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TND6216/D

RHYTHM™ SA3229 Low-Cost Behind-the-Ear (BTE) Hearing Aid Reference Design

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TECHNICAL NOTE

Introduction

The Rhythm SA3229 reference design is a low−cost hardware reference design for a Behind-The-Ear (BTE) hearing aid using the Rhythm SA3229 preconfigured DSP system. It contains a single SA3229 device which enables implementation of an economical digital hearing aid with state-of-the-art features and specifications.

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

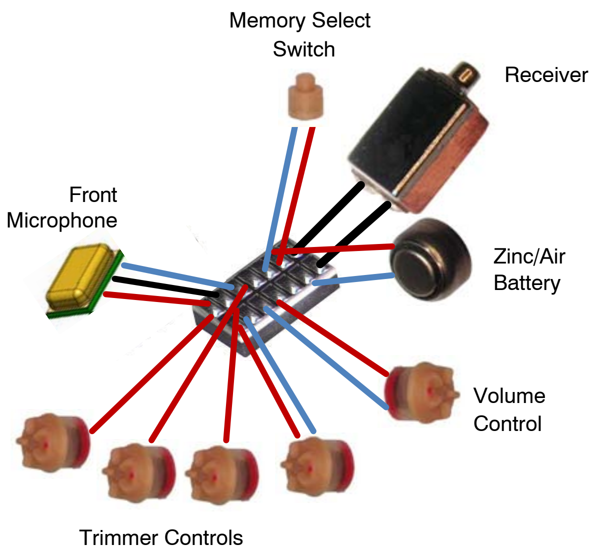

Figure 1. Major Components Included in the Reference Design

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, which instead focuses on describing a low−cost hearing aid solution.

The SA3229 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. Device settings are programmed into the One Time Programmable (OTP) memory during manufacturing; fitting adjustments can be made with up to four trimmers.

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 SA3229 datasheet
2. ARK Installation (requires registration)
3. ARK User's Guide
4. Application Notes

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Product Features

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

- BTE with four channels of WDRC compression
- 96 dB input dynamic range
- Adaptive feedback cancellation
- Programmable crossover frequencies
- 4 memory profiles
- Noise generator for tinnitus masking
- Programmable analog 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 solution

Product Specification

• Frequency response:	100 Hz − 8 kHz
• Battery type	13
• Number of microphones	1 omnidirectional
• Volume control	analog potentiometer
• Memory select	pushbutton
• Number of memory selects	4
• Acoustic output	65 dB
• Trimmers	4

BTE Hearing Aid Components

Figure 2 below shows the components used in this design:

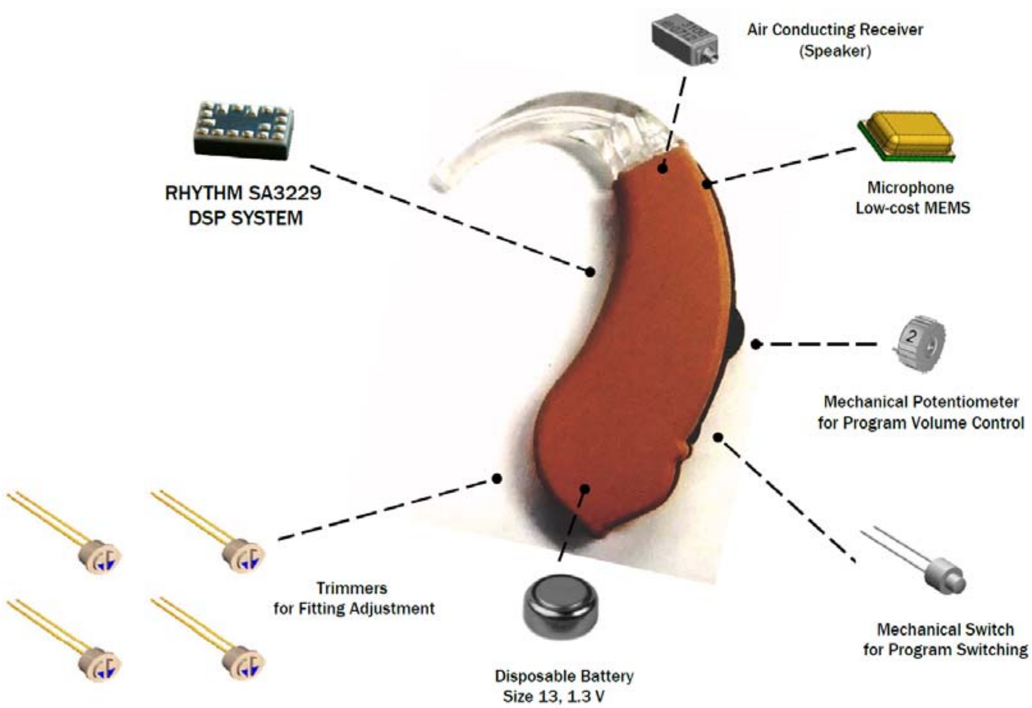


Figure 2. BTE Hearing Aid Components

SA3229

SA3229 is a trimmer−configurable DSP system which is based on a four−channel compression circuit featuring a feedback cancellation algorithm. It has a wide range of configuration options to allow different combinations of pushbutton switches, analog volume adjustment, and automatic telecoil selection.

Microphone

One omnidirectional microphone is used in the design of a low−cost solution based on SA3229.

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

NOTE: For lowest cost, a MEMs microphone is used in this reference design. A MEMs microphone can be operated at 1.25 V; however, noise performance of the microphone needs to be evaluated in order to determine if performance is satisfactory for the individual customer requirements.

Acoustic Receiver

This is a miniature audio transducer that converts the electrical output of SA3229 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.

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 SA3229 memory. The Sonion PB 95 momentary pushbutton is used in this design.

Trimmer Interface

The trimmer interface provides the ability to control up to 19 hearing aid parameters through up to four trimmers. A single trimmer parameter can have up to 16 values; a single trimmer can control multiple parameters.

BTE Shell

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

The In'Tech BTE 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	SA3229	ON Semiconductor
MIC1	SPY0824LR5H−QB	Knowles
RCV1	ED−27303−000	Knowles
VC1	PJ77	Sonion
Push Button	PB95	Sonion
CASE	13 BTE Case Kit GN/EM Series	In'Tech

BTE Schematic

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

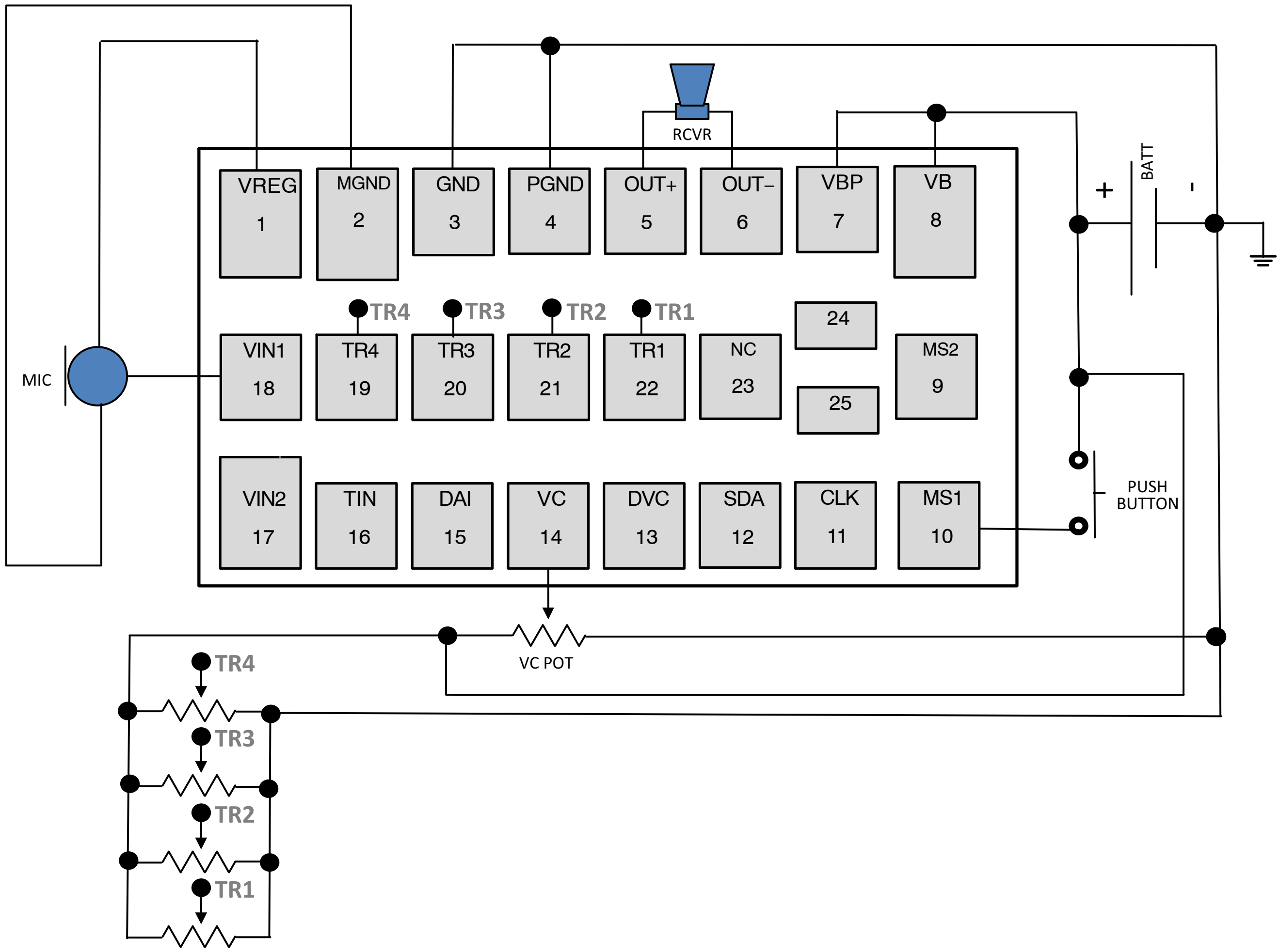


Figure 4. BTE Schematic Diagram

BTE Modeling

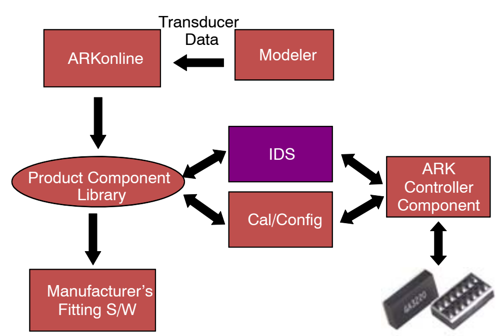
Once the BTE has been assembled, it will be necessary to model the hearing aid transducers (microphones, receiver and telecoil) to allow prediction the performance of a hearing instrument.

NOTE: A sample SA3229 library is 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 making adjustments.

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 SA3229. Acoustic signals inside the anechoic chamber are converted by the microphone to electrical signals going into SA3229. SA3229 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.

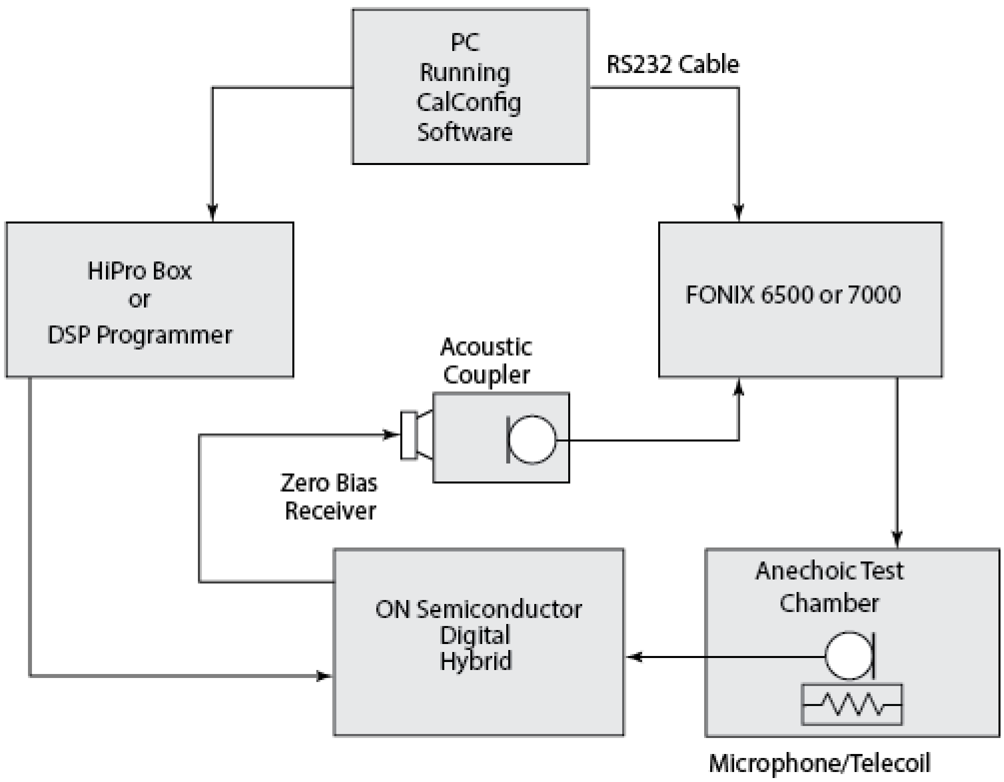


Figure 5. Modeling Setup

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

BTE Configuration

At this point, the BTE prototype is ready for configuration using the device trimmer controls. The SA3229 BTE Reference design does not include a programming port for configuration. In order to configure the device, a SA3405GEVB hybrid evaluation board can be used. See Appendix B for further information on programming the SA3229 OTP.

The following parameters can be assigned to trimmers:

- Low Cut
- Tinnitus (Noise Level, Low Cut Filter, High Cut Filter)
- Crossover Frequency
- Lower Threshold
- Upper Threshold
- EQ Gain
- Squelch Threshold
- High Level Gain
- Low Level Gain
- AGC−O Threshold
- Static Volume Control
- Peak Clipper Threshold

The SA3229 hybrid is a trimmer−configurable DSP system that does not require a programming interface to configure the final settings of the device.

Programming is accomplished as follows:

1. An IDS configuration file is created with default settings for system parameters such as microphone inputs, system gain and frequency response, volume control defaults and Memory Select configuration.
2. The trimmers are assigned a parameter in the Trimmer tab of IDS as shown below in Figure 6:

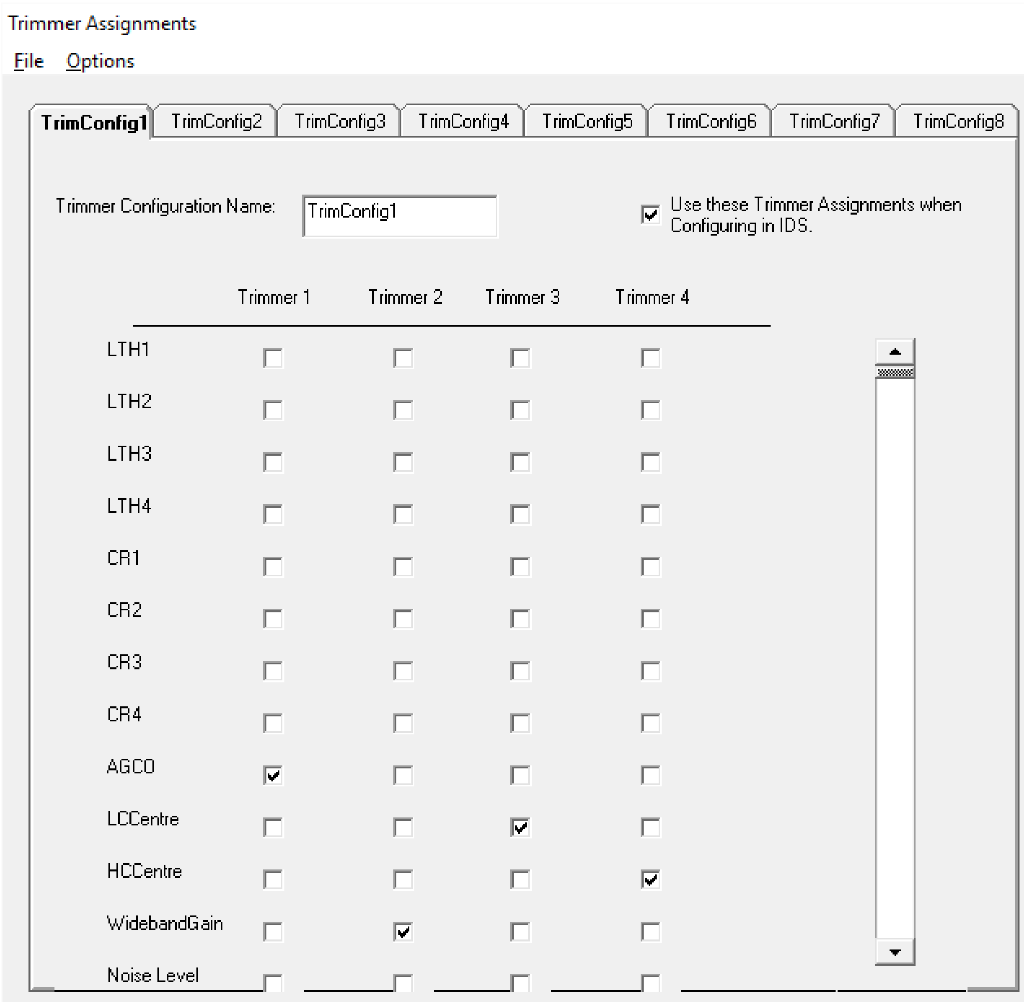


Figure 6. Trimmer Assignments

In the example above, the trimmers are assigned parameters as follows:

Trimmer 1: AGCo
Trimmer 2: Wideband Gain
Trimmer 3: LC Center
Trimmer 4: HC Center

3. The IDS files are then saved for use in the Cal/Config program.
4. Cal/Config is launched, and the IDS file that was created can be selected and used to program the device.

Note that Cal/Config needs to be run the first time from the command line prompt with the workstation file included as an argument:

C:\> ”C:\Program Files (x86)\ON Semiconductor\ARK\CalConfig2.exe” /workfile

Select the workstation file in the popup file selector window that appears. Cal/Config will then run normally with IDS files appearing in the pulldown menu that are at the location specified in the Workstation file.

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 SA3229 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

Appendix B

SA3229 is an OTP based preconfigured product that can be software configured up to 2 times. Cal/Config can be used to check how many times remain that a specific part can be reprogrammed. To do this, load an appropriate configuration and press the Go button. A warning will be displayed to show the remaining burn operations that are possible. The operator can then decide if the settings should be updated and use one of the remaining burn operations, if available.

Note that SA3229 parts CANNOT be used in the IDS software so it is recommended that evaluation is done on the SB3229 (the EEPROM version of the product) before settling on a device configuration.

See the following screenshots:

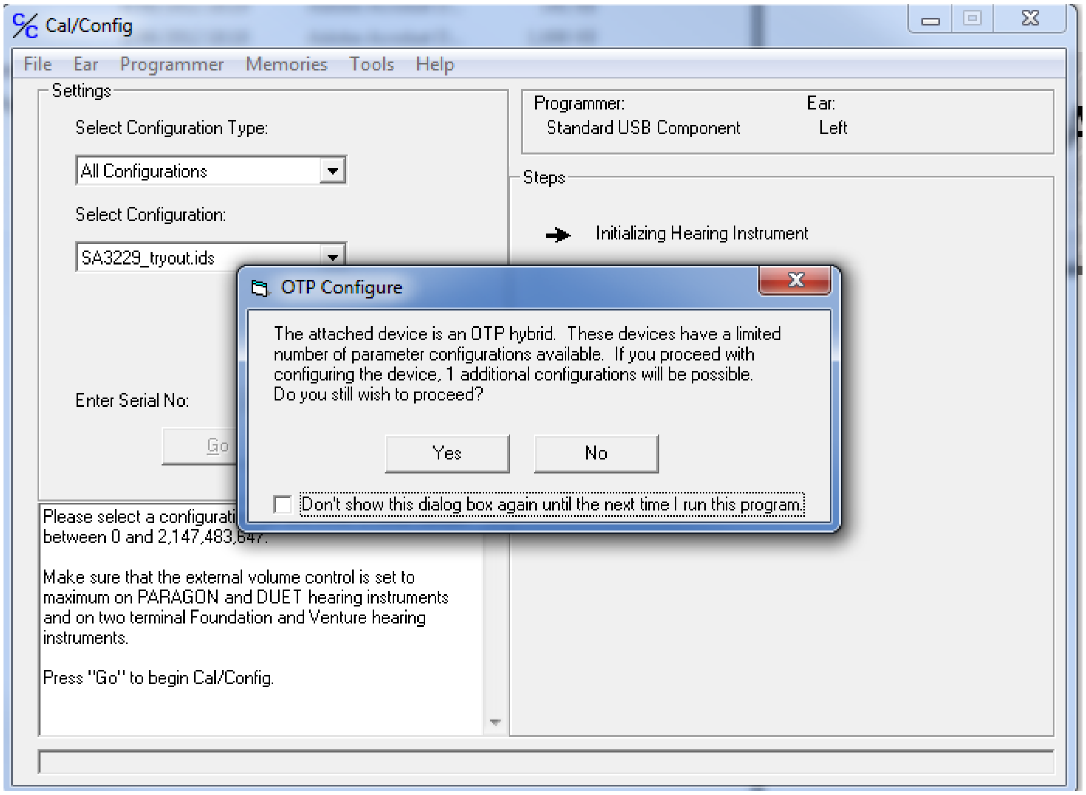


Figure 7.

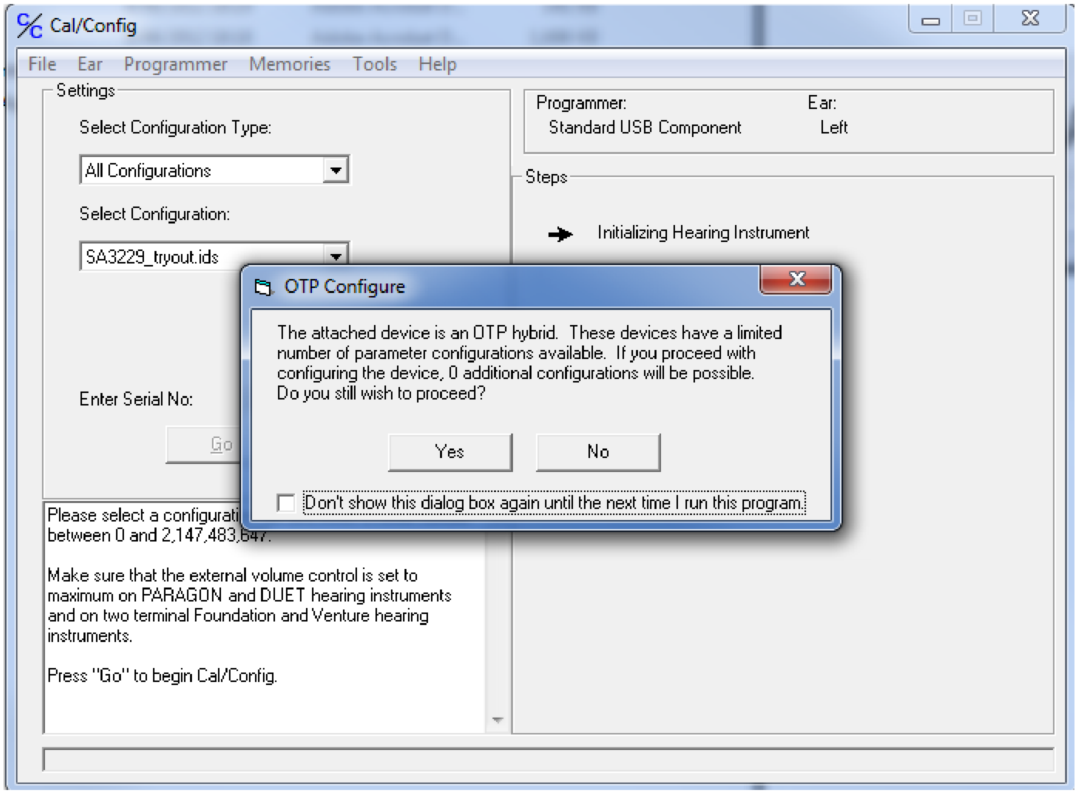


Figure 8.

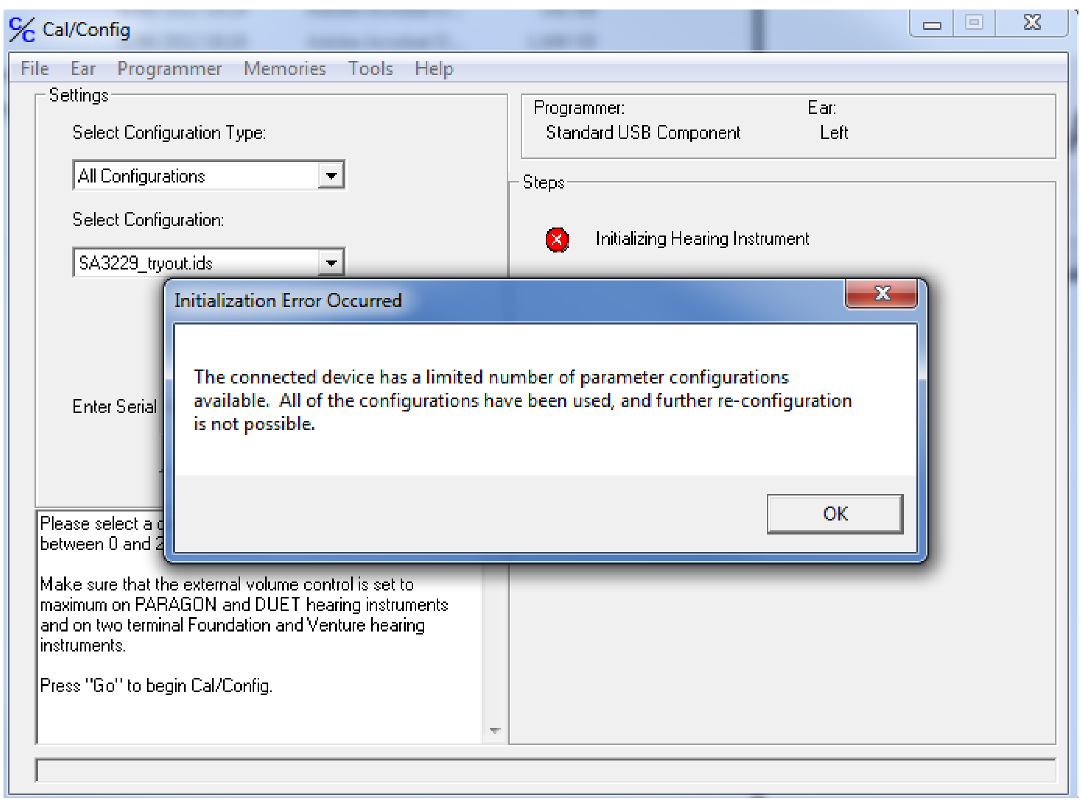


Figure 9.

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