
VS10XX SPECTRUM ANALYZER

VSMPG “VLSI Solution Audio Decoder”

Project Code:

Project Name: VSMPG

| Revision History | | | |
|------------------|------------|--------|---|
| Rev. | Date | Author | Description |
| 1.0 | 2011-05-11 | PO | Added application hook versions of VS1053b plugin. |
| 0.9 | 2008-06-12 | PO | Added VS1033d version and compressed plugin files |
| 0.81 | 2008-02-06 | PO | C loading tables fixed (AIADDR became 0x10 instead of 0xa). |
| 0.8 | 2007-12-31 | PO | VS1053b version, better low-freq res. for VS1011 |
| 0.7 | 2007-03-14 | PO | VS1033b, VS1011e, and VS1011b versions |
| 0.6 | 2006-09-19 | PO | VS1033c version |
| 0.5 | 2005-04-13 | PO | Initial version |

1 Spectrum Analyzer

This patch provides upto 23 spectrum band analyzers for implementing a graphical spectrum analyzer display on the microcontroller. The analyzer works for all audio file types.

The patch code uses the user X and Y memory areas of VS10xx, so you can't use other patch codes that use these areas at the same time. When you upload the code, it will be automatically started. VS1003b, VS1033c, VS1033d, and VS1053b versions can be used simultaneously with patches that use the application hook (SCI_AIADDR), other versions use the application hook to perform the analysis.

Note that the vs1053b patches package can not be used with the default spectrum analyzer version, but the package without FLAC decoder can be used with spectrumAnalyzerAppl1053b-2.

Hardware or software reset will deactivate the patch. You must reload the patch at each hardware reset. You must either set the frequencies or reload the patch at each software reset.

| Chip | File | RAM Usage |
|---------|---|---|
| VS1003b | specana.c spectrumAnalyzer.plg | IRAM 0x050 .. 0x218 XRAM 0x1800 .. 0x187f YRAM 0x1800 .. 0x185b |
| VS1033c | specana1033c.c spectrumAnalyzer1033c.plg | IRAM 0x050 .. 0x217 XRAM 0x1800 .. 0x187f YRAM 0x1800 .. 0x185b |
| VS1033d | specana1033d.c spectrumAnalyzer1033d.plg | IRAM 0x050 .. 0x217 XRAM 0x1800 .. 0x187f YRAM 0x1800 .. 0x185b |
| VS1053b | specana1053b.c spectrumAnalyzer1053b.plg | IRAM 0x050 .. 0x217 XRAM 0x1800 .. 0x187f YRAM 0x1800 .. 0x185b |
| VS1053b | specanaappl1053b.c spectrumAnalyzerAppl1053b.plg | IRAM 0x050 .. 0x228 XRAM 0x1800 .. 0x187f YRAM 0x1800 .. 0x185b |
| VS1053b | specanaappl1053b-2.c spectrumAnalyzerAppl1053b-2.plg | IRAM 0xd00 .. 0xed8 XRAM 0x1810 .. 0x1877 YRAM 0x1820 .. 0x185f |
| VS1033b | specana1033b.c spectrumAnalyzer1033b.plg | IRAM 0x050 .. 0x227 XRAM 0x1800 .. 0x187f YRAM 0x1800 .. 0x185b |
| VS1011e | specana1011e.c spectrumAnalyzer1011e.plg | IRAM 0x050 .. 0x228 XRAM 0x1380 .. 0x13ff YRAM 0x0780 .. 0x07db |
| VS1011b | specana1011b.c spectrumAnalyzer1011b.plg | IRAM 0x050 .. 0x23d XRAM 0x1380 .. 0x13ff YRAM 0x0780 .. 0x07db |

The default number of bands is 14. The default frequencies of the bands are 50, 79, 126, 200, 317, 504, 800, 1270, 2016, 3200, 5080, 8063, 12800, and 20319 Hz. The actual frequencies differ from these slightly, depending among other things on the sampling frequency. Note that the highest bands may not have any information if the sampling frequency is less than 44100 Hz.

With the default 14 bands and 44100 Hz sampling frequency the spectrum analyzer uses about 0.8 MHz of processing power.

The analysis of low frequencies is not very accurate in the VS1011 version.

The default version is not compatible with the VS1053b Patches Package. If you use the VS1053b Patches Package version without the FLAC decoder, you can use spectrumAnalyzerAppl1053b-2.plg (specanaappl1053b-2.c). The memory map is a little different with this version: the structure starts at 0x1810 (instead of 0x1800), and the maximum number of bands is 15, so the results start at 0x1814+16 (instead of 0x1804+24). If you want to configure the bands, the band frequencies are still at 0x1868.

1.1 Communication

| Address VS10x3 | Address VS1011 | Field | Usage |
|----------------|----------------|-------------|----------------------|
| 0x1801 | 0x1381 | rate | Sample rate |
| 0x1802 | 0x1382 | bands | Bands currently used |
| 0x1804..0x181a | 0x1384..0x139a | results | First..last band |
| 0x1868..0x187e | 0x13e8..0x13fe | frequencies | First..last band |

Because VS1011b does not support reading from SCL_WRAM, SCL_AICTRL3 is used for that purpose. To read data from VS1011b spectrum analyzer, first write the address to SCL_WRAMADDR as usual, then perform one dummy read from SCL_AICTRL3. The next read from SCL_AICTRL3 will return the memory data and autoincrement the address. Only X-memory is supported for VS1033b.

1.2 Reading Results

You can read the results from X-RAM addresses 0x1804..0x181a, and the number of used bands from 0x1802. Unused bands are kept at zero, thus you can also skip reading of the bands variable and just read a predefined number of bands.

A suitable update period is from 5 to 20 times per second.

```
#define BASE 0x1800 /* 0x1380 for VS1011 */
    WriteSciReg(SCI_WRAMADDR, BASE+2);
    /* If VS1011b, one dummy ReadSciReg(SCI_AICTRL3); here*/
    bands = ReadSciReg(SCI_WRAM); /* If VS1011b, use SCI_AICTRL3 */
    WriteSciReg(SCI_WRAMADDR, BASE+4);
    /* If VS1011b, one dummy ReadSciReg(SCI_AICTRL3); here*/
    for (i=0;i<bands;i++) {
        int val = ReadSciReg(SCI_WRAM); /* If VS1011b, use SCI_AICTRL3 */
        /* current value in bits 5..0, normally 0..31
           peak value    in bits 11..6, normally 0..31 */
    }
}
```

Six bits are reserved for the current result and a peak value. The values are from zero to 31 in 3 dB steps.

1.3 Setting Bands

You can also change the frequency band center frequencies and the number of bands to best suit your needs. The bands are in XRAM 0x1868..0x187e in ascending order. If not all 23 bands are used, end the list with 25000. To activate the new band selections, write 0 to the sample rate field (0x1801).

```
#define BASE 0x1800 /* 0x1380 for VS1011 */
    int bands = 14;
    static const short frequency[] = {
        50, 79, 126, 200, 317, 504, 800, 1270, 2016, 3200,
        5080, 8063, 12800, 20319
    };
    /* send new frequencies */
    WriteSciReg(SCI_WRAMADDR, BASE+0x68);
    for (i=0;i<bands;i++)
        WriteSciReg(SCI_WRAM, frequency[i]);
    if (i < 23)
        WriteSciReg(SCI_WRAM, 25000);
    /* activate */
    WriteSciReg(SCI_WRAMADDR, BASE+1);
    WriteSciReg(SCI_WRAM, 0);
```

1.4 Reading Frequencies

If you want to read the actual center frequency for each analyzer band, you can use the following code:

```
#define BASE 0x1800 /* 0x1380 for VS1011 */
WriteSciReg(SCI_WRAMADDR, BASE+1);
/* If VS1011b, one dummy ReadSciReg(SCI_AICTRL3); here*/
rate = ReadSciReg(SCI_WRAM); /* If VS1011b, use SCI_AICTRL3 */
bands = ReadSciReg(SCI_WRAM); /* If VS1011b, use SCI_AICTRL3 */

for (i=0;i<bands;i++) {
    int a;
    WriteSciReg(SCI_WRAMADDR, BASE+0x1c+3*i);
    /* If VS1011b, one dummy ReadSciReg(SCI_AICTRL3); here*/
    a = ReadSciReg(SCI_WRAM); /* If VS1011b, use SCI_AICTRL3 */
    freq[i] = (long)rate * a >> 11;

    printf("%2d %3d %5dHz\n", i, a, freq[i]);
}
```

Example output:

```
0  2   43Hz
1  3   64Hz
2  5  107Hz
3  9  193Hz
4 14  301Hz
5 22  473Hz
6 36  775Hz
7 56 1205Hz
8 88 1894Hz
9 128 2756Hz
10 224 4823Hz
11 352 7579Hz
12 576 12403Hz
13 928 19982Hz
```

Note that the actual center frequencies can change when sample rate changes.

2 How to Load a Plugin

A plugin file (.plg) contains a data file that contains one unsigned 16-bit array called plugin. The file is in an interleaved and RLE compressed format. Plugins can be easily combined by using preprocessor `#include` command and the `SKIP_PLUGIN_VARNAME` define. An example of a plugin array is:

```
const unsigned short plugin[10] = { /* Compressed plugin */
    0x0007, 0x0001, 0x8260,
    0x0006, 0x0002, 0x1234, 0x5678,
    0x0006, 0x8004, 0xabcd,
};
```

The vector is decoded as follows:

1. Read register address number `addr` and repeat number `n`.
2. If `(n & 0x8000U)`, write the next word `n` times to register `addr`.
3. Else write next `n` words to register `addr`.
4. Continue until array has been exhausted.

The example array first tells to write 0x8260 to register 7. Then write 2 words, 0x1234 and 0x5678, to register 6. Finally, write 0xabcd 4 times to register 6.

Assuming the array is in `plugin[]`, a full decoder in C language is provided below:

```
void WriteVS10xxRegister(unsigned short addr, unsigned short value);

void LoadUserCode(void) {
    int i = 0;

    while (i<sizeof(plugin)/sizeof(plugin[0])) {
        unsigned short addr, n, val;
        addr = plugin[i++];
        n = plugin[i++];
        if (n & 0x8000U) { /* RLE run, replicate n samples */
            n &= 0x7FFF;
            val = plugin[i++];
            while (n--) {
                WriteVS10xxRegister(addr, val);
            }
        } else { /* Copy run, copy n samples */
            while (n--) {
                val = plugin[i++];
                WriteVS10xxRegister(addr, val);
            }
        }
        i++;
    }
}
```

3 How to Use Old Loading Tables

Each patch contains two arrays: `atab` and `dtab`. `dtab` contains the data words to write, and `atab` gives the SCI registers to write the data values into. For example:

```
const unsigned char atab[] = { /* Register addresses */
    7, 6, 6, 6, 6
};
const unsigned short dtab[] = { /* Data to write */
    0x8260, 0x0030, 0x0717, 0xb080, 0x3c17
};
```

These arrays tell to write 0x8260 to `SCI_WRAMADDR` (register 7), then 0x0030, 0x0717, 0xb080, and 0x3c17 to `SCI_WRAM` (register 6). This sequence writes two 32-bit instruction words to instruction RAM starting from address 0x260. It is also possible to write 16-bit words to X and Y RAM. The following code loads the patch code into VS10xx memory.

```
/* A prototype for a function that writes to SCI */
void WriteVS10xxRegister(unsigned char sciReg, unsigned short data);

void LoadUserCode(void) {
    int i;
    for (i=0;i<sizeof(dtab)/sizeof(dtab[0]);i++) {
        WriteVS10xxRegister(atab[i]/*SCI register*/, dtab[i]/*data word*/);
    }
}
```

Patch code tables use mainly these two registers to apply patches, but they may also contain other SCI registers, especially `SCI_AIADDR` (10), which is the application code hook.

If different patch codes do not use overlapping memory areas, you can concatenate the data from separate patch arrays into one pair of `atab` and `dtab` arrays, and load them with a single `LoadUserCode()`.