



# **FFT Module – User Manual V1.0**

**Mutex Embedded Solutions**

**March 2026**

**This manual highlights the necessary information to use the FFT frequency analysis Module. This includes device specifications, hardware design, serial interface and data formats.**

# Version Control

FFT User Manual update history is highlighted in the following table:

*Table 1: Version Control*

<b>Version</b>	<b>Date</b>	<b>Modified by</b>	<b>Description</b>
1.0	13/03/2026	M.Yaqoob	Create the initial FFT User Manual fully

---

## Table of Contents

1. Specifications .....	3
1.1. Features.....	3
1.2. Electrical Ratings.....	3
1.3. Applications.....	3
2. Hardware .....	4
2.1. Pinout.....	4
2.2. Dimensions .....	5
3. Serial Interface .....	6
3.1. Registers Map.....	6
3.2. UART – Modbus .....	8
3.3. RS485 – Modbus .....	8
3.4. I2C Interface.....	9
4. Extension Board.....	11
4.1. Pinout.....	11
5. PC Application.....	12

# 1. Specifications

The FFT module is an embedded Fast-Fourier Transform real-time frequency analyzer. It has a bandwidth of 24KHz. The module reads an analog signal 0 to 3V peak-to-peak. The module is designed for industrial applications.

## 1.1. Features

The FFT module includes the following features:

- Analog input signal (Single-ended or Differential)
- Built-in Anti-Aliasing filter
- Configurable sampling frequency: 8KHz, 16KHz, 32KHz and 48KHz
- FFT Windows: Rectangular, Hamming, Hann, Blackman, Nuttall and Flat Top
- Top 10 peaks frequency bins summary
- Raw 2048 bins FFT result
- Serial Interfaces: UART-Modbus and I2C

## 1.2. Electrical Ratings

The FFT module electrical specifications are summarized in the following table:

Table 2: Electrical Specifications

Parameter	Minimum	Nominal	Maximum
Power Supply Input	-	3.3V	-
Analog Input	0V	-	3V
Current consumption	-	-	100mA
I2C signal level	-	3.3V	-
UART signal level	-	3.3V	-
RS485 EN signal level	-	3.3V	-

## 1.3. Applications

The real-time FFT embedded module can be used in any frequency analysis applications such as:

- Vibration analysis
- Rotating machines predictive maintenance
- Audio frequency detection
- Noise reduction systems

## 2. Hardware

### 2.1. Pinout

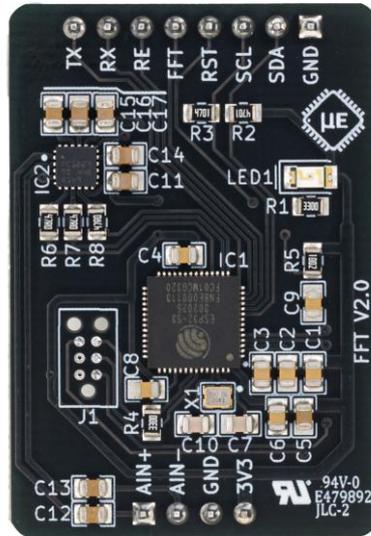


Figure 1: FFT Module

Table 3: FFT digital interface connector pinout

No.	Pin Name	Functionality	Comments
1	GND	Common GND	
2	SDA	I2C_SDA	
3	SCL	I2C_SCL	
4	RST	nRESET MCU	Set to LOW to disable MCU (Power saving mode)
5	FFT	FFT Status	HIGH when FFT is processing
6	RE	RS485_RE	OUT, Used with external RS485 transceiver
7	RX	UART_RX	IN
8	TX	UART_TX	OUT

Table 4: FFT analog and power connector pinout

No.	Pin Name	Functionality	Comments
1	AIN+	Analog In+	Single Ended analog input. 0 – 3V
2	AIN-	Analog In-	Differential ended negative input. 0 – 3V
3	GND	Common GND	
4	3V3	Digital supply	

## 2.2. Dimensions

The dimensions of the FFT module and the Extension board are as shown below:

### FFT Module

- Length = **41 mm**
- Width = **28 mm**
- Distance between pin headers centers = **37 mm**

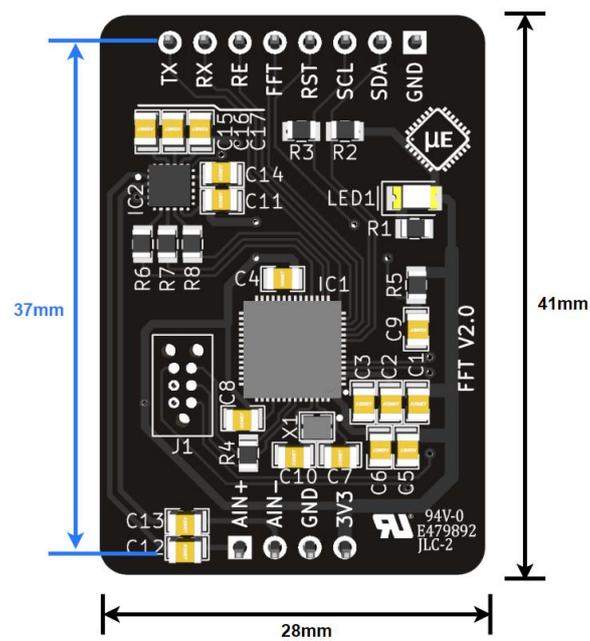


Figure 2: FFT Module Dimensions

### 3. Serial Interface

To communicate with the module and access the internal registers, users need to use one of these interfaces: UART-Modbus, I2C or RS-485 (Requires an external circuitry).

#### 3.1. Registers Map

**Note:** Registers are 16-bit each, based on Modbus standard.

##### Holding Registers (Write / Read)

Table 5: FFT Module Holding Registers

Address	Size / U16	Function	Range	Default	Type	Description
0	1	Slave Address	1 - 127	12	uint16	Modbus/I2C Slave address. (Restart required)
1	2	Baud Rate	0 - 4	4	enum	0: 9600 1: 19200 2: 38400 3: 57600 <b>4: 115200 (default)</b> (Restart required)
3	2	Parity	0 - 3	0	enum	<b>0: None (default)</b> 1: -/ 2: Even 3: Odd (Restart required)
5	2	Sampling Frequency	0 - 3	3	enum	0: 8 KHz [Resolution = 1.95 Hz, Bandwidth = 4 KHz] 1: 16 KHz [Resolution = 3.9 Hz, Bandwidth = 8 KHz] 2: 32 KHz [Resolution = 7.8 Hz, Bandwidth = 16 KHz] <b>3: 48 KHz (default) [Resolution = 11.7 Hz, Bandwidth = 24 KHz]</b> (Restart required) [Output bins N/2 = 2048]
7	2	Window	0 - 5	0	enum	<b>0: Rectangular (default)</b> 1: Hamming 2: Hann 3: Blackman 4: Nuttall 5: Flat Top
9	1	Capture FFT	0 - 1	0	bool	1: Set to 1 to Start full FFT capture, 0: Wait for 0, end of FFT capture and FFT Peaks registers updated
10	1	Update Raw FFT registers	0 - 1	0	bool	1: Set to 1 to update Raw FFT registers 0: Wait for 0, FFT Raw registers updated
39	1	Firmware Update Enable	0 - 1	0	bool	1: Put device into bootloader mode, for FW update.

## Input Registers (Read Only)

Table 6: FFT Module Input Registers - Realtime

Address	Size	Function	Range	Scaling	Default	Type	Description
<b>FFT Peaks - Top 10</b>							
100	1	1 - Frequency	0 - 24000	1	0	uint16	Hz
101	1	1 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
102	1	2 - Frequency	0 - 24000	1	0	uint16	Hz
103	1	2 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
104	1	3 - Frequency	0 - 24000	1	0	uint16	Hz
105	1	3 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
106	1	4 - Frequency	0 - 24000	1	0	uint16	Hz
107	1	4 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
108	1	5 - Frequency	0 - 24000	1	0	uint16	Hz
109	1	5 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
110	1	6 - Frequency	0 - 24000	1	0	uint16	Hz
111	1	6 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
112	1	7 - Frequency	0 - 24000	1	0	uint16	Hz
113	1	7 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
114	1	8 - Frequency	0 - 24000	1	0	uint16	Hz
115	1	8 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
116	1	9 - Frequency	0 - 24000	1	0	uint16	Hz
117	1	9 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
118	1	10 - Frequency	0 - 24000	1	0	uint16	Hz
119	1	10 - Volt	0 - 1500	0.001	0	uint16	Milli Volt
<b>FFT Raw Bins [Bins = 2048] (Frequency = <math>F_s * \text{bin}/4096</math>)</b>							
120	1	bin - 0	0 - 1500	0.001	0	uint16	Milli Volt
121	1	bin - 1	0 - 1500	0.001	0	uint16	Milli Volt
122	1	bin - 2	0 - 1500	0.001	0	uint16	Milli Volt
123	1	bin - 3	0 - 1500	0.001	0	uint16	Milli Volt
...	1	...	0 - 1500	0.001	0	uint16	Milli Volt
2167	1	bin - 2047	0 - 1500	0.001	0	uint16	Milli Volt

### 3.2. UART – Modbus

The module uses a standard Modbus RTU format with the following default specifications:

Parameter	Value
Baud Rate	115200
Data bits	8 bits
Parity	None
Stop bit	1 bit
Flow Control	RS485 - DTR
Mode	RTU
Default Slave Address	12
Functions	03: Holding read 04: Input read 06: Holding write single 16: Holding write multiple
CRC	CRC-16 Modbus

#### Data Format

Accessing Modbus Registers require interpreting the data correctly. An I2C C library is provided that also handles data formats.

The following table highlights the data formats:

Data Type	Registers Count	Value	Data Format
Bool	1	True = 0x0001, False = 0x0000	0x0001
U16	1	0x1234	0x1234
I16	1	-123 = 0xFF85	0xFF85
U32	2	0x12345678	[0] = 0x5678 [1] = 0x1234
I32	2	-123456 = 0xFFFE1DC0	[0] = 0x1DC0 [1] = 0xFFFE
Enum	2	4 = 0x00000004	[0] = 0x0000 [1] = 0x0004
Float	2	12.567 = 0x4149126f (IEEE-754)	[0] = 0x126F [1] = 0x4149
String	ceil(Strlen / 2) e.g. 10 chars = 5 registers	"World" = 0x48 0x65 0x6C 0x6C 0x6F	[0] = 0x6548 "oW" [1] = 0x6C6C "lr" [2] = 0x006F "d"

### 3.3. RS485 – Modbus

To use RS485 Bus, the module provides the RS485 Enable output pin to connect to an external RS485 transceiver as follows:

## RS485

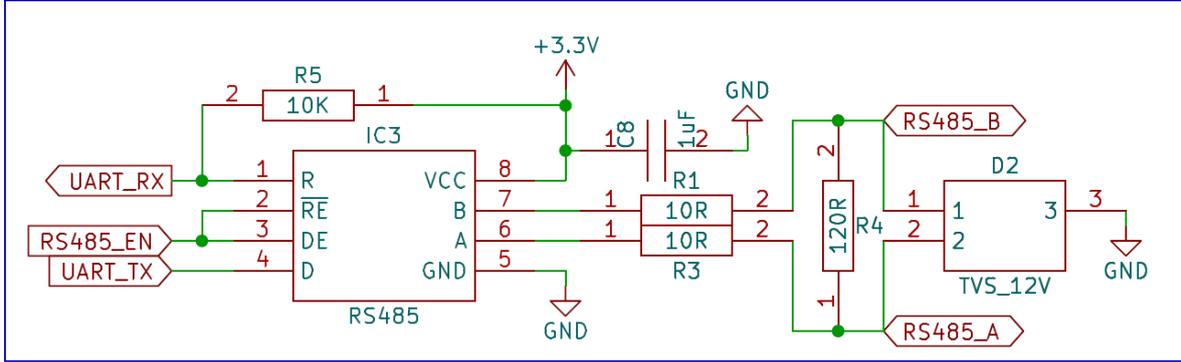


Figure 3: RS485 External Circuit

### 3.4. I2C Interface

This section describes how to communicate with the module via I2C. We provide a universal C library for I2C communication with all our modules.

I2C interface hardware requirements:

- Signal Level is 3.3V
- Pull-up resistors are already included in the module PCB. **No need** to add external pull-up resistors.

#### Write Holding registers

To write holding registers using I2C, the following request shall be sent:

- [0]: 0x01 (Mode = Write holding)
- [1]: Start Register Address LSB
- [2]: Start Register Address MSB
- [3]: Length (Registers count to write)
- [4]: CRC-8 SMBus

Then, followed by registers data:

- Data0-LSB
- Data0-MSB
- ...
- CRC-8 SMBus

The Data will be written to the Register(s) successfully if I2C Write operation succeeded and CRC is correct.

#### Read Holding registers

To read holding registers using I2C, the following request shall be sent:

- [0]: 0x02 (Mode = Read holding)
- [1]: Start Register Address LSB
- [2]: Start Register Address MSB
- [3]: Length (Registers count to read)
- [4]: CRC-8 SMBus

---

After that, you need to wait briefly for processing, at least 5ms.

Then, perform an I2C read for data + CRC byte. CRC shall be verified.

### **Read Input registers**

To read Input registers via I2C, the following request shall be sent:

- [0]: 0x03 (Mode = Read input)
- [1]: Start Register Address LSB
- [2]: Start Register Address MSB
- [3]: Length (Registers count to read)
- [4]: CRC-8 SMBus

After that, you need to wait briefly for processing, at least 5ms.

Then, perform an I2C read for data + CRC byte. CRC shall be verified.

**NOTE:** Mutex provides a C library for handling the I2C packets processing and data formats. It can be used on any Microcontroller, so why not use it!

## 4. Extension Board

An extension board is available to evaluate the module functionality and connect it to the PC App via USB. The Extension board is a great way to test the module.



Figure 4: Extension Board

- Extension Board dimensions: **40 x 75 mm**

### 4.1. Pinout

Table 7: Extension pinout connector

No.	Pin Name	Functionality	Comments
1	+3.3V	Digital Supply	Current supply capability at least 100mA
2	GND	Common GND	
3	SDA	I2C_SDA	
4	SCL	I2C_SCL	
5	RST	nRESET MCU	Set to LOW to disable MCU
6	FFT	FFT Status	HIGH when FFT is processing
7	RE	RS485_RE	OUT, Used with external RS485 transceiver
8	RX	UART_RX	IN
9	TX	UART_TX	OUT
10	AIN+	Analog In+	Single Ended analog input. 0 – 3V
11	AIN-	Analog In-	Differential ended negative input. 0 – 3V
12	GND	Common GND	

## 5. PC Application

The Mutex Connect App is provided to allow users to fully configure and evaluate the FFT Module.

The App provides the following features:

- Holding Registers Read/Write
- Input Registers Read
- FFT Top 10 peaks in tabular form
- FFT full spectrum
- Module firmware update

