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TND6117/D

RHYTHM™ SB3231 BTE 1.0 Reference Design

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TECHNICAL NOTE

Introduction

The BTE 1.0 Reference Design is a hardware reference design for a Behind-The-Ear (BTE) hearing aid using the Rhythm SB3231 preconfigured DSP system. It contains a single SB3231 device which enables implementation of a complete digital hearing aid with state-of-the-art features and specifications.

A diagram of the major components in the design is shown below:

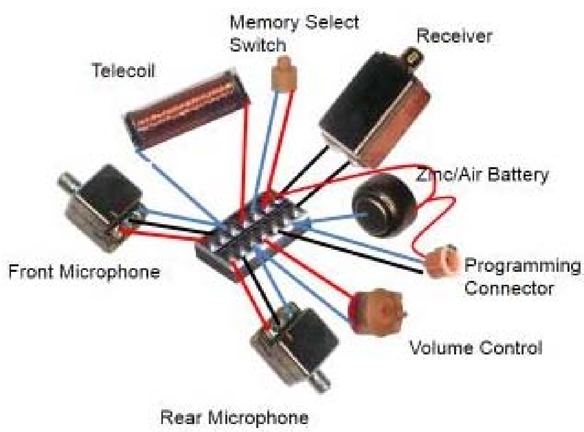


Figure 1. Major Components Included in the Reference Design

This reference design assumes that the BTE will be assembled using point-to-point wiring of the components. Therefore, no description of a PCB design is given. A flex PCB implementation is a preferred component interconnect method for large production volumes, but is beyond the scope of this document.

In addition to this document, a compressed folder (Document ID), is supplied which contains the following configuration files:

Document	Description
BTE_1.0.ids	Configuration file for Interactive Data Sheet
BTE_1.0.dll	Example library using reference design transducers
ED−27303_Receiver.xls	Receiver Model for Ark Online Library creation
ED−2446_microphone_Rear.xls	Microphone Model for Ark Online Library creation
ED−2446_microphone_Front.xls	Microphone Model for Ark Online Library creation

The SB3231 design is supported by an extensive collection of design tools and documentation. This also details how ON Semiconductor ARK tools are used for the design and configuration of a new hearing aid.

Overview

The following steps outline the basic procedure used in this document for the design and assembly of a hearing aid:

1. Specify the requirements of the product which include the desired features and performance
2. Identify the components that will meet the requirements of the design
3. Create the mechanical drawings, schematics, and bill of materials for the design
4. Build a prototype model using the selected components
5. Model the acoustic performance of the device to determine the overall acoustic response
6. Program the device with the desired configuration
7. Calibrate the final assembly
8. Regulatory requirements for hearing instruments vary by country and region. Once the device has been assembled and tested, it will be necessary to submit the device for regulatory testing and approval before it can be sold as a hearing instrument.

Resources

Throughout this article, references will be made to ON Semiconductor software tools and documentation. The links to this information are provided below:

1. Rhythm SB3231 datasheet
   http://www.onsemi.com/pub_link/Collateral/SB3231−D.PDF
2. ARK Installation
   http://ark.onsemi.com/ (requires registration)
3. ARK User’s Guide
   http://ark.sounddes.com/pdf/ARKguide2011.pdf
4. Application Notes
   http://www.onsemi.com/PowerSolutions/supportDoc.do?type=AppNotes&category=101769

Product Features

The design of the BTE device is based on the features described below:

- Programmable BTE instrument with four channels of WDRC compression
- 96 dB input dynamic range
- Compatible with SOUNDFIT™ fitting software
- Adaptive feedback cancellation
- Programmable crossover frequencies
- 4 hearing programs
- Adaptive noise reduction using dual microphones
- Noise generator for tinnitus masking
- Auto telecoil with programmable delay
- Programmable Volume control (VC)
- Pushbutton memory select
- Power−on Delay
- Battery compartment
- Ear hook
- Disposable battery: Size 13
- Programmable acoustic tone for low battery voltage
- Housing available in different colors
- RoHS compliant

Product Specification

• Frequency response:	100 Hz − 8 kHz
• Battery type	13
• Number of microphones	2 omnidirectional
• Volume control	analog potentiometer
• Memory select	pushbutton
• Number of memory selects	4
• Telecoil	passive
• Acoustic output	65 dB

BTE Hearing Aid Components

Figure 2 below shows the components used in this design:

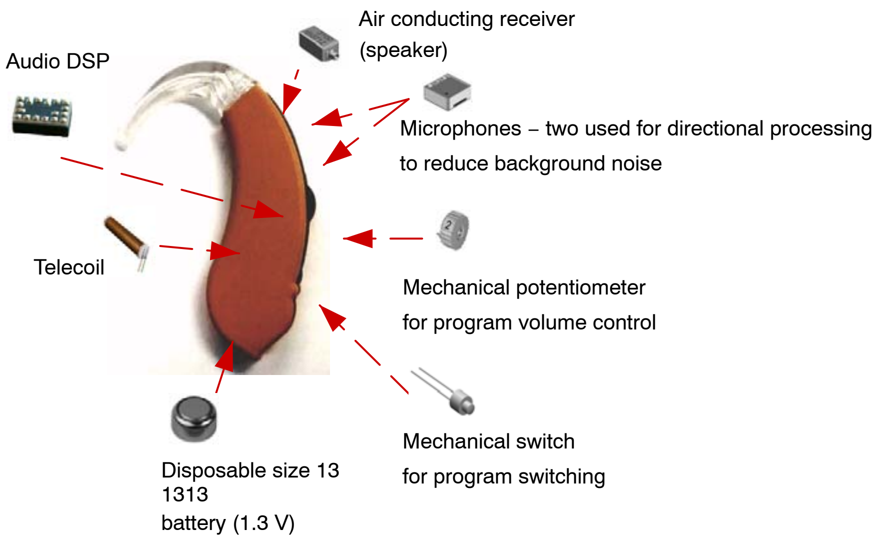


Figure 2. BTE Hearing Aid Components

SB3231

SB3231 is a highly integrated DSP system specifically designed for hearing aids. It has a wide range of configuration options to allow different combinations of pushbutton switches, analog volume adjustment, and automatic telecoil selection.

Microphones

Two omnidirectional microphones are required in order to take advantage of the advanced signal processing provided by SB3231.

In order to achieve the best directional performance, matched microphones should be used.

Both Knowles and Sonion offer a range of suitable microphones for this application.

The microphones used in this design are a matched pair of the omnidirectional EM-24446 models with good sensitivity and noise performance. The matched pair has a separate EM-30083-S11 part number.

A suitable Sonion equivalent microphone would be the 9446M.

Acoustic Receiver

This is a miniature audio transducer that converts the electrical output of SB 3231 to an acoustic signal. The Knowles ED-27303-000 receiver provides a compact and robust receiver for medium power applications.

A Sonion 2016 or 23x93 receiver may also be used.

Telecoil

The telecoil converts the electromagnetic energy from a telephone speaker to an electrical signal for further processing by the audio DSP system.

The Knowles 5100 passive telecoil is used in this design.

Volume Control

This is an analog potentiometer used to adjust the listening level of the hearing aid. The Sonion PJ77 is used in this design, specified with a linear taper.

Pushbutton Switch

This is used to toggle between the different presets stored in the SB3231 memory. The Sonion PB 95 momentary pushbutton is used in this design.

Programming Connector

This connector is used for initial configuration of the device, as well as custom fitting. There are two common methods for device programming; a CS 44 connector and a CS 54 programming flex strip.

In this design, an integral CS 54 flex programming connector is provided by the BTE shell assembly.

The connector system used is a Sonion PN 5054-3014347.

BTE Shell

The BTE shell provides the housing and mounting structure for all components.

The In’Tech BTE Euro 13 kit is used in this reference design.

Figure 3. In’Tech Euro 13 BTE Shell

BTE Bill of Materials

A bill of materials based on the above component selections is provided in the table below:

Table 1. BILL OF MATERIALS

Part	PN	MFGR
Audio DSP	SB3231	ON Semiconductor
MIC1	EM−24446−000*	Knowles
MIC2	EM−24446−000*	Knowles
RCV1	ED−27303−000	Knowles
VC1	PJ77	Sonion
Push Button	PB95	Sonion
telecoil	5100−253441	Knowles
CASE	BTE Euro13 KIT	In’Tech

*Matched pair use EM−30083−S11 part number

BTE Schematic

The schematic diagram for the BTE reference design is shown in Figure 4:

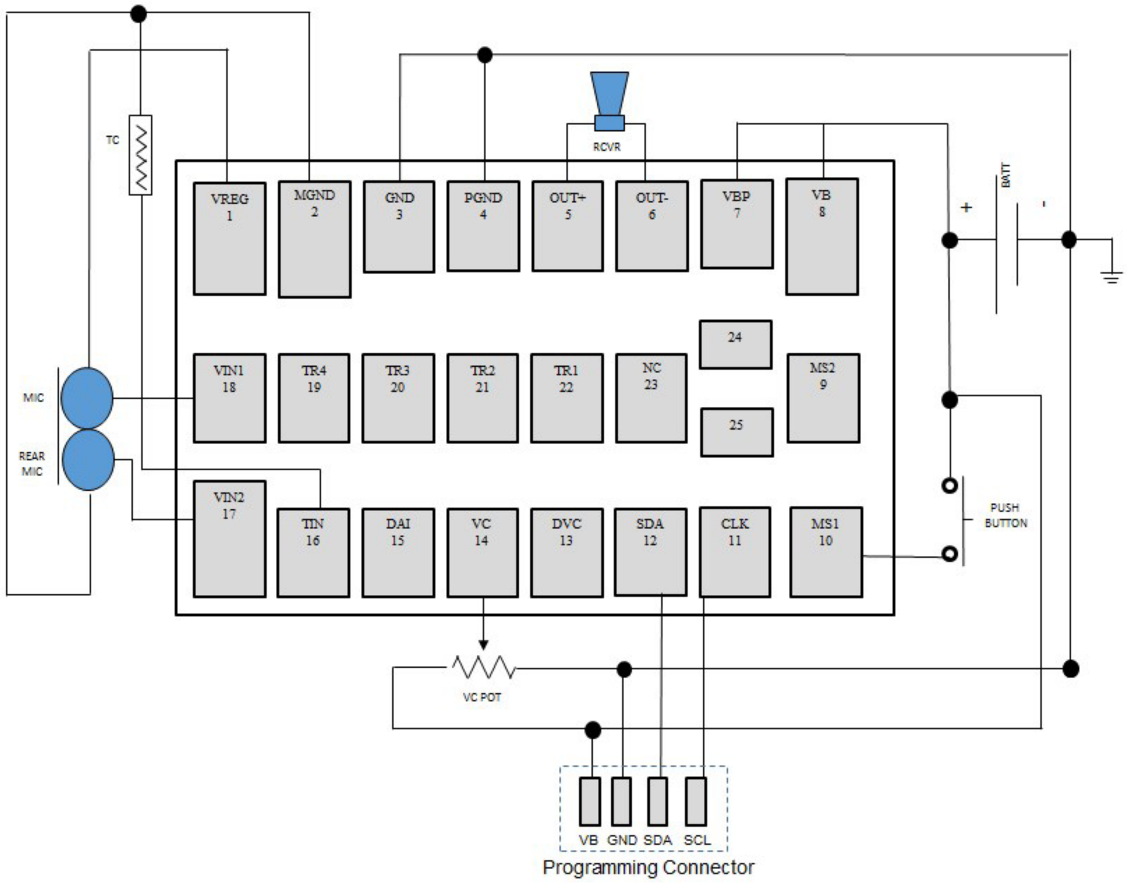


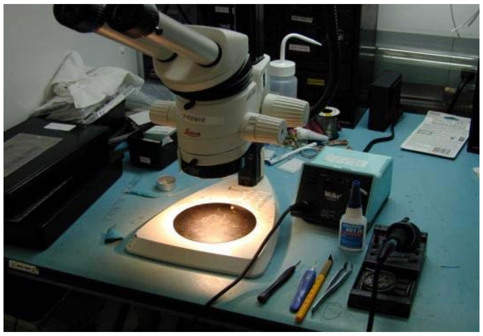
Figure 4. BTE Schematic Diagram

BTE Assembly

This reference design assumes the component interconnect will be point-to-point wiring.

The assembly components should be inspected to confirm they correspond to the recommended part numbers.

The typical equipment and workstation for assembly is shown in the figures below.

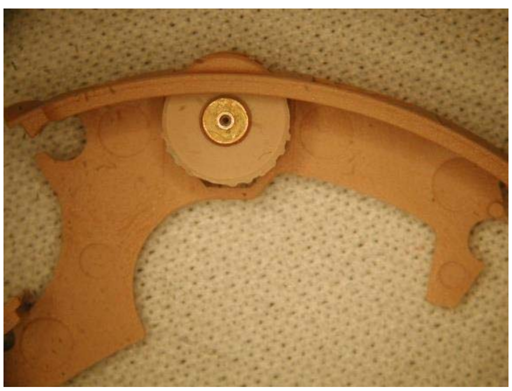


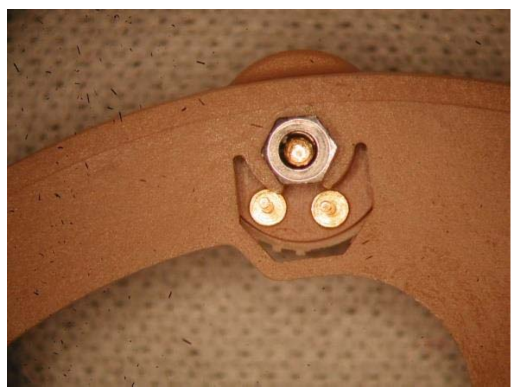
Equipment Required

- Soldering iron. Weller 800 Watt or equivalent
- Transducer holder / heat sink fixture
- Tweezers. Small to medium in size
- Microscope 2 to 10 X power with light source
- Screw drivers. Very small slotted blade
- ESD wrist strap and work surface
- Loctite 401 glue
- Small cutting knife. X−Acto or equivalent
- Pins for dispensing glue
- Close cut side cutters
- Solder
- Dremel or similar tool with rotary cutter bit

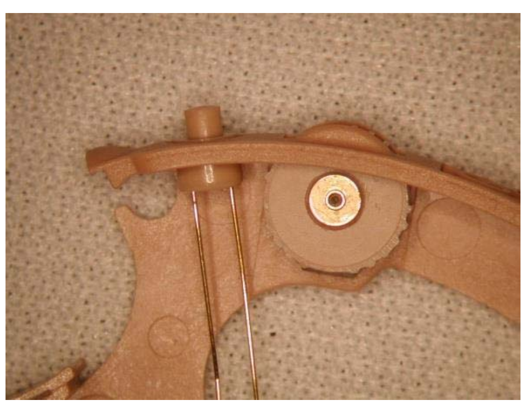
Component placement is important to reduce the possibility of audible artifacts and potential feedback paths. Any digital outputs from the SB3231 are a potential source of interference through radiated or conducted signal paths, and these wires should be separated from the analog input wiring.

The volume control and push button should be attached first.

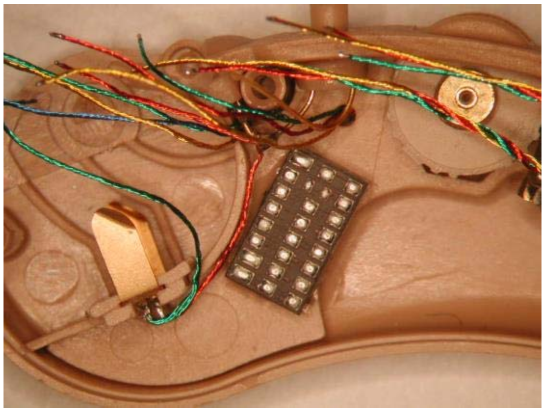


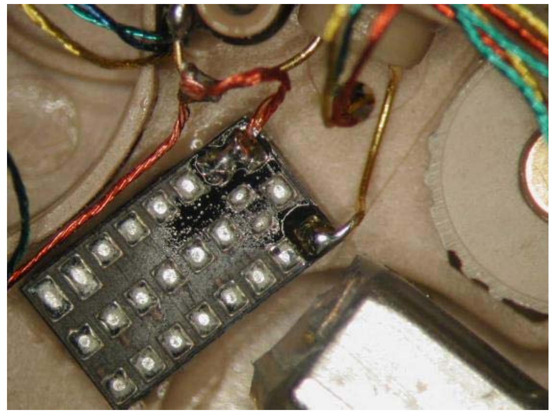


The pushbutton should be glued into place.

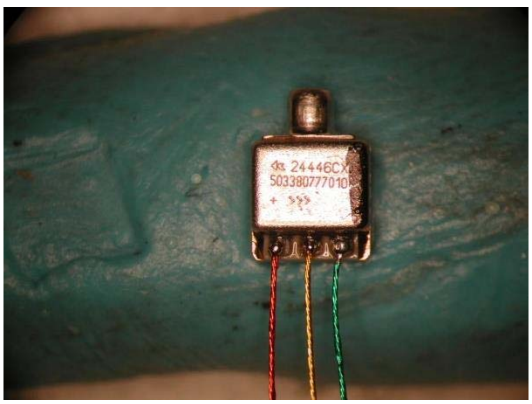


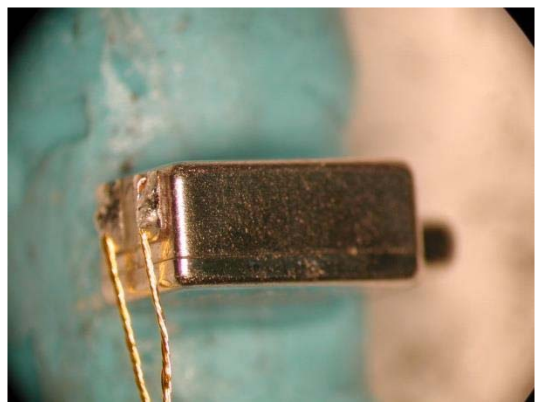
SB3231 should be secured into the shell for easy access to the pin array. It is also optional to prewire the hybrid before attaching it to the BTE shell.



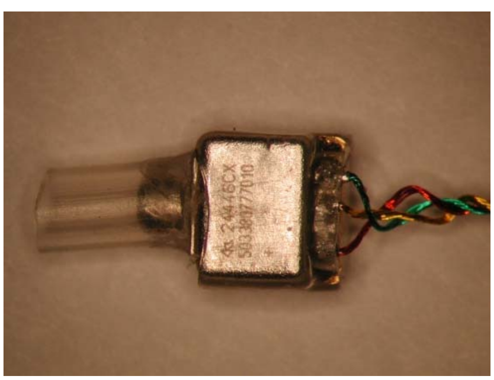


Components should be stabilized with a non−adhesive putty to allow easy access for soldering to the component pins.



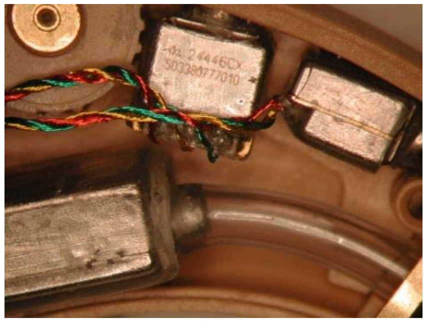


The transducers should be pre wired and sealed with heat shrink as shown in the figures below:

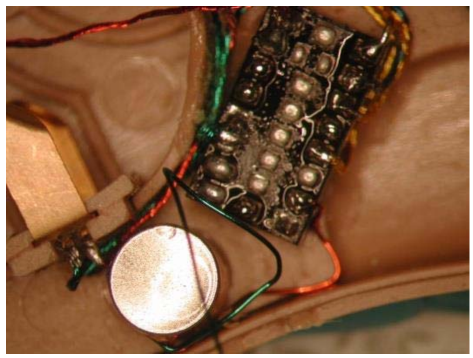


It will be necessary to trim the acoustic tubing for the receiver as shown below.

The receiver acoustic tubing will have a significant effect the electroacoustic performance of the finished BTE, so care should be taken to minimize the length of the tube.

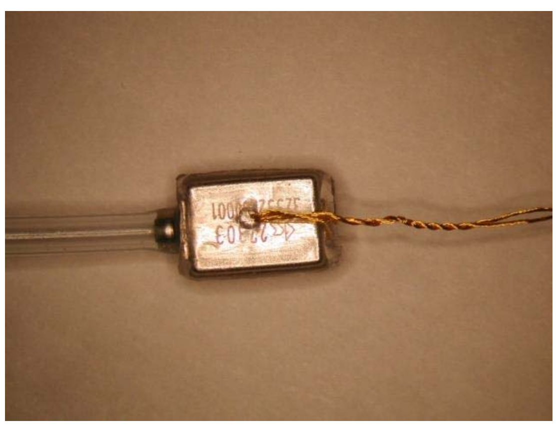


The telecoil is directly attached to the SB3231 TIN inputs using short wires to minimize noise coupling into the analog microphone inputs.

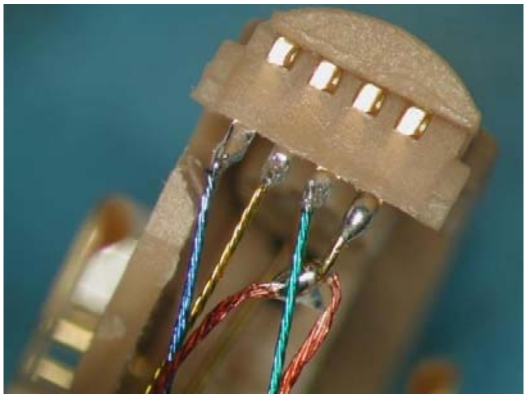
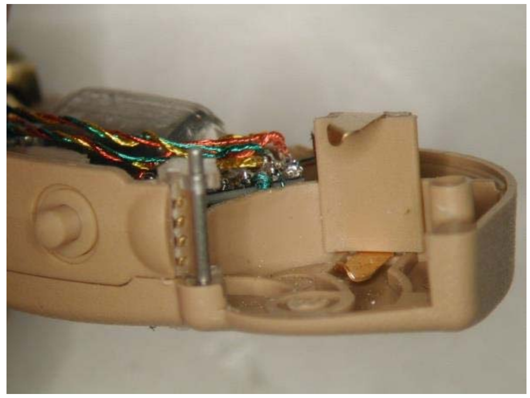


Unused audio input pins are connected directly to MGND to minimize the possibility of noise pickup. Inputs are internally AC coupled, so there is no additional leakage current when inputs are connected directly to ground.

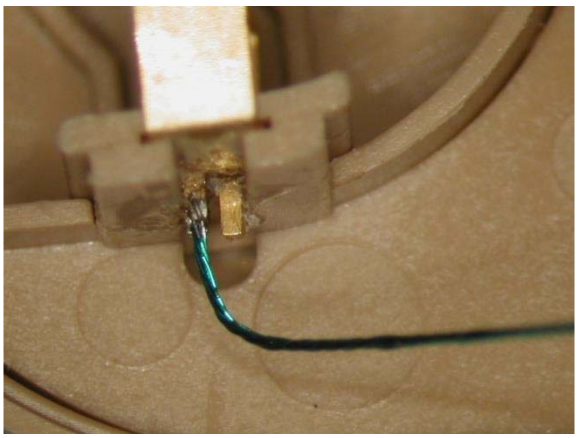
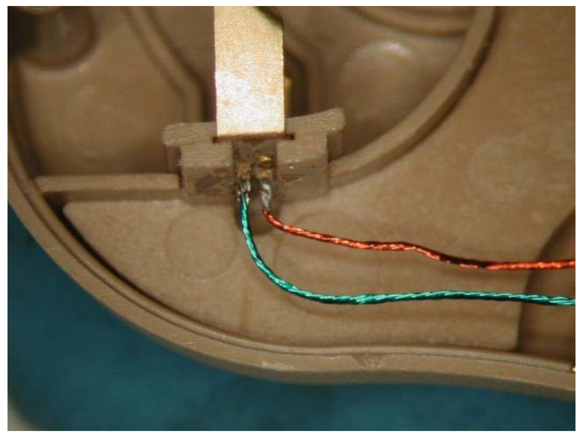
In order to minimize radiated H−bridge noise from coupling into the telecoil and analog inputs, twisted pair wires are used from the hybrid pins OUT+/OUT− to the receiver. The conducted H−Bridge interference is transmitted primarily through the power and ground connections.



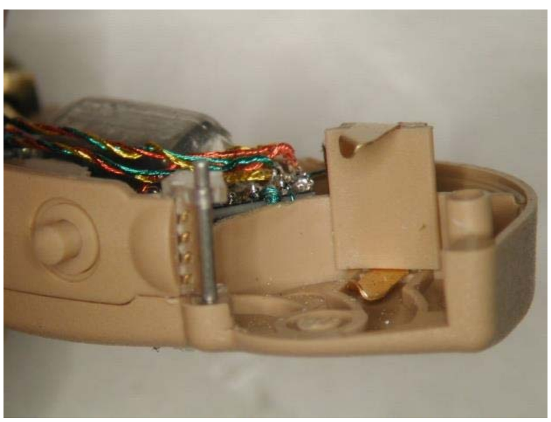
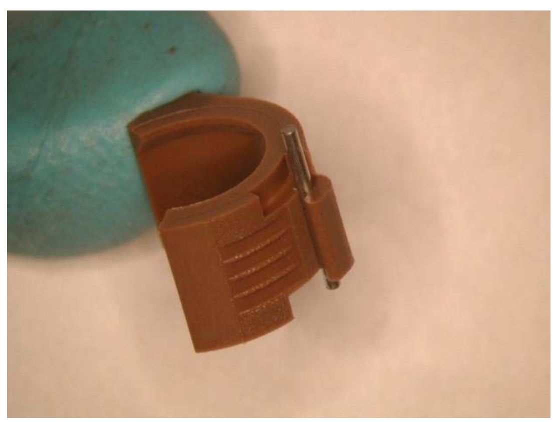
The programming connector is located behind the battery access door, and is wired as shown below.

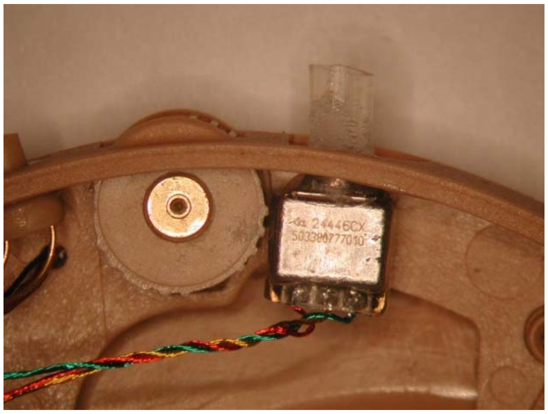
Star routing of the power supply lines back to the battery is performed to minimize noise and crosstalk in the system.

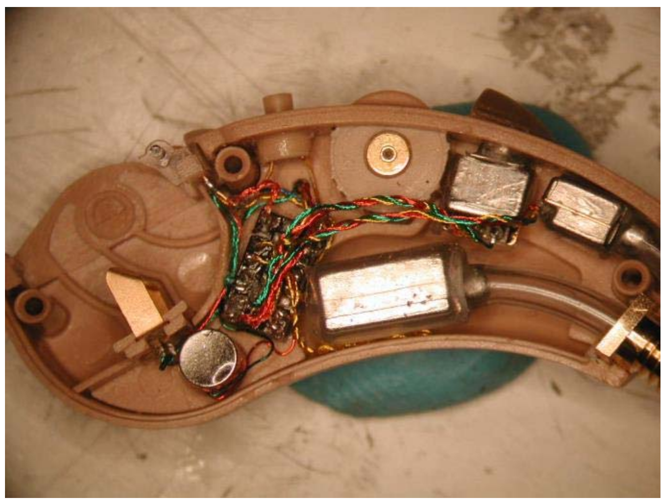
The battery door and hinge is attached to the final open assembly.

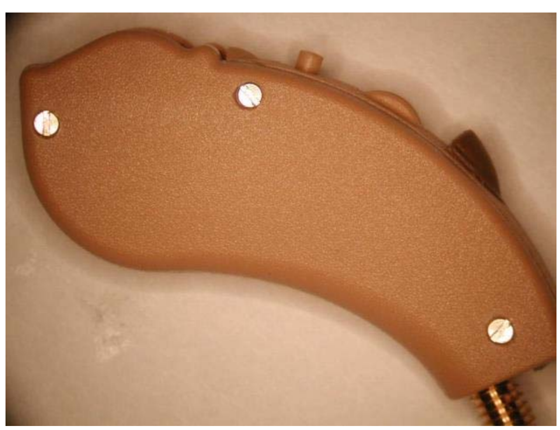
The microphone tubes will require trimming, and the external rear microphone hood should be glued into place.



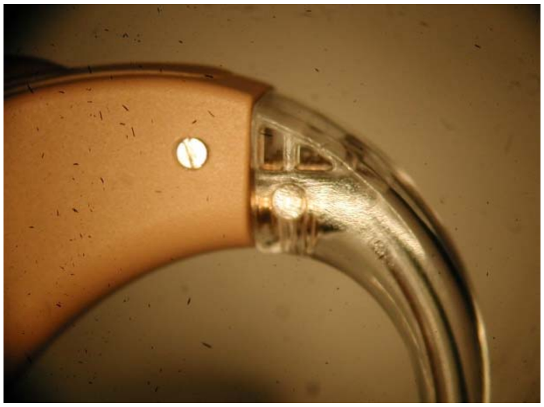
When the components are installed and wired, the assembly should resemble the diagram below.

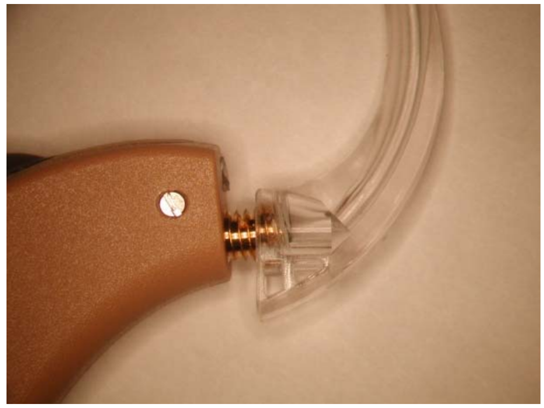


The sealed assembly is shown below.



The sound horn is attached to the final assembly.





BTE Modeling

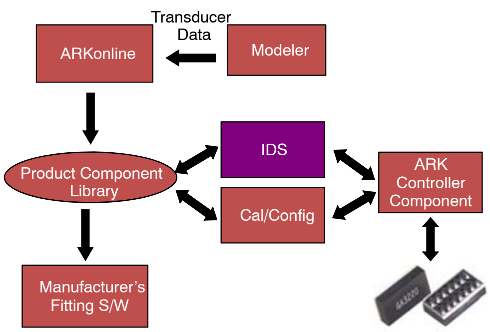
Once the BTE has been assembled, it will be necessary to model the hearing aid transducers (microphones, receiver and telecoil) to allow prediction the performance of a hearing instrument.

NOTE: A sample SB3231 library has been provided with the BTE reference design to allow users who do not have access to the necessary modeling equipment to evaluate the BTE design.

The ability to accurately calculate hearing instrument parameters such as acoustic gain, maximum output level, compression ratios, or shape of frequency response reduces the time required to design a hearing aid and aids the audiologist/dispenser at fitting (autofit).

The process starts with running the Modeler tool to obtain the transfer function of the transducers in the design. Once the data is obtained, it is uploaded to ARKonline®, where a product component library can be created for the device. This library is then used to create a “library file” used by the IDS tool to perform configuration of the device. Finally, the Cal/Config tool can be used to verify and calibrate each individual product as it is manufactured.

The modeling process used in ON Semiconductor ARK tools is summarized in the following diagram:



Microphone Modeling

Measurement of a microphone’s sensitivity versus frequency is required to create the microphone model.

Sensitivity is measured with 90 dBSPL pure tones at the input to the microphone. The frequency of these tones increases from 100 Hz to 8000 Hz in 100 Hz increments.

Receiver Modeling

To measure a zero bias receiver’s parameters, it is required to have the microphone and a zero−bias receiver connected to SB3231. Acoustic signals inside the anechoic chamber are converted by the microphone to electrical signals going into SB3231. SB3231 compensates for the microphone’s frequency response and drives the zero−bias receiver with a constant level electrical signal.

The modeling setup is shown in Figure 5.

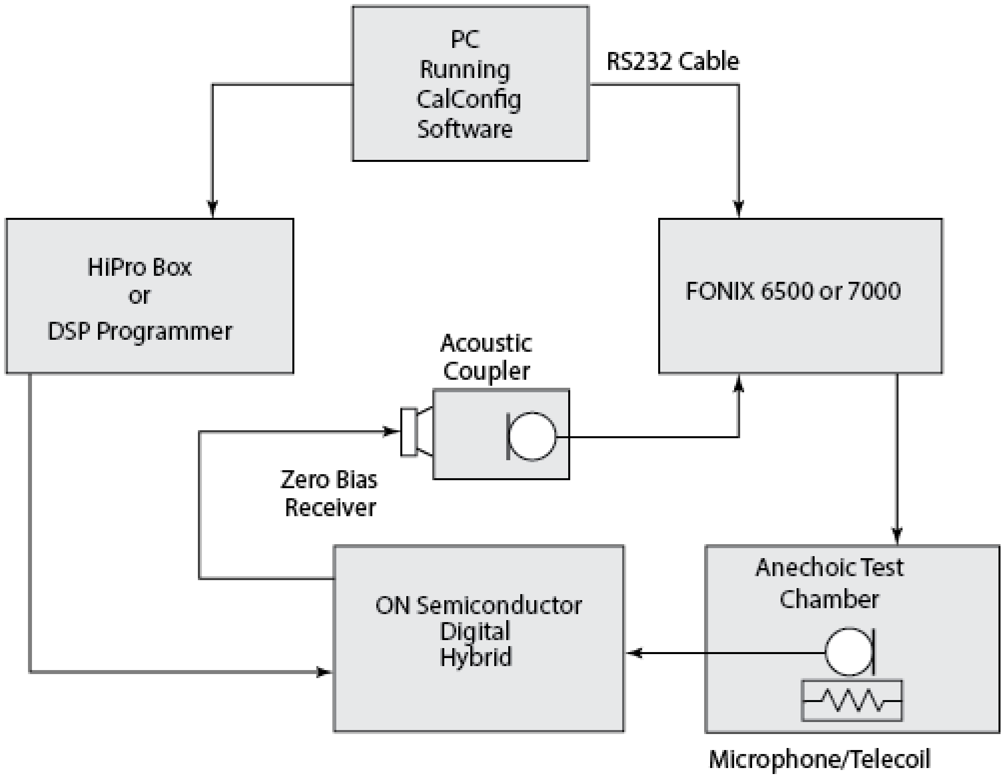


Figure 5. Modeling Setup

For more information on the Modeler tool, please refer to the ARK User's Guide.

BTE Programming and Configuration

At this point the BTE prototype is ready for configuration using the IDS utility in the ARKbase™ tools.

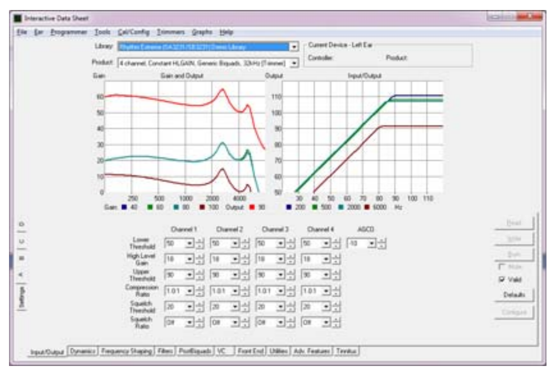
The device requires a suitable programmer and programming cable for configuration. A list of suitable programmers and cables is provided in the *BTE_1.0_Equipment* document included in the BTE 1.0 Reference Design.

Figure 6 below shows the typical programmers used to configure the device:

HI−PRO USB NOAHlink DSP3 Programmer

Figure 6. Device Programmers

1. Open IDS and connect to the device. A screenshot of the IDS program is shown below.



2. Register the custom BTE library by selecting the "ARK Component Manager" in the Tools menu and "Select Files to install"
3. Navigate to the library created, or provided with the reference design.
4. Load the library that was registered in the above step
5. Load the BTE1.0.ids file (included in the reference design) using the File/Load menu.
6. From the Programmer menus, select "Burn All"

After the BTE has been programmed by the steps above, the device is operational, and can be evaluated to ensure the features and functions are enabled.

BTE Calibration

Although the design has been modeled using the transducers specified in the design, there will be some variation in performance if a number of assemblies are manufactured. For this reason, the ARK tools include a comprehensive Calibration and Configuration toolset for use in a manufacturing design.

Settings for manufacturing are selected in IDS via the Cal/Config pull down menu. These settings then provide the necessary information to allow devices to be calibrated on an individual basis in the manufacturing environment.

The ARK Cal/Config calibration tools are fully described in the ARK User's Guide.

Conclusion

This document has described the components, tools and procedure to create a custom BTE hearing aid using the SB3231 DSP system for hearing aids.

The point−to−point wiring procedure described here is usually sufficient for prototype evaluation, but production devices will require a flexible PCB to provide a more robust and manufacturable design.

Appendix A

Table 2. TROUBLESHOOTING

Troubles		Reason	Method
No Sound	1	Power supply problems	Check the battery and connections
	2	Bad VC or connections	Check VC and connections
	3	Bad board connections	Check all connections
	4	Defective parts	Replace parts
Sound leakage	1	Ear plug too small	Replace ear plug
	2	Too high gain setting	Adjust gain
	3	Earplug to ear hook loose	Replace earplug
	4	Faulty ear hook	Replace ear hook
	5	Ear hook and case connection loose	Replace ear hook
Weak Sound	1	Faulty receiver	Replace receiver
	2	Volume turned down	Turn up volume
Feedback	1	Gain too high	Adjust gain
	2	Receiver tube not sealed	Re−seal receiver tube
	3	Receiver position	Re−adjust receiver
	4	Bad wiring	Clean up wires or rewire
	5	Poor solder joints	Re−solder
	6	Defective receiver	Replace receiver
High current drain.	1	Connections made incorrectly	Check all wiring
	2	Defective receiver	Replace receiver
	3	Shorts on board	Check all connections for shorts
Low gain	1	Bad mic.	Replace mic
	2	Defective VC or trimmer	Replace as required
	3	Poor solder joints or shorts	Check and re−solder as required
High noise	1	Defective mic	Replace mic
	2	Poor solder joints	Re−solder as required
	3	Defective receiver	Replace receiver
High distortion.	1	Defective receiver	Replace receiver
VC not controlling	1	Poor solder contact to VC	Check and re−solder
	2	Defective VC	Replace VC

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