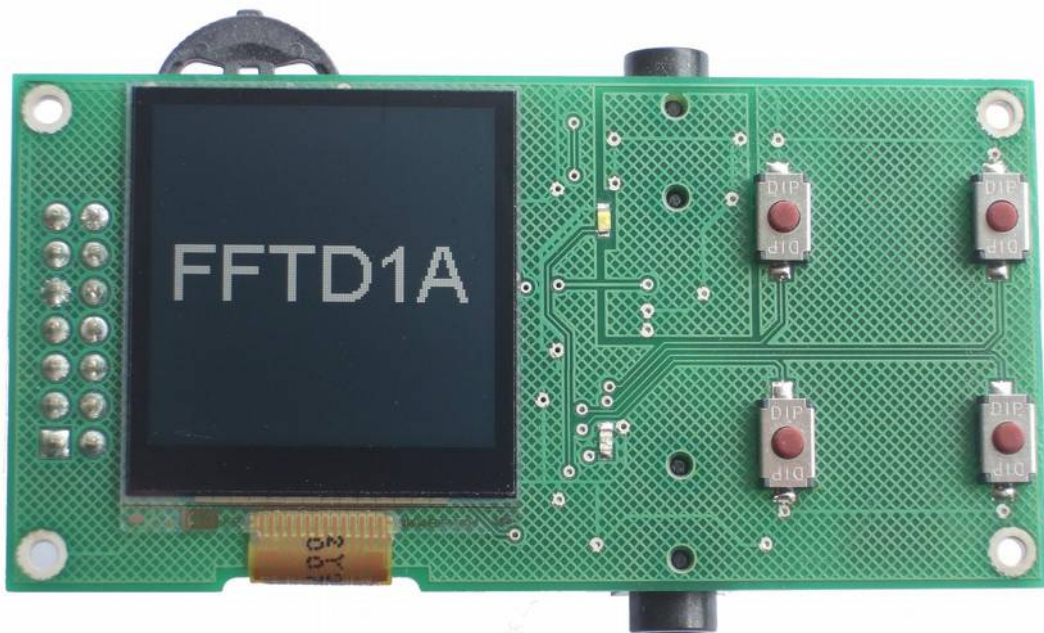


# FFTD1A

## Ultra Low Power MSP430 Development Board

### User Guide



**1 INTRODUCTION.....3**

**2 PRODUCT FEATURES.....4**

2.1 ABSOLUTE MAXIMUM RATINGS.....4

2.2 BATTERY AND SUPPLY.....4

2.3 PROGRAM AND DEBUG PORT.....4

2.4 RS232 PORT.....4

2.5 GRAPHICAL DISPLAY.....4

2.6 AUDIO PORT.....5

2.7 EXPANSION PORT A.....5

2.8 EXPANSION PORT B.....5

2.9 EXPANSION PORT CONNECTORS.....5

2.10 SWITCHES.....5

2.11 LEDs.....5

2.12 SUPPLY MONITORING.....6

2.13 OSCILLATOR USE.....6

**3 GETTING STARTED.....6**

3.1 FUNCTIONAL TEST.....6

**4 DEMO SOFTWARE.....7**

4.1 PERMITTED USE.....7

4.2 COMPILING.....7

4.3 DEMO 1 – HARDWARE TEST PROGRAM.....7

4.4 DEMO 2 – FAST FOURIER TRANSFORM.....8

4.5 DEMO 3 – SEQUENTIAL IMAGE DISPLAY.....9

4.6 DEMO 4 – AUDIO SPECTRUM ANALYSER.....10

4.7 DEMO 5 – OSCILLOSCOPE WITH FFT OPTION.....12

**5 CUSTOM FIRMWARE.....14**

**Copyright.**

The FFTD1A product, including schematics, PCB Layout and the contents of the accompanying CD are copyright © June 2012 RHDC Services Ltd with all rights reserved.

**Disclaimer.**

The FFTD1A development board is intended for experimental use in a controlled engineering environment. In no event shall RHDC Services Ltd be held liable for any damages arising from its use.

## 1 Introduction

The FFTD1A development board combines two complimentary parts. A Texas Instruments MSP430F5418A microcontroller and a Sharp LS013B7DH03 128x128 graphic display. The result is a development platform targeting ultra-low-power applications.

If you are not familiar with the LS013B7DH03 Memory LCD, the ultra-low-power label is well deserved. Not only is the display refresh flicker-free but it can hold an image using just a few  $\mu\text{W}$ , so combining this part with an MSP430 makes perfect sense. The FFTD1A can typically display an image and maintain a Real Time Clock using less than  $15\mu\text{W}$ . Assuming a CR2032 coin-cell delivers 200mAh, that's nearly 6 years battery life!

In a market dominated by displays that are often difficult to read outdoors, the LS013B7DH03 LCD is also unique in providing a high-contrast image in bright sunlight and without the need for a backlight.

The FFTD1A board can either be powered directly off a CR2032 coin cell or from an external supply via either of two expansion ports. Note. Any external supply must be regulated to 3.0V.

The FFTD1A expansion ports use miniature JST connectors. Port A brings out connections to GND, VDD and universal serial ports UCA1, UCB1. This enables you to interface to many different types of peripheral using either SPI, I2C or RS232 protocols. Port B provides an additional GND and VDD connection plus 2 GPIO ports P2.0/TA1CLK/MCLK and P2.1/TA1.0. These were specifically selected to provide scope for synchronisation with external devices as well as for counting fast pulses and interrupt based triggering.

Programming and debug is via the standard 14-Way 0.1" header, compatible with the Texas Instruments MSP-FET430UIF interface. In addition, an RS232 debug port is provided on a 3.5mm jack connector specifically wired for use with FTDI USB to RS232 cables.

The design philosophy for the board has been to avoid unnecessary power consumption and clutter by choosing just a few carefully selected peripherals. In addition to the display and expansion ports described above, there are 3 LEDs, 4 tact switches, a 3-Way scan switch and a 3.5mm line-level audio input jack connected to the MSP430's 12 bit ADC.

The display and tact switches have been placed on the back so that if you need to mount the board in a box or against a panel, you can do so using the four mounting holes and still have access to the programming port and other electronics.

Using the FFT Designer software together with the FFTD1A development board allows users to develop application software that performs Fourier analysis. Users can thus experiment with audio Digital Signal Processing techniques such as might be required for a guitar tuner or simple audio spectrum analyser.

The board is shipped ready-programmed with a demonstration application installed, so you will be up and running within minutes. The accompanying CD also contains other demonstration applications. One that calculates a 256 point FFT and displays the result on the LCD, one that displays a sequence of images and one that implements a miniature audio spectrum analyser.

For anyone wishing to experiment with Fast Fourier Transforms on the MSP430 or create ultra-low-power solutions based on a Sharp Memory LCD, the FFTD1A is simply the best development platform available.

## 2 Product Features

The image below shows the main features of the FFTD1A.

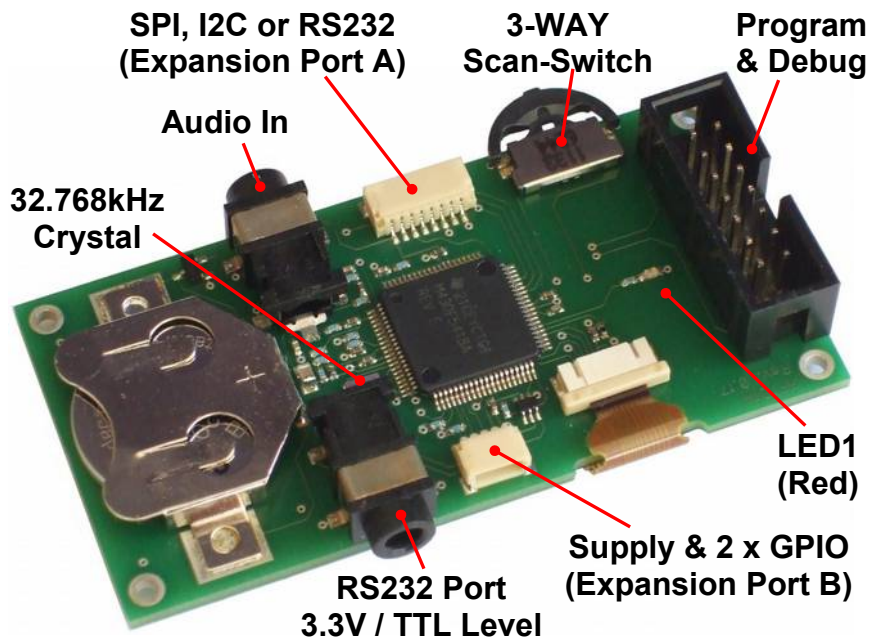


Figure 1. FFTD1A Board (Top)

### 2.1 Absolute Maximum Ratings

Please refer to the MSP430F5418A and LS013B7DH03 data sheets.

### 2.2 Battery and Supply

The FFTD1A is designed to be powered directly from a CR2032 coin-cell. Therefore user applications should ensure proper use is made of the MSP430 supply monitor to handle brown-out conditions etc.

Important. When supplying external power, the battery must first be removed and the voltage must never be allowed to exceed 3.3V.

### 2.3 Program and Debug Port

The FFTD1A uses the Spy-Bi-Wire debug interface protocol and connects via a standard 14-Way debug header. The debug interface is compatible with the MSP-FET430UIF adapter Ver 1.4a or later. Older versions may not support the Spy-Bi-Wire protocol and so may not be suitable for use with the FFTD1A.

### 2.4 RS232 Port

The FFTD1A RS232 port is compatible with 3.3V TTL inverted-logic RS232 signal levels. The port is wired for use with the FTDI USB to RS232 interface cable TTL-232R-3V3-AJ, available from a number of outlets.

### 2.5 Graphical Display

The onboard 128 x 128 pixel graphical display is an ultra-low-power LS013B7DH03. The display is from the Sharp Memory LCD product family and is interfaced to the MSP430 using four I/O lines and an SPI port. Refer to the FFTD1A schematic, display datasheet and demo code for more information.

## 2.6 Audio Port

The FFTD1A audio port may be used to acquire an audio signal from a suitable line-level source. The interface comprises a stereo 3.5mm line-in jack socket which is connected via decoupling, filtering and biasing components to two channels of the 200ksps ADC of the MSP430. To successfully acquire an audio signal from this port, application software should ensure:-

1. The ADC reference output on P5.0/VREF+ is enabled to provide a low-noise DC bias to the ADC inputs.
2. Approximately 1s settling-time is allowed between enabling the reference and signal acquisition.
3. The ADC reference voltage is set to 1.5V to ensure adequate supply-noise immunity.
4. The ADC sampling trigger is derived from a crystal oscillator source to ensure low-jitter sampling.
5. The ADC reference output is disabled when not needed as it draws around 1mA when enabled.

Following these guidelines, a line-level audio signal of around 2Vp-p can normally be sampled with a SFDR of over 50dB. If required, oversampling and decimation-filtering may be used to improve on this performance.

Note. To avoid clipping, the audio input peak-to-peak amplitude should not exceed 3.0 V. Typical audio equipment output voltages are as follows.

Pro-audio equipment line-out	+4dBu (3.472 Vp-p)
Consumer audio equipment line-out	-10dBV (0.894 Vp-p)
PC sound-card headphone output	2.0 Vp-p.

**Table 1. Typical Audio Equipment Output Levels**

## 2.7 Expansion Port A

This port brings out connections to the second USCI module and is capable of providing two separate serial interfaces. Please refer to the FFTD1A schematic and MSP430x54x User Guide for more details.

## 2.8 Expansion Port B

This port provides connection to two additional pins, P2.0 and P2.1. As well as the standard port function, these pins provide access to a variety of special functions.

## 2.9 Expansion Port Connectors

To make use of the FFTD1A expansion ports, a JST series connector will be required. There are two types you can use, IDC (e.g. 08SR-3S) or crimp (e.g. SHR-08V-S-B housing + contacts). The IDC connector requires special wire and tools and the crimp contacts themselves also require a special tool. However, there is an easy option. Use a crimp housing with ready crimped contact leads. See below.

Port	Housing	Contacts
A	SHR-08V-S-B	8 x SH3-SH3-28300 pre-crimped contact on 300mm length of wire
B	SHR-04V-S-B	4 x SH3-SH3-28300 pre-crimped contact on 300mm length of wire

## 2.10 Switches

The FFTD1A has five switches in total. Four single-contact push-switches and one twin-contact scan-switch. To use the switches, user software should configure the six corresponding port resistors for weak pullup to VDD. See ports.c file in demo code.

## 2.11 LEDs

The FFTD1A has 3 LEDs in total. A Red LED on the component side and a White and Blue LED on the display side. Each LED draws approximately 0.5mA when lit.

## 2.12 Supply Monitoring

The FFTD1A is normally powered directly from a CR2032 coin-cell. To allow application software to determine the battery condition, VDD is connected to Pin 8 of the MSP430F5418A (P7.7) via a potential divider and RC filter. Using the internal 12 bit ADC and 1.5V reference, application software can therefore measure the battery voltage and from this determine its condition. In addition, application software can make use of the MSP430F5418A's built-in supply monitoring features to detect brown-out situations etc.

## 2.13 Oscillator Use

The FFTD1A has one 32.768kHz crystal installed on the low power oscillator pins P7.0 and P7.1. In a typical application, ACLK will be derived directly from this oscillator to clock peripherals and timers. MCLK will typically be derived from the DCO which in turn may be frequency locked to the 32.768kHz oscillator. This configuration is a good starting point for FFTD1A application software as it facilitates low quiescent power levels, precise timing, low interrupt latency and fast code execution.

Note. If your application requires MCLK rates above 8MHz, take care to ensure the required CPU core-voltage has first been set, in strict accordance with the MSP430x54xx User Guide.

## 3 Getting Started

The FFTD1A Development Board comes ready programmed with a simple demonstration application (see Demo 1 on CD) and just requires the addition of a CR2032 coin-cell (not included) for normal operation. Insert the coin-cell into the holder and the text "FFTD1A" should be displayed on the LCD panel.

### 3.1 Functional Test

The demonstration application allows the switches, LEDs, RS232 port and display to be tested as follows.

1. Rolling SW1 changes the display between "FFTD1A" and "MSP430 + SHARP MEMORY LCD".
2. Pressing SW2 turns LED 3 (White) - ON
3. Pressing SW3 turns LED 3 (White) - OFF
4. Pressing SW4 turns LED 2 (Blue) - OFF
5. Pressing SW5 turns LED 2 (Blue) - ON
6. Characters received on the RS232 port (9600 8N1) are echoed back and cause LED1 (Red) to blink.

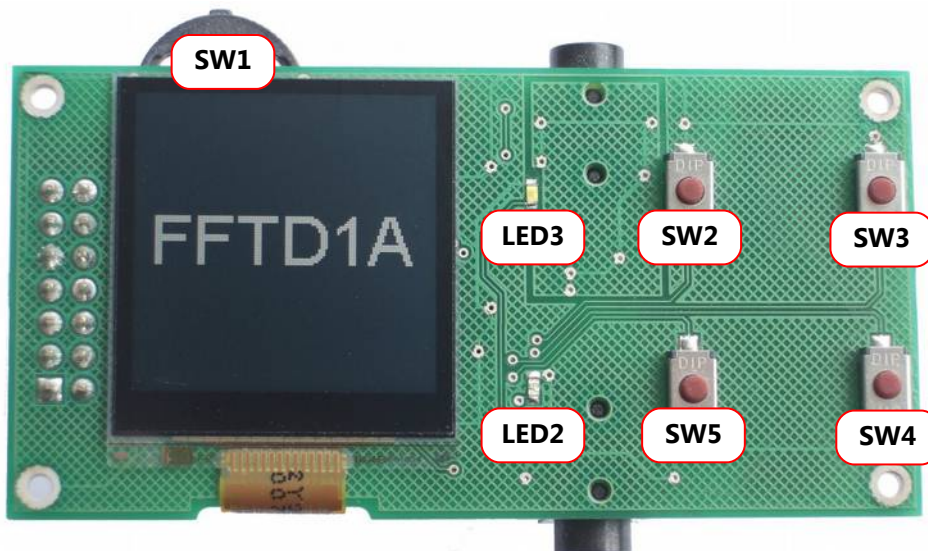


Figure 2. FFTD1A Switches and LEDs

## 4 Demo Software

The FFTD1A product includes a CD containing a number of demonstration applications including a driver for the LS013B7DH03 display.

Please Note. The demo software is supplied on a CD with the product. It is not available for download.

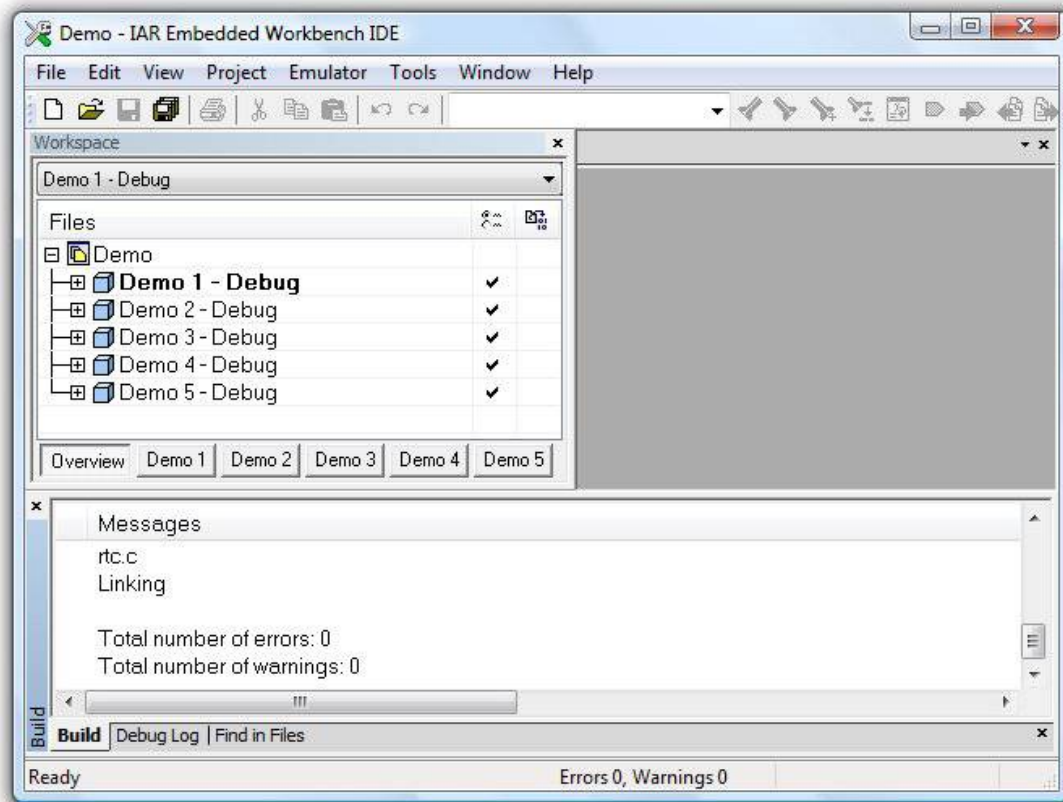
### 4.1 Permitted Use

The FFTD1A demo software may only be used in conjunction with an FFTD1A development board. Use on any other platform, whether commercial or not, requires written permission from RHDC Services Ltd.

### 4.2 Compiling

The FFTD1A demo software is intended for compilation using Embedded Workbench for the MSP430. The code was developed and tested using version 5.4 Kickstart Edition which allows up to 8k of object code.

Assuming Embedded Workbench is already installed, double-click the "Demo.eww" file to open the workspace. In the workbench side-pane, there should be a number of project tabs as shown below.



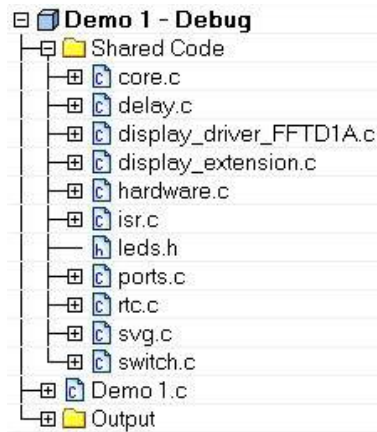
**Figure 3. Demo Software Workspace**

To compile a particular demo, select the corresponding project tab and press F7. Once compiled, the code may be transferred to the target board in the normal way.

### 4.3 Demo 1 – Hardware Test Program

This application allows operation of the switches, LEDs, RS232 port and display to be verified. See section Functional Test above.

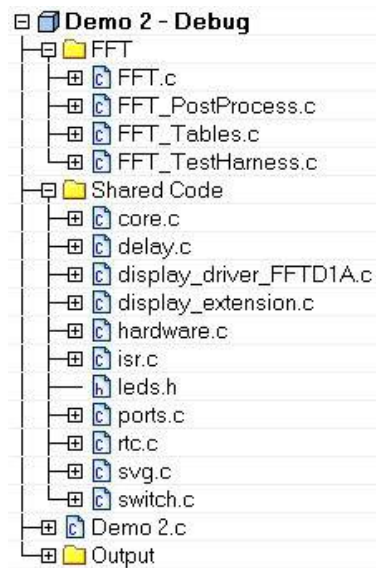
To compile the demo, select the Demo 1 tab in the provided EW project or create your own project and add the files listed below.



**Figure 4. Demo 1 Files**

#### 4.4 Demo 2 – Fast Fourier Transform

This application shows how FFT code generated by FFT Designer can be used with the FFTD1A. In this example, the FFT is performed on test vectors in flash (also generated by FFT Designer) containing two sine-waves of equal amplitude at bin 20 and bin 30.



**Figure 5. Demo 2 Files**

Once the code has been programmed into the FFTD1A board, it will display the complex FFT result in dB Magnitude form, as shown below.

Note. The FFT demo code is supplied exclusively for use with the FFTD1A development board. If you wish to use FFT Designer generated code on another platform, you must purchase an FFT Designer licence.



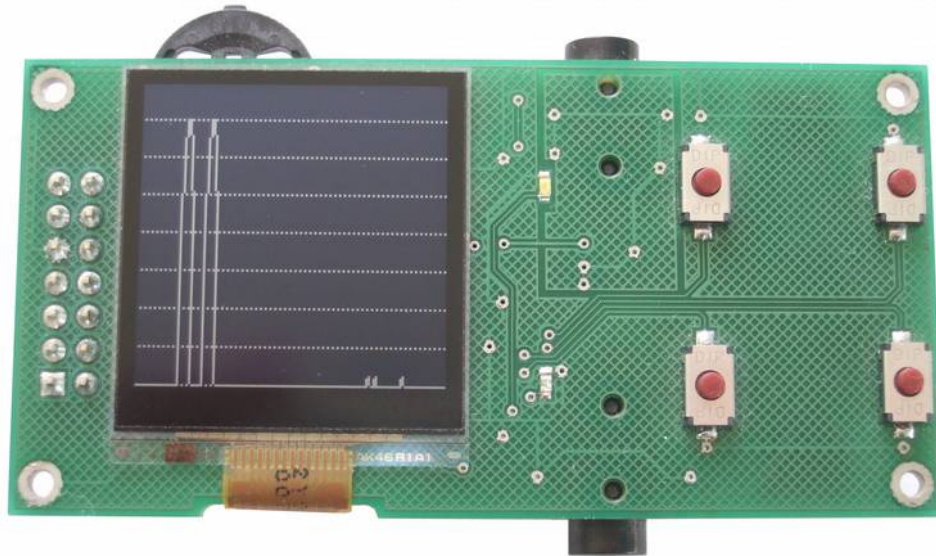


Figure 6. FFTD1A showing a complex FFT Result in dB magnitude form. Ref=0dB. 10dB/div

#### 4.5 Demo 3 – Sequential Image Display

This application demonstrates how a sequence of bitmap images stored in program FLASH memory can be directly displayed on the LCD. The image changes automatically every second and the number of images in the sequence is set at compile time by a #define.

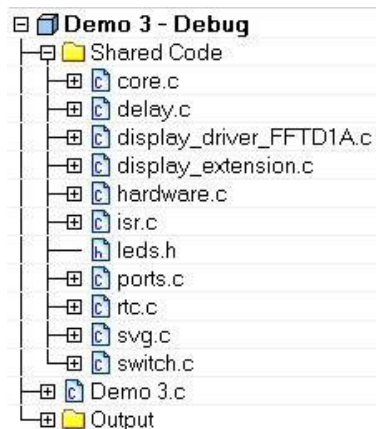


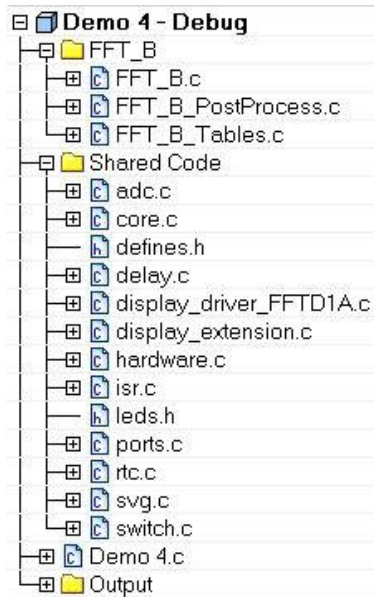
Figure 7. Demo 3 Files



Figure 8. FFTD1A showing a sequence of images direct from FLASH program memory

## 4.6 Demo 4 – Audio Spectrum Analyser

This application shows how the FFTD1A's audio port can be used along with FFT code generated by the FFT Designer software to create an audio spectrum analyser.

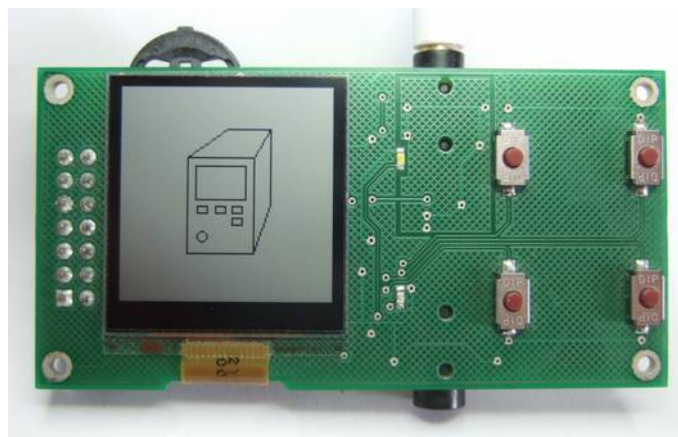


**Figure 9. Demo 4 Files**

The analyser specifications are as follows.

Acquisition	12 bit sampling at 32.768kHz.
Window Function	Kaiser ( $\alpha 2.8$ )
Frequency Conversion	256 point Radix 2 FFT (Cooley Tukey)
Resolution Bandwidth	32.768kHz / 256 = 128Hz
Span	DC to 16.384kHz
Vertical Scale	10dB / Division
Spurious Free Dynamic Range	>50dB
Input Clipping Level	3V p-p
Scale Reference (top)	2V p-p

**Table 2. Spectrum Analyser Demo Specifications**



**Figure 10. Spectrum Analyser Demo showing Icon**

Note. In order to make use of this demo, you will need an audio signal generator. If you don't have one of these, you can also use a PC and software such as "Spectrum Lab".

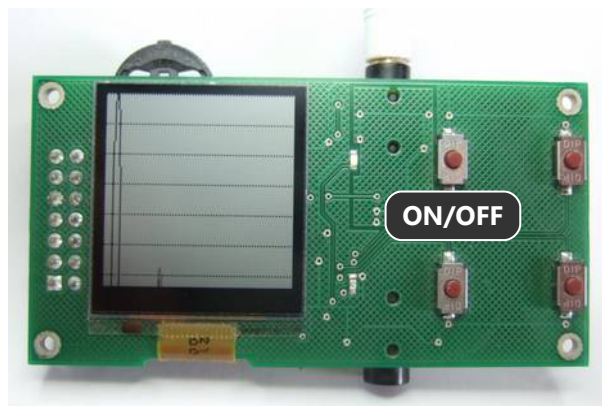
You will also need an audio lead to connect your FFTD1A to the generator. For example a 3.5mm male jack to male jack lead, to connect from a PC headphone socket and the FFTD1A audio port.

Here's what to do...

1. Program Demo 4 into the FFTD1A board and run. The display should resemble Figure 10.
2. Connect the audio signal generator to the FFTD1A's audio port.
3. Set the audio signal generator output frequency to 1kHz.
4. Set the audio signal generator waveform to sinewave.
5. Set the audio signal generator output level to between 1V and 2V peak-to-peak.

Now Press the top-left button to start the demo. The white LED should illuminate and the display should resemble the figure below showing a single peak.

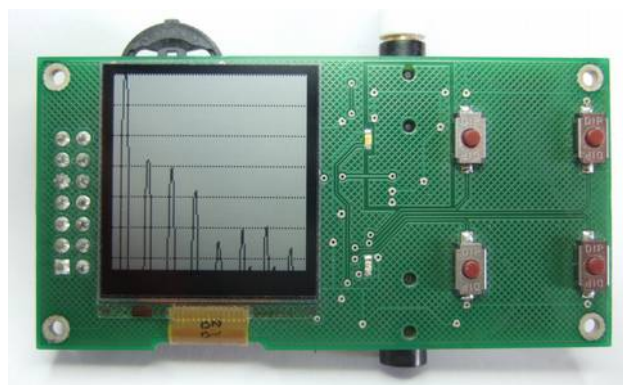
Note. The sample rate is set to 32.768kHz, so the display represents frequencies from DC to 16.384kHz.



**Figure 11. Spectrum Analyser Demo with 1kHz sine-wave at 2V p-p.**

However, if you get a display like the one below, some likely causes are listed below.

1. The signal generator or soundcard output is too high and is clipping (as is the case below)
2. The signal generator output is not set to a sinewave (e.g. square-wave or triangular-wave)
3. The input level is too high for the FFTD1A audio port causing the ADC input to saturate.



**Figure 12. Spectrum Analyser Demo with PC soundcard output-level set too high.**

Note. The FFT demo code is supplied exclusively for use with the FFTD1A development board. If you wish to use FFT Designer generated code on another platform, you must purchase an FFT Designer licence.

### 4.7 Demo 5 – Oscilloscope with FFT Option

This application shows how the FFTD1A can be used to create an oscilloscope combined with a spectrum analyser. Building on demo 4, samples are acquired from the audio port to a circular buffer then displayed as a waveform on the LCD. The scope has variable trigger delay (negative or positive), variable timebase (sampling frequency) and variable volts per division (vertical gain).

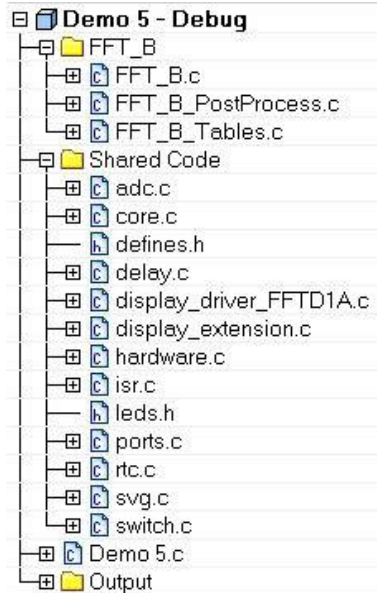


Figure 13. Demo 5 Files

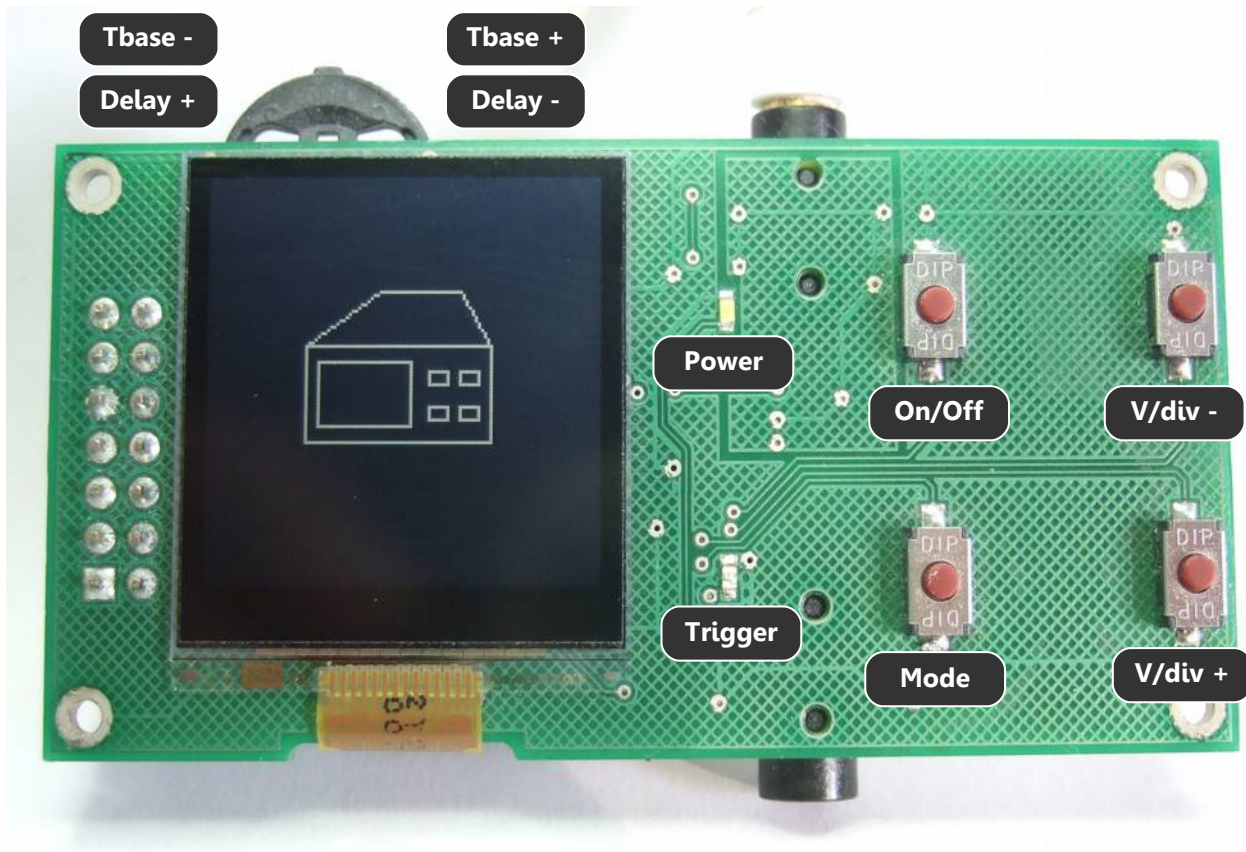


Figure 14. Oscilloscope Demo showing Icon and Controls

The specifications are as follows.

Acquisition	12 bit sampling (internal ADC)
Sample Rate	Variable from 1024Hz to 32.768kHz
Timebase (assuming 4 divisions)	Approximately 1, 2, 4, 8, 16, 32 ms/div
Vertical Scale (4 divisions)	10, 20, 50, 100, 200 or 500mV/div
Triggering Delay	Variable +/- 120 samples
FFT	Same as for demo 4 but with variable sample rate
Input Coupling	AC Only
Input Range for trigger lock	10mV to 3V p-p

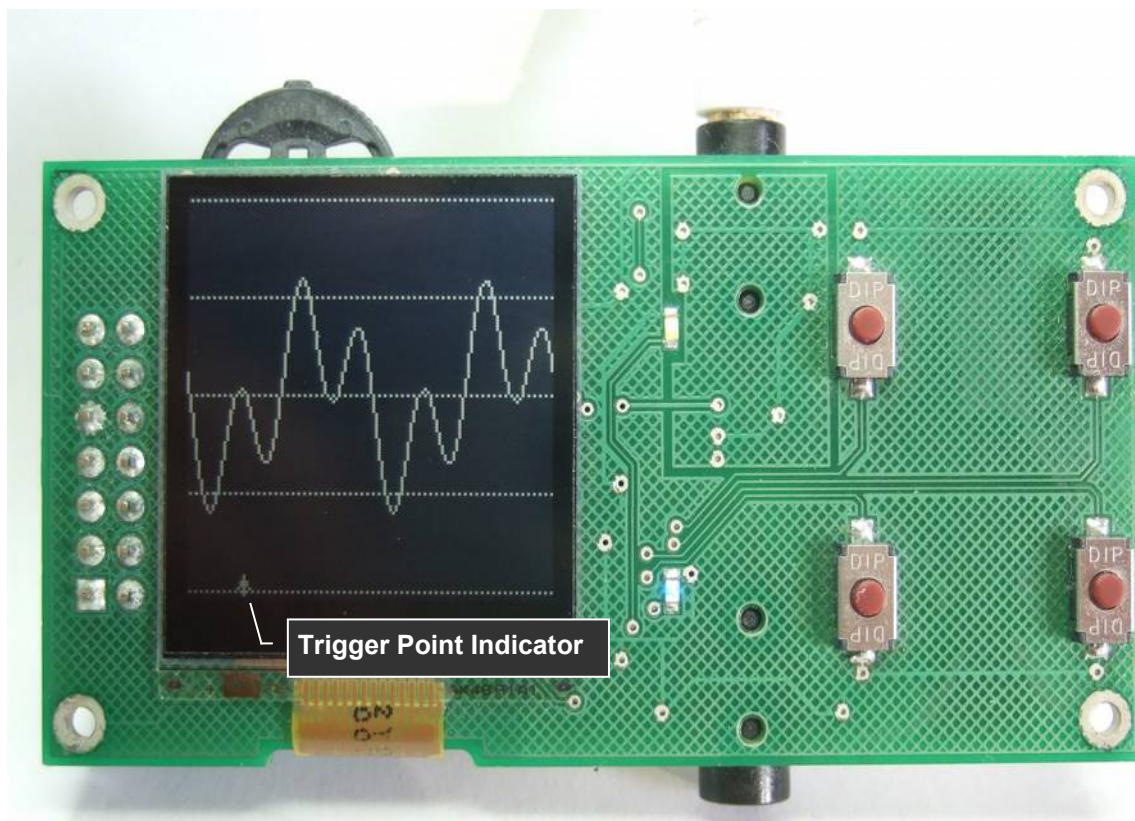
**Table 3. Mini Oscilloscope Demo Specifications**

Note. In order to make use of this demo, you will need an audio signal generator. For the purposes of this document, it is assumed you are using the Spectrum Lab software. See Demo 4.

Here's what to do...

1. Program Demo 5 into the FFTD1A board and run. The display should resemble Figure 14
2. Connect the audio signal generator to the FFTD1A's audio port
3. Set the audio signal generator to output two frequencies, 512Hz and 1536Hz
4. Set the audio signal generator waveform to sinewave
5. Set the audio signal generator output level so it is 2V peak-to-peak.

Now Press the top-left button to start the demo. The white LED should start pulsing and the display should resemble the figure below.



**Figure 15. Oscilloscope Demo showing twin tone signal with -ve trigger delay**

Note. The Blue LED will flash each time a trigger condition is detected.

### Oscilloscope Control

Depressing the 3-way scan-switch SW1 toggles it between controlling trigger delay and sample rate.

Pressing the Mode button SW5 toggles the display between oscilloscope and spectrum analyser.

The right-hand tact switches SW3 and SW4 control the vertical scale.

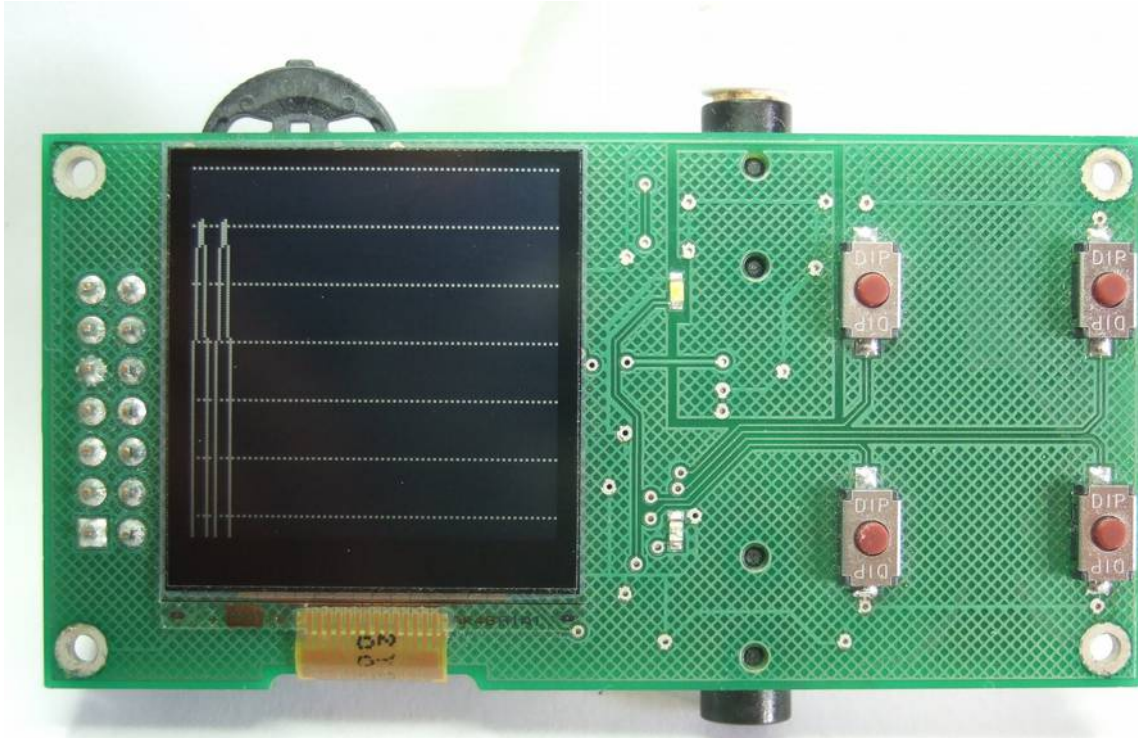


Figure 16. Oscilloscope in FFT spectrum analyser mode

## 5 Custom Firmware

If you require custom firmware for the FFTD1A or MSP430 project, such as an extended Sharp Memory LCD display driver or other DSP functions, please contact RHDC Services Ltd with your enquiry by emailing [sales@fft designer.com](mailto:sales@fft designer.com).