

# Getting started with Automotive Audio Bus (A<sup>2</sup>B) – it's not just for autos.

Part 4 – Designing and building systems – supplement to magazine article.

Supplement to article series appearing in AudioXpress magazine. See <https://audioxpress.com/> for more information

Written by: Brewster LaMacchia, Clockworks Signal Processing. <https://clk.works/>

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Part 1, published in the September '20 issue of AudioXpress, examined the basics of A<sup>2</sup>B<sup>1</sup> technology and how data moves between nodes bidirectionally under the auspices of the system's master node. In October's part 2 we looked at phantom power in an A<sup>2</sup>B system. November's part 3 examined the chip's LVDS interface.

Part 4 takes a step back and looks at creating systems and the tools that are available to speed up that process. We do this both to create prototypes for evaluating A<sup>2</sup>B as well as providing a platform for software development. We'll also look at off the shelf boards for A<sup>2</sup>B bus master use as picking one for development that is similar to your planned actual hardware can save time and effort. One of the nice things about A<sup>2</sup>B development is not only is its use license/royalty free, but ADI offers the software libraries and SigmaStudio design tool at no charge as well.

This supplement provides a detailed look at the off the shelf hardware that can be used for A<sup>2</sup>B prototyping and system building. For more about A<sup>2</sup>B please see the previously published parts in AudioXpress magazine.

## Host/Master node

The table below summarizes the current offerings for a host node. Most of these can also be A<sup>2</sup>B client/slave nodes in an A<sup>2</sup>B network. Later in this article we'll look at each of these master boards in more detail.

*Table 1 A<sup>2</sup>B master boards*

Model	Vendor	Processor	Description
EVAL-AD2428WD1BZ	ADI	ADAU1452	ADI's general purpose master node includes analog and ToS (digital) audio I/O
ADZS-SC589-MINI (SHARC Audio Module)	ADI	ADSP-SC589	Triple core SC589 with ARM and two SHARC cores along with accelerators. Analog and ToS I/O, Ethernet, USB, easy expansion

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<sup>1</sup> A<sup>2</sup>B and Automotive Audio Bus are a registered trademark of Analog Devices, Inc.

EV-21569-EZKIT	ADI	ADSP-21569	1 GHz single core DSP. Add-on board needed for EZKIT to add A <sup>2</sup> B
Thor 96	Arrow	i.MX 8M	Quadcore ARM-53 board following the 96Boards.org standards. Ethernet, USB, WiFi, HDMI, easy expansion (Master only)
EVMA2B02	Clockworks	ADAU1761	Basic master node using Clockworks A <sup>2</sup> B module. Analog I/O.
EVMA2B03	Clockworks	None/user supplied	Clockworks A <sup>2</sup> B module and I/O breakout board for interconnection with external host boards

A host node has two primary responsibilities; setting up the network and providing the clock that defines the audio sample timing. All nodes I<sup>2</sup>S clocks are slaved to the master node's clock source.

To use ADI's SigmaStudio tool for A<sup>2</sup>B development ADI's USBi emulator module is used. It provides a USB connection for the development PC and connects to the host's I<sup>2</sup>C bus. USBi interfaces boards are available from ADI as well as several 3<sup>rd</sup> party board vendors and can be used for any SigmaStudio target.

## Client/Slave node

With the exception of the Thor96 board listed in Table 1, the A<sup>2</sup>B host/master boards can also function as A<sup>2</sup>B client/slave nodes. There are a number of additional slave only boards for system building. Slave nodes may be locally powered or phantom (bus) powered. An important consideration is phantom powered slave boards can not be easily probed with a scope because their local ground node is not the same as the system ground (see part 2 of this article series).

The next table summarizes the boards available at the time this article was written, but please check the listed vendor's websites for any new additions.

*Table 2 A<sup>2</sup>B slave boards*

Model	Vendor	Function	Description
EVAL-AD2428WB1BZ	ADI	2 PDM Mic + 2 ch analog I/O	Bus (phantom) powered. Uses ADAU1761
EVAL-AD2428WC1BZ	ADI	4 PDM mic	Bus (phantom) powered.
EVAL-AD2428WG1BZ	ADI	2 ch analog I/O	Locally powered. Uses ADAU1761
ADZS-AUDIOA2BAMP	ADI	4 ch class D audio amp	Locally powered. Uses SSM3582 (approx. 15W/ch)
EVMA2B01	Clockworks	2 ch analog I/O	Locally powered. Uses ADAU1761
EVMA2B04	Clockworks	4 PDM Mic	Bus (phantom) powered.
A2B01/A2B03	Clockworks	I <sup>2</sup> S, I <sup>2</sup> C, GPIO breakout	For integration with development boards or embedded in products.
EVMA2BMIC	Clockworks	8 channel PDM mic array	Locally powered. Uses ADAU7118

SYS05	Clockworks	8 chan ADC and DAC system	Locally powered. Part of SignalBlox module series. Can be expanded to 16 ADC or 16 DAC channels.
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## A<sup>2</sup>B bus analyzers

For each new standard interconnect method a market quickly develops to take the raw bits and turn them in to information that can be helpful when diagnosing system problems. For A<sup>2</sup>B that breaks down in to two basic categories: the electrical levels/timing (eye diagram), and everything else. Since the primary data movement is a fixed TDM structure in one direction at a time there isn't the need for complex protocol analysis like that that occurs on PCIe or Ethernet interfaces.

The electrical analysis can be performed with a decent bandwidth scope (1 GHz) and differential probes that match that bandwidth. Keep in mind the large DC voltage from the 2 wire phantom power – not all probes can handle that. The 50 MHz data rate and heavy analog filtering keeps most of the signal below 500 MHz, hence ultra high end scopes aren't needed.

Bus analysis lets the details of the data and control packets be examined. The AD2428 device supports a sniffer mode that puts the bits out the chip's I<sup>2</sup>S ports. To use this the bus must also be electrically sniffed by tapping in to the connection between two nodes. Since it's only monitoring/receiving, this isn't a hard requirement to meet. What is more effort is making sense of all of those bits, and that's where companies such as Audio Precision, Mentor, Total Phase, and others (see full list on ADI's website) can offer value to the developer.

Diagnostics can be done from the host processor. Using SigmaStudio to drop in a node to monitor audio data or inject test signals is an easy operation, though it could change the network routing and for a highly utilized bus that could be an issue. Adding a node does not affect audio latency.

The ADI provided software stack handles quite a bit of the functionality for most application needs. If the project can stick to using SigmaStudio for the A<sup>2</sup>B network design and the ADI A<sup>2</sup>B software driver then a protocol analyzer probably won't be needed. If your project skips those tools and you write your own software for accessing the 200+ registers on each device then you're definitely going to need the protocol analyzer. In return you will be able to push the chip to its full capabilities

## Host/Master node board comparison

Table 1 listed the available master node boards that can be used to create a system for evaluation and prototype development. This last section provides more details on those boards design and features.

Understanding these boards will be helpful in designing your own system architecture to best use the capabilities of A<sup>2</sup>B technology.

All of these boards use the Molex DuraClik 2 pin connector for the A<sup>2</sup>B interface. The AD2428 IC is used for the A<sup>2</sup>B interface.

Also needed is the USBi (Figure 1) or equivalent to communicate between SigmaStudio and the target hardware.



Figure 1 USBi interface that provides I<sup>2</sup>C connectivity to SigmaStudio during development

## ADI 'WDZ board

This board is simplest to use as the processor on it, the ADAU1452 SigmaDSP, is programmed with the graphical SigmaStudio<sup>2</sup> tools. This makes it very easy to develop DSP application without needing to write code and learn a lot of details about managing I<sup>2</sup>S audio data.

The 'WDZ board (part number EVAL-AD2428WD1BZ) does not have an onboard microprocessor; tasks that involve reading and writing I<sup>2</sup>C registers in reaction to events in the system can be created in SigmaStudio but any complex conditional processing becomes awkward. If these are important to the application then adding a separate host processor board to the system and connecting it to the I<sup>2</sup>C and GPIO would be needed. There is an expansion connector on the 'WDZ but it is a fine pitch style so some intermediate board will be needed to access the signals on it. I<sup>2</sup>S connections for the host to send or receive audio are also available on this connector.



<sup>2</sup> [https://www.analog.com/en/design-center/evaluation-hardware-and-software/software/ss\\_sigst\\_02.html](https://www.analog.com/en/design-center/evaluation-hardware-and-software/software/ss_sigst_02.html)

*Figure 2 Analog Devices' 'WDZ board for A<sup>2</sup>B development based on the ADAU1452 SigmaDSP*

The AD2428's I<sup>2</sup>S lines are fully connected to the ADAU1452 to support 32 channels in a single direction by running each line in TDM16 mode. 3.3V I/O is used. The A<sup>2</sup>B input power voltage is nominally 7V but can be increased to 8V to support additional phantom powered nodes.

As with all ADI products, support is offered through ADI's EngineerZone forums.

## ADI SHARC Audio Module (SAM)

The SAM<sup>3</sup> board is a flexible ARM+DSP board with a number of peripheral and expansion options. The SC589<sup>4</sup> processor's ARM core can be used to run Linux or it can just be treated as a basic ARM platform for applications where Linux would be overkill. The board has connectivity features like USB, Ethernet, SD card, serial, etc., that make Linux or other OS use possible.

The two DSP cores can be programmed in C/C++ via ADI's CrossCore<sup>5</sup> Embedded Studio (CCES) IDE environment. CCES is based on Eclipse but it is a licensed piece of software; the SAM board includes a free version of CCES locked to the SAM board.

An official release of SigmaStudio for the SC5xx series of SHARC processors is in a beta release at the time this guide was written, and the author has used it with only minor issues related to the procedure used to correctly initiate the target hardware.

The 450 MHz A5 ARM core of the SC589 provides a way to write code to handle processing that doesn't map well to SigmaStudio. The two 500 MHz SHARC cores, along with the FFT and filter accelerators, provide a high performance DSP environment that can easily handle the needs of a 32 channel A<sup>2</sup>B system.

The A<sup>2</sup>B startup sequence of I<sup>2</sup>C transactions can be saved as .xml files that in turn can be used with the A<sup>2</sup>B software to create the I<sup>2</sup>C sequences needed. When combined with slave nodes that use a local EEPROM for startup the resource needs of the master node for setup are minimal.

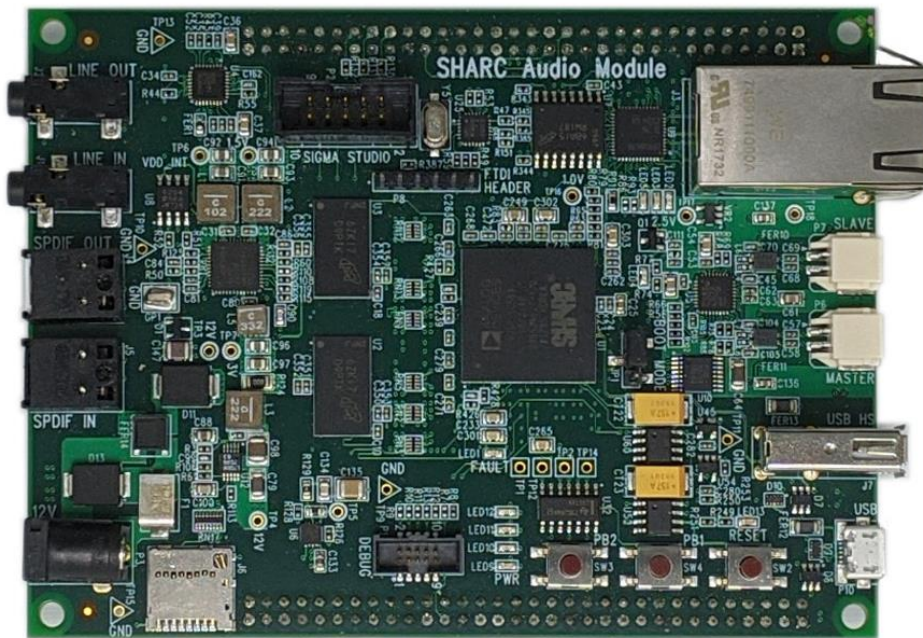
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<sup>3</sup> Part number ADZS-SC589-MINI <https://wiki.analog.com/resources/tools-software/sharc-audio-module>

<sup>4</sup> <https://www.analog.com/en/products/adsp-sc589.html>

<sup>5</sup> <https://www.analog.com/en/design-center/evaluation-hardware-and-software/software/adswt-cces.html>





*Figure 3 ADI SHARC Audio Module (SAM) board can be used for A<sup>2</sup>B development. Based on ADI's SC589 SoC, it provides enough DSP capability to handle the processing for typical applications that would use the 32 channel I/O capability of A<sup>2</sup>B.*

Designed to be a general purpose platform like RPi or Beagle, SAM is less expensive than the 'WDZ board. Though price should not be the primary consideration in selecting development system components - development time will be the biggest cost. Even if the final application does not need all of the compute power available from this board it's convenient to have since time won't need to be spent on code optimization.

The SAM module makes an extensive amount of I/O available via two 64 pin .1" headers. ADI calls boards that plug in to this *Fins* (as in SHARC Fins) but the concept is the same as *Hats* for RPi or Arduino. The SAM I/O expansion is much more extensive than those other boards, particularly for audio.

The AD2428's I<sup>2</sup>S lines are fully connected to the SC589 to support 32 channels in a single direction by running each line in TDM16 mode. 3.3V I/O is used. The A<sup>2</sup>B input power voltage is nominally 8.5V to allow support of a number of phantom powered nodes; most likely the current limit will be reached before the voltage at the farthest node drops too low.

The downside of this compute power is the associated complexity. JTAG is needed to load initial boot loaders and work with the DSP cores or for bare metal ARM development, and a serial console connection is required as well. The USBi adapter is used for loading the A<sup>2</sup>B network from SigmaStudio; this step can also be performed with the software driver libraries and custom code. Figure 4 shows the interconnections used for a two board A<sup>2</sup>B development setup. If using Linux on the ARM then Ethernet would also be connected. SAM with its SC589 processor can run Linux, but at the time this article was

written doesn't support Linux out of the box when used with the SAM software, including the A<sup>2</sup>B support. Instead SAM support for these is with what ADI calls the *bare metal* (ARM) framework.

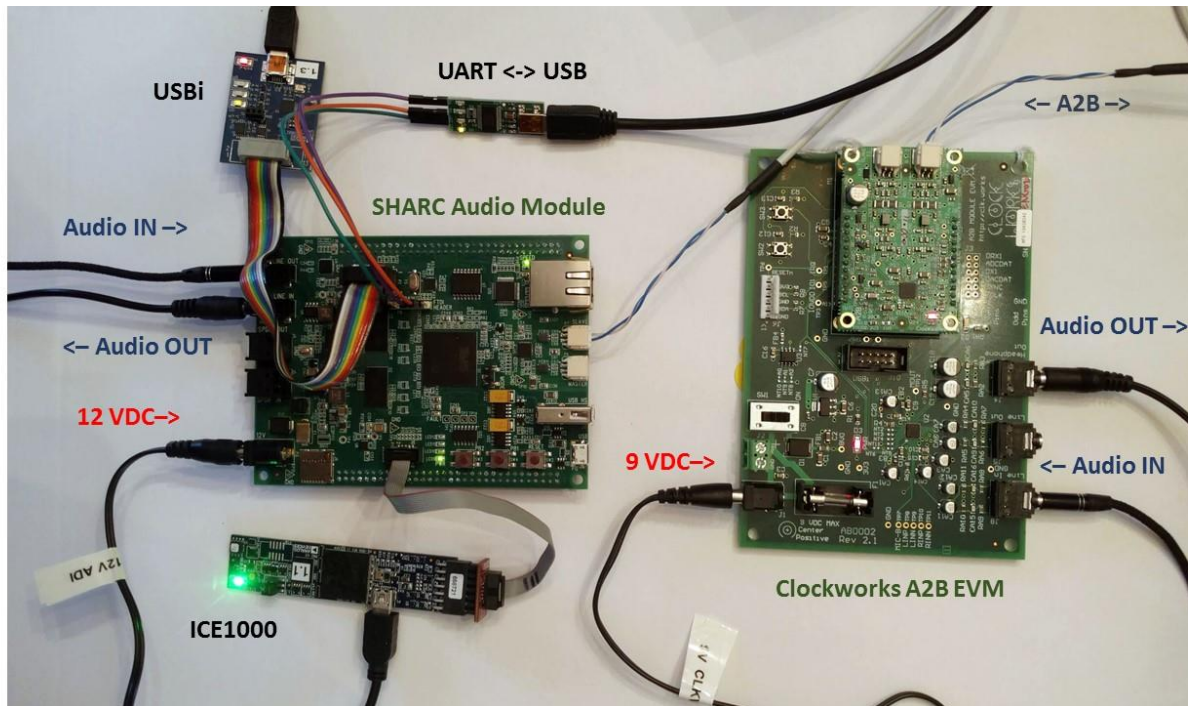


Figure 4 ADI SAM along with Clockworks EVM board to illustrate the connections used by the SAM board when developing.

For developers of SHARC software not having the complexity of Linux on the ARM side might be considered an advantage. If the application needs to use Ethernet or USB then the support from Linux makes that the better choice for the ARM side.

Like most ARM+Linux platforms, software tool support is a rapidly evolving area and the reader is encouraged to check ADI's website for updates on Linux, SHARC, and A<sup>2</sup>B software integration.

Buildroot is used to create the Linux kernel and ADI provides a cookbook approach to getting started with that. There's a general assumption of familiarity with embedded Linux and cross platform development. Support is offered through ADI's EngineerZone forums.

There is another SC589 based development board, ADI's SC589-EZLITE, that does support Linux out of the box, but that board does not offer A<sup>2</sup>B. The SC584-EZLITE based on the SC584 does offer A<sup>2</sup>B interfaces. A third board, the SC573-EZLITE board based on the SC573 which also include A<sup>2</sup>B capability. Like the Sam board, the EZLITE boards also include a CCES license tied to the board. The EZLITE boards do not come with a released version SigmaStudio but like the SAM board a beta release has been made available.

## Arrow Thor96

This board follows Linaro's 96boards standard for *Consumer Edition* hardware, which means it offers both the low speed and high speed expansion connectors. This provides a standardized software environment among a range of processor and hardware vendors. Based on NXP's 1.3 GHz quad core iMX 8M<sup>6</sup> (A-53 core) the board offers significant compute power even without the DSP specific hardware. Unfortunately the iMX 8M's sixteen I<sup>2</sup>S ports are not accessible, only a single pair of I<sup>2</sup>S ports (SAI2) is available on the low speed connector. If the master node doesn't need audio I/O other than A<sup>2</sup>B then this won't be an issue.

The AD2428 is connected through a single pair of I<sup>2</sup>S data lines, if operating A<sup>2</sup>B primarily in one direction TDM32 mode would need to be used for the 32 available channels. This is not recommended for the AD2428 with 48 kHz 24 bit data when using 3.3V I/O (16 bit data would be OK) and not possible with the 1.8V I/O voltage used in this board design. 16 upstream and 16 downstream channels would not be an issue as that keeps the BCLK rate at 24.576 MHz. The A<sup>2</sup>B section's input voltage is nominally 5V which will limit the number of phantom powered nodes before a locally powered node would be required.

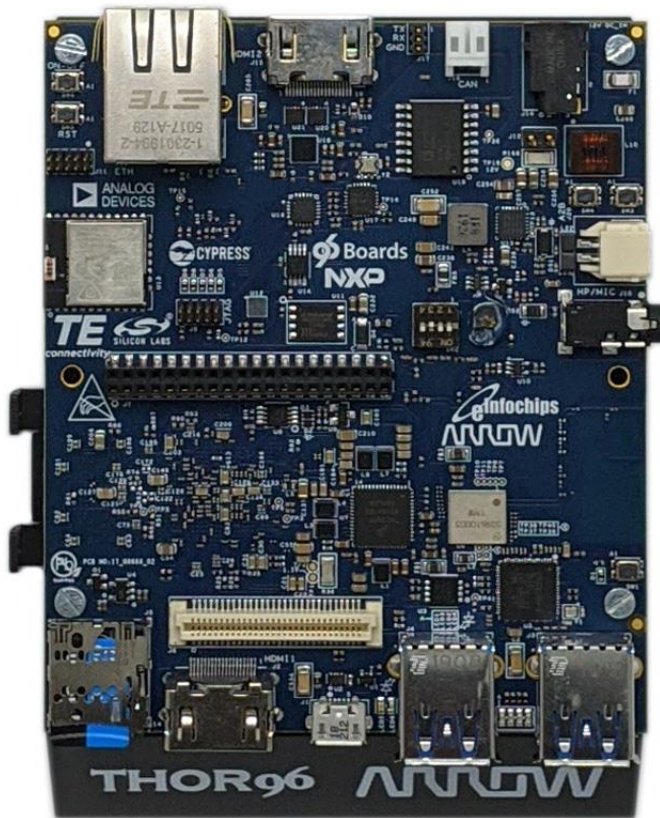
Unlike the other boards for A<sup>2</sup>B development, this board can only be an A<sup>2</sup>B master.

While this board may be somewhat limited in the A<sup>2</sup>B and I<sup>2</sup>S sections it makes up for it in raw compute power and a large amount of peripheral connectivity like USB, Ethernet, HDMI, WiFi, ZigBee, and Bluetooth. The iMX processor series has been available for a long time so there's a large software ecosystem for use in embedded applications, either with Linux or an embedded RTOS.

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<sup>6</sup> <https://www.nxp.com/part/MIMX8MQ6CVAHZAB#/>





*Figure 5 Thor96 board with 1.3 GHz iMX M8 (four A-53 cores)*

Thor96 doesn't have a USBi connector for using SigmaStudio for A<sup>2</sup>B development but the I<sup>2</sup>C2 bus (e.g. there are four I<sup>2</sup>C busses on the iMX M8, labeled 1, 2, 3, and 4) that the AD2428 uses is accessible from the low speed expansion connector, allowing access to the I<sup>2</sup>C that the USBi needs.

Software development for the Thor96 is done from a Linux environment. Those new to embedded Linux and cross compilation environments will find the Thor96 a bit daunting. The iMX8 kernel build is via Yocto. Support is offered through the 96board.org forum and Discord server.

At the time of writing the documentation for the Thor96 was slightly out of sync with where some of the software for the demo programs is found.<sup>7</sup> The documentation (at the time of writing) assumes you're moving from a different iMX platform and don't need information on setting up a workflow and are familiar with the drivers used by the iMX and on board peripherals.

## Clockworks EVMA2B02

This board is just the Clockworks A<sup>2</sup>B module and EVM board with an oscillator added to generate the MLCK signal that is used by the ADAU1761, which in turn generates the other I<sup>2</sup>S clock signals that the AD2428 needs. The ADAU1761 is not as powerful as the ADAU1452 in the ADI 'WDZ board.

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<sup>7</sup> [https://github.com/ArrowElectronics/l.IMX8\\_Thor96/releases](https://github.com/ArrowElectronics/l.IMX8_Thor96/releases)

The ADAU1761 only has one external I<sup>2</sup>S in and one out, so processing is limited to 8 channels in each direction as the ADAU1761 supports up to TDM8.

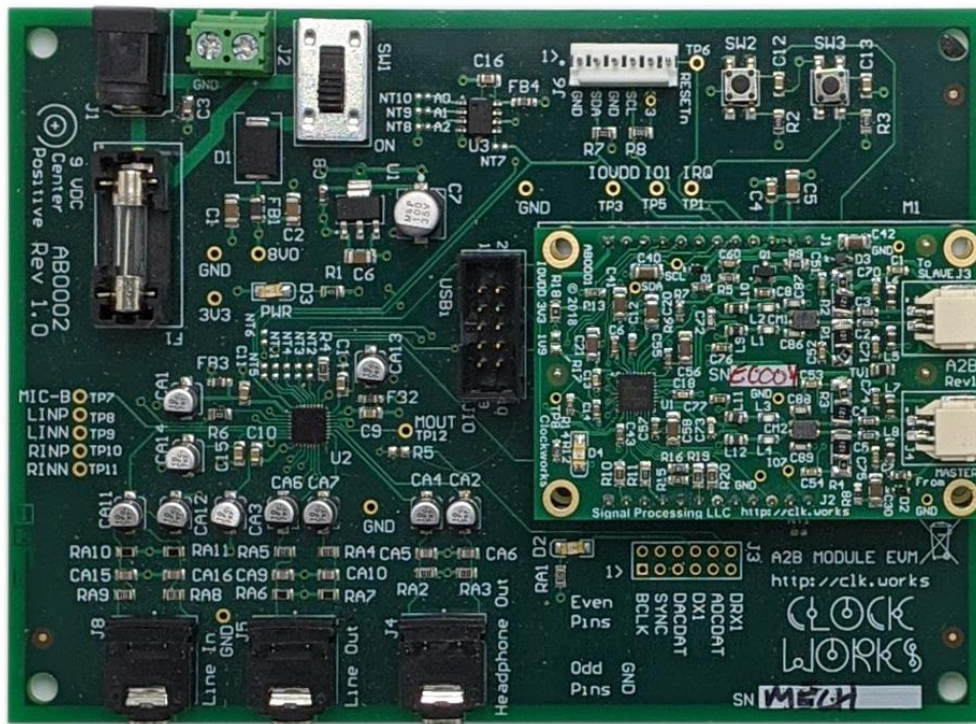


Figure 6 Clockworks ADAU1761 based board can be master or slave.

The value here is the same hardware can be master or slave, which is also true with the 'WDZ or SAM board.

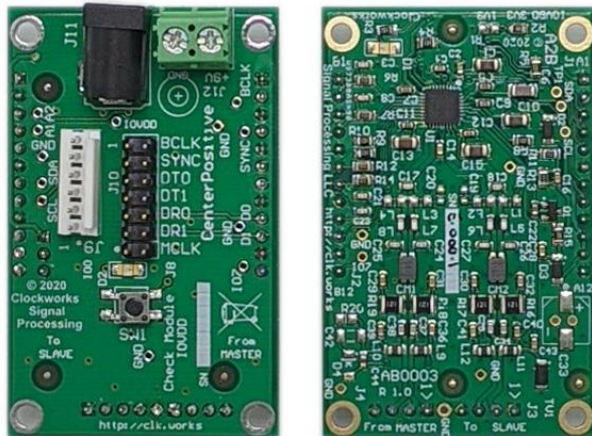
Perhaps of more interest is the A<sup>2</sup>B module plugged in to the EVM baseboard shown in Figure 6. This can be used with any host board that supports the required I/O to make an A<sup>2</sup>B master node.

Support of the Clockworks hardware is direct from them, but specifics of the ADI chip's operation would be via the ADI EngineerZone.

## Clockworks EVMA2B03

This isn't a specific host setup versus a way to connect your own host board to an A<sup>2</sup>B master node. This kit consists of two boards: the OEM version of the Clockworks A<sup>2</sup>B breakout module, and a secondary breakout and I<sup>2</sup>S buffer board. The OEM module version allows use of different A<sup>2</sup>B connectors, the standard A<sup>2</sup>B breakout module (shown mated to the host board in Figure 6) includes the DuraClik connectors.

It's also possible to just use the Clockworks A<sup>2</sup>B breakout module of Figure 6 and attach it to a custom board or even a piece of perf board to make an adapter to mate with a host processor board that has easily accessible connectors.



*Figure 7 Top and bottom of EVM2AB03 two board stack configured for a locally powered node with an external host processor than can connect for I<sup>2</sup>C control (6 pin white connector) and I<sup>2</sup>S audio data (14 pin header) to make a master node. The A<sup>2</sup>B connectors are on the opposite side of the first board. Depending on what's needed just the module pictured on the right can be used as a master.*

This particular combination does not offer a USBi connector so it will be necessary to make a small splitter cable to connect the I<sup>2</sup>C SDA and SCLK signals and ground to both the USBi and your host processor board.

It is recommended to start with one of the other solutions versus connecting this to your own host as the others work out of the box and are supportable by the companies that sell them. When integrating your own host board it's difficult to know where the problems may be; having a known working system to compare against is a huge plus.

If you're not sure, start with ADI's 'WDZ board as the master node and a set of slave nodes that roughly match your I/O needs. With that combination you can get basic audio flowing in just a few hours even if you're never used SigmaStudio before, and the 'WDZ is versatile for debug/test with its ToS (digital audio) connectivity.

## About the Author

Brewster LaMacchia started in signal processing working on military satellite communications systems. Since then he has worked on a wide range of signal processing systems, including a number of years on video processing and surround sound audio for consumer home theaters. Recently, he started Clockworks Signal Processing to develop open-source hardware for multichannel signal processing. He also dedicates time to public astronomy events to expose people to science and critical thinking. In the past 10 years, he's helped more than 7,000 people look through a telescope for the first time.

## Resources

A<sup>2</sup>B information: ADI's main A<sup>2</sup>B web page provides links to part information, ADI tools, and related design information. <https://www.analog.com/en/applications/technology/a2b-audio-bus.html>

The ADI page lists 3<sup>rd</sup> party A<sup>2</sup>B analyzer providers, including a list of test tools from Audio Precision, HEAD acoustics, Mentor, NOFFZ Technologies, and Total Phase.

Analog Devices SHARC Audio Module (SAM) board: <https://wiki.analog.com/resources/tools-software/sharc-audio-module>

Arrow Thor96 development board: <https://www.arrow.com/en/products/i.mx8-thor96/arrow-development-tools>

Clockworks A<sup>2</sup>B development boards: <https://clk.works/products/a2b-products/>

NVIDIA DRIVE AGX development system includes A<sup>2</sup>B but is not a directly purchasable product so was not included.