AVR32134: AVR32 UC3 3D Graphic Rendering Application

Features

- 3D Rotating Cube Application
- Graphical 3D Software Library Engine
- EVK1101 Extension-Board Schematics
  - Graphical LCD Display
  - Audio Codec
  - DC-DC converter on power supply 5V to 7V
  - Low level Graphical LCD Display driver

1. Introduction

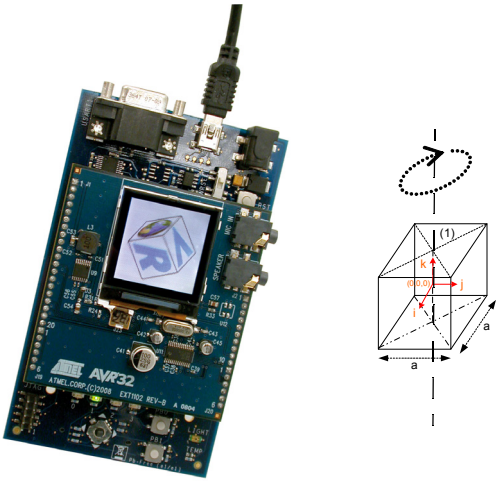
This application note demonstrates a real time bitmap texture mapping on a 3D rotating Cube. The real time image is processing using DSP instructions without any hardware acceleration.

An extension board example with graphical LCD and audio module. It demonstrates how to use a 32-bit AVR® microcontroller to control a 128x128 pixel graphical LCD and an audio codec module.

This extension board is designed to be plugged on top of the EVK1101 evaluation kit.

This extension board is not available in production: schematics and layout are provided as examples in the appendices.

Figure 1-1. 3D Graphic Rendering Application



32-bit AVR® Microcontrollers

Application Note

32100C–AVR32–04/09

2. EVK1101 Extension-Board Hardware

2.1 Feature Overview

The schematics and bill of materials can be found in the Appendix.

Table 2-1. Package description

Type	Names	Description
Hardware Package	AVR32134/HW	Schematics Layout files Bill of Materials

2.2 LCD display

The EVK1101 Extension-Board features a Nokia® LCD Graphical Display, a 128x128 pixel graphical LCD (4096 colors) interfaced with a serial controller Epson® S1D15G10 (in SPI mode).

2.3 Audio Codec Interface

The EVK1101 Extension-Board features an audio codec TLV320AIC23B with a serial mode for configuration and I2S mode for data stream.

2.4 Power supply - battery

The EVK1101 Extension-Board is powered from the EVK1101 on which it is plugged. In order to correctly power up the LCD, a 7V voltage DC-DC converter is required.

Table 2-2. The EVK1101 Extension-Board connection

Pin	Net Name	Pin	Net Name
J1.1	VCC5	J2.1-J2.8	Not Connected
J1.2	GND	J2.9	VCC3
J1.3-J1.11	Not Connected	J2.10	GND
J1.12	/CS / PA9	J20.1	Not Connected
J1.13	/RESET / PA10	J20.2	SSC_RX / PB7
J1.14-J1.16	Not Connected	J20.3	SSC_SYNC_RX / PB8
J1.17	SDATA- TLV_MISO / PA14	J20.4	SSC_CLOCK_TX / PB9
J1.18	SCLK - TLV_CLK / PA15	J20.5	SSC_TX / PB10
J1.19	VCC3	J20.6	SSC_SYNC_TX / PB11
J1.20	GND		
J19.1-J19.4	Not Connected		
J19.5	TLV_CS / PB4		
J19.6	Not Connected		

3. 3D Graphic Rendering Software

3.1 Package Description

Table 3-1. Package description

Type	Names	Description
Firmware Package	AVR32134/SW	Source Code Package for UC3B-ES (revB only) and UC3B parts

3.1.1 Implementations Details

3.1.1.1 Compiler

The IAR® project is located here:

- AVR32134/SW/3D_CUBE_x.y.z/APPLICATIONS/EVK1101-3D-DISPLAY/3D_CUBE/AT32UC3B0256xx/IAR

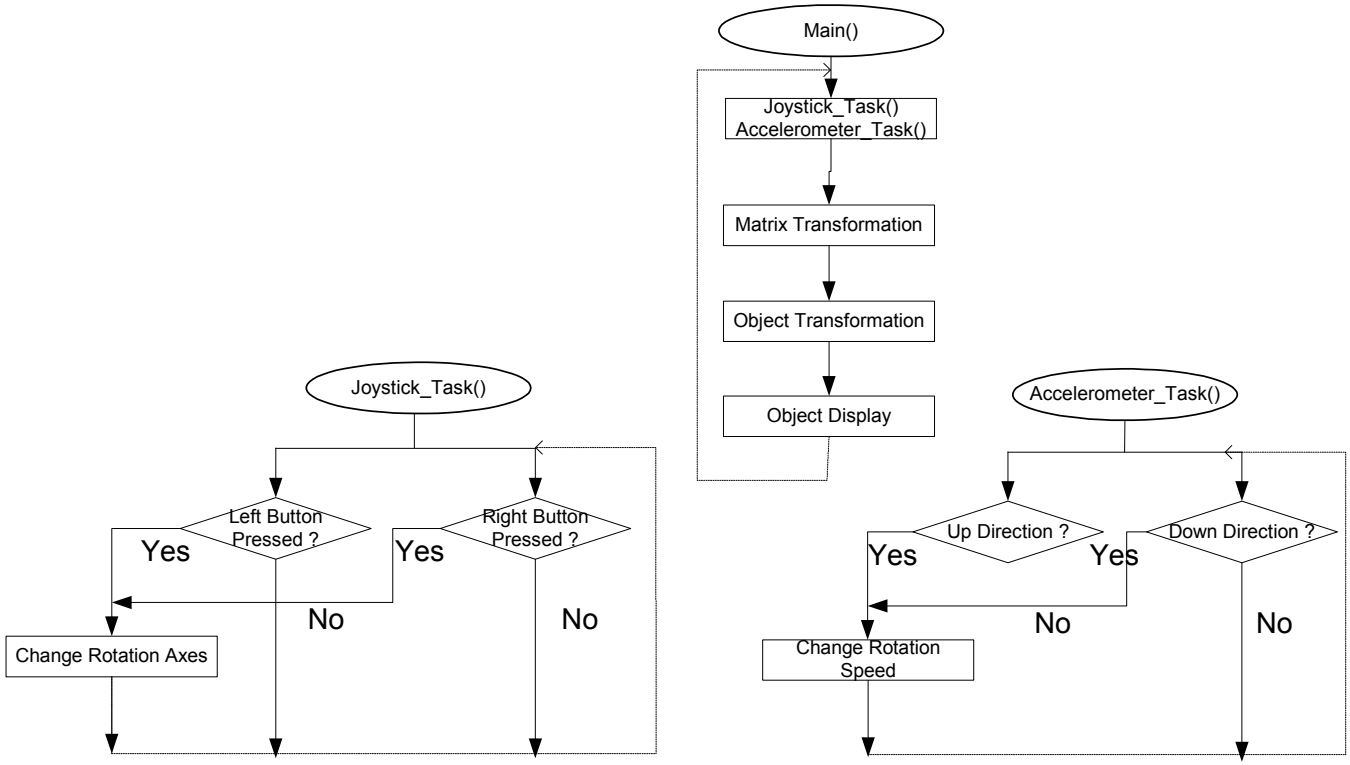
The GCC project is located here:

- AVR32134/SW/3D_CUBE_x.y.z/APPLICATIONS/EVK1101-3D-DISPLAY/3D_CUBE/AT32UC3B0256xx/GCC

3.1.1.2 Application State Machine

The 3D cube application is based on two independent tasks. The first one responds to joystick changes. When left/right button is pressed, the rotation axe of the 3D cube is changed. The second task responds to the accelerometer changes. When an up/down direction is detected, the speed rotation of the 3D cube is changed. So rotation axes and speed are controlled on the fly.

Figure 3-1. . 3D Cube Application State Machine



3.1.1.3 *Main ()*

The Main project is located here:

`AVR32134/SW/3D_CUBE_x.y.z/APPLICATIONS/EVK1101-3D-DISPLAY/3D_CUBE/`

With:

- /CONF: configuration header files of demo modules:
  - CPU settings
  - Peripheral Clock settings
  - Display settings
  - Board Connection
- application.c is the main module of the demo. It contains the main () function and state machine description.

3.2 Drivers

All paths given in Table 3-3. Library file names3-2 are relatives to this path:

`AVR32134/SW/3D_CUBE_x.y.z/APPLICATIONS/EVK1101-3D-DISPLAY/3D_CUBE/`

Table 3-2. Driver file names

Driver name	Source file	Header file
LCD Display Driver	`lcd_nokia.c`	`lcd_nokia.h`
Accelerometer Driver	`dv_accelerometer.c`	`dv_accelerometer.h`
Joystick Driver	`dv_joystick.c`	`dv_joystick.h`

3.2.1 LCD display

The LCD display driver contains useful interface functions to setup the LCD serial controller. This driver delivers basic low level functions for applications for pixel manipulation *_put_pixel()* and string manipulation *_string(char *lcd_string,…)*

3.2.2 Accelerometer

The accelerometer driver manages the 3-axis accelerometer and controls the cube rotation speed

3.2.3 Joystick

The joystick controls the cube rotation axe.

.

3.3 Library

All paths given in Table 3-3. Library file names3-3 are relative to this path:

`AVR32134/SW/3D_CUBE_x.y.z/APPLICATIONS/EVK1101-3D-DISPLAY/3D_CUBE/`

Table 3-3. Library file names

Library name	Source file	Header file
3D Engine that computes 3D matrix	`3D_engine.c`	`3D_engine.h`
3D Objects that contains 3D objects definition (3D cube, structural bitmap)		`picture_objects.h`

3.3.1 Basic principles

3.3.1.1 Matrix Transformation

A 3D transformation is based on matrix multiplications. One vector $\vec{U}$ in an orthogonal base $(\vec{i},\vec{j},\vec{k})$ could be expressed with its 3 coordinates:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} (\vec{i},\vec{j},\vec{k})$$

A rotation is expressed with an angle φ and a rotation axe called $\vec{N}$ defined in the $(\vec{i},\vec{j},\vec{k})$ base.

The vector $\vec{N}$ with its 3 coordinates is:

$$\begin{bmatrix} n_x \\ n_y \\ n_z \end{bmatrix} (\vec{i},\vec{j},\vec{k})$$

If $\vec{V}$ is the transformed vector of $\vec{U}$, the new coordinates could be expressed as:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = [M] \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

We will admit that M is expressed as:

$$M = \cos\varphi \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + (1-\cos\varphi) \begin{bmatrix} n^2{}_x & n_x n_y & n_x n_z \\ n_x n_y & n^2{}_y & n_y n_z \\ n_x n_z & n_y n_z & n^2{}_z \end{bmatrix} + \sin\varphi \begin{bmatrix} 0 & -n_z & n_y \\ n_z & 0 & -n_x \\ -n_y & n_x & 0 \end{bmatrix}$$

In order to normalize $\vec{N}$ vector during computation, we have chosen to scale (n_x, n_y, n_z) components on a signed 16bits variable.

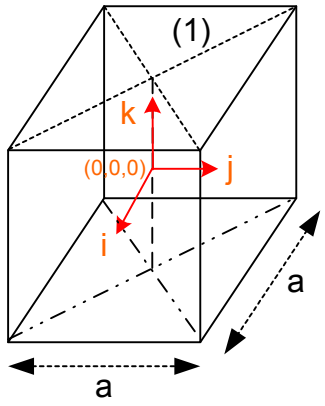
So the data range is defined from 0x8000 (-1 value) to 0x7FFF (+1 value)

Picture Encoding

In order to optimize data encoding, some choices have been made to describe pictures.

For a 3D cube the landmark is centered in the middle of th cube.

Figure 3-2. . 3D Cube representation



Thus every face is encoded by its four vertexes as:

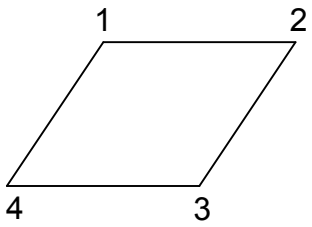
Table 3-4. Vertex encoding

Face	Coordinate (i ,j, k)
(1)	(-a/2,+a/2,+a/2); (-a/2,-a/2,+a/2); (+a/2,-a/2,+a/2); (+a/2,+a/2,+a/2);
(2)	(-a/2,+a/2,-a/2); (-a/2,-a/2,-a/2); (+a/2,-a/2,-a/2); (+a/2,+a/2,-a/2);
(3)	(-a/2,+a/2,-a/2); (-a/2,+a/2,+a/2); (-a/2,-a/2,+a/2); (-a/2,-a/2,-a/2);
(4)	(+a/2,+a/2,-a/2); (+a/2,+a/2,+a/2); (+a/2,-a/2,+a/2); (+a/2,-a/2,-a/2);
(5)	(-a/2,+a/2,-a/2); (-a/2,+a/2,+a/2); (+a/2,+a/2,+a/2); (+a/2,+a/2,-a/2);
(6)	(-a/2,-a/2,-a/2); (-a/2,-a/2,+a/2); (+a/2,-a/2,+a/2); (+a/2,-a/2,-a/2);

With this information we are only able to describe vertices but one other information is necessary, the link between every vertex on one face.

If we encode the 4 vertices of one face with values (0,1,2,3) we can describe path from 0 to 1, then 1 to 2, then 2 to 3 and 3 to 0 as (0,1,1,2,2,3,3,0)

Figure 3-3. Face representation



Therefore the encoding solution could be:

– A first structure describing n*(x, y, z) coordinates for every face

– A second structure describing n*link for every vertex on one face.

If we consider in a second time a 2D picture. This picture is encoded in (x,y) with a 8 bits resolution for every color: 3 bits for Red, 3 bits for Green and 2 bits for Blue.

The goal of the application is to display picture on one face of the 3D cube. This means that the z coordinate is expressed as a value equal to –a/2 or + a/2.

Therefore the encoding solution could be:

- A first structure describing n*(x,y,z) coordinates for every face.
- A second structure describing n*color expressed.

Remarks:

For a 60x60 pixels picture, the size of the encoded picture with:

- 8 bits resolution for x
- 8 bits resolution for y
- 8 bits resolution for z
- 8 bits resolution for color

The total size is equal to **14.4ko**

3.3.2 3D Usage Library

3.3.2.1 Matrix computation

As stated in Matrix Transformation, the rotation vector should be defined as an angle φ and a rotation axes called $\vec{N}$. The combination of these two elements defines the matrix M.

We should respect that:

$$\left\|\vec{N}\right\| = \sqrt{(x^2 + y^2 + z^2)} = 1$$

With the encoding data solution chosen, the 1 value corresponds to the hexadecimal value 0x7fff.

For example:

In case we want to initialize M matrix with an φ angle equal to 60 degrees and a $\vec{N}$ rotation axe equal to:

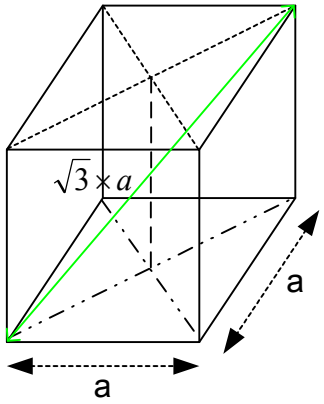
$$\vec{N} = \begin{bmatrix} 0.5 \\ 0.5 \\ 0.5 \end{bmatrix} (\vec{i}, \vec{j}, \vec{k})$$

We can call specific function:

```
// N = (0.5,0.5,0.5) so x = y = z = 0x7000/sqrt(3) = 0x49E6
// Teta = 60°
mrot_C8_FULL_FFIX(MYTSFMATR, teta, 0x49E6, 0x49E6, 0x49E6);
```

3.3.2.2 *Maximum cube size*

Figure 3-4. . Maximum Display Size



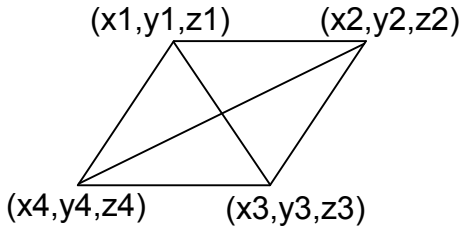
The LCD Display screen gets 120x120 pixels. In order to be able to display a complete diagonal, we need to take care that:

$\sqrt{3} \times a_{\max} = 120$ So $a_{\max} \approx 68$ pixels.

3.3.2.3 *Display Optimization*

In order to optimize display, one solution is to calculate the center of each face.

Figure 3-5. Face Coordinates



The principle of the optimization is if the next face to display has a center with a z value lower than the current one, it means the next one is hidden. The algorithm is the following:

```
//! Preamble: zbuffer contains z values of the 6 centers
//! corresponding to the 6 faces of the 3D Cube


// 3D Cube faces Declaration, 6 faces
int Faces[6] = {0, 1, 2, 3, 4, 5};

int swap, temp, i;
do
{
  swap = 0;
```

```
    // For the 6 faces of the Cube
    for (i = 0; i < 5; i++)
      // If Next Buffer to display has an z value higher than //
      current one, swap current z with new z face value
      if (zbuffer[Faces[i]] > zbuffer[Faces[i+1]])
      {
        temp = Faces[i];
        Faces[i] = Faces[i+1];
        Faces[i+1] = temp;
        swap = 1;
      }
  }
  while (swap);

  Number_Face_to_print = 0;
  // Display the 3 first one faces
  for (i = 0; i < 3; i++)
  {
    Face_to_prints[i] = Faces[5-i];
    if (zbuffer[Face_to_prints[i]]) Number_Face_to_print++;
    else break;
}
```

4. Running the Application

The AVR32 UC3 ISP solution offers an easy way to download files into AVR32 products on Atmel® Evaluation Kits through the JTAG link (via the JTAGICE mkII debugger tools) or the USB bootloader.

Follow the steps below to build the application, load and run the code:

If you are using GCC with the AVR32 GNU Toolchain:

- Make sure the board is powered off.
- Plug power cable on EVK1101 and power it at 9V.
- In case you use a JTAG link
  - Plug the JTAGICE mkII between the PC and the EVK1101 using the JTAG connector.
  - Open a shell, go to the APPLICATIONS\EVK1101-3D-DISPLAY/3D_CUBE/AT32UC3B0256ES/ directory and type :

    make rebuild program run
- In case you use USB bootloader:
  - Plug the USB cable between the PC and the EVK1100 using the USB connector.

Open a shell, go to the APPLICATIONS\EVK1101-3D-DISPLAY/3D_CUBE/AT32UC3B0256ES/GCC directory and type:

make rebuild isp program run

If you are using AVR32 Studio:

Place and extract the content of the AVR32134.zip file in D:\temp\

- Open AVR32Studio
- Click on File -> new -> AVR32 C Project
  - New name: 3D
  - Specify the target UC3B0256
- Right click on project -> import -> Archive File ->
  - Select from archive D:\temp\AVR32134\SW\3D_CUBE_x.y.z.zip
  - Into folder: select the created project 3D.
- Right click on project -> Build Project

If you are using IAREmbedded Workbench® for Atmel AVR32:

- Make sure the board is powered off.
- Plug the JTAGICE mkII between the PC and the EVK1100 using the JTAG connector. Plug power cable on EVK1101 and power it at 9V.
- Open IAR and load the associated IAR project of this application (located in the directory: APPLICATIONS/EVK1101-3D-DISPLAY/3D_CUBE/AT32UC3B0256ES/IAR).
- Press the “Debug” button at the top right of the IAR interface. The project should compile.
- Then the generated binary file is downloaded to the microcontroller to finally switch on the debug mode.
- Click on the “Go” button in the “Debug” menu or press F5.

The code then starts running.

5. Appendix

5.1 Schematics

Figure 5-1. Expansion Headers

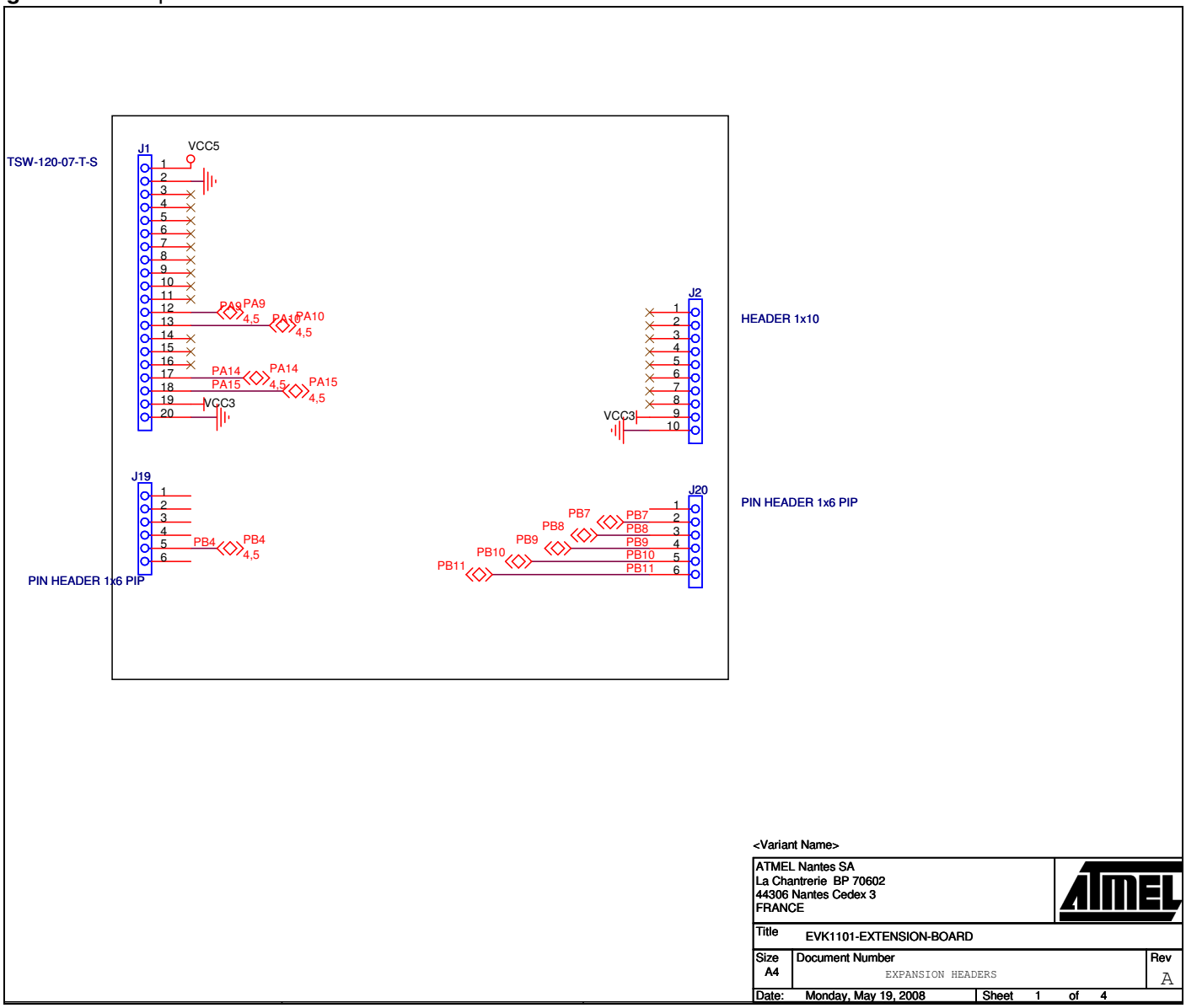


Figure 5-2. Display Connection

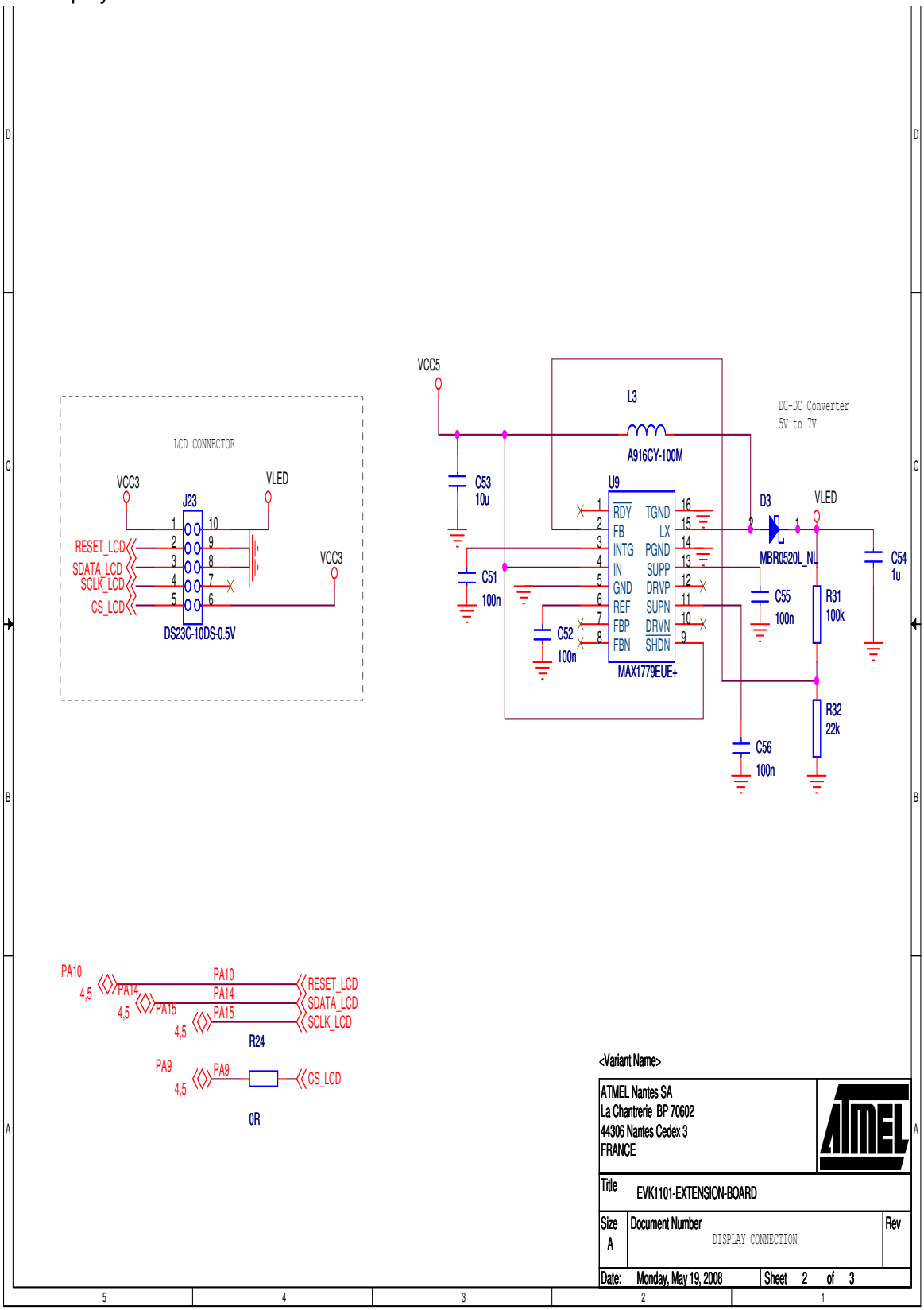
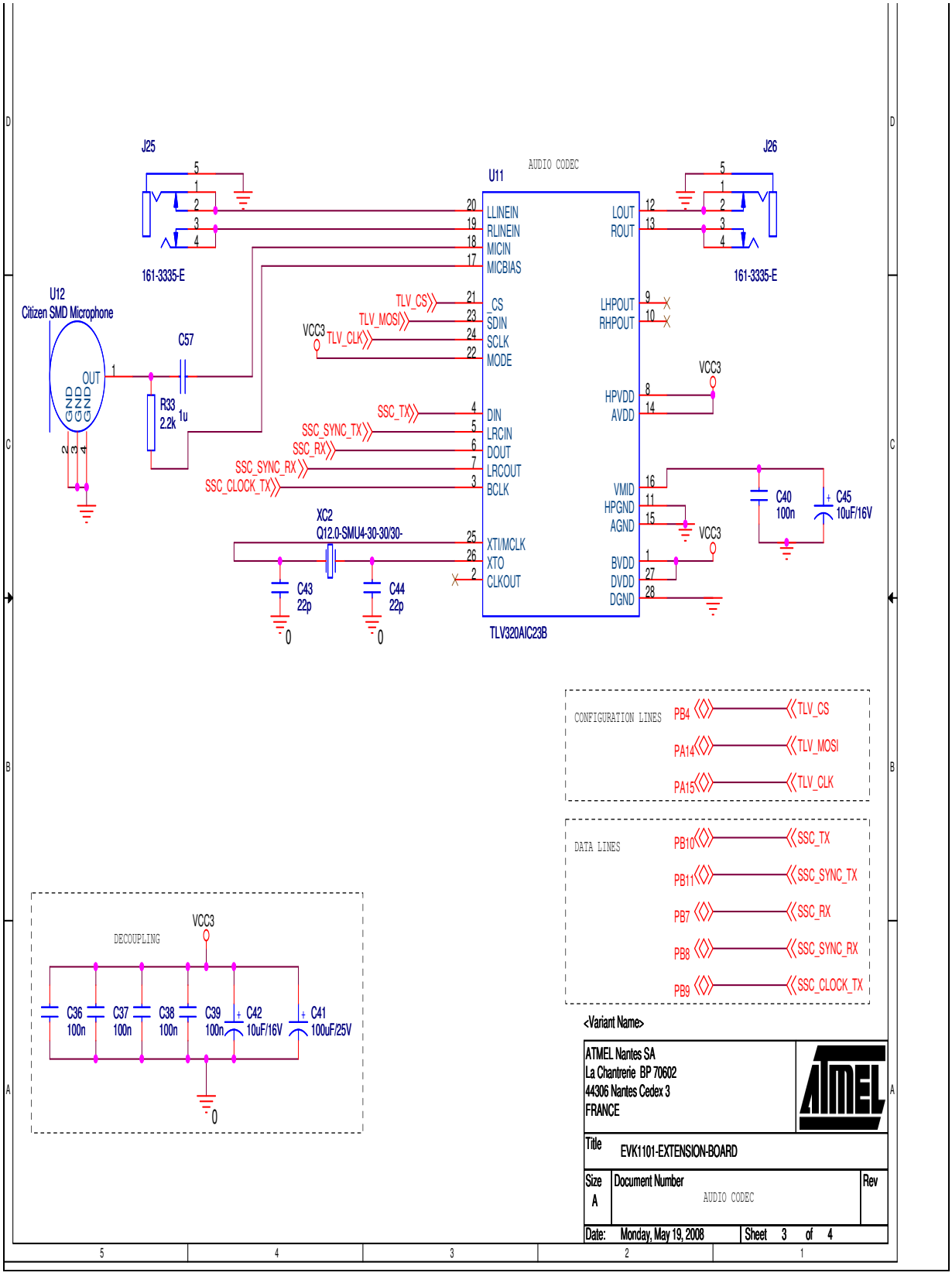


Figure 5-3. Audio Codec



5.2 Bill of Materials

Table 5-1. Bill of Materials for EVK1101-Extension-Board (rev A).

Quantity	MPN/ brief	Manufacturer	Description	Designator
9	100n	Kemet®	Ceramic capacitor, SMD 0402, X7R, 16V, +/-10%	C36 C37 C38 C39 C40 C51 C52 C55 C56
1	100uF/25V		SMD aluminium electrolytic capasitor Ø8mm, H10mm, 85degC, 16V, Max rippel=0.180(@105degC, 120Hz), Tan=0.16	C41
2	10uF/16V		SMD aluminium electrolytic capacitor Ø4mm, H5.3mm, 85degC, 16V, Max rippel=0.017(@85degC, 120Hz), Max ESR=26.52(@20 degC, 120Hz), Tan=0.16	C42 C45
2	10n	Kemet®	Ceramic capacitor, SMD 0603, NP0, 50V, ±5 %	C43 C44
1	10u		Ceramic capacitor, SMD 0805, Y5V, 10V, -20/+80 %	C53
1	1u		Ceramic capacitor, SMD 0805, X7R, 10V, ±10 %	C54
1	1u		Ceramic capacitor, SMD 0805, Y5V, 16V, +80/-20 %	C57
1	MBR0520L_NL	Fairchild	SMD Schottky diode, 0.5A 20V	D3
2	TSW-120-07-T-S	SAMTEC	1x20 pin header, 2.54 mm pitch THM	J1 J2
2	PIN HEADER 1x6 PIP	Freber	1x6 pin header, 2.54mm pitch, THM Pin-In-Paste	J19 J20
1	DS23C-10DS-0.5V	HIROSE	2x5 receptacle 0.5 mm pitch for LCD display	J23
2	161-3335-E	Mouser	SMD 3.5 mm stereo phone jack	J25 J26
1	A916CY-100M	TOKO	10uH SMT power inductor	L3
1	0R		Thick film resistor, SMD 0603, 1/10W, 1%	R24
1	100k		Thick film resistor, SMD 0603, 1/10W, 1%	R31
1	22k		Thick film resistor, SMD 0603, 1/10W, 1%	R32
1	2.2k		Thick film resistor, SMD 0603, 1/10W, 1%	R33
1	MAX1779EUE+		LCD Voltage Regulator	U9
1	TLV320AIC23B		Stereo Audio Codec	U11
1	Citizen SMD Microphone		Citizen 4.2x4.2mm SMD electmic	U12
1	Q12.0-SMU4-30-30/30-		12.0MHz crystal, SMD	XC2

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