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AYRE™ SA3291 Hardware Design Guide

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APPLICATION NOTE

Introduction

AYRE SA3291 is a pre-configured wireless DSP system designed for use in hearing aids. Ayre SA3291 is designed to work in multi-transceiver wireless systems that can include capabilities such as streaming audio (Stereo or Mono), binaural telecoil, and remote control of volume and memory select between two hearing aids and a relay device. The AYRE SA3291 can also operate in a binaural system where there is no remote control or relay device present.

This document describes how to optimize the hardware design and layout of a typical hearing aid based on the AYRE SA3291. Options are presented for antenna selection and placement, as well as component layout and optimization.

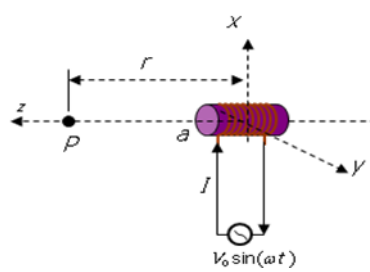
Network Configuration

There are two basic modes of communication that AYRE devices use to talk to each other, with each method having its own unique characteristics:

- **Network Mode**: As the name suggests it places all AYRE devices in a network where information can be exchanged back and forth between all devices. The network mode is used when one hearing aid wants to send an audio signal, such as a telephone telecoil signal, to the hearing aid on the opposite ear, or when one hearing aid wants to send a volume up or down command to the opposite device. Network mode is primarily a two way mode, where devices are exchanging information back and forth. This mode can operate only over a small distance due to the small antennas used in the hearing aids. Network mode requires the devices to have identical Vendor and Network ID.
- **Blast Mode**: This mode is used for one way communications between a relay device or a remote control device, and all devices within its transmission range that have the same vendor ID and network ID as the relay device or remote control. Blast mode is primarily a one way mode, with the blast master streaming audio or commands to all devices within its range. Blast mode devices can operate across a greater distance due to the larger transmit antenna and greater transmit power. A receiver must be configured in IDS to allow streaming audio or remote control commands to be received

Near-field Magnetic Induction (NFMI) Antenna Link Characteristics

The AYRE SA3291 contains a NFMI transceiver that provides a digital wireless link by magnetically coupling two inductors. The NFMI link for wireless data communication behaves exactly like an inductively coupled transformer, based on a transmitter antenna acting as the primary transformer winding and the receiver antenna acting as the secondary winding. An AC current, modulated by the data to be transmitted, flows through a transmitter coil, which is similar in design to a solenoid. A magnetic field is generated by the transmitter which induces a current in the winding of the antenna in the receiver, which is then demodulated. The magnetic strength generated by the solenoid in Figure 1 below is directly proportional to its circular dimension, the number of turns, and the quantity of the current flowing in the coil. Larger coils will generate a stronger magnetic field.



$\mu_0 = 4\pi \times 10^{-7}$
N = number of turns
I = current in the loops
a = radius of coil
r = distance between centre of coil to point of measurement P

Figure 1. Typical Solenoid Design

Magnetic Field Intensity of Antenna

By Biot-Savart Law:

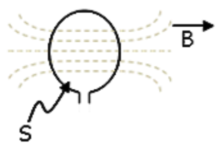
$$B_Z = \frac{\mu_0 \cdot I \cdot N}{2} \cdot \frac{a^2}{(a^2 + r^2)^{3/2}} \quad \text{(eq. 1)}$$

for $r^2 >> a^2$;

$$B_Z = \frac{\mu_0 \cdot I \cdot N}{2} \cdot \frac{a^2}{r^3} \quad \text{(eq. 2)}$$

AYRE SA3291 Receiver Antenna Design

The antenna design for a hearing aid is primarily based on the size of the antenna, and is a trade-off between a large antenna size for increased range, and small size for compact form factor. A pair of coils with perfect parallel or coaxial alignment yield the maximum induced voltage; the minimum occurs when the coils are perpendicular or orthogonal to each other. The induced voltage is directly proportional to the size of the coil, its Q-factor, and the number of turns, N.



$$\Psi = \int \overline{B} \cdot d\overline{S} \quad \text{(eq. 3)}$$

Ψ = the magnetic flux incident through each turn of the coil

By Faraday's Law:

$$V = -N \cdot \frac{d_{\Psi}}{dt} \quad \text{(eq. 4)}$$

Voltage developed across the coil:

$$V_O = 2 \cdot \pi \cdot f \cdot N \cdot S \cdot Q \cdot B_Z \cdot \cos(\alpha) \quad \text{(eq. 5)}$$

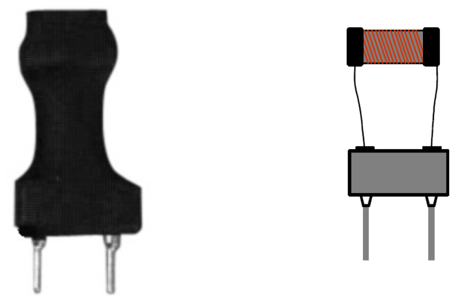
where:
- f = frequency of the carrier signal
- N = number of turns of the receiver coil
- S = surface area of the loop, in sq-m
- Q = quality factor of receiver coil
- B_Z = strength of magnetic field
- α = angle of arrival of the magnetic strength vector

Figure 2. Basic Antenna Design

Antenna Selection

In practice, an optimum antenna design for a small hearing aid is based on the following miniature ferrite-load coil:

- Frequency of Operation: 10.579 MHz
- Nominal Inductance Value: 3.6−4.4 μH
- Self-resonance Frequency: > 25 MHz
- Coil Inductance Tolerance: 5%
- Q-factor at Operating Frequency: 30
- Ferrite Rod Material: K40 or Equivalent
- μROD: 11.0
- Numbers of Turns of Winding: Adjust for Inductance (approx 25)
- Termination: Leaded Through-hole
- Diameter: 1.5 mm
- Length: 5.4 mm Overall



Information for the materials mentioned above is available online here:

http://www.fair−rite.com/newfair/ferrite_rod_ad.htm

For the mini-antenna, Fair-Rite material 306−799−0831 is recommended. This material can be trimmed to the desired length.

NFMI Range Considerations

The small size of the antenna in a hearing aid will limit the range over which the antenna can transmit and receive a signal.

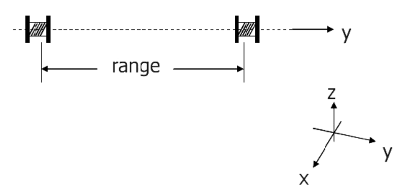


Figure 3. NFMI Range in HI Application

When two hearing aids are communicating with each other, the symmetrical size of the antennas will cause receive and transmit distances to be equal. In a configuration where there is a relay device or remote control device with a larger antenna, there is an asymmetrical receive and transmit distance due to the difference in size of the antennas.

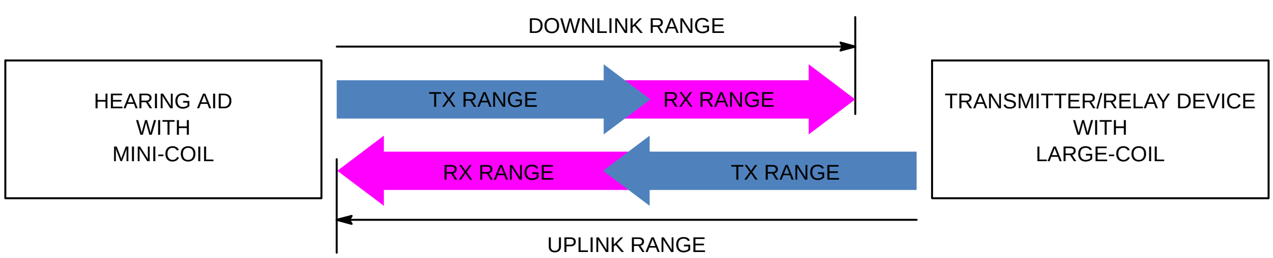


Figure 4. NFMI Range in Relay Device Application

In Network-mode, both transmitter/relay device and hearing aids must maintain communication for a link to exist. Because the antenna in a hearing aid is small, the down-link range is always shorter than the uplink range

- Once the transmitter is outside of the downlink range, it will go into acquisition mode
- In acquisition mode, the audio link is broken and will be muted

Increasing NFMI Network Mode Range

- Since current consumption is limited in the hearing aids, increase TX power can only be minimal
- Increase the size of the relay device antenna to maximize the induced voltage
- Use a different type of antenna with a large circular surface area to intercept a larger amount of B-field line
  - Wire-loop antenna
  - Printed circuit loop
  - Large neck loop (hidden in lanyard)
- Use external receiver amplifier (higher current consumption and manual antenna tuning required)

Increasing NFMI Blast Mode Range

In Blast mode, the transmitter/relay device and hearing aid do not need to maintain two-way communication for a link to exist. In this case the overall range is the uplink range of the blast transmitter or relay device.

- When the transmitter is outside of the downlink range, it will continue to stream audio
- The audio link will be interrupted and muted at the receiver output only if the range exceeds the uplink range
- The up-link range is about 75 to 80 cm when the highest TX power is used and can exceed 1 meter when a relay device transmit power booster is used
- Increase the size of the relay device antenna to maximize the induced voltage
- Use other type of antenna with a large circular surface area to intercept a larger amount of B-field line
  - Wire-loop antenna
  - Printed circuit loop
  - Large neck loop (hidden in lanyard)
- Use external transmitter amplifier (higher current consumption and manual antenna tuning required)

PCB and Component Layout Considerations

The PCB design and component placement in an AYRE SA3291 design can affect the maximum range of the NFMI system. Any digital signal present in the AYRE system is a potential source of interference through radiated or conducted signal paths. The use of a metallic shield around the entire AYRE SA3291 hybrid is an excellent technique to minimize radiated noise.

H-bridge Interference

The pulse width modulation of the H-bridge output can cause harmonic interference into the 10 MHz band of the NFMI carrier. Interference to the NFMI radio is due to high-frequency noise generated by the H-bridge circuit coupled through radiated or conducted means as shown below.

The amount of interference generated by the H-bridge is proportional to the size of the audio receiver it is driving. A low impedance receiver with a large audio output will generate considerably more interference than a low power receiver. Special attention must be paid to layout techniques when a high power, low impedance receiver is used.

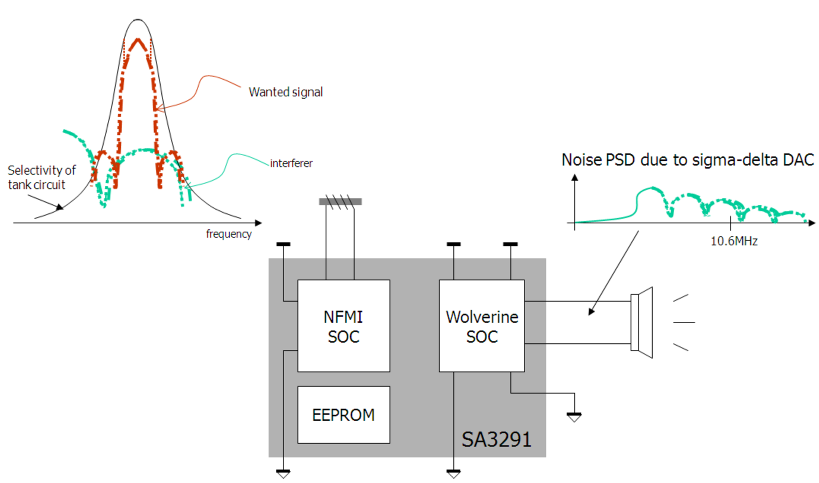


Figure 5. H-bridge Interference into NFMI Signal

Minimizing Radiated H-bridge Noise

The following techniques should be used to minimize the impact of the radiated H-bridge noise on the NFMI signal:

- Use twisted pair of wires from the hybrid pins L1/L2 to coil antenna
- Use twisted pair of wires from the hybrid pins OUT+/OUT− to high power receiver
- Ensure hybrid IO solder bump side is facing away from the coil antenna
- Elevate the coil antenna away from the plane of the PCB as much as possible
- Keep supply and ground connections short and avoid running them in parallel to each other

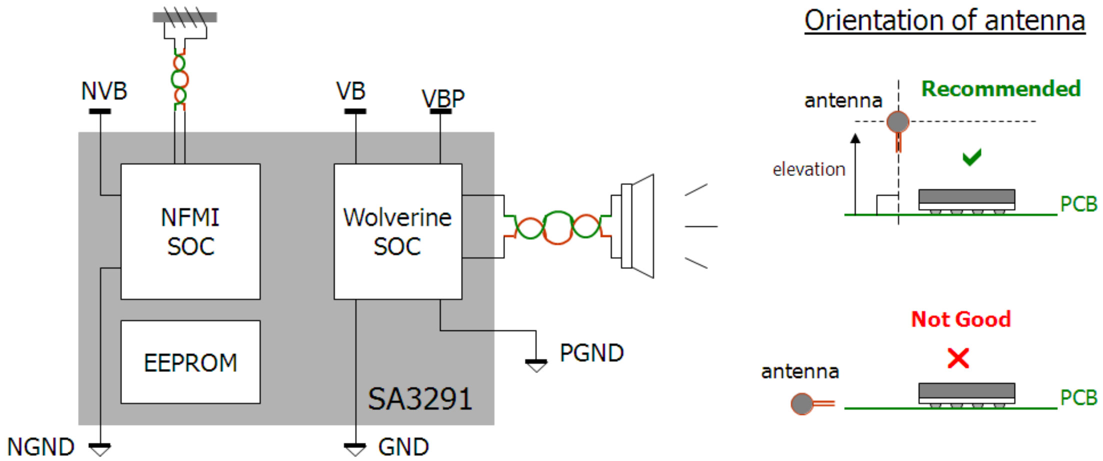


Figure 6. Alignment of Antenna and AYRE SA3291

Minimizing Conducted H-bridge Noise

The conducted interference is transmitted primarily through the power and ground traces in the design. The following steps can be taken to minimize the conducted interference:

- Keep the noisy current flow within the H-bridge circuit by connecting VBP and PGND to a decoupling cap directly and connect them to the battery terminals with very short interconnect
- Use star-connection on the other grounds and supplies; parasitic resistance in interconnects provide impedance to high frequency current
- Use general good RF layout techniques as described below

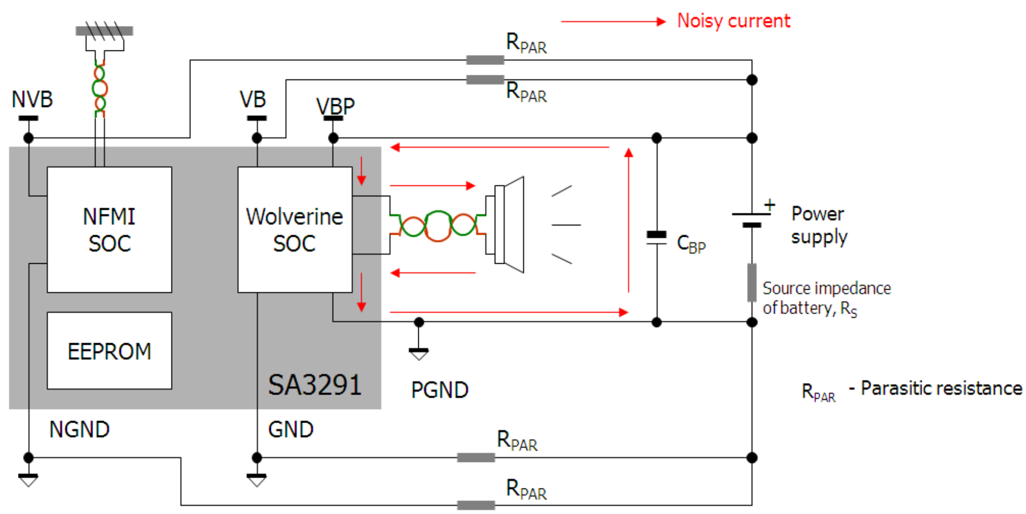


Figure 7. Power Supply PCB Star Routing

General Good RF Layout Practices

Cross-talk is least when signal lines cross each other orthogonally.

Radio: L1/L2	←
H-bridge: Switching Signal	→
Supplies and Grounds	↑ ↓
Decoupling	Right Next to the IO Pads

Choice of Decoupling Capacitor

The choice of decoupling capacitor value is dependent upon the inductance of the power supply signal traces, with a long signal trace increasing the inductance in a resonant circuit.

- If interconnect traces are longer between the IO pads to the component pads, use a 680 nF capacitor as described below
- If interconnect traces are short and the component pads are right next to the IO pads, use a 2.2 μF capacitor as shown below

It is essential to provide a very low impedance path at 10 to 11 MHz through this capacitor; its impedance must be the lowest among the other paths including the star-connected supply and ground lines and the source impedance of the battery.

- Murata GRM155R60J684KE19, 0402 680 nF 6.3 V X5R
- Murata GRM155R61A105KE15, 0402 1.0 μF 6.3 V X5R
- Murata GRM188R60J225KE19, 0603 2.2 μF 6.3 V X5R

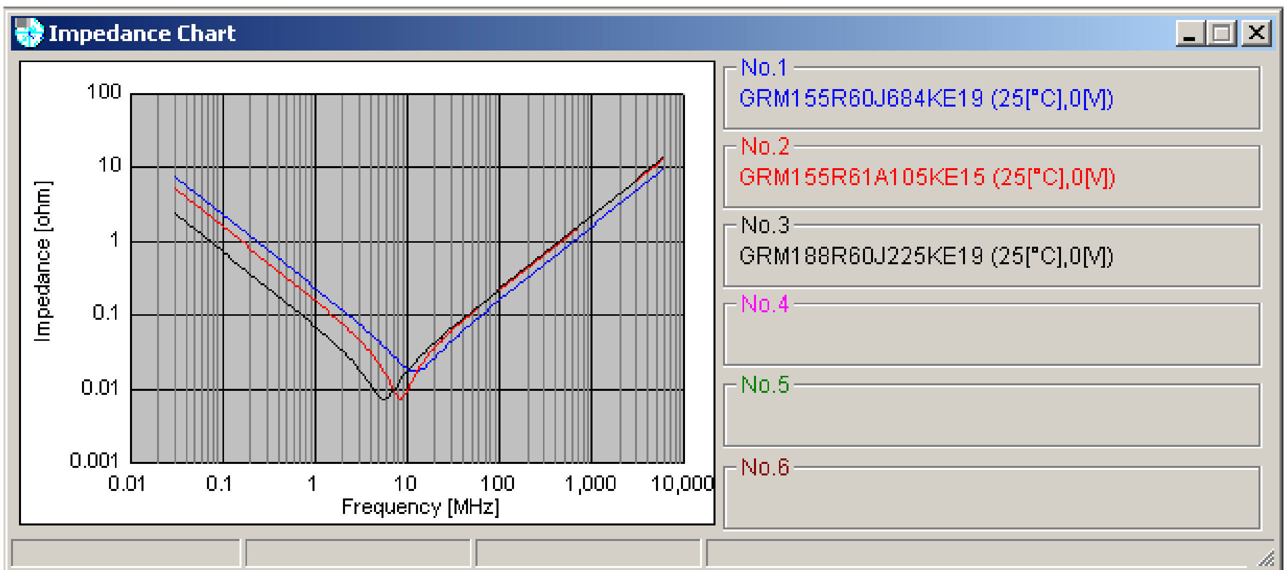


Figure 8. Decoupling Capacitor Impedance

PCB Layout

A suggested PCB layout is shown below. In general, star routing power supply lines back to the power source or battery is recommended to minimize noise and crosstalk in the system.

- Keep the 2.2 μF capacitor close to PGND and VBP. Traces should be short
- Wire battery positive terminal to VBP/2.2 μF capacitor point
- Star Ground all ground traces. Separate ground planes for PGND, NGND and GND are okay when connected together with narrow width traces. Connect battery negative terminal as close to PGND as possible
- RF traces should route at 90 degrees to supply/ground traces where possible
- Keep as much of the area under the antenna traces open

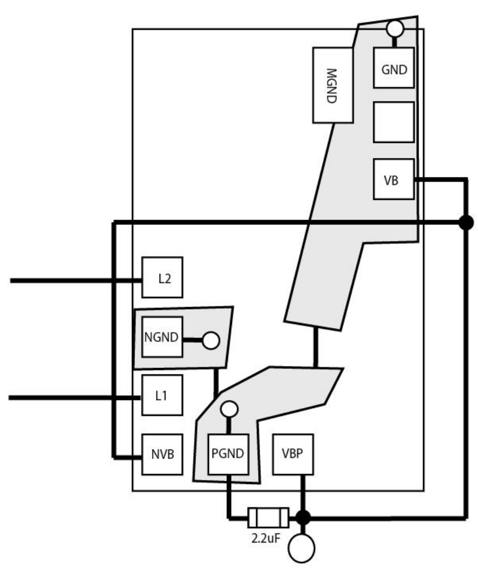


Figure 9. PCB Ground Plane Isolation

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