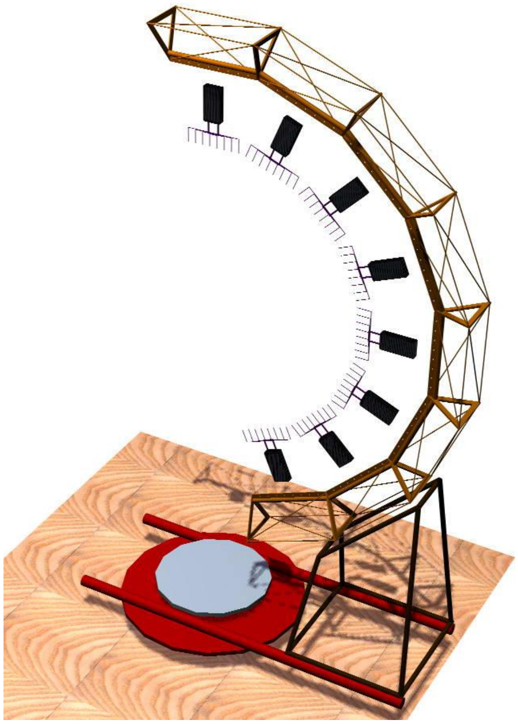
McGill AMMAR
Acoustic Measurement Microphone Array and Robot



Document Guide and Reference

v0.4

1. Getting Started

This document represents a launching point for finding information. If the information is located in another document, a reference is herein given.

1.1. Description

The Acoustic Measurement Microphone Array and Robot (AMMAR) is a specially-designed 72-element audio sampling system with two distinct array structures:

- A reconfigurable 8-segment 180-degree arc with 64 evenly distributed transducing elements at a radius of 550 – 590 mm.
- A dynamically positioned 8-element linear array comb. Comb positioning is numerically controlled in two linear axes of 1400 mm (resolution 0.15 mm) and 800 mm (resolution 0.08 mm). Comb positioning is manually controlled in two rotational axes of 180 degrees each.

Emission elements may be mounted on a numerically control rotary stage. The rotary stage may turn infinitely with a resolution of 7 arc minutes.

All 72 elements may be sampled simultaneously at 48 kHz. The array can be extended to 128 elements by simply adding additional mics, pre-amps, and digital converters.

Emitters can be driven with computer-generated signals for closed-loop measurements, or independently for open-loop measurements.

1.1.1. Microphone Combs

The microphone "combs" are designed to modularize linear arrays of microphones into easily managed 8-channel sets. Professional digital audio systems are often modularized to multiples of 8 channels, so this was a reasonable design.

The microphone combs have an even element spacing of 28.0 mm. The elements are Sennheiser KE4-211-2 electret capsules featuring a measurement-quality response characteristic.

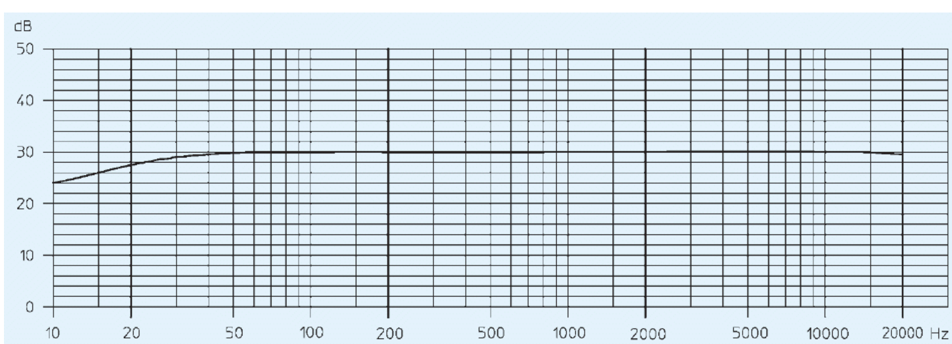


Figure 1 - KE4-211-2 capsule response.

The combs terminate into a DB-26-HD connector integrated into a keyed slide mount for easy/quick mounting. The DB-26-HD pin-out is given in the Appendix section 8.2. The slide mount is rounded to minimize reflections near the microphone elements.

1.1.2. Digital Preamplifer – USBAD-ADAT

The USBAD was developed to put a high-quality, multi-channel pre-amplifier with integrated digital conversion in fairly tight locations. Two versions were developed: USBAD-DSP and USBAD-ADAT. The ADAT version utilizes an FPGA for control. Once the FPGA is setup, the USBAD-ADAT can boot and run without host on power only. The USBAD-DSP version delivers audio over USB, and thus needs to be connected to a host in most applications.

The USBAD-ADAT supports 44.1, 48, 88.2, and 96 kHz digital operation, with both internal and external clocks. External clock is derived from a Toslink optical input signal. The analog to digital converters (ADC) are AK5386 with exceptional quality 110 dB SNR.

1.1.3. Arc Array Structure

The Arc Array structure is specially designed to have minimal acoustic impact/impedance while providing high-rigidity for accurate and consistent mic positioning. The modular segments provide flexibility with different arc lengths.

Note: The arc segments were designed to have tension cross-bracing. The fabricator insisted on making the material cross-sections thicker and eliminating the cross-bracing. AuSIM hesitantly approved this change without performing structural analysis, believing the fabricator’s assertion that it was equally stiff. Unfortunately, the cross-bracing is not replaceable. It was added back to the critical segment #2. The truss stiffness can be considerably improved with cross-bracing.

1.1.4. Multi-channel Audio Digital Interface – MADI

There are many proprietary multi-channel digital audio interfaces to stream audio data into and out from a digital audio workstation. However, there is only one AES professional standard: MADI. Each MADI channel can carry up to 64 single-rate digital audio channels (44.1 & 48 kHz). MADI supports double and quadruple rate digital audio with an associated division of the channel count.

To support 72 channels of single-rate sampling and 64 channels of double-rate sampling, AMMAR employs two MADI interfaces.

1.1.5. Cito Motion Control Axes

Motion of the robot can be realized on three axes: X, Y, and Z. The X and Y axes reference the robotic arm’s forward extension and height, respectively, while the Z axis determines the angle of rotation of the stage.

A more detailed explanation on robotic movement can be found in the AMMAR_Scripting_Guide.docx file.

1.1.5.1. Stage (Z)

The stage is referenced by the Z axis (in degrees) and can be free rotated indefinitely. A software limit of 720 degrees in each direction is imposed on all commands set to rotate the stage to a specific heading.

1.1.5.2. Arm (X & Y)

The arm's forward extension and height axes keep track of its position. As noted earlier it is important to remember that the origin is initially set by the position of the arm upon powering up the robot. The default software limit for moving the horizontal axis is between 0 and 700 mm while the default software limit restricts the vertical axis between 0 and 1400 mm. These limits are imposed on any command using a specific target coordinate to move to, the arms can still moved along the axis outside these zones with free move commands.

1.1.6. Acronyms

1.1.6.1. AMMAR

Acoustic Measurement Microphone Array and Robot

1.1.6.2. AMR

Acoustic Measurement Robot

1.1.6.3. AMCS

Advanced Motion Control Server

AMCS is the robotic controller from Cito Systems, which provides closed-loop feedback control of the servos powering the AMMAR robotic axes.

1.1.6.4. MADI

Multi-channel Audio Digital Interface

1.1.6.5. ASIO

Audio Streaming Input & Output

1.1.6.6. ADAT

Alesis Digital Audio Tape

1.1.6.7. RME

RME Audio AG in Haimhausen Germany

1.1.6.8. HDSP

Hammerfall Digital Signal Processing

A product-line of computer digital audio interfaces from RME which feature a powerful processor with matrix-mixing DSP functionality.

HDSP typically refers to the processing available on the interface card.

1.1.6.9. API

Application Programming Interface

1.1.6.10. GUI

Graphical User Interface

1.1.6.11. TCL

Tool Control Language ("tickle")

TCL is a common embedded systems interface language developed at UC Berkeley. A TCL server is embedded on the motion control server (AMCS) and all robotic commands are carried from the client/host to the robot controller via TCL.

1.1.6.12. FPGA

Field Programmable Gate Array

The AuSIM USBAD-ADAT and RME HDSP feature an FPGA for digital audio processing at its core.

1.1.6.13. LAN

Local Area Network

1.1.6.14. TCP/IP

Transport Control Protocol over Internet Protocol

1.1.6.15. TOSLINK

Toshiba Link

Toslink is a low-cost fiber-optic standard adopted for ADAT and S/P-DIF, featuring plastic fibers and visible light frequency.

1.1.6.16. USBAD

AuSIM USB Analog/Digital audio interface

1.1.6.17. AuAIO

AuSIM Audio Input/Output

1.2. Mechanical Assembly

See AMMAR_Assembly document in section.

1.3. Cable Connections

See AMMAR_Assembly document in section.

1.4. Robot Safety

The robotic system design incorporates several safety measures, implemented to prevent personal injury and equipment damage. They are mostly realized inside the controller; however, no automatic safety protocols are any substitute for operator vigilance. The operator has an emergency stop switch available which once pressed immediately cuts off power to the servo amps causing immediate stop of the motors.

In general, the AMMAR robotic system does not operate at high speeds. Even so, at low speeds the robotic axes are very strong and can break or crush obstacles in its operating path. The servo power should not be turned on without the operator having full control of the robot's surroundings including objects which may impede movement of robotic axes or people in the general area. This means that no one should be able to enter the proximity of the robot without being aware the robot is active and the operator being aware of their activity. The operator should carefully examine the operation envelope to ensure that the robotic axes can translate in their full motion without interference. Of particular concern are cables nearby or attached to items fixed to the rotary stage. Such cables should be able to accommodate the full intent of rotation of the stage.

Unattended robot activation is forbidden by the manufacturer, and violates any written or implied warranty or liability.

See the AMR Operation Manual document for more detailed information.

1.5. Powering

Powered devices are generally categorized into two classes: controllers and peripherals. Controllers should be powered off when not in use to maximize life and minimize power consumption. Peripherals consume much less power and are generally designed to be powered 24/7, but may be powered off when not in use. Peripherals should be powered before the controllers, so that the controllers can recognize their devices upon boot.

Powered devices are grouped into three locations to which power must be provided:

- remote workstation,
- robot pedestal, and
- truss-base.

Most of the peripherals source power from the integrated power strip in the truss-base. The workstation with its peripherals (monitor) may require its own powering because of its remote location. The AMCS provides power for all of the peripherals, incorporated at the robot pedestal end of the platform base, including any mic-array-module mounted on the robot wrist. These peripherals are thus dependent on the AMCS power switch.

1.5.1. Audio Equipment Rack

All of the audio equipment mounted on the arc-truss base is powered through the mounted power bar affixed to the base. All of the units may be left with their power switches on and have their power controlled by turning the power bar on or off as desired. It should be noted however that delivering power to the Altec emitter amplifier is not sufficient for operation. Powering the amplifier places it in a “stand-by” state. To be functional, the operator must ready the amplifier by using the “on/standby” button on the amplifier’s remote control.

1.5.2. Robotic Control System

All of the AMMAR’s power for robotic movement is delivered by the power cord attached to the ACMS which distributes power as necessary to the servos and itself.

1.5.3. Workstation

The workstation has only two independently powered components: LCD monitor and DAPU. Both require a standard IEC-C13 to NEMA-5 power cord. Using a power strip will conditioned and surge-protected power will provide the best performance and longest life for the DAPU.

Turn ON the LCD monitor first. There is a toggle power switch on the back adjacent to the IEC-C13 receptacle and a momentary switch on the front.

The DAPU has no mechanical power switch. It is ready to boot as soon as power is supplied.

1.6. DAPU Boot-Up and Login

At this point all devices are powered and the DAPU is ready to boot.

Momentarily depress the power button in the front of the DAPU, and the computer should begin booting Microsoft Windows XP SP2.

There are three standard login accounts:

- **goldminer**
  Standard AuSIM3D run-time account with very limited user/workstation resources, optimized for real-time performance.
  Password = “nugget”
- **goldsmith**
  Standard GoldSeries administrative account.
  Password = “smitty”
- **Measure**
  Special AMMAR account for user workstation usage. Has full administrative privileges.
  Password = “ammar”

The system automatically logs into the Measure account.

2. Operation

At this point, the AMMAR system should be fully assembled, connected, and powered-up. Please see sections 1.1.6 through 1.5 above if this is not the status.

The focus of this apparatus is to sample sound across a vast microphone array, which is covered in the next sections. To satisfy any anxiety to exercise the robotic system, an operator is welcome to jump forward to section 2.4 on Motion Control.

2.1. *Basic Array and Connectivity Tests*

Several MATLAB scripts have been included for testing the status of the AMMAR. ConnectionCheck can be run to test the status of the emitters mounted on the AMMAR's frame as well as the status of the 72 input channels.

2.2. *Signature and Validation*

The individual module arrays were calibrated at the factory. A calibration is expected to survive physical setups and only be required if capsules, combs, or modules are replaced. Please see section 4 for more information on calibration.

The system signature captured at the factory is likely not to be valid in a new acoustic environment. The operator is encouraged to check the current setup against any previous signature. However, upon any new setup, it is very advisable to capture a fresh signature.

See QuickValidationTools.pdf for details on signatures and the validation process.

2.3. *Array Sampling*

See AMMAR_ArraySampling.pdf, section 3.

2.3.1. Demo – Loudspeaker Radiation

See AMMAR_ArraySampling.pdf, section 3.1.

2.3.2. ASIO Application

Any ASIO compatible application such as Cakewalk Sonar, Steinberg Cubase, DigiDesign ProTools, or Sony Acid Pro.

See AMMAR_ArraySampling.pdf, section 3.

2.4. *Motion Control*

The AMMAR apparatus features three axes which can be mechanically moved via computer control. This computer control of mechanical devices may be called "numerical control", "robotic control", or "motion control" by various sources. Within the AMMAR document set, the terms "robotic" and "motion" control are used interchangeably meaning the same thing.

See AMMAR_Scripting_Guide.pdf for details.

2.4.1. AMR Graphical User Interface

The amrGUI dialog window is shown below in Figure 2.

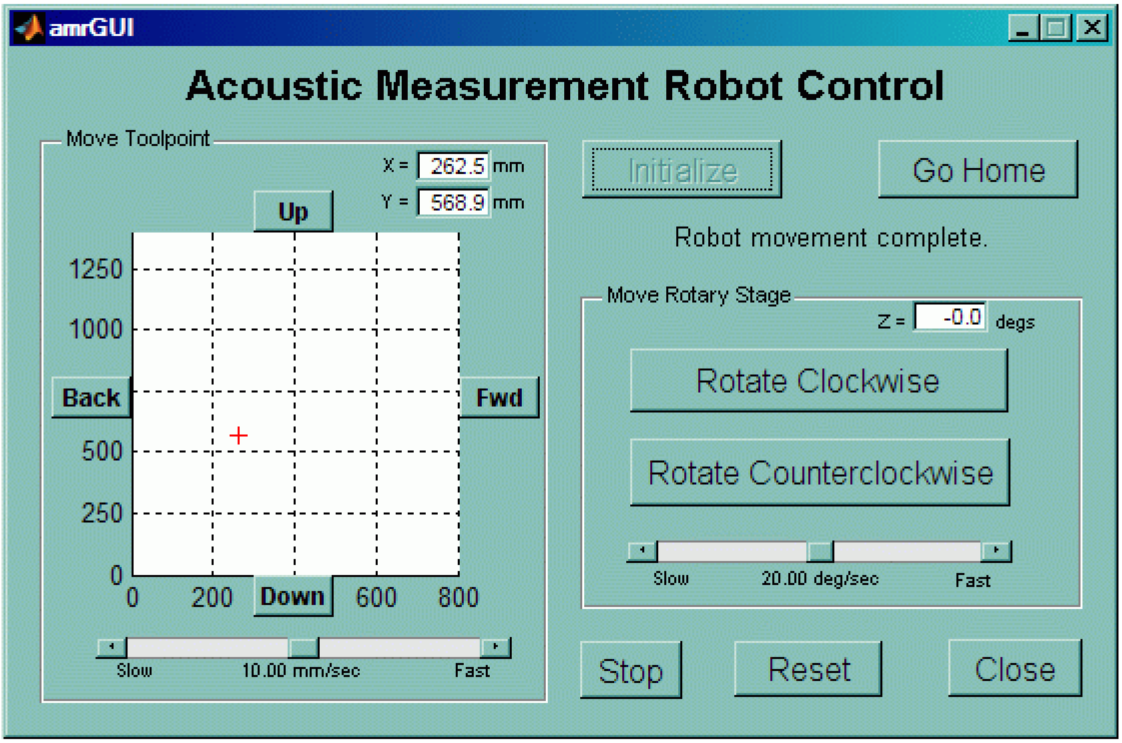


Figure 2 – amrGUI Matlab dialog.

3. Programming

3.1. Array Sampling

See AMMAR_ArraySampling.pdf, section 4.

3.1.1. Matlab

See AMMAR_ArraySampling.pdf, section 4.1.

3.1.1.1. AuProbe

See AMMAR_ArraySampling.pdf, section 4.1.1.

3.1.1.2. ChnlMgr2Matlab

See AMMAR_ArraySampling.pdf, section 4.1.2.

3.1.1.3. AuAIO2Matlab

See AMMAR_ArraySampling.pdf, section 4.1.3

3.1.2. AuAIO

See AMMAR_ArraySampling.pdf, section 4.2.1

3.1.3. ASIO

See AMMAR_ArraySampling.pdf, section 4.2.2

3.2. Robot Motion Control

Motion control can be programmed through Matlab using the AMR API or through C using the low-level AMCS API. The AMCS API is a command set implemented over TCL. TCL is easily accessed through a wide variety of popular programming languages, including Visual BASIC, Java, and Python.

3.2.1. Matlab – AMR

AMMAR-specific control was developed in a Matlab wrapper of the TCL AMCS interface called the AMR Matlab API. The API serves both as a useful tool and as a programming example.

See AMR_MatlabAPI.pdf for details.

3.2.2. Advanced Motion Control Server – AMCS

See "Cito AMCS Programming Manual - rev.1.0.pdf" for details.

3.3. Signal Routing

Needs write-up here.

3.3.1. AuSIM AuMatrixMixer

Needs reference to document.

3.3.2. RME HDSP Mixer

4. Calibration

4.1. Microphone Preamplifier

4.1.1. FPGACal

See document MicArrayCalibration.pdf

4.2. Analysis and Visualization

Needs reference to document.

5. Advanced

5.1. Assembly

See AMMAR Assembly document.

5.2. Disassembly, Crating, and Transportation

See AMMAR Disassembly and Transport document.

5.3. Workstation

5.3.1. Cooling

MADI interfaces run hot. Two MADI interfaces run hotter. The DAPU was designed using an ultra-cool mobile, dual-core processor, for high performance without extraneous heat dissipation. The power-supply is also extra quiet and efficient. Still cool air must be drawn through the system to cool the MADI interfaces.

Nothing should block the vents on the top, sides, and rear of the DAPU chassis. Generally the air flow is into the top vent over the power supply and out to the rear.

The DAPU includes a manual fan-switch controlling the extra dual-fans on the rear panel. The fan can be turned on HIGH, LOW, or OFF. OFF may be used when the room air-conditioning is kept cool and circulation is good near the DAPU.

5.3.2. Networking

There are two networks associated with the AMMAR system: an internal network for motion control and an external network for data exchange with other systems. The internal network is between the DAPU and AMCS. The external network is between the DAPU and other systems. Both networks conform to TCP/IP protocols and addressing.

5.3.2.1. DAPU Addressing

The DAPU's internal network is identified as "AMR LAN". The DAPU's internal static address is 192.168.2.90. This address remain on the 192.168.2.x subnet, and must not be set to 192.168.2.91, which is the AMCS. The host "AMCS" is defined as 192.168.2.91 in the /windows/system32/drivers/etc/hosts file. Most TCP/IP applications can find the AMCS by hostname via this mechanism.

The DAPU's external network is defined as "External LAN". The DAPU's external static address is 192.168.0.180. This address may be changed to conform to any network it is attached to, including enabling DHCP.

5.3.2.2. AMCS Addressing

The AMCS IP address is factory set statically to 192.168.2.91.

5.3.3. File Locations

5.3.3.1. System (C Drive)

Home of the Operating System ("Windows") and the operating system's most important two file branches: applications ("Program Files") and user-specific data (“Documents and Settings”).

Matlab is also installed on this drive, but outside the standard “Program Files” to make the path more manageable.

The drive will be written to often and thus eventually fragmented. It contains the user data, which is constantly updated by Windows. It contains the virtual memory swap file, which is constantly updated by Windows.

5.3.3.2. AuSIM (D Drive)

Home of AMMAR-specific and AuSIM-specific code, applications, and documentation. This drive is essentially read-only.

This drive should normally never be written to, except via a software upgrade. The AuSIM3D structure does contain several repositories for possible user data including filter maps, equalization filters, event lists, and wavefiles.

AMMAR Documentation

All AMMAR-related documents in one place. There may be additional copies in other locations, but one copy of everything is here.

AuSIM3D

This is the standard AuSIM3D installation folder. The DAPU is a fully-functional, fully-licensed 3D audio server.

AuSIMTools

AHMTools

AMMAR

AMR

AuAIO_Matlab

AuProbe

CalVal

ChnlMgr2Matlab

HDSPCtrl

HeadZap

USBAD_ADAT

CitoSystems

5.3.3.3. Data (E Drive)

5.4. Input Paths

The DAPU system supports 128 digital input channels. The AMMAR system is supplied with 9 microphone array modules, each integrating 8 analog-to-digital converted channels, totaling 72 channels. At 48 kHz all 72 channels may be sampled simultaneously. At 96 kHz the data rate is doubled and thus the maximum channels is halved to 64.

Table 1 – Input Paths

Origination	Module Arc-1	Module Arc-N	Module Robot
Mic Comb	1-8	1-8	1-8
USBAD-ADAT	1-8	1-8	1-8
RME ADI-648	A1.1-A1.8	AN.1-AN.8	A9.1-A9.8
MADI	MADI-1 1-8	MADI-X Y-Z	MADI-2 1-8
RME HDSP	HDSP-1 1-8	HDSP-X Y-Z	
RME TotalMix	Mixer-1 1-8	Mixer-X Y-Z	
ASIO	1-8	U-V	65-72
AuMatrixMixer[1]	1-8	U-V	65-72
AIO Channel	1-8	U-V	65-72

5.5. Output Paths

While the system supports 128 digital output channels, which are shown in the RME TotalMix interface, the system has only 4 channels with digital-to-analog conversion (DAC). All 128 channels terminate at the RME ADI-648 as ADAT optical channels. The output ADAT fiber-optic Toslink cables propagating from the ADI-648 to the USBAD-ADAT modules carries output signals, but the USBAD-ADAT only to utilizes the distributed common master clock signal.

The four available analog output channels are built-in to the RME HDSP MADI interfaces. There are two PCI-to-MADI interfaces: MADI-A for channels 1-64 and MADI-B for channels 65-128. Each has a single stereo "monitor" output in the form of a TRS phone (1/4" tip-ring-sleeve) jack. These signals are unbalanced.

Table 2 – Output Paths

Destination	ArcTruss	Pedestal	Near Rail	Far Rail	Stage
AIO Channel	1	2	65	66	1
AuMatrixMixer[2]	1	2	65	66	1
ASIO	1	2	65	66	1
RME TotalMix	1	2	65	66	1
RME HDSP	MADI-1	MADI-1	MADI-2	MADI-2	MADI-1

[1] The AuMatrixMixer is an optional path component and not recommended for use with the microphone array. AuAIO should be directed to connect directly to ASIO.
[2] The AuMatrixMixer is an optional path component and not recommended for use with the microphone array. AuAIO should be directed to connect directly to ASIO.

Analog Cable	Left Front Tip	Right Front Ring	Left Surround Tip	Right Surround Ring	Left Center Tip
A-L Amp Ins	Front Left	Front Right	Surround Left	Surround Rear	Center
A-L Amp Outs	Pedestal	ArcTruss	Near Rail	Far Rail	Stage
Loudspeaker	Pedestal	ArcTruss	Near Rail	Far Rail	Stage

5.6. Hardware Components

Consider more hardware components such as Altec Lansing speakers, robot, etc.

5.6.1. USBAD_ADAT

Needs reference to document.

5.6.2. RME HDSP MADI

See RME_HDSP_MADI.pdf.

5.6.3. RME ADI-648

See RME_ADI648.pdf.

5.6.4. Altec-Lansing Amplifier and Loudspeakers

6. Utilities

6.1. RME TotalMix

Needs reference to document.

6.2. HDSPSet

Needs reference to document.

6.3. Cito EasyMotion

Needs reference to document.

6.4. AuSIM3D

6.4.1. GoldServer

Needs reference to document.

6.4.2. Rendograph

Needs reference to document.

6.4.3. HeadZap

Needs reference to document.

6.4.4. AHMTools

Needs reference to document.

7. Trouble Shooting

7.1. Mic-preamp Module

Symptom	Possible Problem	Solution

7.2. MADI-ADAT Converter

Symptom	Possible Problem	Solution

7.3. Emitter Amplifier

Symptom	Possible Problem	Solution

7.4. HDSP MADI

Symptom	Possible Problem	Solution

7.5. Robotic System

For the AMR robotic system trouble-shooting, see the AMR_Operation.pdf document.

8. Appendix

8.1. Document List

8.1.1. Getting Started

8.1.2. Assembly

8.1.3. Disassembly

8.1.4. Calibration, Signature, and Validation

8.1.5. Array Sampling

8.1.6. AMR Operation

8.1.7. AMR Matlab Application Programming Interface

8.1.8. USBAD_ADAT

8.1.9. Sennheiser KE4-211-2

8.1.10. RME TotalMix

8.1.11. RME HDSP MADI

8.1.12. RME ADI-648

8.1.13. Cito AMCS

8.2. Microphone Comb DB-26-HD Pinout

Pins 1-8 are signals with bias voltage for mics 1-8 respectively.

Pins 10-17 are grounds for mics 1-8 respectively. All grounds are tied together.

Pins 9 and 18 are connected to ground.

Pins 19-26 are used for other signals for other applications. Do not connect.

AMCS Programming Manual	Lists, describes, and shows example usage for the system-level API used to control the movement of the robotic axes. Provided by robot manufacturer Cito Systems.

Shortcut: Start Menu/AMMAR/Docs/AMCS Programming Manual
Location: D:/CitoSystems/manual/AMCS Programming Manual - rev.1.0.pdf

AMMAR Assembly Instructions	Guide to the assembly of the robot axes, support structure, truss, and mic array, including cable installation and connection. Provided by AuSIM.

Shortcut: Start Menu/AMMAR/Docs/AMMAR Assembly Instructions
Location: D:/CitoSystems/manual/AMMAR Assembly Instructions.pdf

EasyMotion User's Guide	Guide to the operation of EasyMotion, a very thorough example application with a GUI that can be used to control all aspects of robot motion and display a wide variety of robot status flags. Provided by robot manufacturer Cito Systems.

Shortcut: Start Menu/AMMAR/Docs/EasyMotion User's Guide
Location: D:/CitoSystems/manual/EasyMotion manual ver.4.02.pdf

RME-ADI-648 Maunal	Guide to the physical operation and maintenance of the two ADI-648 units. Provided by ADI-648 manufacturer RME.

Shortcut: Start Menu/AMMAR/Docs/RME-ADI-648 Manual
Location: D:/AuSIM3D/Doc/RME-ADI648_2_e.pdf

Robot Matlab API	Guide to the Matlab API provided as a user-friendly wrapper around the lower-level Cito Systems robot commands. Provided by AuSIM.

Shortcut: Start Menu/AMMAR/Docs/Robot Matlab API
Location: D:/AuSIM/AMR/RobotMatlabAPI.pdf

Robot Operation Manual	Guide to the physical operation and maintenance of the robot hardware. Pictorially identifies system components, recommends safety guidelines, identifies maintenance requirements, and specifies maximum operational parameters. Provided by robot manufacturer Cito Systems.

Shortcut: Start Menu/AMMAR/Docs/Robot Operation Manual
Location: D:/CitoSystems/manual/Robot operation manual - rev.1.0.pdf

TotalMix Demo Guide	Guide to operation of the RME TotalMix application, a full channel mixer, a full channel matrix router that is MIDI remote-controllable. Provided by ADI-648 and MADI card manufacturer RME.

Shortcut: Start Menu/AMMAR/Docs/TotalMix Demo Guide
Location: D:/AuSIM3D/Doc/TotalMix_Demo_e.pdf