exc} := ((i < M) \vee (i > n) \Rightarrow \text{OOR})$$

where M is 0 for X=A and 1 for X=B.

## 8 MIS of Linear Solver

### 8.1 Module

Linear Solver.

### 8.2 Uses

Infrastructure.

### 8.3 Syntax

#### 8.3.1 Export Access Programs

Name	In	Out	Exceptions
LinSolve	$m: \mathbb{N}$ $A: \text{seq}(\text{FLOAT}, m, m)$ $b: \text{seq}(\text{FLOAT}, m)$	$x: \text{seq}(\text{FLOAT}, m)$	Solution non-exist Solution not unique .

### 8.4 Semantics

#### 8.4.1 Assumptions

#### 8.4.2 Access Routine Semantics

This part follows the most common semantics of linear solvers solving the equation  $Ax = b$  for  $x$ , and for simplicity, we do not elaborate on it.

## 9 MIS of Integral

### 9.1 Module

Integral.

### 9.2 Uses

Infrastructure.

## 9.3 Syntax

### 9.3.1 Export Access Programs

Name	In	Out	Exceptions
Integral	f: FLOAT→FLOAT a, b: FLOAT	res: FLOAT	Integral non-exist or not computable .

## 9.4 Semantics

### 9.4.1 Access Routine Semantics

Integral(f, a, b):

- output:  $\int_a^b f(t)dt$
- exception: Evident

## 10 MIS of Conversion

### 10.1 Module

Conversion.

### 10.2 Uses

Data Definition.

## 10.3 Syntax

### 10.3.1 Export Access Programs

Name	In	Out	Exceptions
ConvertFrom	$n \in \mathbb{N}$ $\omega$ : FLOAT $A$ : sequence of FLOAT $B$ : sequence of FLOAT	CFST CFS	OOR: $\omega \leq 0$ MC: Mismatch between $n$ , (size of $A$ -1), and size of $B$
ConvertTo	CFST CFS $n, \omega, A, B$ : same type as their namesakes in CFST	Same as inputs of ConvertFrom	None

## 10.4 Semantics

### 10.5 Access Routine Semantics

ConvertFrom( $n, \omega, A, B$ ):

- output:  $\text{CFS}.n, \text{CFS}.\omega, \text{CFS}.A, \text{CFS}.B := n, \omega, A, B$
- exception:  $\text{exc} := (\omega \leq 0 \Rightarrow \text{OOR} \mid |A| \neq n + 1 \Rightarrow \text{MC} \mid |B| \neq n \Rightarrow \text{MC})$

The semantics for ConvertTo is straightforward, and we do not elaborate on it.

## 11 MIS for Transformation

### 11.1 Module

Transformation.

### 11.2 Uses

Data Definition, Integration.

## 11.3 Syntax

### 11.3.1 Export Access Programs

Name	In	Out	Exceptions
TransformTo	$f \in \{\mathbb{R} \rightarrow \mathbb{R}\}$ $n \in \mathbb{N}$ $\omega \in \mathbb{R}^+$	CFST CFS	None.
FunctionValue	CFST CFS $t \in \mathbb{R}$	$V \in \mathbb{R}$	None.

## 11.4 Semantics

### 11.5 Access Program Semantics

TransformTo( $f, n, \omega$ ):

- output:

$$\begin{aligned}
 A_0 &:= (1/2\pi) \int_{-\pi}^{\pi} f(t) dt, \\
 A_i &:= (1/\pi) \int_{-\pi}^{\pi} f(t) \cos(i\omega t) dt, \\
 B_i &:= (1/2\pi) \int_{-\pi}^{\pi} f(t) \sin(i\omega t) dt \\
 A &:= \langle A_0, \dots, A_n \rangle, \\
 B &:= \langle B_1, \dots, B_n \rangle, \\
 \text{CFS}.n, \text{CFS}.\omega, \text{CFS}.A, \text{CFS}.B &:= n, \omega, A, B
 \end{aligned}$$

FunctionValue(CFS,  $t$ ):

- output:  $V := \sum_{i=0}^{\text{CFS}.n} \text{CFS}.getAi(i) \cos(i\omega t) + \sum_{i=1}^{\text{CFS}.n} \text{CFS}.getBi(i) \sin(i\omega t)$

## 12 MIS of Basic Operation

### 12.1 Module

Basic Operations.

### 12.2 Uses

Data Definition, Linear Solver

## 12.3 Syntax

### 12.3.1 Export Access Programs

Name	In	Out	Exceptions
CFSTMatch	CFST CFS1, CFST CFS2	Bool res	None.
Addition	CFST CFS1, CFST CFS2	CFST CFSres	MC
Subtraction	CFST CFS1, CFST CFS2	CFST CFSres	MC
Multiplication	CFST CFS1, CFST CFS2	CFST CFSres	MC
Divison	CFST CFS1, CFST CFS2	CFST CFSres	MC
Amplitude	CFST CFS1	FLOAT amp	None.

## 12.4 Semantics

### 12.4.1 Access Program Semantics

CFSTMatch(CFST CFS1, CFST CFS2):

- output:  $(CFS1.n = CFS2.n) \wedge (CFS1.\omega = CFS2.\omega) \Rightarrow \text{TRUE} | \text{TRUE} \Rightarrow \text{FALSE}$

The semantics of **Addition**, **Subtraction**, and **Multiplication** are similar in structure, and the only difference is the calculation of the  $A$  and  $B$  variables shown below, which is consistent with the corresponding theories introduced in SRS.

As an example, we give the semantics of the **Addition** function.

Addition(CFST CFS1, CFST CFS2):

- output:  $A_i := CFS1.\text{getAi}(i) + CFS2.\text{getAi}(i)$ ,  $B_i := CFS1.\text{getBi}(i) + CFS2.\text{getBi}(i)$ ,  
 $A := \langle A_0, \dots, A_{CFS1.n} \rangle$ ,  $B := \langle B_0, \dots, B_{CFS1.n} \rangle$ ,  
 $CFSres.n, CFSres.\omega, CFSres.A, CFSres.B := CFS1.n, CFS1.\omega, A, B$
- exception:  $\text{exc} := (CFSTMatch(CFS1, CFS2) = \text{FALSE}) \Rightarrow \text{MC}$

As for **Division**, the difference is much significant. The  $A$  and  $B$  is computed as follows

$$\begin{aligned}
 x &:= \text{LinSolve}(2n + 1, M, y), \\
 A &:= x[0, CFS1.n + 1], \\
 B &:= x[CFS1.n + 1, |x|]
 \end{aligned}$$

where  $M$  and  $y$  are constructed in accordance with the theories for division in SRS.

Amplitude(CFST CFS1):

- output:  $\text{amp} := \sqrt{CFS1.\text{getAi}(0)^2 + (1/2) * \sum_{i=1}^{CFS1.n} (CFS1.\text{getAi}(i)^2 + CFS1.\text{getBi}(i)^2)}$

## 13 MIS for Advanced Operation

### 13.1 Module

Advanced Operation.

### 13.2 Uses

Basic Operation.

### 13.3 Syntax

In the following section,  $\text{TST}$  is a function type  $\mathbb{Z}^* \rightarrow \text{FLOAT}$ , and for any object  $\text{TS}$  of this type associated with a mathematical function,  $\text{TS}(i)$  gives the  $i$ -th Taylor coefficient of this mathematical function.

#### 13.3.1 Export Access Programs

Name	In	Out	Exceptions
ToleratedEquality	CFST CFS1, CFST CFS2, FLOAT tol	Bool res	MC
Power	CFST CFS, $m \in \mathbb{Z}^*$	CFST CFSres	None.
Function	CFST CFS, TST TS	CFST CFSres	None.

### 13.4 Semantics

#### 13.4.1 Access Routine Semantics

$\text{ToleratedEquality}(\text{CFST CFS1}, \text{CFST CFS2}, \text{FLOAT tol})$ :

- output:  $\text{res} := (\text{Amplitude}(\text{Subtraction}(\text{CFS1}, \text{CFS2})) \leq \text{tol} \Rightarrow \text{TRUE} | \text{TRUE} \Rightarrow \text{FALSE})$
- exception:  $\text{exc} := (\text{CFSTMatch}(\text{CFS1}, \text{CFS2}) = \text{FALSE} \Rightarrow \text{MC})$

$\text{Power}(\text{CFST CFS}, m \in \mathbb{Z}^*)$ :

- output:

$$A := \langle 1, 0, \dots, 0 \rangle, |A| = (n + 1);$$

$$B := \langle 0, 0, \dots, 0 \rangle, |B| = n$$

$$\text{CFSzero}.n, \text{CFSzero}.\omega, \text{CFSzero}.A, \text{CFSzero}.B := n, \omega, A, B$$

$$\text{CFSres} := (m = 0 \Rightarrow \text{CFSzero} | \text{TRUE} \Rightarrow \text{Multiplication}(\text{CFS}, \text{Power}(\text{CFS}, m - 1)))$$

$\text{Function}(\text{CFST CFS}, \text{TST TS})$ :

- output:  $\text{CFSres} := \sum_{i=0}^{\text{CFS}.n} (1/i!) \text{TS}(i) \text{Power}(\text{CFS}, i)$

## References

- Carlo Ghezzi, Mehdi Jazayeri, and Dino Mandrioli. *Fundamentals of Software Engineering*. Prentice Hall, Upper Saddle River, NJ, USA, 2nd edition, 2003.
- Daniel M. Hoffman and Paul A. Strooper. *Software Design, Automated Testing, and Maintenance: A Practical Approach*. International Thomson Computer Press, New York, NY, USA, 1995. URL <http://citeseer.ist.psu.edu/428727.html>.



## 14 Appendix

[Extra information if required —SS]