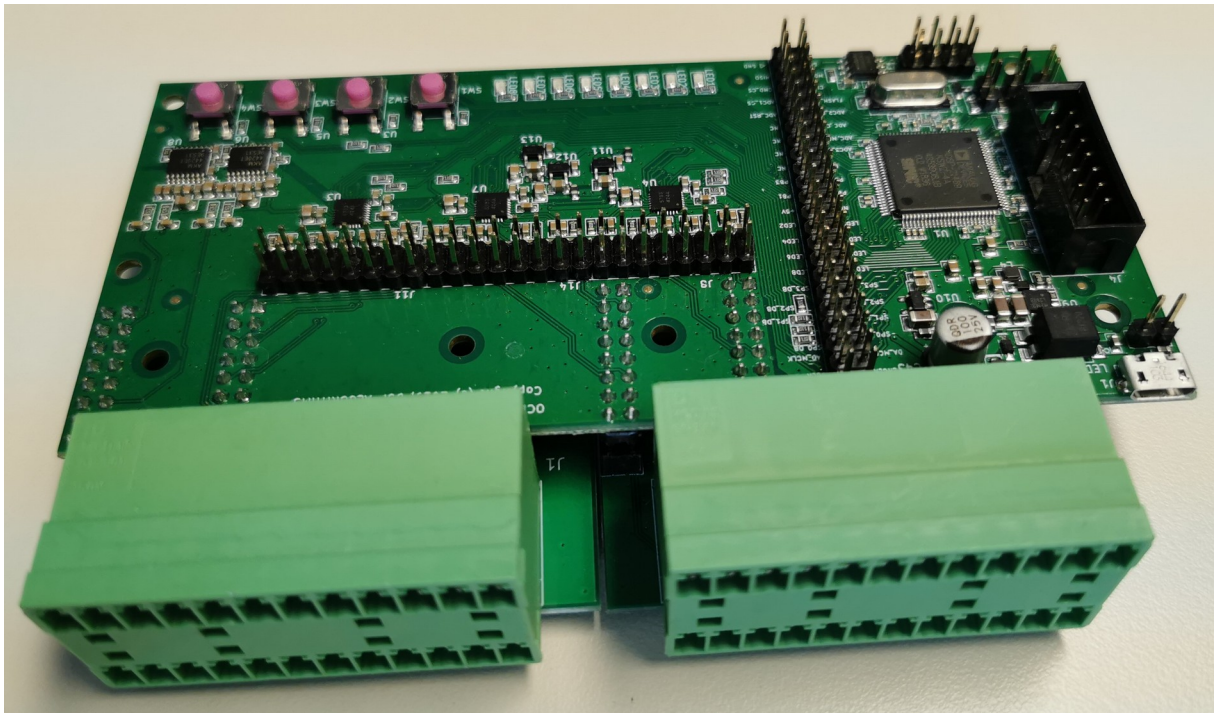

OCEAN-ADSP21489-1204HC Hardware

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1 Introduction

This document describes the hardware features of the OCEAN-ADSP21489-1204HC audio real-time processor. The hardware is based on the Analog Devices ADSP-21489 SHARC floating-point Digital Signal Processor (DSP). This hardware platform has been designed for processing multiple audio channels as required in many high end audio applications such as multichannel acoustic echo cancellation, multi-microphone noise reduction, fixed and adaptive microphone arrays, and much more. Both hardware and software are developed, maintained, and marketed by DSP Algorithms.

The OCEAN-ADSP21489-1204HC hardware includes all the necessary components that efficiently implement a complete stand-alone multi-channel audio application. The hardware includes an Analog Devices ADSP-21489 SHARC processor, 12 analog input channels, 4 analog output channels, and simple user interface consisting in 4 buttons and 8 Light Emitting Diodes (LED). Full control (through for instance a web browser) is also possible using an external microcontroller which communicate with the SHARC DSP through SPI or UART.

The application programs are stored in the on-board non-volatile flash memory. On powering the hardware, the processor copies the software from non-volatile memory to internal RAM and starts executing the program instructions. The real-time application reads the 12 analog audio inputs, processes the audio samples through the audio algorithms, and plays the processed audio samples to the 4 analog outputs.

The analog inputs and outputs on the OCEAN-ADSP21489-1204HC are provided through industry standard 0.1" headers. Those headers can be used to offer the inputs and outputs on a variety of audio connectors, such as XLR, RCA, jacks, or terminal blocks, as needed to interface to microphones, loudspeakers, and other audio equipment.

2 The OCEAN-ADSP21489-1204HC Hardware

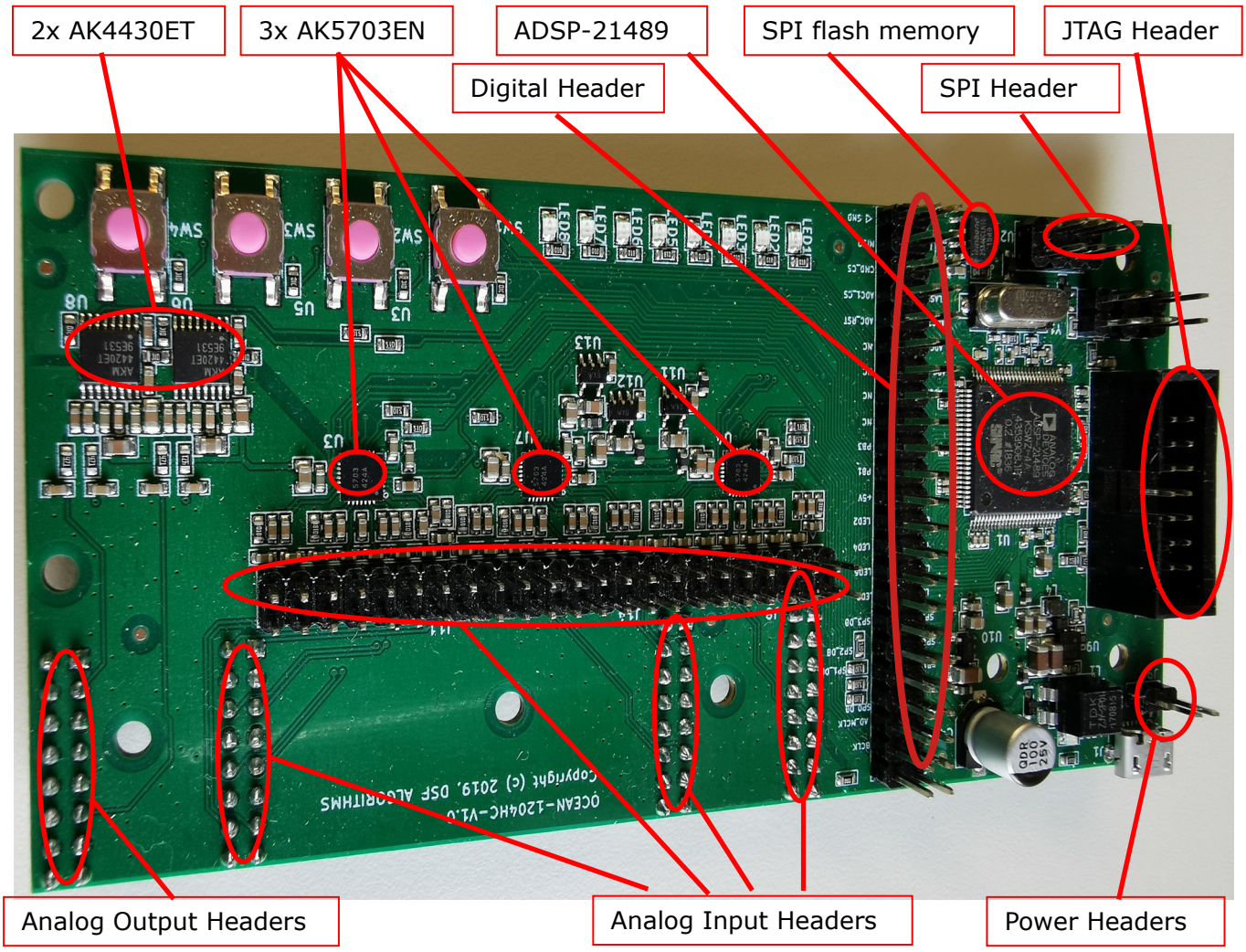

Figure 1: OCEAN-ADSP-21489-1204HC hardware

The OCEAN-ADSP21489-1204HC main PCB is shown in Figure 1 and provides the following functions.

- **Analog Input Headers**: Support 12 differential or single-ended inputs. Both microphone level as well as line level inputs are supported. The header also provides 6 separate low noise microphone bias (2.4v typical) for biasing electret/condenser/MEMS microphones. Each two microphones share one bias signal. Each pair of inputs can be configured as microphone or line level using software.
- **Analog Output Headers**: Support 4 single-ended outputs with 2.0v rms line level drivers.

- **Digital Header**: This header allows digital interface to the PCB and brings out all processor's 20 DAI pins, all 14 DPI pins, all 4 FLAG pins, CLKIN, regulated supply voltages, and digital ground. The Digital Header is optional and may be left unpopulated in some hardware versions.
- **Power Supply Headers**: The hardware is powered by a 5 volt DC that can be applied through the two-pin power header or the micro USB connector. One green LED power-on indicator is also provided.
- **JTAG Header**: Allows debugging the hardware and software and reprogramming the non-volatile memory using an emulator. The JTAG header is optional and may be left unpopulated in some hardware versions.
- **SPI Header**: Used to program the on-board non-volatile flash memory. It can also be used to send commands from a microcontroller to the DSP to enable/disable processing algorithms or set/get algorithm parameters.
- **Boot and Clock Configuration**: Three jumpers are provided to allow configuring whether the processor boots from on-board non-volatile memory (SPI master), or booted by a host processor (SPI slave). External clock can also be used instead of the on-board crystal.
- **Crystal**: A single high precision crystal (24.576 MHz, 10ppm frequency tolerance and 10ppm frequency stability) for both audio and processor clock.
- **Sampling Frequency**: Supports common sampling rates between 8 kHz and 48 kHz. Sampling rates of 8, 12, 16, 24, 32, 48 kHz are accurately supported. Default sample rate is 48 kHz and all algorithms process audio at 48 kHz sampling rate.
- **Processor**: The standard PCB is shipped with the ADSP21489KSWZ-4A which provides maximum performance of 400 MIPS and internal memory of 5M bits. However, the hardware is compatible with other 100-LQFP processors from the same family including the ADSP-21489KSWZ-3A (350 MIPS, 5M bit), ADSP-21489BSWZ-3A/4A (-40 to +85 °C), ADSP-21488KSWZ-4A (400 MIPS, 3M bit), ADSP-21488KSWZ-3A (350 MIPS, 3M bit), 21488BSWZ-3A/4A (-40 to +85 °C). Also lower performance compatible processors in the ADSP-2147x family can be used for performance/cost optimization.
- **Analog to Digital Converters**: 12 analog inputs using 3 x AK5703EN ADC chips.
- **Digital to Analog Converters**: 4 analog outputs using 2 x AK4430ET DAC chips.
- **User Interface**: 8 LEDs and 4 push-buttons.
- **Power Supply**: All necessary voltages are generated on-board using high quality voltage regulators.
- **SPI flash Memory**: this non-volatile memory is used to store the application firmware and supports IP protection. It can be programmed using either the SPI Header or through a utility program running on the DSP.

All headers are through hole components and can be placed on either side of the PCB as needed.

The OCEAN-ADSP21489-1204HC PCB measures 60mm x 130mm with amble space left to add additional hardware features in the future. To create a stand-alone application, additional small interface boards are also available. Those include

- 8-element linear microphone array using 8x MEMS microphones arranged on one line separated by 5cm apart.
- 10-element linear microphone array using 10x MEMS microphones arranged on one line separated by 5cm apart.
- 8-element and 10-element arbitrary shape microphone array using 8x and 10x MEMS microphones, respectively. Each microphone is installed on a separate tiny PCB that connect to the Analog Header using cables. This is useful to create different microphone array shapes, such as circular, hexagonal, rectangular, spherical, cubical, conical, etc.

- 12x RCA mono inputs and 4x RCA mono output connectors.
- 12x mono 3.5mm audio jack inputs and 4x 3.5mm audio jack output connectors.
- 12x input terminal blocks and 4x output terminal blocks.

3 Hardware System Components

The functional block diagram of the OCEAN-ADSP21489-1204HC is shown in Figure 2. The following sections explain the purpose of each functional block.

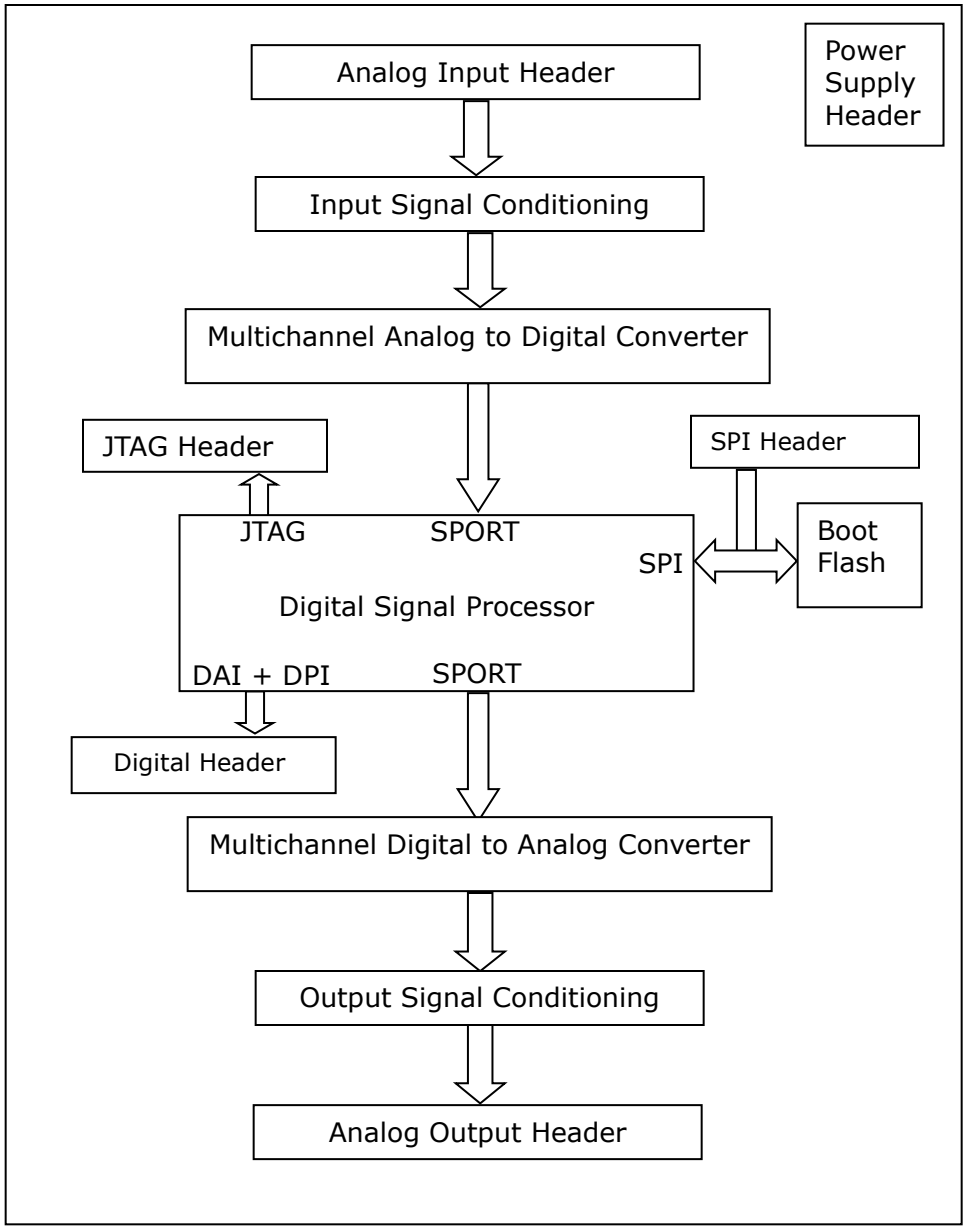

Figure 2: Hardware functional block diagram.

3.1 Analog Input Header

There are 6 analog input headers, namely J2, J3, j6, J8, J14, and J11. From those, three headers (J8, J14, and J11) are intended to interface to microphones as shown in Figure 3. Each 4 pins on J8, J14, and J11 provide microphone bias, +IN, -IN, and analog ground for each microphone. If single-ended microphones are used, -IN input should be connected to the analog ground on the microphone PCB. Low noise microphone bias (2.4V typical, for powering electret, condenser, and MEMS microphones) is provided on those three headers. If the used microphones need +48 volt phantom power, external phantom power circuitry must be used on the microphones PCB.

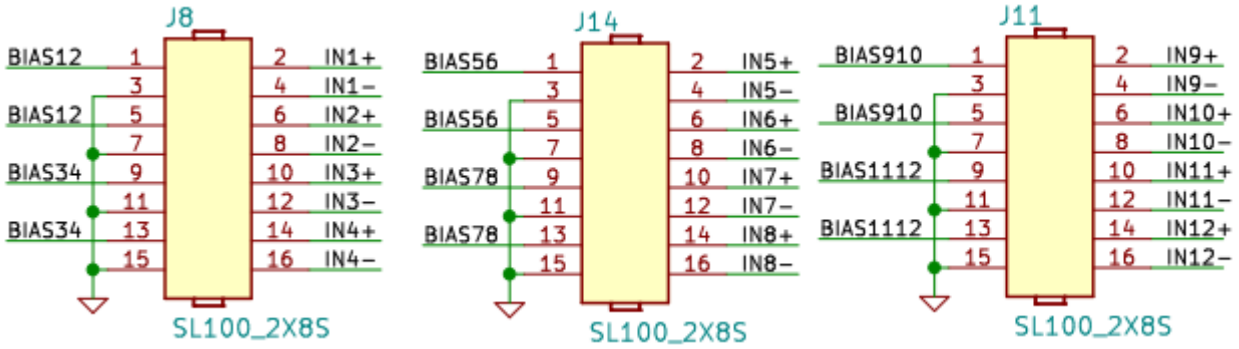

Figure 3: J8 ,J14, and J11 Analog Input Headers.

Additionally, J2, J3, and J6 are provided in parallel to J8, J14, and J11. J2, J3, and J6 are intended to bring analog inputs to the main PCB through audio connectors (XLR, RCA, jacks, terminal blocks, combo XLR/6.5mm Jack, etc). The signals on J2, J3, and J6 are shown in Figure 4. If single-ended inputs are used, the -IN input of each channel should be connected to analog ground.

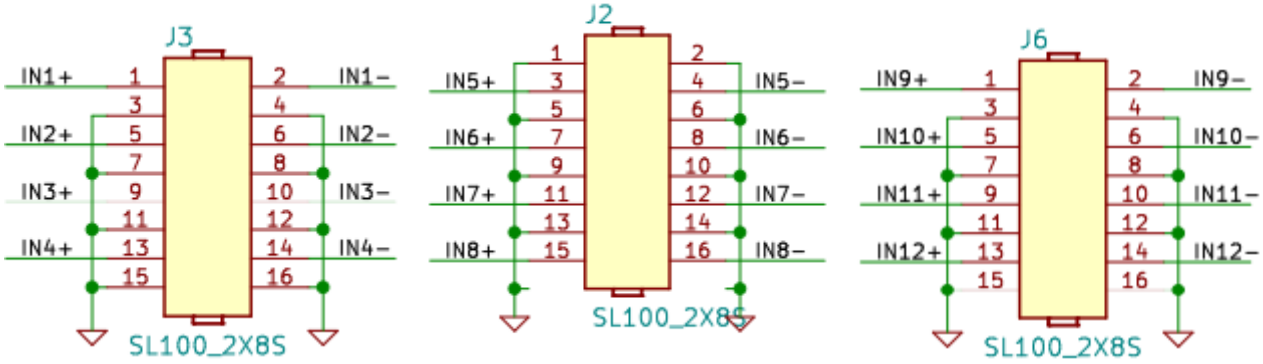

Figure 4: J2, J3, and J6 Analog Input Headers

3.2 Input Signal Conditioning

The OCEAN-ADSP21489-1204HC supports both microphone input level as well as (consumer) line-input level. This means a low noise analog Programmable Gain Amplifier (PGA) for each input channel is included on-board. The amount of the analog gain to suit the needs of the selected microphones sensitivity is adjusted by software. The analog gain supported ranges from 0 dB to +36 dB in varying steps, so that microphones with different sensitivities can be used. The above analog signal conditioning function is provided by the AK5703EN Analog to Digital Converter chip.

3.3 Light Emitting Diodes and Buttons

To ensure that the OCEAN-ADSP21489-1204HC can function in a stand-alone application without external microcontroller, 8 LEDs and 4 push-buttons are included for simple user interface. The software uses the LEDs to indicate when ADC inputs are overloaded (input signal levels exceed the ADC input specifications), but also indicate that a specific function is enabled (LED ON) or disabled (LED OFF). The push-buttons are used to enable or disable specific functions, such as AEC, beamformer, or noise reduction.

3.4 Analog to Digital Converters (ADC)

The analog signals from the Analog Input Headers must be converted to digital form to be processed by the digital signal processor (DSP). The ADC section of the OCEAN-ADSP21489-1204HC provides the following functions.

- Sampling of 12 independent analog input channels simultaneously.
- Direct support for common sampling rates from 8 kHz to 48 kHz.
- Provides high quality, low noise signal conditioning for low level microphone signals.
- Supports microphone as well as (consumer) line level input signals.
- Supports differential as well as single-ended inputs.

All the above functions are provided by three **AK5703EN** Analog to Digital Converter chips. The AK5703EN is designed specifically for microphone array applications and therefore includes software-controlled microphone bias and low noise programmable analog gain ranging from 0dB to +36 dB. Each chip includes 4 differential or single-ended independent analog to digital converters. The maximum typical input signal level for the AK5703EN is 1.8 Vpp in line level mode (PGA gain=0 dB) and 0.057 Vpp when PGA gain=30 dB.

3.5 Digital Signal Processor

The standard PCB is populated with the **ADSP-21489KSWZ-4A,** providing 5M bit of internal RAM and runs at 400 MHz core clock. The ADSP-21489KSZW-4A is available in 100-LQFP package and is pin and software compatible with several other members of the 2148x and 2147x families, therefore sufficient options are available to optimize performance and cost based on the application at hand without any need to modify the hardware.

The selected 100-LQFP package does not have any external memory pins. However, no external memory is needed for the intended applications, all firmware packages can run from internal memory. The LQFP package simplifies the board layout and reduce PCB production cost compared to BGA packages.

3.6 Digital to Analog Converter (DAC)

The processed digital audio signals must be converted back to analog form to be, for example, played to loudspeakers. The DAC section of the OCEAN-ADSP21489-1204HC provides the following functions.

- Conversion of 4 independent digital channels simultaneously to analog domain.
- Direct support for common sampling rates from 8 kHz to 48 kHz.
- Supports single-ended output to directly interface with common devices.
- Includes consumer line level driver so that no additional circuitry is needed.

The above functions are accomplished using two **AK4430ET** DAC chips, each chip converting two channels. When not all 4 output channels are needed, only the needed channels may be populated and the rest left unpopulated without any side effects. The typical maximum output voltage of the AK4430ET chip is 2.0 Vrms or 5.658 Vpp.

3.7 Output Signal Conditioning

The AK4430ET DAC chip used on-board the OCEAN-ADSP21489-1204HC includes a line level buffer with 2V RMS output driver.

3.8 Analog Output Header

The output of the two AK4430ET DAC chips are brought out to the Analog Output Header J7. Industry standard 0.1" (2.54mm) through holes headers are used. The outputs are brought out in single-ended form to this header as they come out of the AK4430ET DAC. The signals on the Analog Output Header are shown in Figure 5. This header is typically used to provide the 4 analog outputs to the end user on commonly used audio connectors, such as RCA, 6.5 mm jacks, or terminal blocks, as needed.

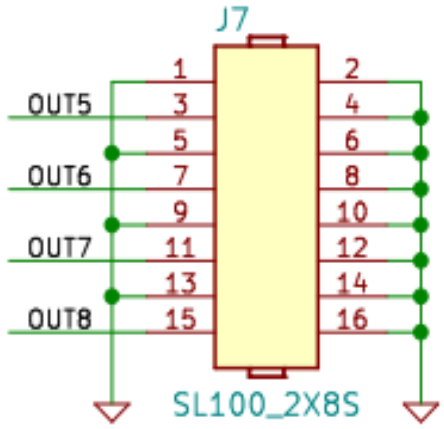

Figure 5: J7 Analog Output Header

3.9 Digital Header

The Digital Header brings out the DSP peripheral's pins to an industry standard 0.1" header where direct communication with the DSP is made possible. The Digital Header brings out all 20 DAI pins, all 14 DPI pins, all 4 FLAG pins, RESET pin, regulated supply voltages, CLKIN signal, and digital ground. This allows taking full advantage of the DSP peripherals. Figure 6 shows the signals on the Digital Header. The digital header may be left unpopulated if not needed.

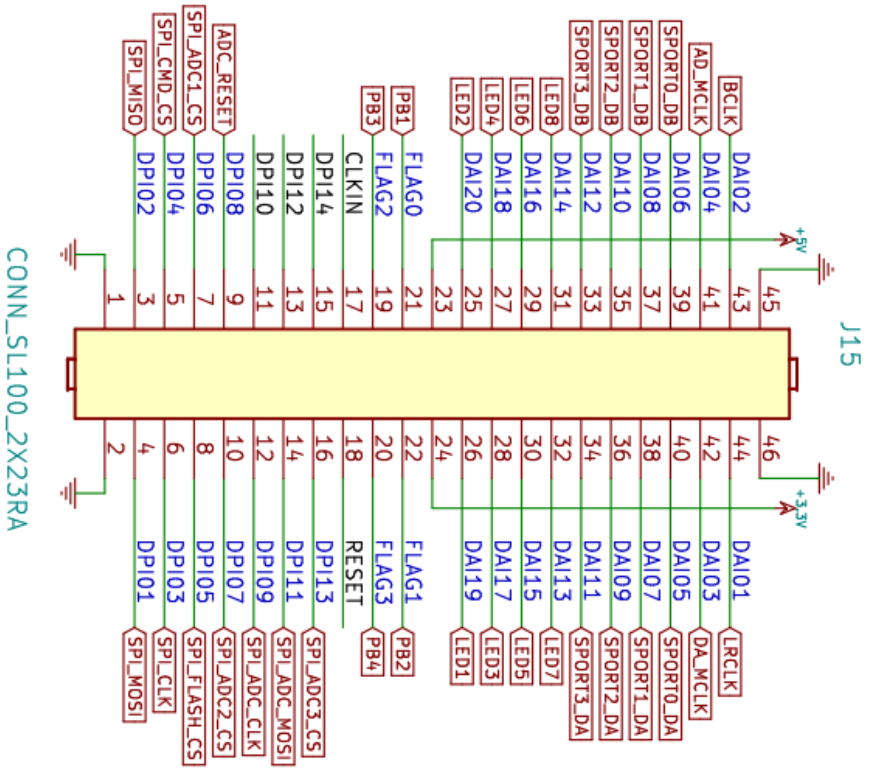

Figure 6: Digital Header signals for the single PCB design.

3.10 Power Supply Header

The Power Supply header is used to power the OCEAN-ADSP21489-1204HC from an external unregulated 5V DC source. The standard OCEAN-ADSP21489-1204HC is supplied with a micro USB connector so that it can be easily powered from a standard mobile phone charger for quick testing. However, in parallel to the micro USB connector, an additional 2-pin power supply header is also available for embedded applications.

The necessary low-noise linear voltage regulators for all the components (DSP, ADC, DAC, flash memory, etc) are included on-board. A green LED indicates when the OCEAN-ADSP21489-1204HC is connected to a power source.

3.11 JTAG Header

The JTAG header allows an Analog Devices emulator to connect to the board and control the SHARC processor. This JTAG header is needed for developing, debugging, and testing the hardware and software. Figure 7 shows the JTAG Header schematics. The JTAG header may be left unpopulated if not needed.

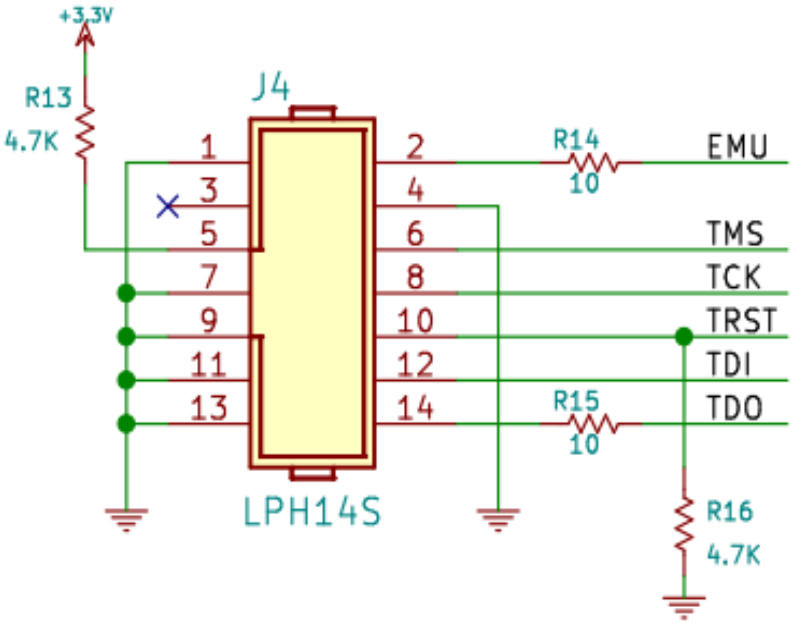

Figure 7: JTAG Header signals.

3.12 Boot and Clock Configuration

The OCEAN-ADSP21489-1204HC allow selecting whether the DSP boots from the flash memory or from a host microprocessor. This is basically done using the processor's boot configurations pins. The 100-LQFP package has two boot configuration pins (pin3:BOOT_CFG0 and pin 6:BOOT_CFG1). The default boot option is SPI master (01) so that the DSP boots by default from the on-board flash. However, the option is available to change this default to SPI slave (00) so that the DSP boots from an external host microprocessor. The boot and clock configurations headers may be left unpopulated if not needed.

The design also allows providing the CLKIN signal (available on the Digital Header) from an external source so that the audio clocks and I/O clocks can be synchronized with another motherboard clocks (to do so, the crystal on the OCEAN-ADSP21489-0808HC should be removed). To give full flexibility, the design also allows setting the CLKIN (input clock) to CCLK (core clock) ratio by providing access to the CLK_CFG0 and CLK_CFG1 pins. The default clock configuration is (01) or 16x so that a CLKIN of 25MHz provides 400 MHz core clock at reset. After booting, the core clock can be changed to the desired value using the PLLM bits in software, if necessary.

The above boot and clock configuration functionality is implemented as shown in Figure 8. To change the boot configuration to boot from host microprocessor, R6 should be populated with 0 Ω resistor; otherwise leaving it unpopulated (default) configures the processor to boot from on-board flash memory.

Similarly, to change the clock configuration either R7, or R8, or both should be populated with 0 Ω resistors as necessary.

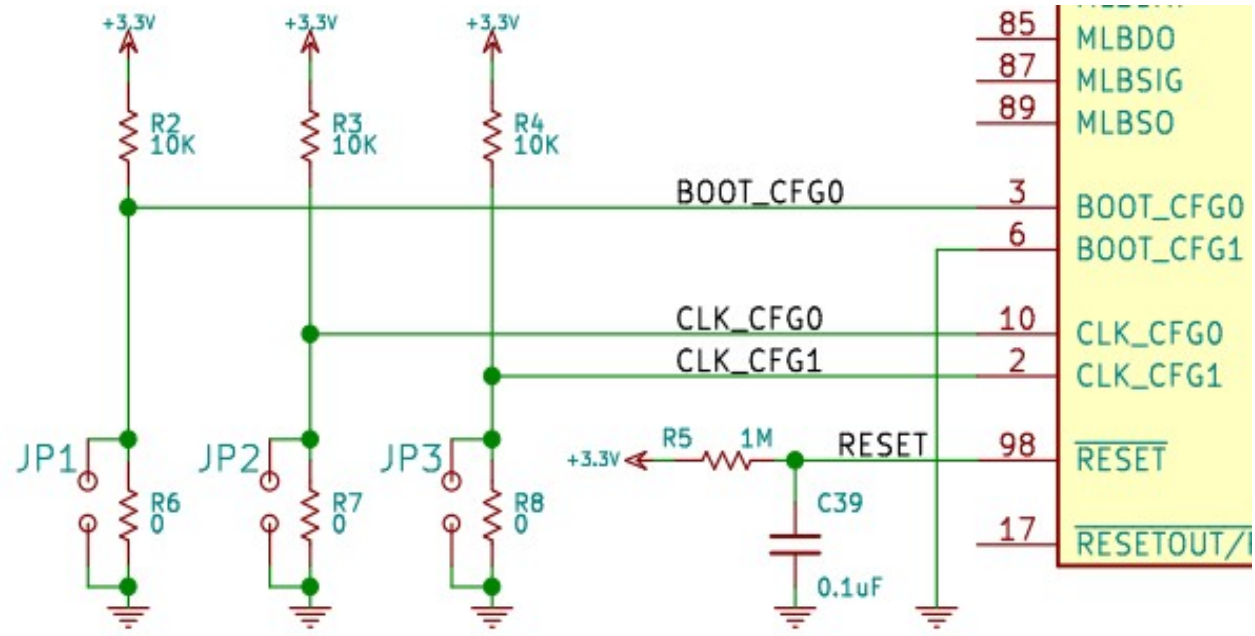

Figure 8: Boot and Clock Configuration control.

3.13 Flash Memory

The boot flash memory is where the application code and data are stored. Once the hardware and software are finalized for a specific application and all the parameters are fixed, a boot image is created that includes a boot loader and the application itself. This image is then programmed onto the on-board flash memory. At power up, the DSP boots from the flash memory and starts running the application code.

The DSP is connected to the SPI flash through the SPI interface. At boot time, the DSP reads the boot loader from the flash memory. The boot loader copies the application code to the DSP internal memory. Once copying is done, the application starts running from the DSP internal memory, recording from the ADCs, processing, and sending the result to the DACs.

The Boot Flash memory is accessible through two different paths.

1. Using in-circuit flash programmer utility running on the DSP. This access mode is used during development only.
2. Using SPI flash programmer to program the flash through the SPI Header.

3.14 SPI Header

The SPI header allows programming the SPI flash memory in-circuit using an external flash programmer. The flash programmer connects to the OCEAN-ADSP21489-1204HC through the SPI Header and at the same time connects to a Personal Computer (PC) through USB. A software program running on the PC allows the flash programmer software to select the flash memory device to be programmed on the OCEAN-ADSP21489-1204HC and the file to be programmed onto the device. This simple method can be used to write the final application code onto the flash memory at production time, but also for maintenance when new software is released that may fix bugs or add features.

The SPI header can also be used to send commands from a microprocessor to the OCEAN-ADSP21489 SHARC processor. The commands can for instance implement the user interface to enable or disable software functions, configure inputs as line or microphone levels, set the microphones analog gain, or copy filter coefficients. Additional software is needed to implement SPI commands on the SHARC DSP as well as on the host microprocessor. All standard firmware packages for the OCEAN platform support a web interface implementing all necessary control functions.

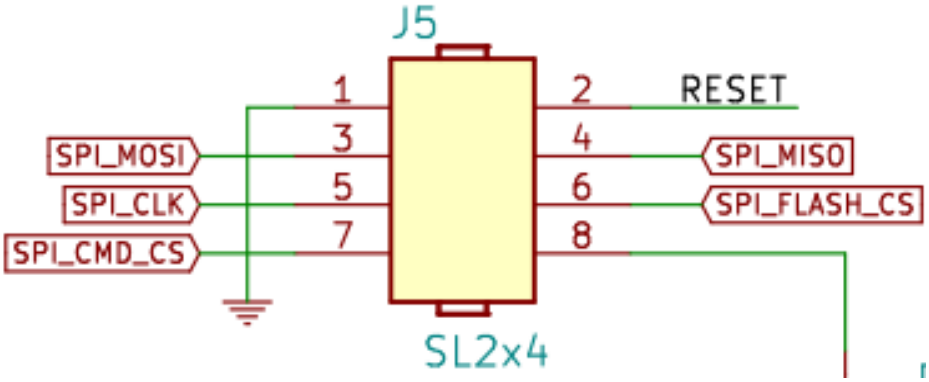

Figure 9: SPI Header.

4 Peripheral Boards

To implement a fully functional stand-alone application, the OCEAN-ADSP21489-1204HC needs to be connected to some microphones and loudspeakers. To do so, several small peripheral boards are available as described in this section.

4.1 Linear Microphone Array

The OCEAN-ADSP21489-1204HC can be used as a stand-alone or embedded microphone array by connecting maximum 12 microphones to the analog input header. Two separate boards which implement linear MEMS microphone arrays are available for the OCEAN-ADSP21489-1204HC. The first is populated with 8 omnidirectional SPW2430HR5H-B MEMS microphones from Knowles, and the second is populated with 10 microphones. In both cases, the microphones are arranged in one line spaced by 5 cm apart, as shown in Figure 10; forming a linear array of 35 cm total length (8 microphones), and 45 cm length (10 microphones).

For both 8- and 10-element arrays, the microphone array is split into 2 PCBs (OCEAN-04/05-MIC-LEFT and OCEAN-04/05-MIC-RIGHT). Each PCB including 4 (or 5) microphones and plug directly onto J8, J14, and J11 Analog Input Headers on the OCEAN-ADSP21489-1204HC. The two microphone PCBs are not identical and can not be interchanged. To correctly connect the linear microphone array to the OCEAN-ADSP21489-1204HC, refer to Figure 10.

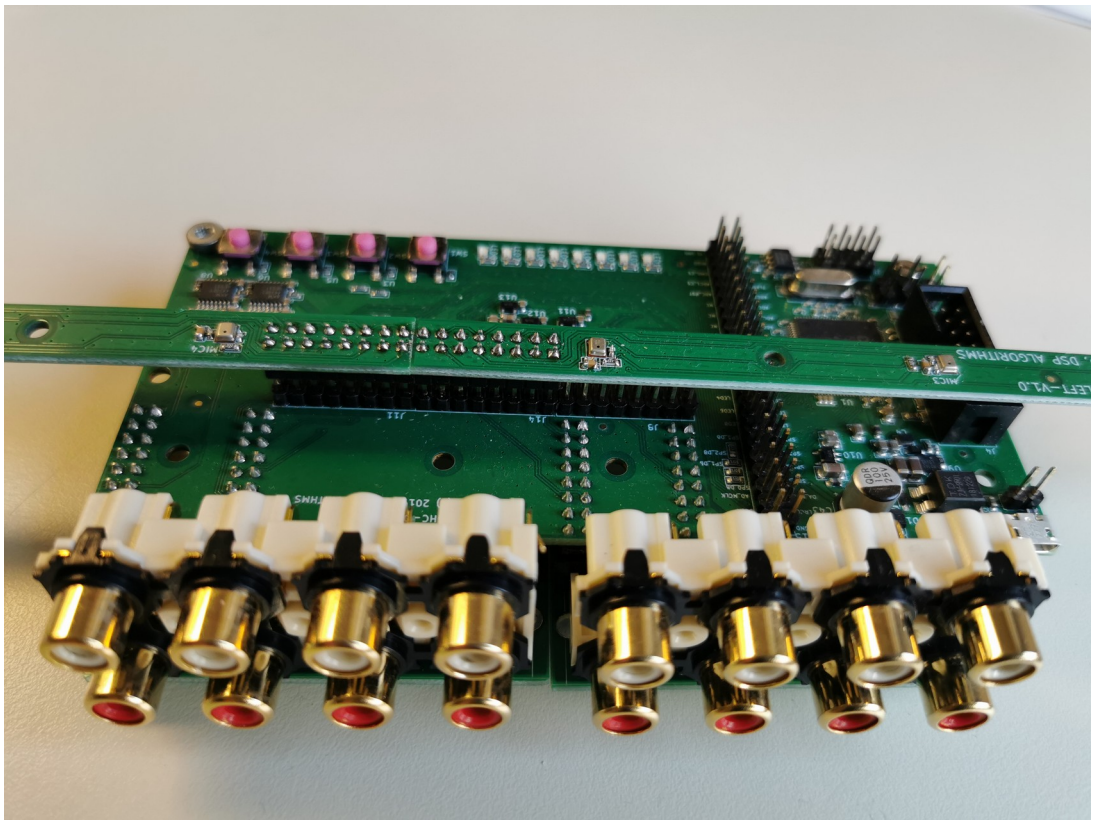

Figure 10: Microphone array PCB.

4.2 Arbitrary Shape Microphone Array

To implement any microphone array shape other than linear, the OCEAN-01-MIC is available as shown in Figure 11. The OCEAN-01-MIC is a tiny 9mm x 14mm PCB that includes one Knowles SPW2430 MEMS microphone. It is designed to be connected with wires to an IDC connector compatible with the OCEAN-ADSP21489-1204HC differential analog input header. Eight or 10 OCEAN-01-MIC PCBs can be easily mounted on a frame using the 1.5mm holes to form any microphone array shape (circular, hexagonal, rectangular, conical, etc) depending on the frame shape.

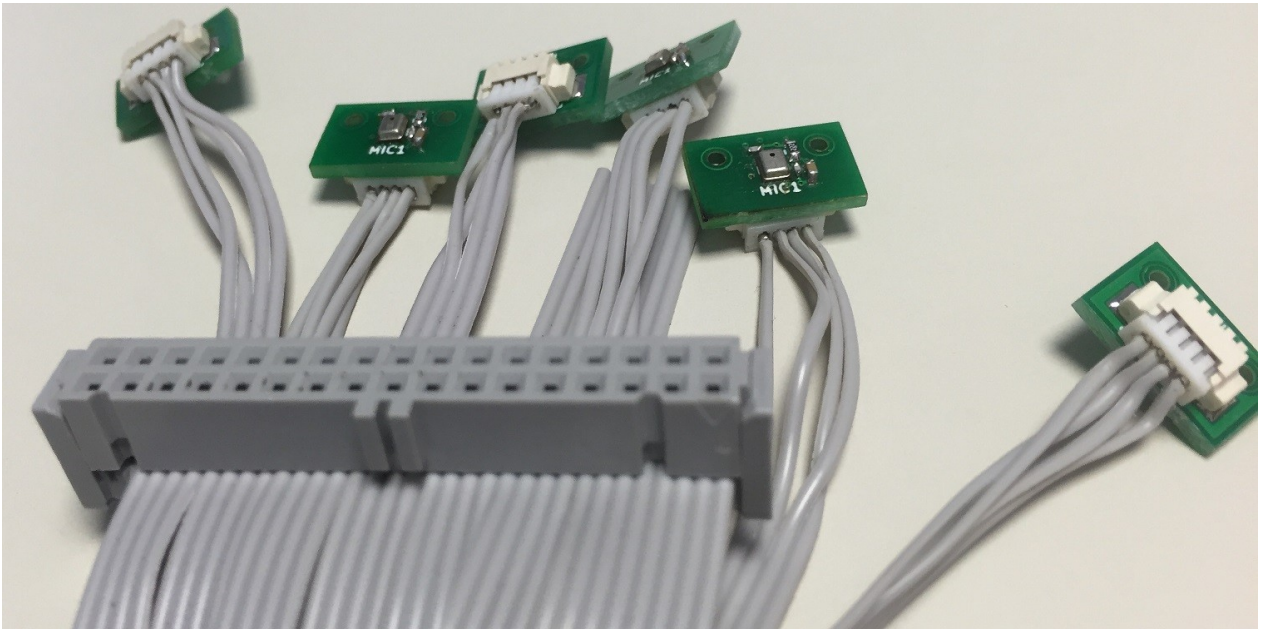

Figure 11: OCEAN-01-MIC for implementing arbitrary shape microphone array.

4.3 RCA, Jack, and Terminal Block IO Boards

Several separate small PCBs are available to allow connecting input and output signals to the OCEAN-ADSP21489-1204HC using commonly used audio connectors and cables. Currently three options are available, one populated with RCA connectors (the OCEAN-08IO-RCA), another with 3.5mm mono jacks (the OCEAN-08IO-JACK), and a third with 3.5mm euro terminal blocks (OCEAN-08IO-TB). All three peripheral boards are shown in Figure 12.

Each PCB contains 8x single-channel audio connector, each of which can be used as analog input or analog output. The RCA and Jack versions are single-ended, while the terminal block version is fully balanced. To use the audio connectors PCB as input, mate the two 0.1" female headers with J2, J3, J6 male headers on the OCEAN-ADSP21489-1204HC. To use the audio connectors PCB as output, mate the two 0.1" female headers with J7 male headers on the OCEAN-ADSP21489-1204HC.

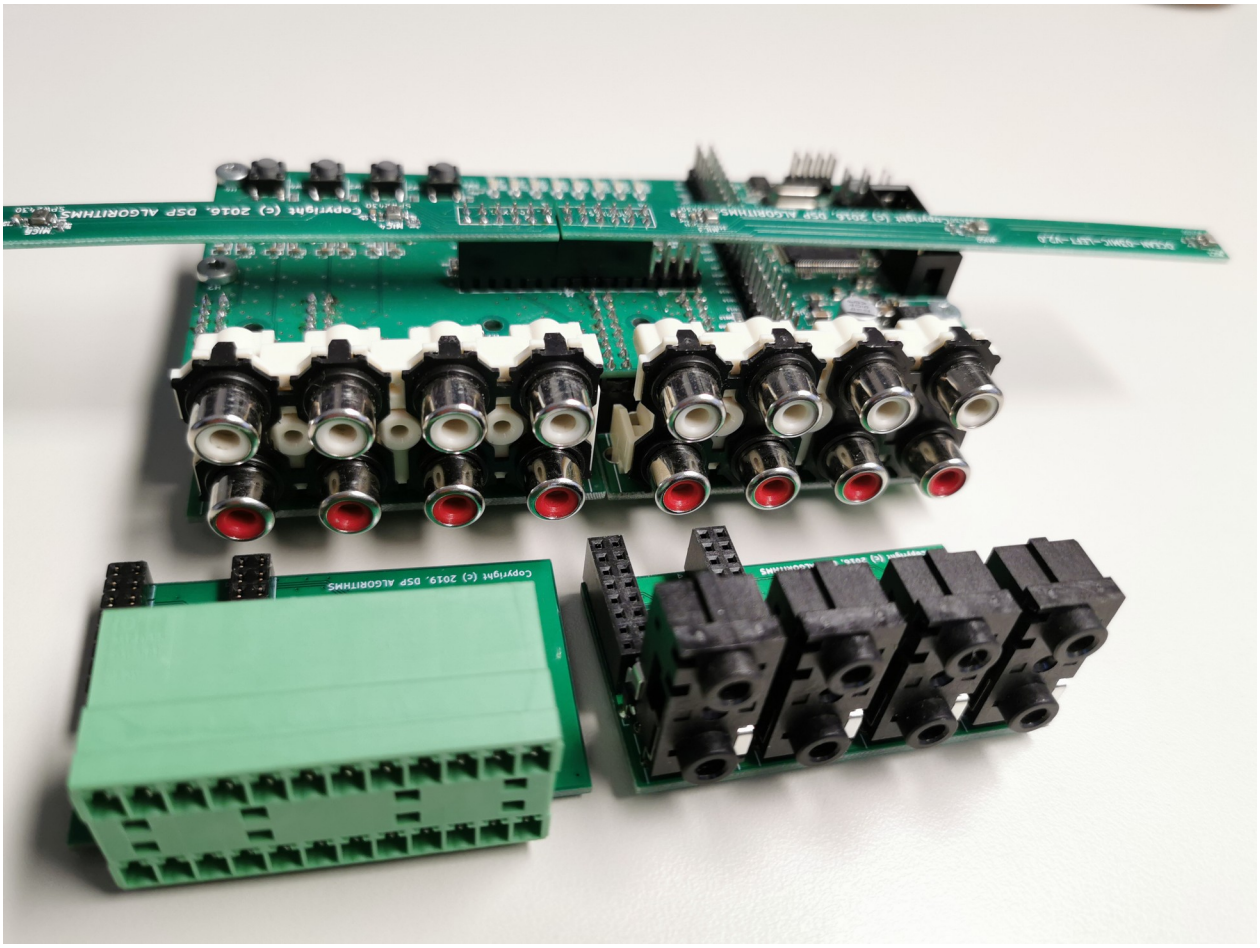

Figure 12: Analog audio connectors boards.