Application Report

SLAA541–June 2012

PCM512x ROM Code

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Audio Converters

ABSTRACT

This application note describes the operation of the PCM512x fixed function stereo DAC using PurePath Studio's Graphical Development Environment (GDE). Set up and configuration of the associated PCM51xxEVM-U is also covered in this application note. The PCM512x provides for embedded signal processing features incorporating multiple programmable biquad filters, mixers, muxes, and a 3-band DRC, as well as zero-crossing volume control for optimizing audio quality for either 2.0 or 2.1 functionality. Audio input is supported via a digital audio interface (that is, I2S) while a high performance DAC implemented with an 8x oversampled digital FIR filter outputs analog signals via the 2.1 Vrms ground-centered outputs. This allows designers to eliminate DC blocking capacitors on the output, as well as external muting circuits traditionally associated with single supply line drivers. On optional subwoofer channel is provided on a digital audio interface.

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1 Introduction

The PCM512x DAC is a member of Texas Instrument's widely adopted family of audio codecs that incorporates both analog and digital technologies for a highly integrated single-chip audio system. This application note describes the features, control capabilities, and operating procedures for the PCM512x fixed function stereo DAC development system including PurePath Studio's Graphical Development Environment (GDE). Set up and configuration of the associated PCM51xxEVM-U is also covered in this application note.

The PCM512x provides for imbedded signal processing features incorporating multiple programmable biquad filters, mixers, muxes and a 3 band DRC as well as zero crossing volume control for optimizing audio quality for either 2.0 or 2.1 functionality. These processing features are defined as individual components implemented in a PurePath Studio processing flow supported by various control properties and GUIs. Audio input is supported via a digital audio interface (that is, I2S) while a high performance DAC implemented with an 8x oversampled digital FIR filter outputs analog signals via the 2.1 Vrms ground centered outputs. This allows designers to eliminate DC blocking capacitors on the output, as well as external muting circuits traditionally associated with single supply line drivers. On optional subwoofer channel is output on a digital audio interface.

2 PCM512x ROM Overview

The PCM512x is a monolithic CMOS integrated circuit that includes a stereo digital-to-analog converter and additional support circuitry in a small TSSOP package. The PCM512x uses the latest generation of TI's advanced segment DAC architecture to achieve excellent dynamic performance and improved tolerance to clock jitter. The PCM512x incorporates a set of fixed function processing blocks referred to as components implementing features such as biquad filters (that is, EQ), 3-band dynamic range compression, zero crossing volume control and a separately controlled subwoofer channel. Each of these components is described in this application note. Other features not associated with the programming and control of the processing components are not covered by this application note.

3 Getting Started

PurePath Studio is opened by double clicking the PurePath Studio GDE icon: 

The GDE window opens in Edit Mode with the Properties window shown on the right and the Processing Flow environment empty. To open the PCM512x ROM process flow chose the "Open ROM" option from the file menu.

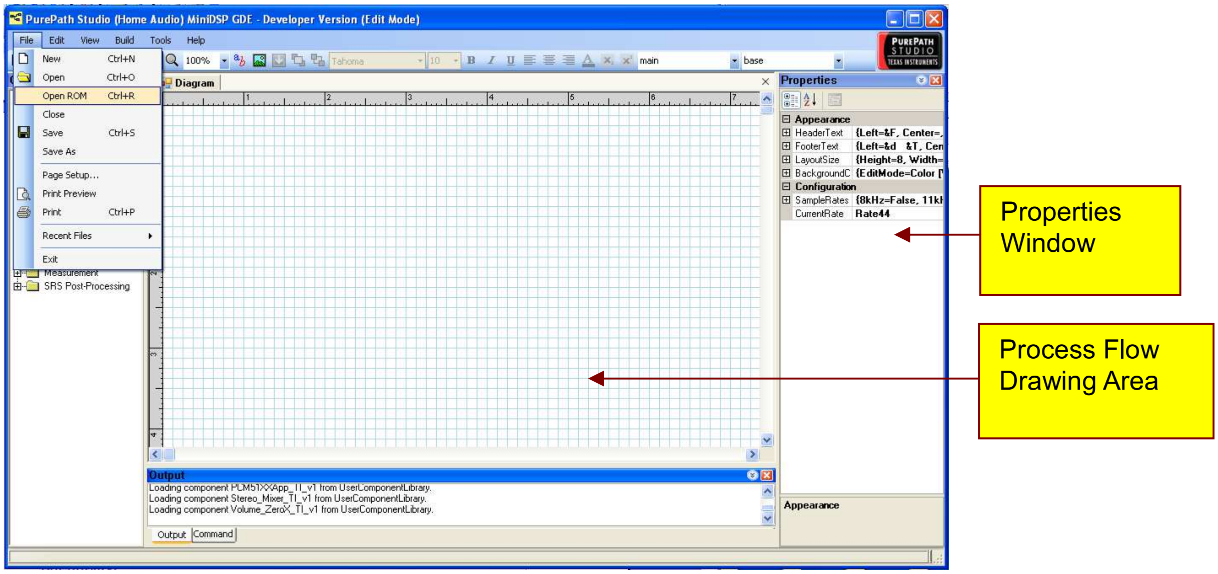


Figure 1. PurePath Studio Graphical Development Environment (GDE)

3.1 Input Options

There are three audio input options including input via the EVM's SPDIF-Coax connector, SPDIF-Optical connector or the USB connector. A window is displayed following when choosing the "Open ROM" option.

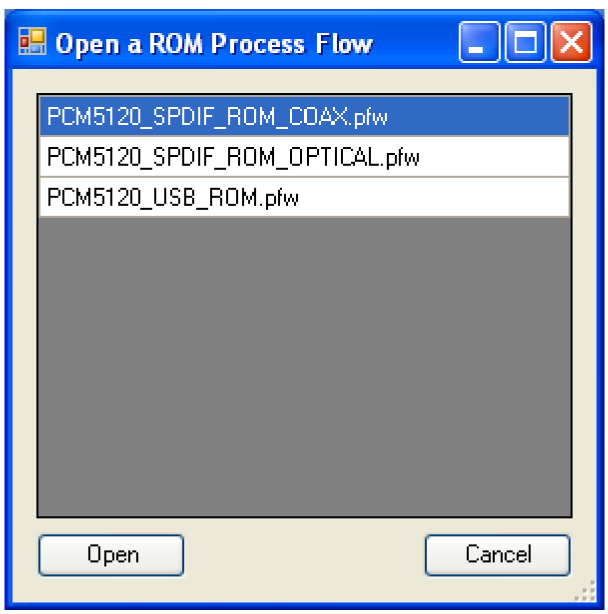


Figure 2. PCM51xxEVM-U Audio Input Options

After choosing the input option, click “Open”. The PCM512x ROM process flow appears in the Process Flow environment as shown below with instructions on how to configure your EVM for the chosen input option.

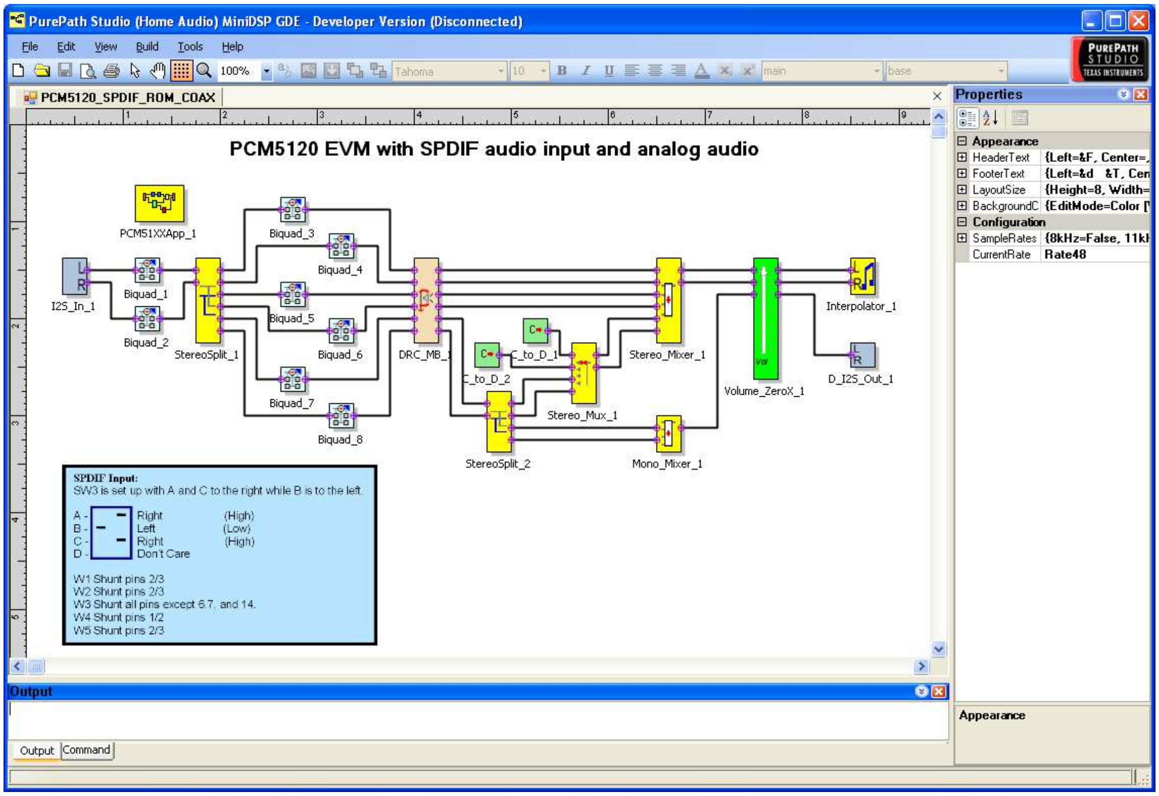
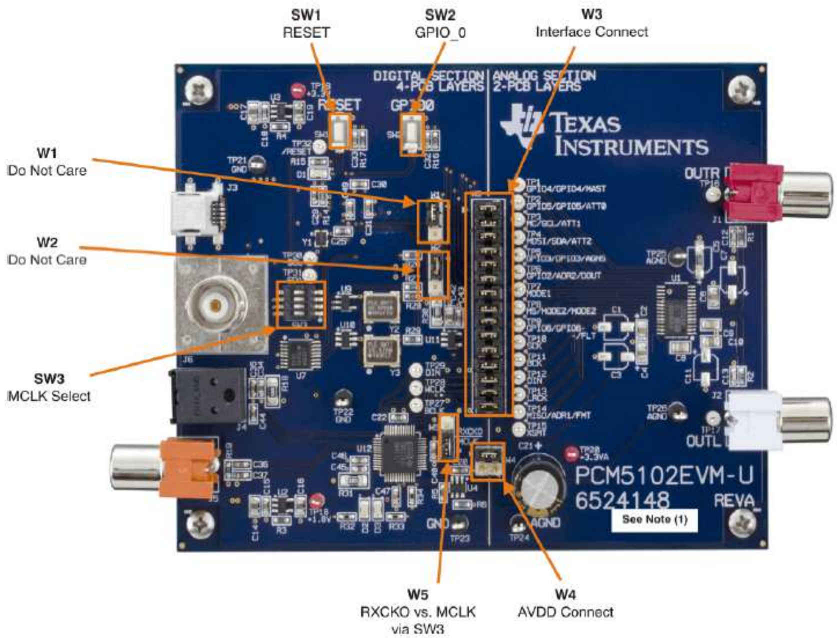


Figure 3. PCM512x ROM Process Flow

3.2 Connecting to the EVM

Connect your computer to the PCM51xxEVM-U via the USB connector. This allows PurePath Studio to load the program and communicate directly with the PCM512x. This connection also streams audio from your laptop to the EVM if you have chosen the USB input option.

Configure the jumpers and switch settings as described by the instructions provided in the process flow. These instructions are duplicated below. These settings configure the EVM for the appropriate clocking configuration and audio routing. Note that the jumper and switch settings are the same for SPDIF-Coax and SPDIF-Optical.



(1) The silkscreen label shown on the board may be different to indicate a specific device. Otherwise, the EVM is identical to the one shown here.

Figure 4. PCM512x EVM

SPDIF Input:
SW3 is set up with A and C to the right while B is to the left.

A -	Right	(High)
B -	Left	(Low)
C -	Right	(High)
D -	Don't Care	

W1 Shunt pins 2/3
W2 Shunt pins 2/3
W3 Shunt all pins except 6.7, and 14.
W4 Shunt pins 1/2
W5 Shunt pins 2/3

USB Input:
SW3 is set up with A, B, and C to the left.

A -	Left	(Low)
B -	Left	(Low)
C -	Left	(Low)
D -	Don't Care	

W1 Shunt pins 2/3
W2 Shunt pins 2/3
W3 Shunt all pins except 6.7, and 14.
W4 Shunt pins 1/2
W5 Shunt pins 1/2

Figure 5. PCM512xEVM-U Configuration Overview

Connect your output device to the analog RCA connectors (OUTL/OUTR) and your input source to the appropriate connector (SPDIF-Coax (J5), SPDIF-Optical (J4), USB – (J3)). Note that after loading the executable in the next step audio is streamed through the EVM. Set the output amplifier to low, reasonable level before loading the executable.

To load the PCM512x executable to the EVM chose the “Connect” option from the Build menu.

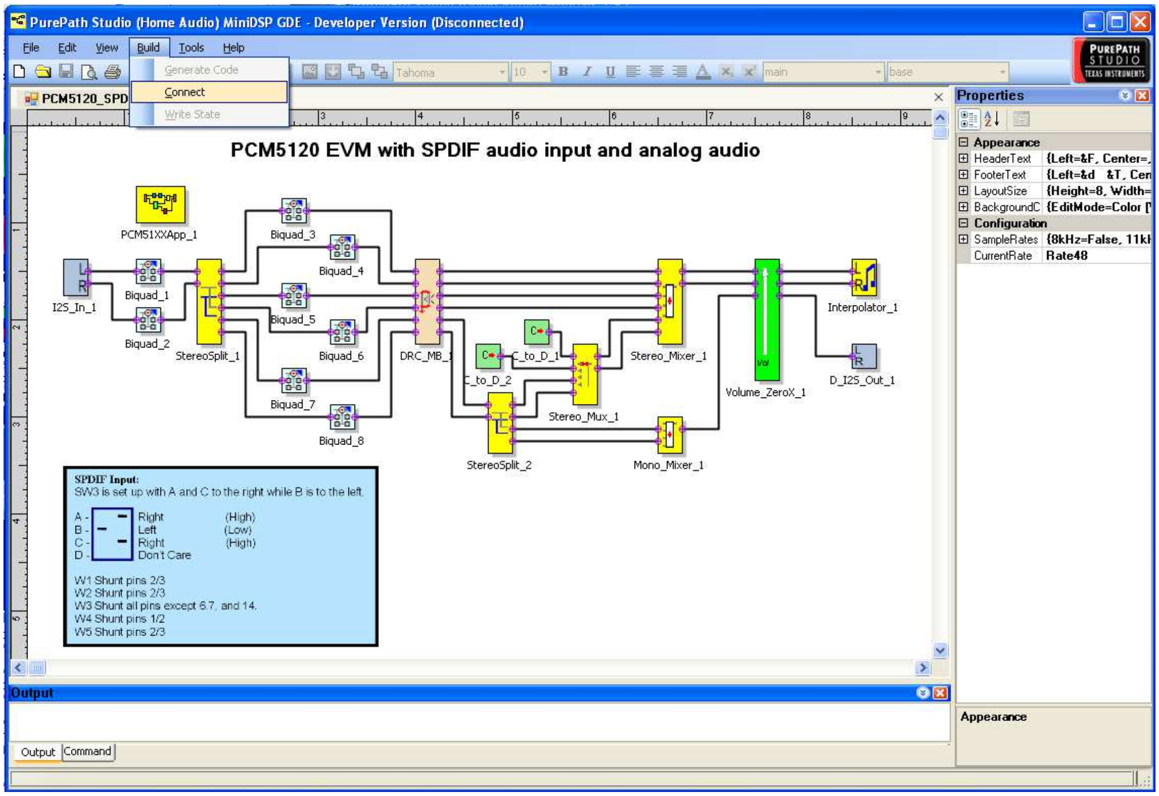


Figure 6. Connecting to the EVM

3.3 Firmware Startup

PurePath Studio automatically loads the executable and configures the board to input audio from the chosen port. The EVM is now configured to pass audio. The process flow environment is shaded blue when the executable has been completely loaded.

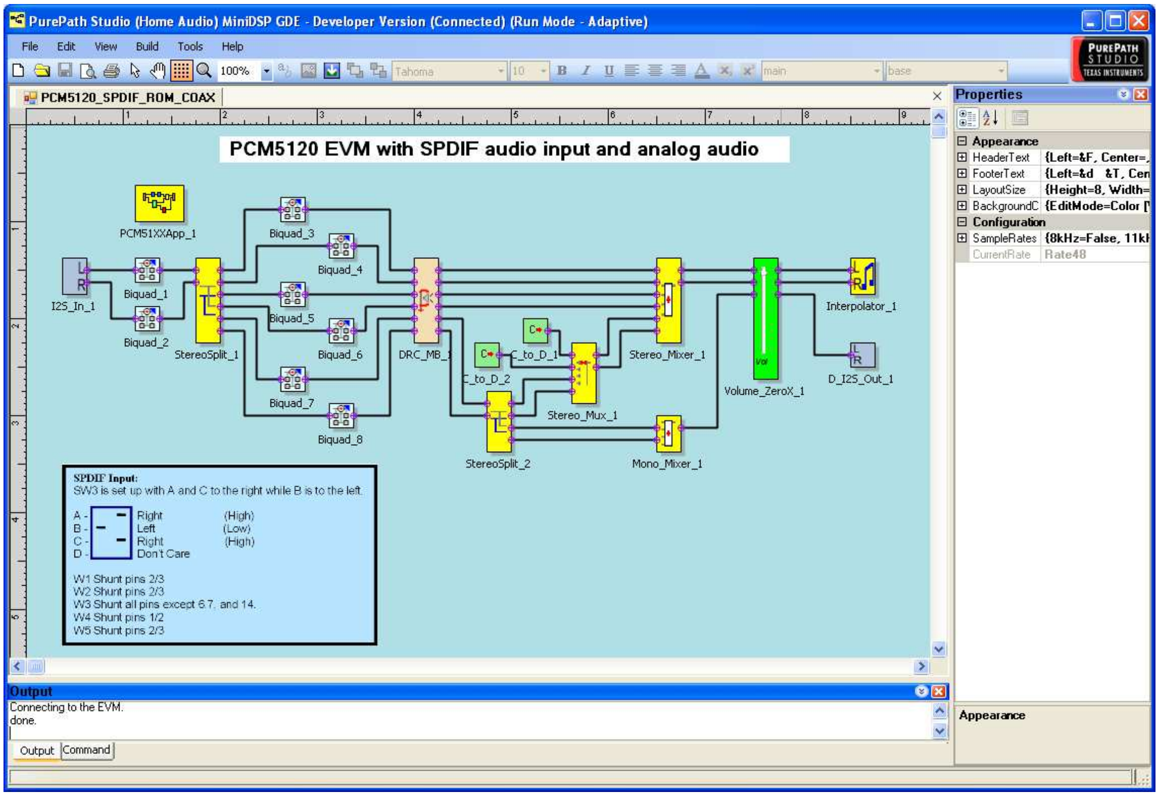


Figure 7. Loading Executable

4 Firmware Controls

The PCM512x ROM process flow represents the digital audio input port through the I2S_In_1 component and filtered via Biquad_1 and Biquad_2 prior to being split into and being input to the 3-band crossover filters (Biquad_3 through Biquad_8). The signal is processed by a 3-band dynamic range compressor (DRC_MB_1). The subwoofer output can be mixed into the stereo output by the Stereo_Mux_1 component or output separately by the Mono_Mux_1 component. A zero crossing volume control manages the output level which is presented to the DAC following interpolation (Interpolation_1). The optional subwoofer output is presented at the digital audio interface from the D_I2S_Out_1 component. Each of these components is described in the following sections.

4.1 Input filter bank (Biquad_1 and Biquad_2)

The input Biquad GUI can be opened by double clicking on the Biquad_1 icon in the process flow environment. Biquad_2 is aliased to Biquad_1 so it always reflects the same values. Only the values in Biquad_1 need to be adjusted as Biquad_2 automatically adjusts to match.

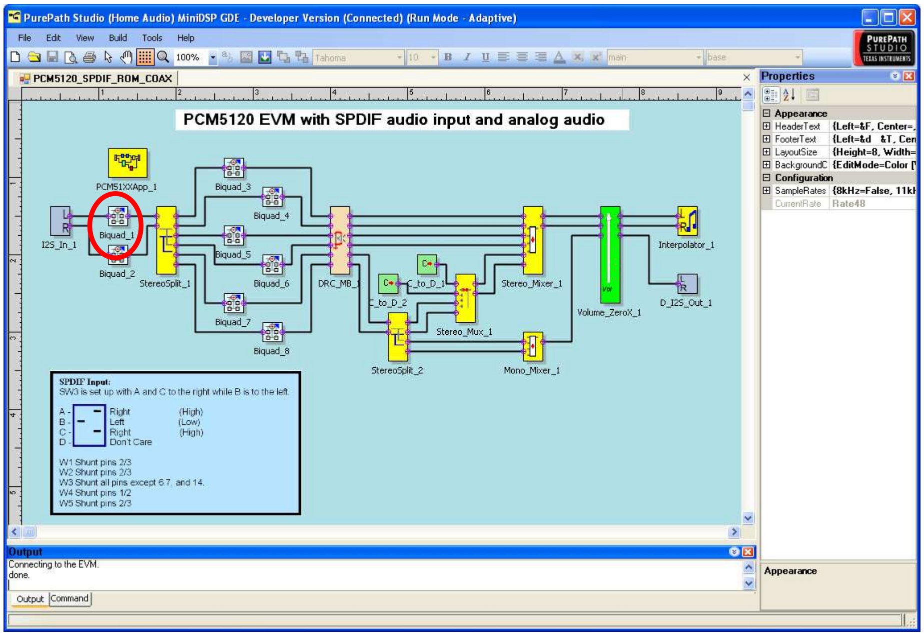


Figure 8. Biquad_1 and Biquad_2 control

The Biquad GUI opens displaying various controls as shown below. Several filter parameters are available. Biquads 1 and 2 contain an optimized implementation of 6 IIR filters (Direct Form 1, 2^{nd} order) connected in series. Click on the Frequency Response Graph tab or Phase Response tab and see the corresponding responses displayed. When the filter information is entered the coefficients can be loaded to the PCM512x by clicking on “Apply”. Click “OK” to exit the biquad GUI.

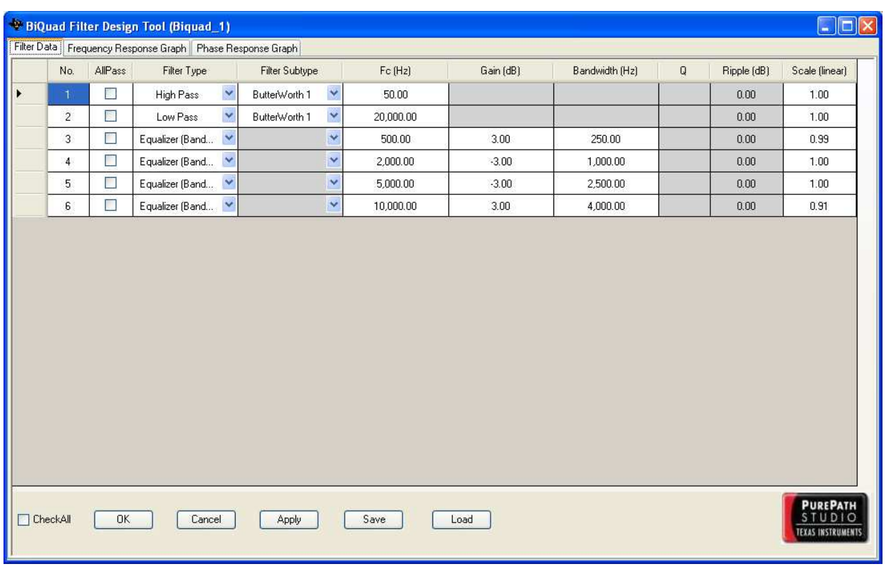


Figure 9. Biquad GUI

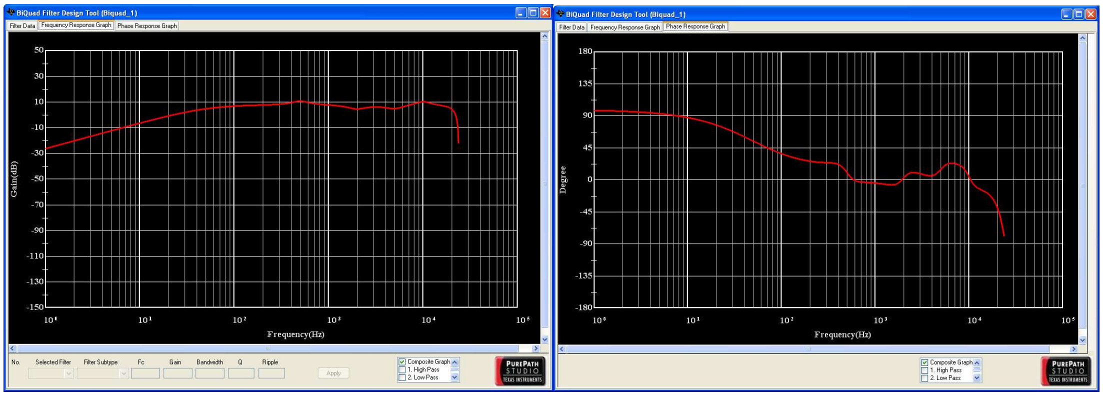


Figure 10. Frequency and Phase Response

4.2 DRC filter Banks (Biquad_3, Biquad_4, Biquad_5, Biquad_6, Biquad_7 Biquad_8)

The input signal is split into three bands via the biquad filters 3 through 8. Biquad 3 and 4 are aliased, biquads 5 and 6 are aliased and biquads 7 and 8 are aliased. Only Biquads 3, 5 and 7 need to be edited. The treble frequencies are filtered via biquads 3 and 4 with a default high pass filter at 8000 Hz. The mid frequencies are filtered via biquads 5 and 6 with band pass filter 250 Hz and 8000 Hz while the low frequencies are low pass filtered at 250 Hz. Each of these filter cut off frequencies a can be adjusted with their respective Biquad GUIs. Each of these respective signals are input to the multiband dynamic range compressor.

4.3 Multi-Band Dynamic Range Compressor (DRC_MB)

The 3-band multiband DRC applies DRC to 3 different stereo signals with 3 different time constants. The same DRC curve is applied on all the signals. The DRC is comprised of three main elements:

Average Absolute Estimator (AAV) – This DRC element derives an estimate of the average absolute value (AAV) of the audio data stream into the DRC. The DRC can receive input from either one channel (mono) or two channels (stereo). For a stereo DRC, the individual channel estimates are computed and the output of the estimator is compared and the larger value is forwarded to the compression/expansion coefficient computation engine. A time constant, t_{energy}, is used to control the effective time window over which the AAV estimate is made. From this value, two programmable parameters, a_e and $(1 – a_e)$, are derived as input to the DRC. The two programmable parameters, ae and (1-ae). apply to both the channels for a stereo DRC. For a given sampling rate (Fs) the time window over which the AAV estimation is defined by:

$$t_{energy} = \frac{1}{Fs\ln(1-a_e)}(\text{seconds}) \quad (1)$$

For energy averaging, two methods can be used which controlled by the EnergyAveragingMethod parameter – Alpha Filter, Peak Detector.

Compression/Expansion Coefficient Computation – This DRC element converts the output of the AAV estimator to a logarithmic number, determines the region where the input resides, and then computes and outputs the appropriate gain coefficient to the attack/decay element.

Attack/decay control – This DRC element controls the transition time of changes in the gain coefficient computed in the compression/expansion coefficient computation element. User specified parameters t_{attack} and t_{decay} are used to set the attack and decay time constants used in the gain adjustment. From these, four parameters are computed as input to the DRC to define the operation of the attack/decay behavior of the DRC gain.

Each of these features is controlled by the DRC GUI shown below. After editing the DRC parameters click Apply to load the updated coefficients to the EVM. Click OK to close the DRC GUI. Additional control information is provided in the extensive help file displayed by right clicking on the DRC_MB_1 icon and choosing “Help”.

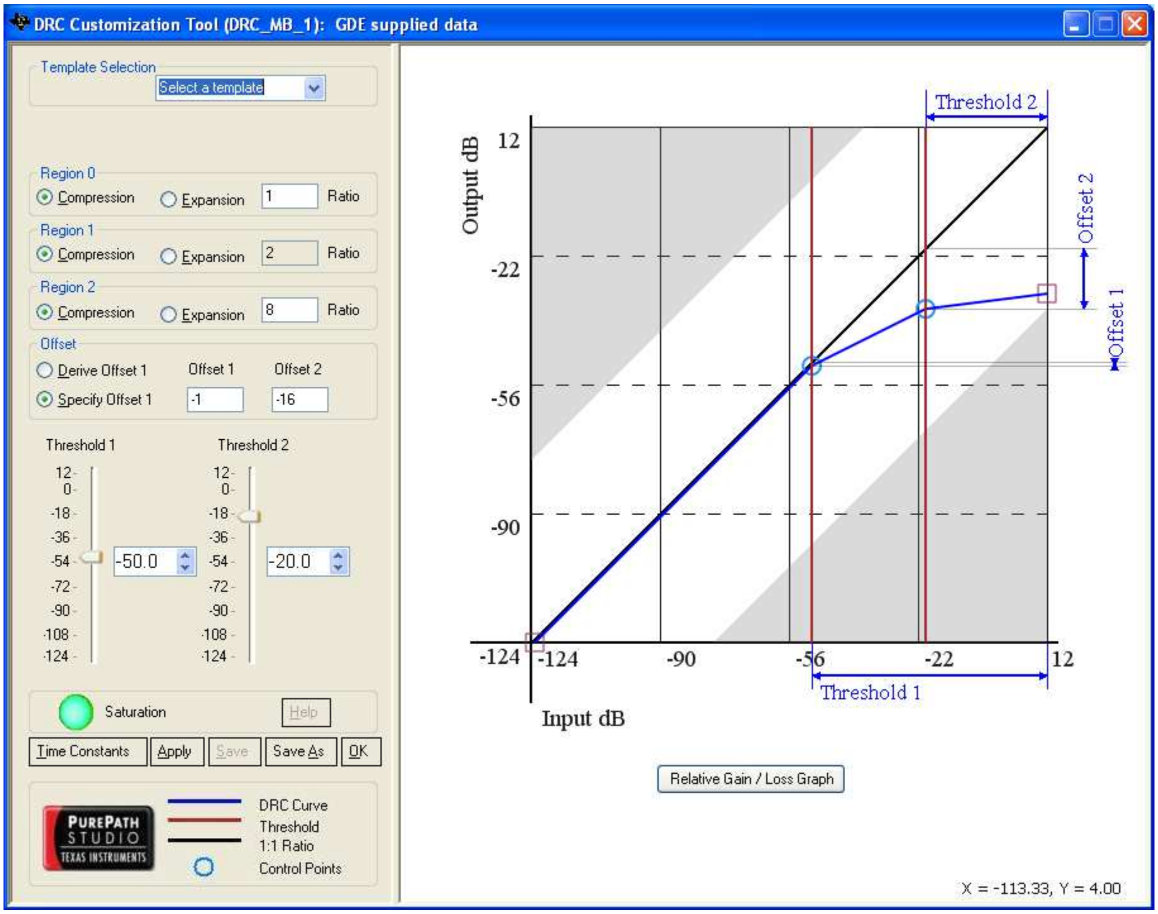


Figure 11. DRC GUI

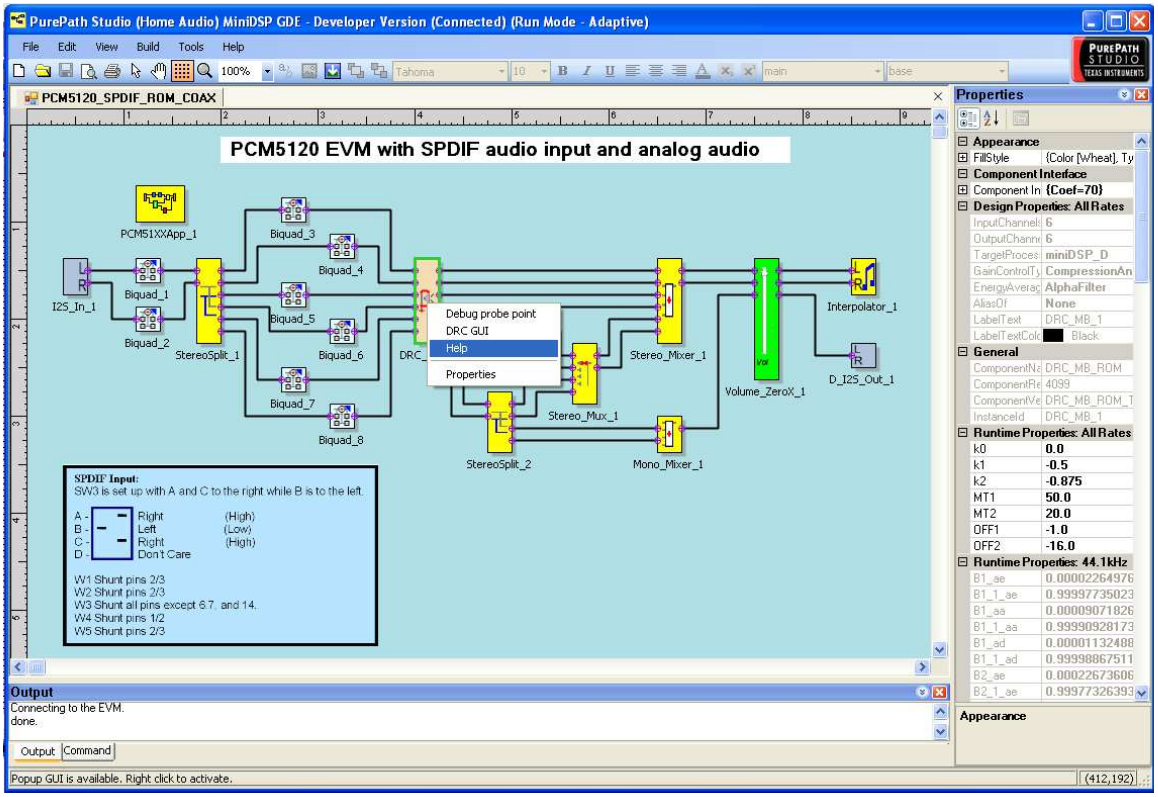


Figure 12. Component Help File

4.4 Stereo_Mux

The stereo mux is in the subwoofer processing chain and acts as a switch to direct the subwoofer signal to the main stereo output. It may be desirable to mix in the subwoofer channel when a full bandwidth 2.0 audio system is implemented. The mux setting is controlled as a runtime property in the Properties window. The mux setting can only be edited after connecting to the EVM. Setting the mux to 0x1 disconnects the subwoofer channel from the main channel. In this scenario, the main stereo output only mixes the mid and treble signals. The subwoofer signal is directed to the main stereo output when set to 0x2.

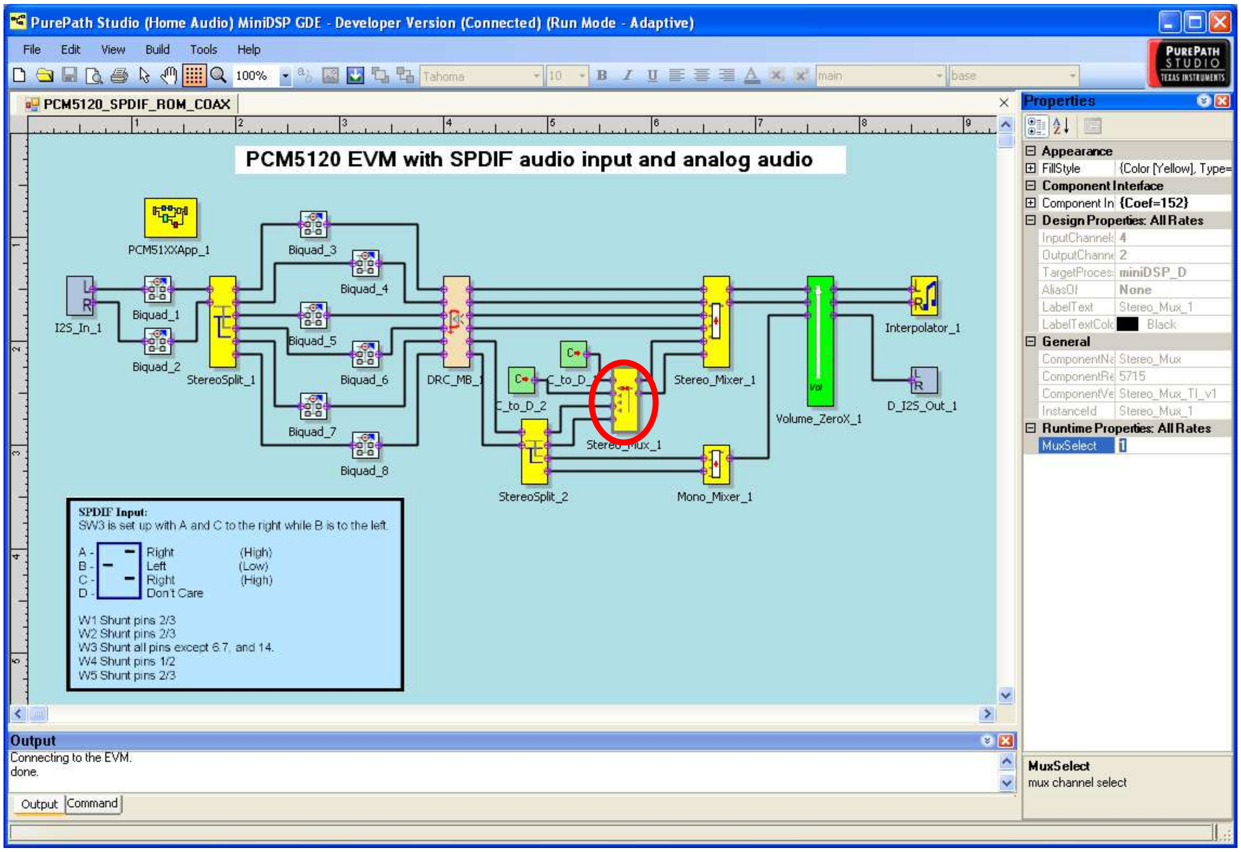


Figure 13. Mux Select

4.5 Stereo_Mixer

The Stereo mixer sums the three inputs from the treble, mid and subwoofer channels. These signals are each summed at a default level of 0.6. The mix level is controlled as a runtime property in the Properties window. The mix level can only be edited after connecting to the EVM.

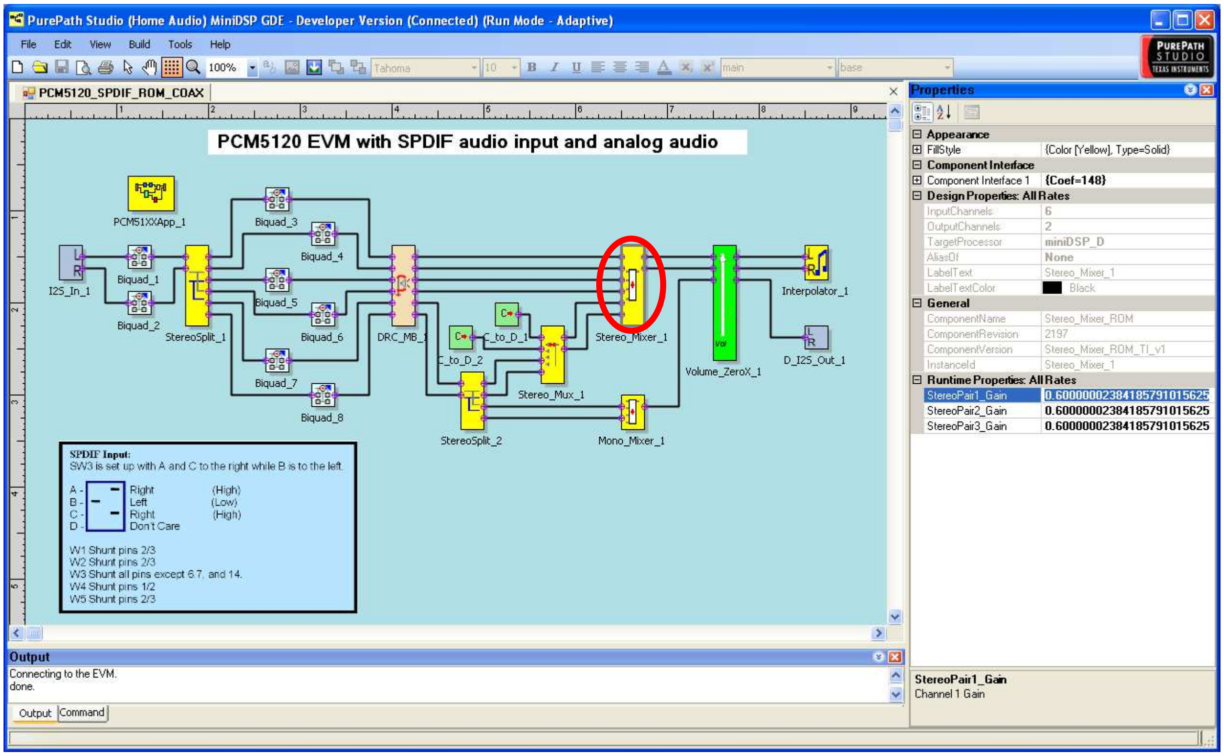


Figure 14. Stereo Mix Gain Control

4.6 Mono_Mixer

The stereo subwoofer channels are summed together in the Mono_Mixer component for output as a mono subwoofer channel. The default mix level for each channel is 0.5. The mono mix levels are controlled as a runtime property in the Properties window. The mono mix can only be edited after connecting to the EVM.

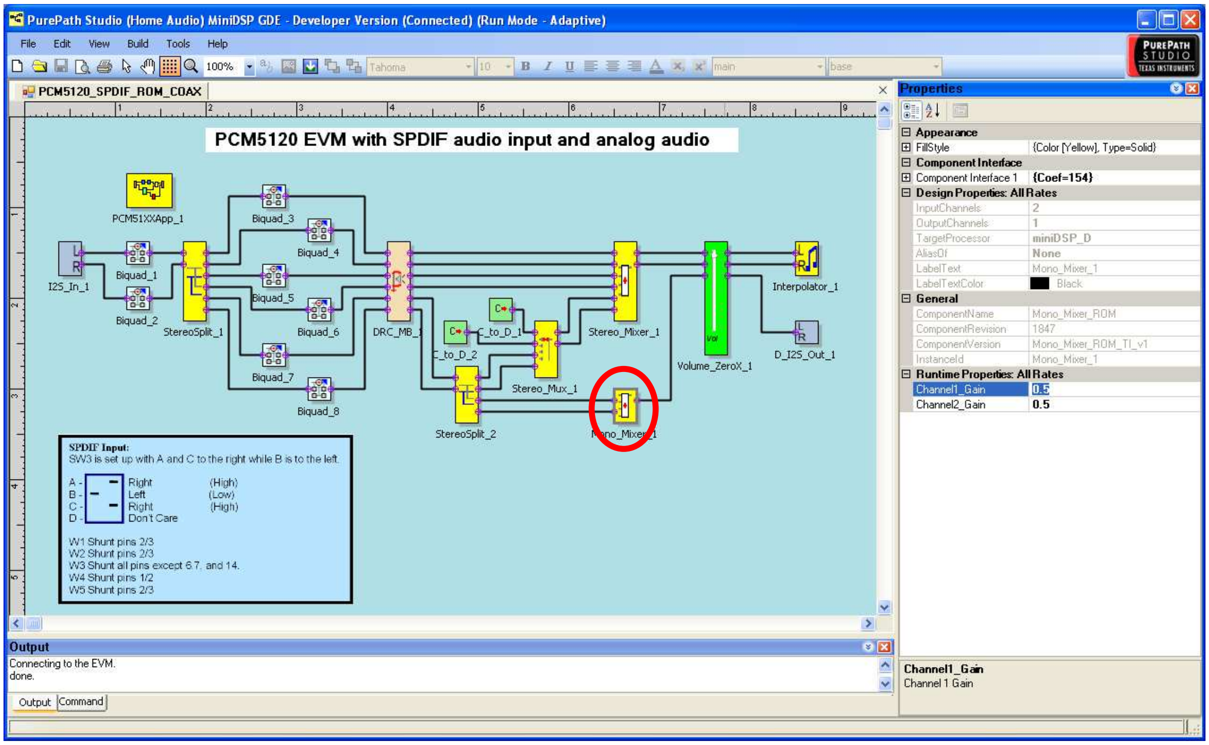


Figure 15. Mono Mixer Channel Gain Control

4.7 Zero Crossing Volume control

The volume control for each of the main stereo output channels as well as the separate subwoofer channel (when enabled) is controlled by the zero crossing volume control component. Control is managed by a slider with a default setting of -6 dB. The volume control can only be edited after connecting to the EVM. The volume control can optionally be managed by the Volume property in the Runtime Properties window shown in Figure 16

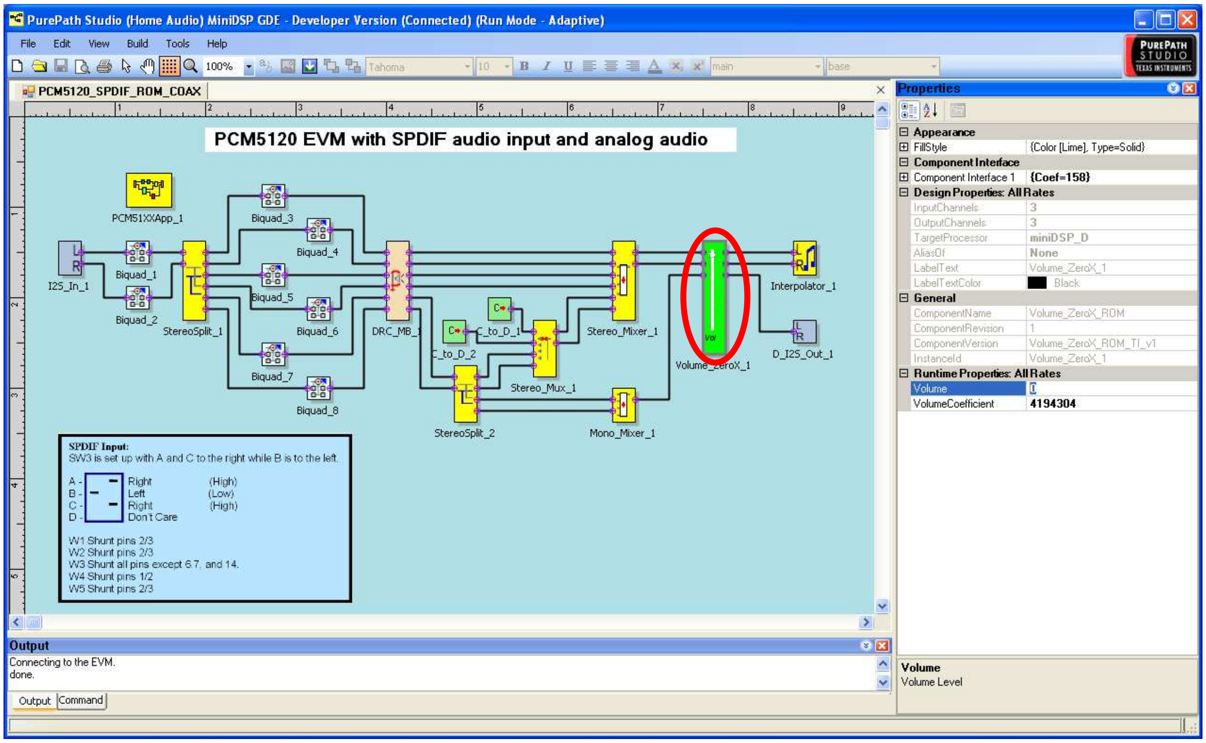


Figure 16. Volume Control

5 PurePath Studio Additional Features

5.1 PPS Environment

The development environment for the noise reduction implementation is based on the PurePath Studio (PPS) tool set which incorporates a drag and drop style Graphical Development Environment (GDE) for simple development of process flows (that is, systems) based on standard and custom components as described in the following sections.

PurePath Studio incorporates a Graphical Development Environment (GDE) as shown in the Figure 17. This environment is used to display software.

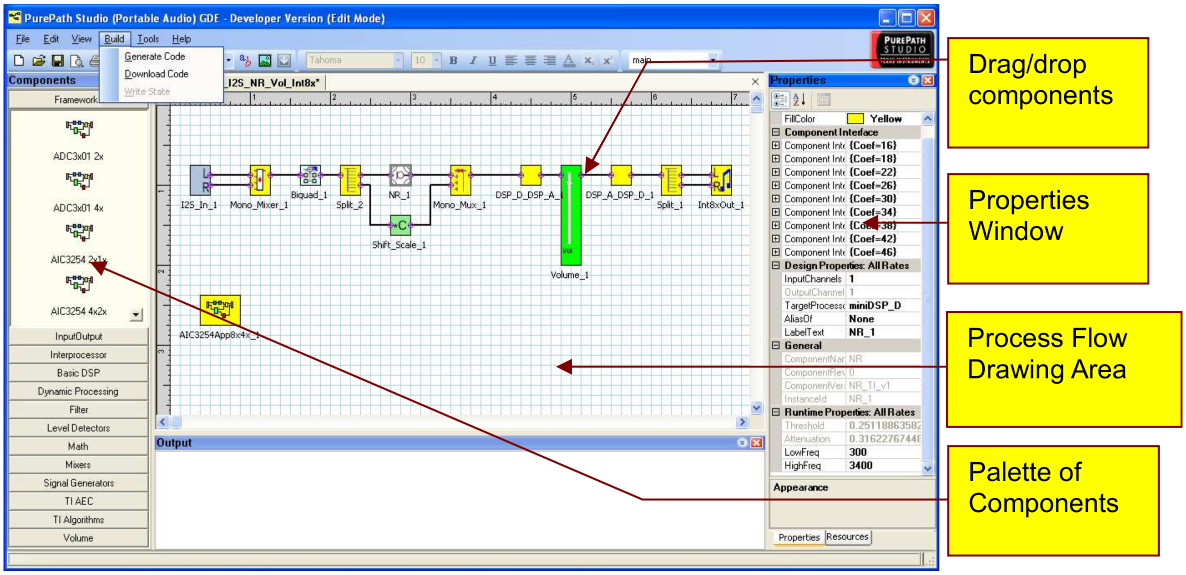


Figure 17. PurePath Studio Features

The environment defines various system parameters such as the sample rate. These can be viewed in the configuration window by clicking on the Process Flow Drawing area.

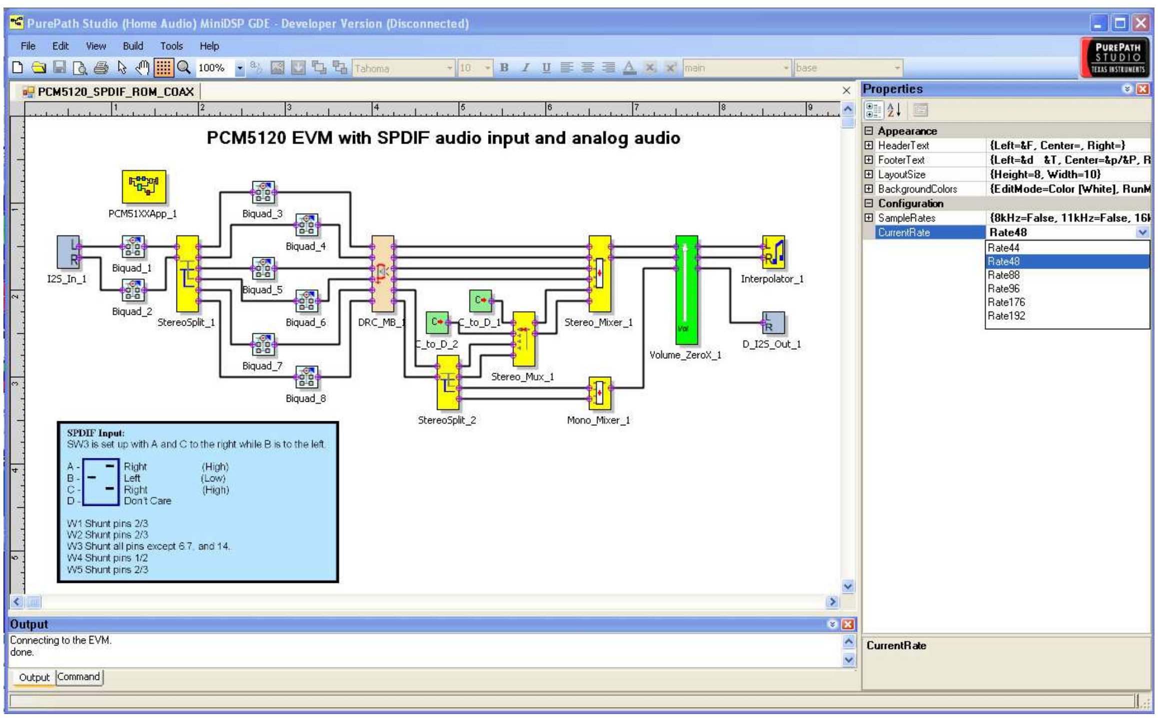


Figure 18. PurePath Studio Sample Rate Control

PurePath Studio help files can be accessed by the help menu.

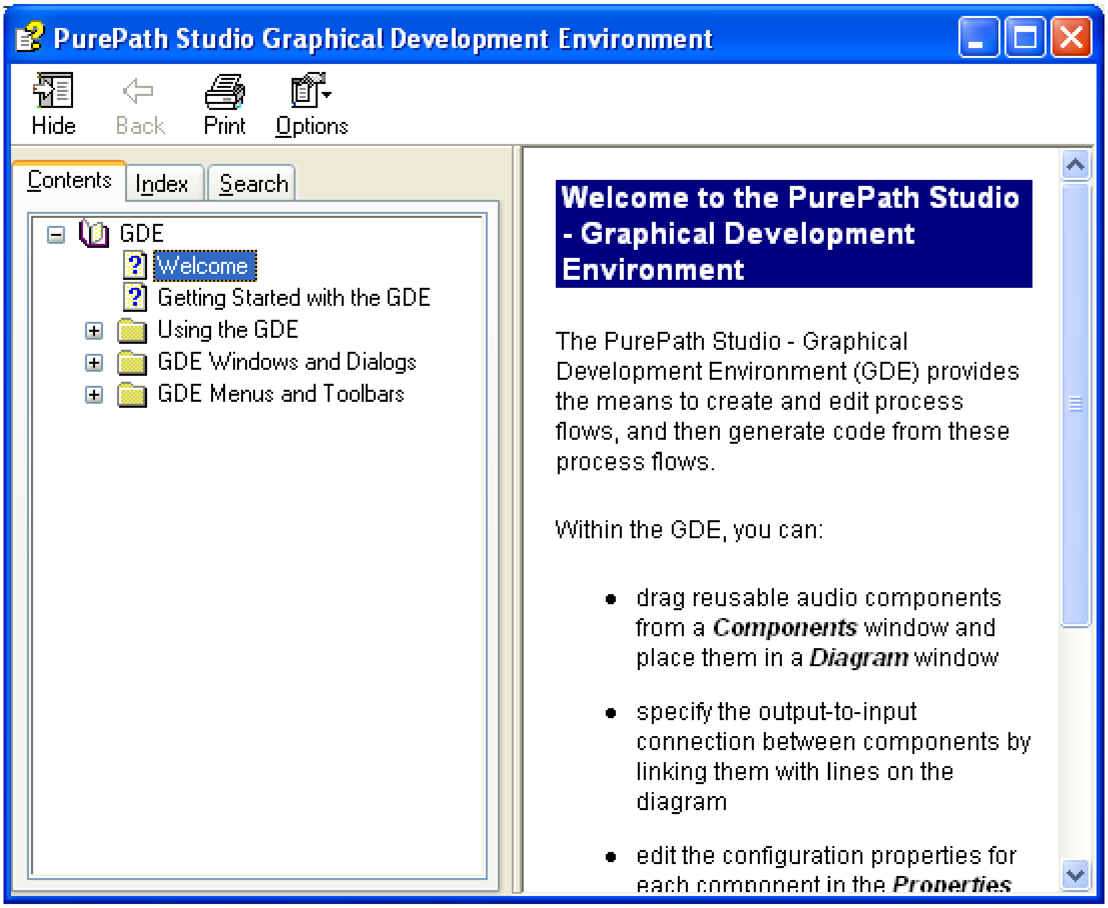


Figure 19. PurePath Studio Tools Help File

5.1.1 PPS Components

By right clicking on a component the user can access either a help file describing the operation of the component or view available run time properties and/or design properties which are displayed on the right side of the drawing area. Run time properties can be changed while the processor is running, but design properties can only be changed before building the process flow. To change the value of properties, right click on the component and choose Properties option. The component properties are displayed on the right of the drawing area, and those properties that can be changed are displayed in bold type.

5.1.2 Loading Scripts

Once the code has been loaded and is running, changes to the code, coefficients or registers may be made dynamically using scripts. Scripts may be loaded by pulling down the “Tools” menu and choosing the “I2C Command” File option as shown in Figure 6. Scripts are text files formatted to be read by the processor. Script files may be edited using any text editor.

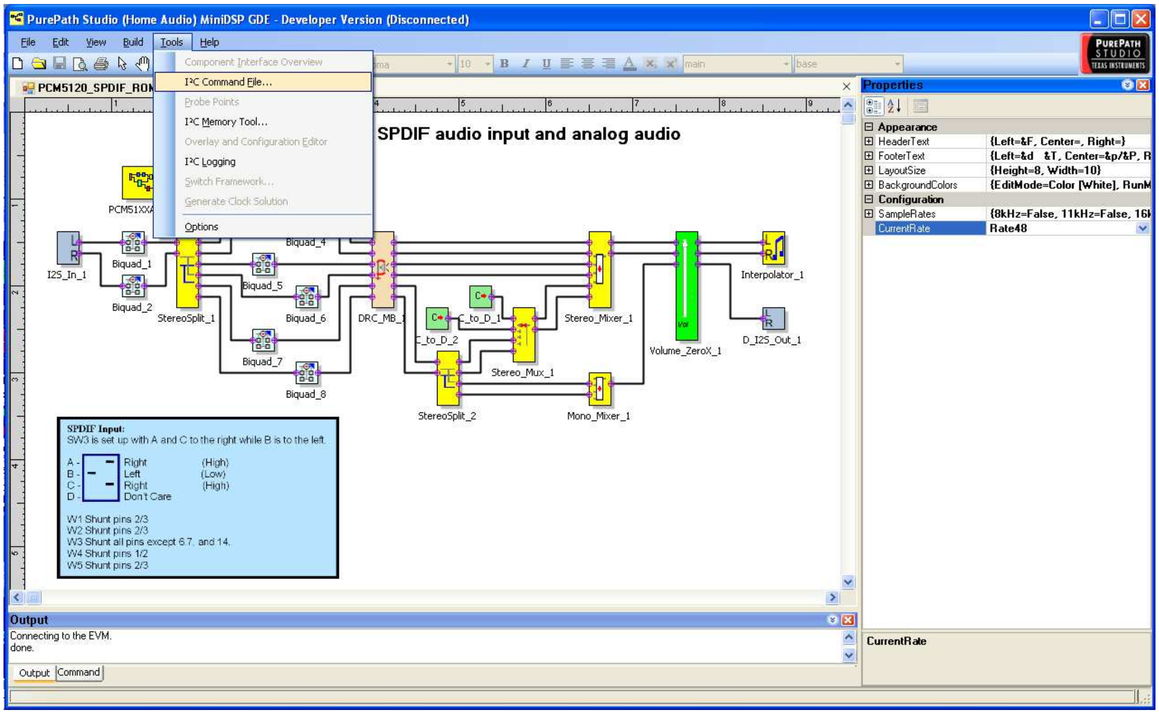


Figure 20. PurePath Studio Configuration File Option

The following window opens and the user can browse to locate the desired script file and click on "Execute now". This loads the script to the target processor.

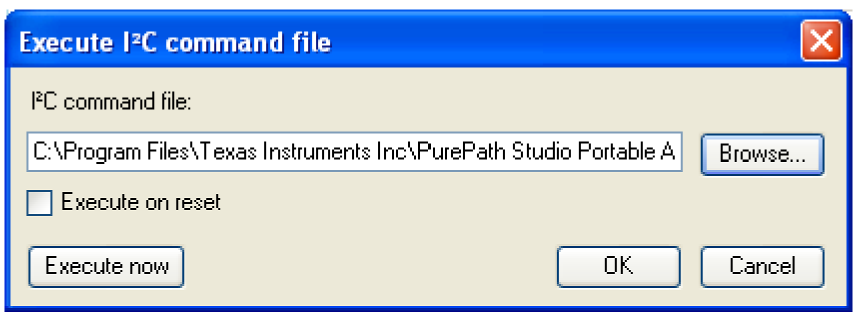


Figure 21. I²C Command Window

6 References

1. PCM512x Preliminary Technical Data Sheet, April 2011.
2. EVM User's Guide, PCM510xEVM-U, SBAU190A-May 2011 – Revised June 2011.

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