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## Using DSP Hybrids in High Power Applications Initial Design Tips

### APPLICATION NOTE

#### Introduction

This Information Note describes how to use ON Semiconductor's DSP hybrids in high gain, high power applications. The GB3211 Power PARAGON® was ON Semiconductor's first DSP hybrid, suitable for such applications. Since then, all other DSP have been designed for use in high gain, high power applications. These hybrids include GB3212 Duet, GA3216 FOUNDATION®, GA3217/18/19 VENTURE™, GA3222 Advanta and GA3280 VOYAGEUR™.

This document contains information about Power-On-Reset (POR) – the power management circuit (first implemented on the GB3211) – and explains in detail how the POR circuit functions to ensure the circuit's stability.

This document also describes what causes an AC ripple on the power supply line in high power applications and why the ripple needs to be filtered out. It also provides guidelines for hearing instrument designers on how to design RC power supply filter networks to minimize the ripple in the high power circuits that use ON Semiconductor's DSP hybrids.

#### High Power Circuits

One of the most common challenges in designing high gain, high power hearing instruments is to maintain the circuit stability, particularly around the end of battery life.

The GB3211 was the first device designed with power concern in mind. The POR circuit controls the operation of the system so the circuit does not 'motorboat' as the battery's voltage decreases. Once the supply voltage at the VB pad drops to approximately 1.0 Vdc (turn-OFF threshold), the POR turns off the system. The system then remains turned off until the supply voltage is turned off and then on again, and the supply voltage is higher than the turn-ON threshold. This method of operation is also called *deep reset* and can be implemented, via ARKonline® on ON Semiconductor's other DSP hybrids (with the only exception of GB3212 Duet).

The battery's voltage decreases around the end of its life, but it can also reduce instantaneously due to the AC ripple on the supply. To avoid that, an external power supply filter needs to be implemented.

#### Power Management Circuit

The GB3211 PARAGON and other DSP hybrids mentioned earlier were specifically designed to be suitable for high gain, high power applications. The output stage on all of those hybrids is a digital drive H-bridge with an output impedance of no more than 20 Ω and is capable of driving zero-bias receivers of very low impedance. Laboratory measurements show that these hybrids can drive receivers with an impedance as low as 10 Ω.

All of these hybrids have separate power supply and ground connections for the output stage. This arrangement enables hearing instrument designers to accommodate external RC filters to minimize (or eliminate) an AC ripple from the supply line. Reducing the AC ripple greatly improves the stability of the circuit – by preventing an unwanted reset caused by spikes on the supply line.

*Deep reset* mode was first implemented on the GB3211 and has two power management components on the controller chip – the Power-On-Reset sequence and turn off/end of battery life system. The diagram in Figure 1 depicts a hypothetical supply voltage as a function of time.

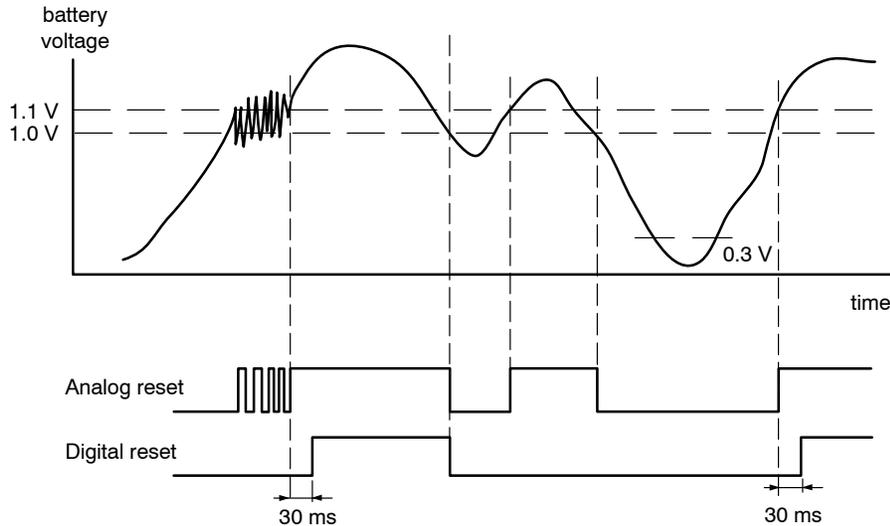
The Power-On-Reset block's purpose is to ensure that a stable turn-ON state is achieved. The following blocks are kept turned-OFF: the A/D and preamp channels (both front and rear), the controller, the DSP chip, and the EEPROM power. A small portion of the controller is enabled to monitor the signals coming from the analog POR block.

An analog voltage comparator monitors the supply voltage and feeds its output to a digital timer used to 'deglitch' a bouncy turn-ON. When the supply crosses the 1.1 Vdc level, the timer starts, and if the supply voltage maintains a level above 1.0 Vdc for at least 30 ms, the disabled blocks are enabled. Otherwise, the timer is reset and waits for the analog comparator to signal that supply is again above 1.1 Vdc. This ensures rejection of any turn-ON transients. Only after this 30 ms finishes can the part start to download EEPROM configuration data, and then to configure and activate the DSP.

Once the part is ON, dropping the supply below 1.1 Vdc causes the Lowbat signal to become active, but otherwise the

part continues to operate as normal. The Lowbat signal's true condition requires that the supply voltage remain below 1.1 Vdc for at least 30 ms. (This action is not shown in Figure 1.)

Once the Lowbat signal becomes active, the audible low battery voltage indicator produces a series of three beeps – 0.5 second long, 30 seconds apart. During that period of time, communication with the hybrid is not possible.



**Figure 1. Power-On-Reset Operation**

This power-down sequence could occur as a result of the following two conditions:

- The hearing aid is being turned off.
- The battery is at end of life.

Additional rules apply to ensure that the unloading of the battery does not cause a bounce back above 1.1 Vdc, initiating a motorboating situation, where the power on sequence results in current draw from the battery, tripping the 1.0 Vdc turn-OFF condition. Once the turn-OFF condition is satisfied, the supply voltage must also drop below 0.3 Vdc before a valid turn on sequence is possible.

The other DSP hybrids that followed the GB3211 offer flexibility in selecting other Power-On-Reset reset modes. For example, on Venture, the user can choose one of four different POR modes. For detailed information on these Power-On-Resetschemes, as well as the turn-ON and the turn-OFF threshold levels, refer to Venture's technical data sheet (Document GA3219). For information about the POR modes implemented on other DSP hybrids, refer to their individual technical data sheets.

#### **Zinc-Air Battery and Zero-Bias Receiver Impedance**

The amplitude of the AC ripple injected into the supply line by the receiver is proportional to the ratio of the zinc-air

If the supply drops below 1.0 Vdc, then the part is put into an OFF state. There is no debouncing of this signal, the action is immediate. This level was chosen because the regulator has a 950 mV regulation voltage. The regulator needs some headroom to ensure that it maintains good supply rejection, which is critical in high gain, high power applications to prevent system instability.

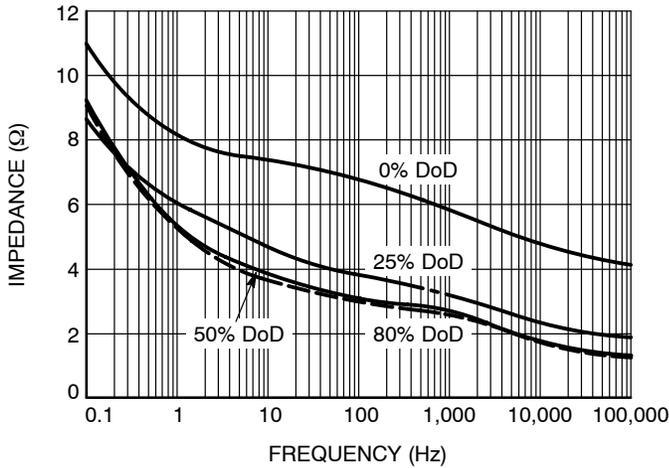
battery's impedance to the impedance of the receiver being used.

Most hearing instruments are powered by zinc-air batteries. The impedance of a zinc-air battery depends on its type. The impedance is also a function of frequency and the depth of discharge.

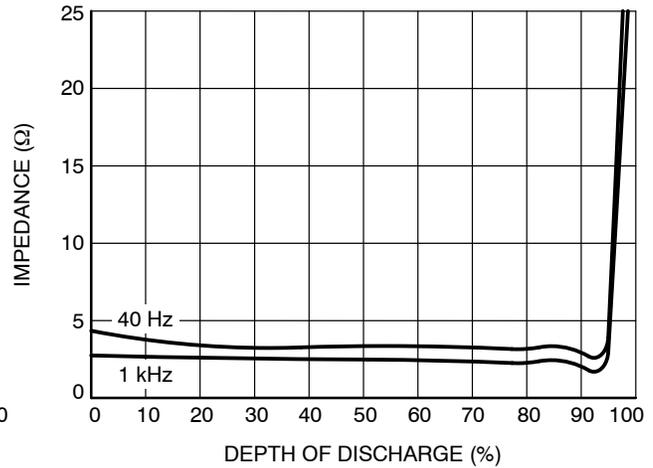
Measurements show that the battery's impedance increases as the frequency at which it is measured decreases. Measurements also show that the impedance tends to be higher immediately after the zinc-air battery is activated by opening the air vents, and then it remains relatively stable throughout the battery's life. The impedance then increases again at the end of battery's life.

The graphs shown in Figures 2 thru 5 were taken from documents published by Energizer and are available at Energizer's website at <http://www.energizer.com>. The graphs show a zinc-air battery's impedance as a function of frequency and the depth of discharge (DoD). The impedance graphs of type 13 and 675 zinc-air batteries are shown here as those two types of zinc-air batteries are most suitable for high power applications. The graphs show the Energizer battery's impedance, however, the impedance of zinc-air batteries made by other manufacturers exhibit similar characteristics.

**ENERGIZER AC675 BATTERY IMPEDANCE**

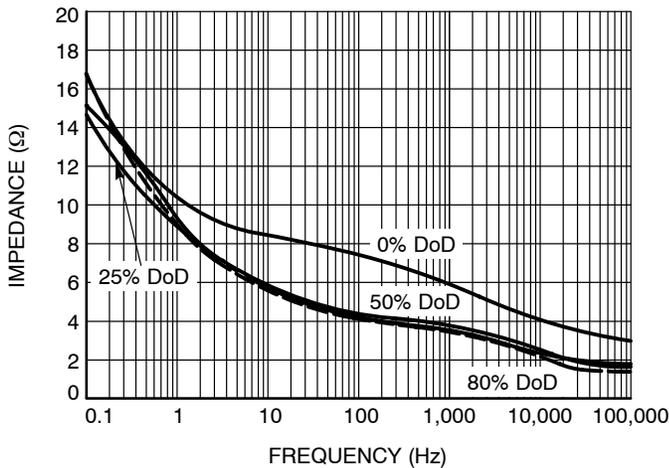


**Figure 2. Impedance vs. Frequency**

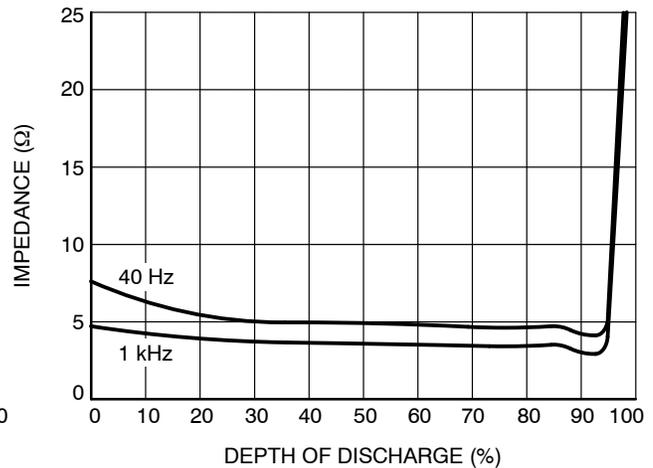


**Figure 3. Impedance vs. Depth of Discharge**

**ENERGIZER AC13 BATTERY IMPEDANCE**



**Figure 4. Impedance vs. Frequency**



**Figure 5. Impedance vs. Depth of Discharge**

**IMPEDANCE (Z)** : The total opposition that a battery offers to the flow of alternating current. Impedance is a combination of resistance and reactance.

**IMPORTANT NOTICE**

This application note contains information specific to batteries manufactured at time of its publication. Please contact your Energizer representative for most current information. Contents herein do not constitute a warranty.

Characteristics of a zero-bias receiver's impedance are quite different. Since the receiver's impedance is mainly resistive-inductive, it increases with frequency.

Measurements show that for low frequencies (up to approximately 100 Hz), the resistive component is dominant. As the frequency increases above 100 Hz so does the impedance due to the inductive component becoming significantly larger.

The impedance of three different receivers were measured as a function of frequency. The receivers were in a free field and loaded by a 2cc BTE coupler. The differences between the free field and the 2cc load impedance measurements are caused by different acoustic loading.

The figures (graphs) below show the results of those measurements.

TYPICAL CHARACTERISTICS

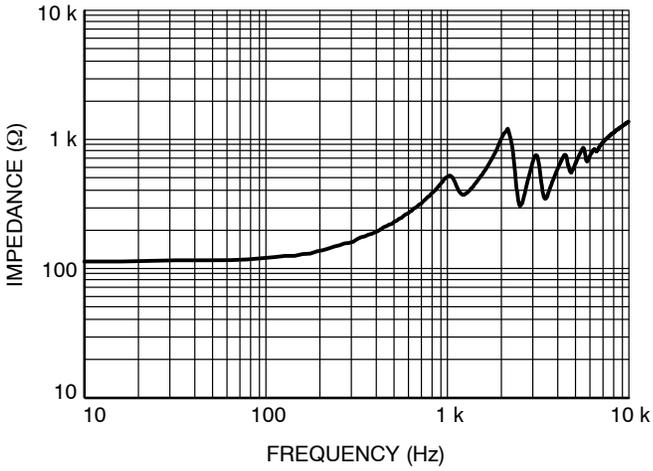


Figure 6. Knowles EF7505 Receiver with BTE Coupler

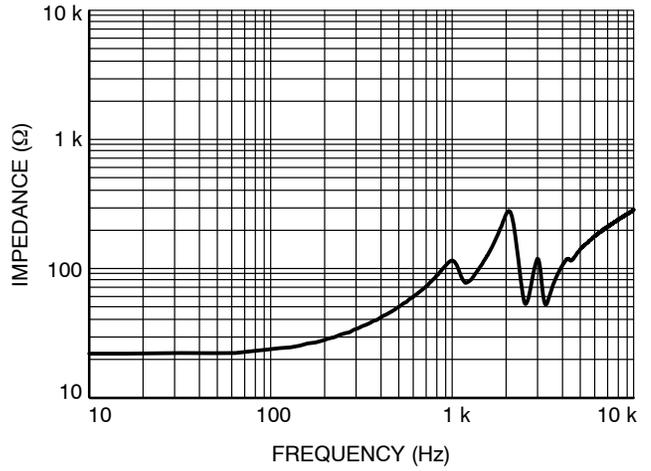


Figure 7. Knowles BK1610 Receiver with BTE Coupler

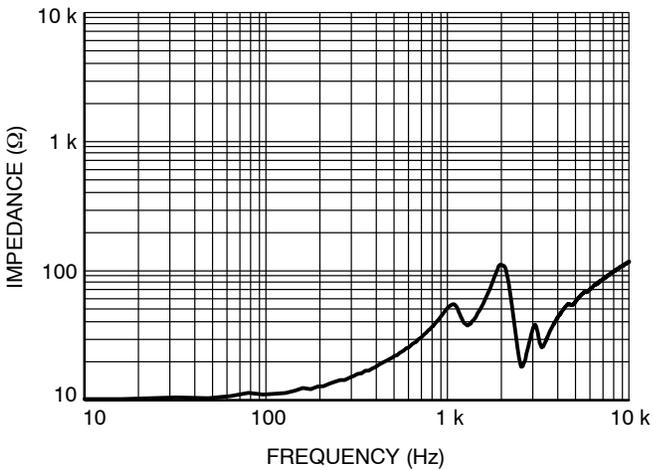


Figure 8. Sonion 1980 Receiver with BTE Coupler

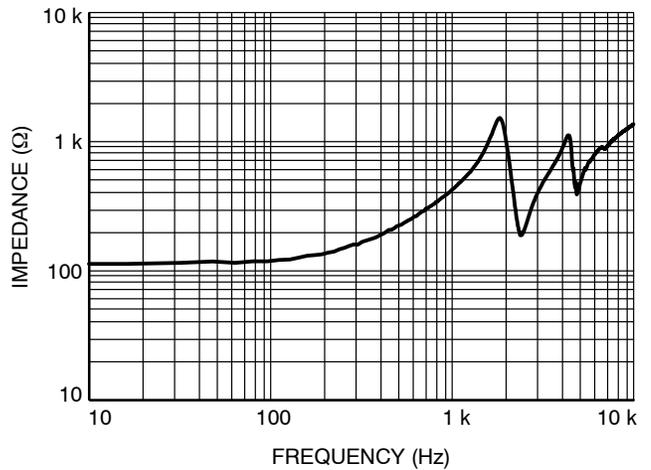


Figure 9. Knowles EF7505 Receiver in Free Field

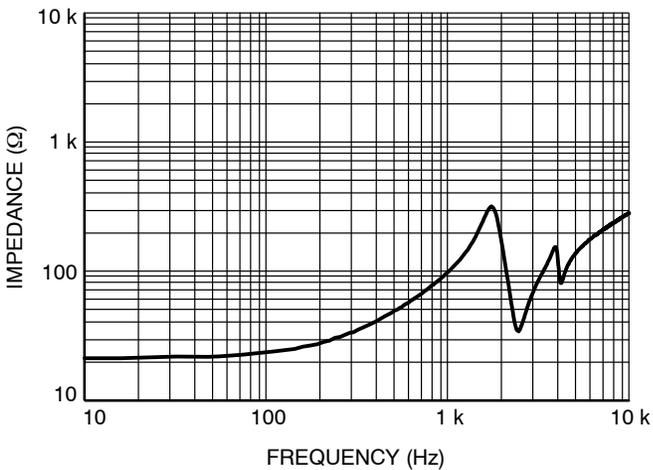


Figure 10. Knowles BK1610 Receiver in Free Field

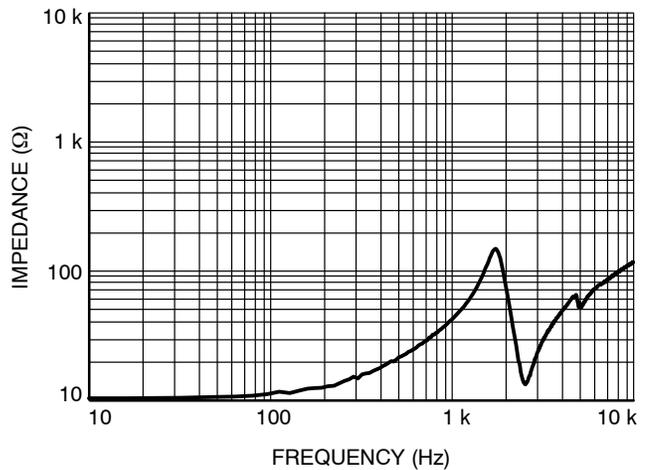


Figure 11. Sonion 1980 Receiver in Free Field

**Power Supply AC Ripple and RC Filters**

As mentioned earlier, the output stage of the GB3211 and other DSP hybrids listed above injects a signal (AC ripple) into the power supply line. The amplitude of the ripple depends on the ratio of the battery’s impedance to the receiver’s impedance.

The following measurements were done using the GB3211 hybrid. The amount of AC ripple appearing across the power supply’s resistance was measured. A separate low impedance power supply with 5 Ω resistor in series was used to supply the output stage; the AC ripple was measured across that resistor.

An electrical input signal of –40 dBV was used and the GB3211 was set to four channel linear mode with 40 dB of channel gain. At those settings, the signal entering the output stage was at maximum. The amplitude of the AC ripple was measured using the three different zero–bias receivers (see Table 1).

The main concern with the AC ripple on the power supply line is that it would cause the Power–On–Reset circuit to turn the system off. The system turns off when the AC ripple causes the supply voltage at the VB pad (Pad #12 on the GB3211) to instantaneously drop below 1.0 Vdc (Power–On–Reset turn–OFF threshold).

**Table 1. AC RIPPLE AMPLITUDE MEASUREMENTS**

Input Signal Frequency [Hz]	AC Ripple [mVpk] 1980	AC Ripple [mVpk] BK1610	AC Ripple [mVpk] EF7505
10	16	10	2
15	85	59	14
20	122	96	29
50	130	98	30
100	131	98	29
200	135	101	28
300	135	97	24
500	126	76	15
1000	65	28	6
2000	28	10	3
3000	71	30	5

The schematic diagram in Figure 12 shows how an external RC filter could be implemented to filter out the AC ripple.

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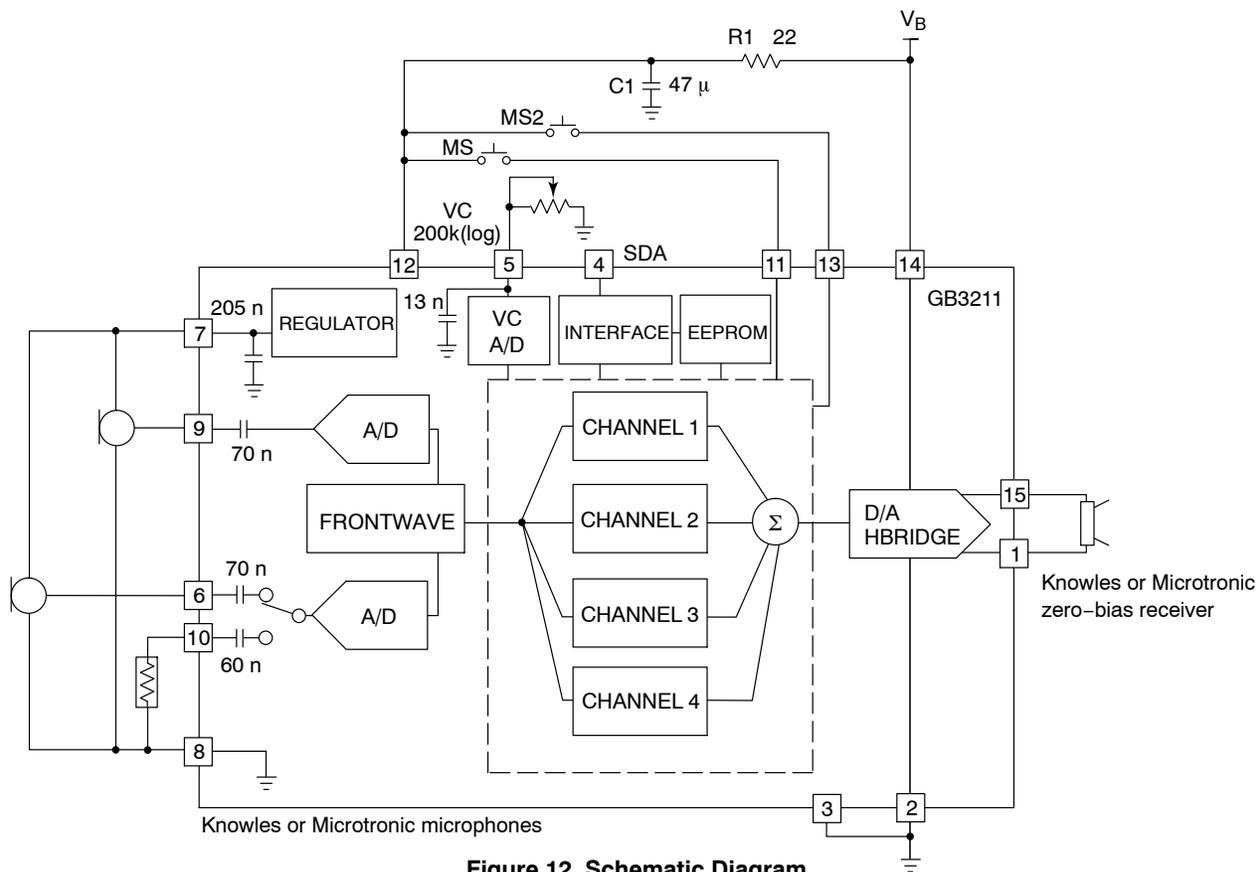


Figure 12. Schematic Diagram

### GB3211 Application Circuit with RC Filter Network

When selecting the resistor and capacitor values for the RC filter the following factors must be considered:

- The GB3211 shuts down when the supply voltage at the Power-On-Reset drops below the turn-OFF threshold of 1.0 Vdc.
- The turn-OFF threshold could be as low as 0.94 Vdc, but it could also be as high as 1.05 Vdc.
- If a zinc-air battery is allowed to operate down to 1.1 Vdc, and the turn-OFF threshold is 1.05 Vdc (worst case), the maximum AC ripple cannot exceed the peak value of 50 mV.
- The 50 mV is further reduced by the voltage drop across the filter's resistor. The current flowing through the filter's resistor supplies the front end of the GB3211 and the microphones. That current is approximately 0.5 mA, so if the resistor value were 22  $\Omega$ , then the resulting voltage drop would be 11 mV. That value effectively reduces the allowed minimum battery voltage to 1.089 Vdc (instead of 1.1 Vdc) and the maximum allowed AC ripple from 50 mV peak to 39 mV peak.

NOTE: It is important to remember that the amplitude of the AC ripple is at its highest in the lower frequencies (high battery impedance and low receiver impedance). Reducing the low frequency gain could also reduce the amplitude of the ripple.

### Designing Power Supply Filters

The following are guidelines for designing a simple, first order RC low pass filter to be used with ON Semiconductor's DSP hybrids in high power applications:

1. Use a separate low impedance power supply with a series resistor for the output stage. Select the resistor value to approximate a battery's impedance at a given frequency. Alternately, use a fresh zinc-air battery to supply the power to the output stage.
2. Use a signal generator to provide an input signal to the hybrid. Adjust the gain of the hybrid so the output stage drives a zero-bias receiver at full scale.
3. Measure the AC ripple across the resistor or the battery.
4. Calculate how much attenuation is required for the ripple to be reduced to maximum allowed value. Example: 39 mV peak when the battery is allowed to operate down to 1.1 Vdc, the turn-OFF threshold is 1.05 Vdc and the filter resistor is 22  $\Omega$ .

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5. Based on the required attenuation, calculate the corner frequency of the low pass RC power supply filter. Example: If the first order filter is to be designed and the required attenuation is 12 dB at 300 Hz, then the required corner frequency of the filter is 75 Hz.
6. Based on the corner frequency and the resistor used in the filter, calculate the required capacitor value. In this example, the required capacitance is 96  $\mu$ F.

### Power-On-Reset Timing Considerations

An important consideration when designing an RC filter network for a hybrid operating in deep reset mode is how that network affects turn-OFF/turn-ON operation of the hybrid.

Once the power supply is turned off (or if the supply voltage at the Power-On-Reset supply pad reduces to approximately the turn-OFF threshold) the Power-On-Reset initiates the system shut down sequence.

That sequence involves turning off sections on the hybrid until the system is fully reset. The supply voltage then has to drop to approximately 0.3 Vdc (reset threshold) to reset the system so it can be turned on again.

Without an external RC filter network, the power down sequence takes approximately 0.35 seconds. With the external RC filter network, the power down sequence takes a longer amount of time. Any capacitors connected to the Power-On-Reset either directly or through resistors, have to discharge to the reset threshold level before the hybrid can be turned on again.

After the system is turned off by physically disconnecting the battery, the only discharge path for the capacitors is through the hybrid itself. The rate of discharge is determined by the decreasing amount of current being used by the hybrid as the individual sections of the hybrid are being turned off.

Measurements show that it takes approximately 1.3 seconds for the GB3211 to reset when the power supply filter has a 47  $\mu$ F capacitor. The system has to wait at least that long before it could be turned on again.

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