*20111 Stevens Creek Blvd., #260*
*Cupertino, CA 95014. U.S.A.*
*Tel: 408.253.3883*
*Fax: 408.253.6630*

# Lanwave Technology, Inc.

---

## System Application Note

AN-7 *Audio Section noise reduction methods in SATURN Cordless Phone Design*

L9002VX / VX2 Code Division Spread Spectrum Telephone Chip

---

Revision: V1.2
Date: April 1999

*20111 Stevens Creek Blvd., #260*
*Cupertino, CA 95014. U.S.A.*
*Tel: 408.253.3883*
*Fax: 408.253.6630*

# Audio section noise reduction methods

Digital Cordless Phone with high power radio design requires special layout precautions to minimizing audio noise due to RF AM coupling and TX/RX switching current change (commonly known as TDD noise). These problems exists in narrow band cordless phones to a smaller degree due to their low radiated power. In digital cordless phone design such as using the SATURN processor, in particular with 2 layer PCB limitation, these precautions are absolutely essential to producing a high sound quality.

The audio noise coming out of the ear piece of the handset is a summation of the following four factors, all can be traced back to the high power radio emission (generally 100mW antenna output), and the rapidly switching ground current from the RF section during TX/RX transition cycles (generally a swing of more than 100mA in a 166Hz cycle, producing fundamental and harmonics related to 166Hz in the audio band.)

1. Amplitude modulation (AM) coupling from the 900MHz antenna output to the wire traces feeding into the audio codec section's high impedance input pins. (AM coupling.)
2. Ground inductive pulling generated by the RF ground plane (100mA in 6ms cycle time), affecting the codec analog ground plane. (Ground inductive pulling.)
3. Reference signals for telephone hybrid op amp interface circuit, experiencing fluctuation from the power regulator and battery Vcc shifts due to the supply current fluctuation drawn from the RF section (RF Vcc noise.)
4. Shifts in Analog Reference input to the audio codec internal bias circuit. (Analog Vref noise.)

The following will explain the source of these 4 problems and suggest layout and design precautions suitable for low cost, 2 or 1-layer PCB, cordless phone designs.

Note: Contrary to believe, good RF design in a digital phone do not solve the audio noise problem. (It is because, in the end, the RF section only transmits a logical ONE, or a logical ZERO, which has a high noise margin in between. And any single bit noise will be filtered through the baseband *CD/SS*™[1] decoder and the voice codec algorithm.) All of the above noise source occurs in the audible band (100Hz to 3.5KHz) and their remedy is in the analog and PCB design outside of the RF section.

## 1. Noise from AM coupling

The 900MHz RF emission from the antenna is inducing a small (900MHz) current in every metal trace on the PCB acting like a small antenna. This is due to basic EM wave

[1] *CD/SS*™ is a registered trademark by Lanwave Technology, Inc.

*20111 Stevens Creek Blvd., #260*
*Cupertino, CA 95014. U.S.A.*
*Tel: 408.253.3883*
*Fax: 408.253.6630*

induction in between any 2 conductors. Sometimes this is also inducing current inside the silicon package but generally the effect is small[2]. The exact amount of alternate cycle (ac) current induced is dependent on many factors such as the length and orientation of the trace with respect to the antenna dipole. Due to the parasitic and actual capacitance associated between these trace to ground, a small AM (Amplitude Modulation) current is generated from the 900MHz TDD signal envelop. This amount of AM coupling can be as high as 50 to 250uV peak to peak. If this noise is added (say, to the microphone input) and feed into a high gain op amp input, the noise will be amplified at the output which will be presented to the ADC of the PCM codec. This noise is AM modulating at the TX/RX pulsation rate of 166Hz and is well within the audible band.

There are 4 major traces that typically pick up AM coupling from the TDD envelop:

The first and foremost is the microphone input line to the CODEC mic input pin. The problem is severe because this trace can be quite long due to the MIC placement, and the fact that the CODEC mic is connected to a high impedance input typically amplified 20 to 50 times internally to feed the ADC. There are 4 remedies and we recommend applying a combination of all four under reasonable cost consideration.)

a. Minimize trace length. (Minimize induction.)
b. Use dual ended (differential) mic to op amp input design. (Somewhat balance and cancel the AM noise. Most cellular phones adopt this approach.)
c. Completely shielding the microphone input to the CODEC input pins. (Shield to minimize induction, as much as allowed in a 2-layer PCB.)
d. Amplify the mic input with an external amp placed close to the MIC, before wiring traces to the CODEC input and its ADC. (Increase signal to induced noise ratio.)

The second pickup source is the signal trace from the telephone hybrid to the CODEC input. (This is the conjugate of the microphone trace problem.) Since the signal amplitude is generally higher so the degree of noise relative to signal is comparatively less.

The third and fourth are the intermediate op amp signal traces wired through the gain setting (and for external speaker mixing) R, C components in both ADPCM codec. The remedy is in general the same as described in a – d above. In addition, whenever is allow by power dissipation, a higher signal level should be used to reduce the relative noise level.

## 2. Ground Inductive Pulling

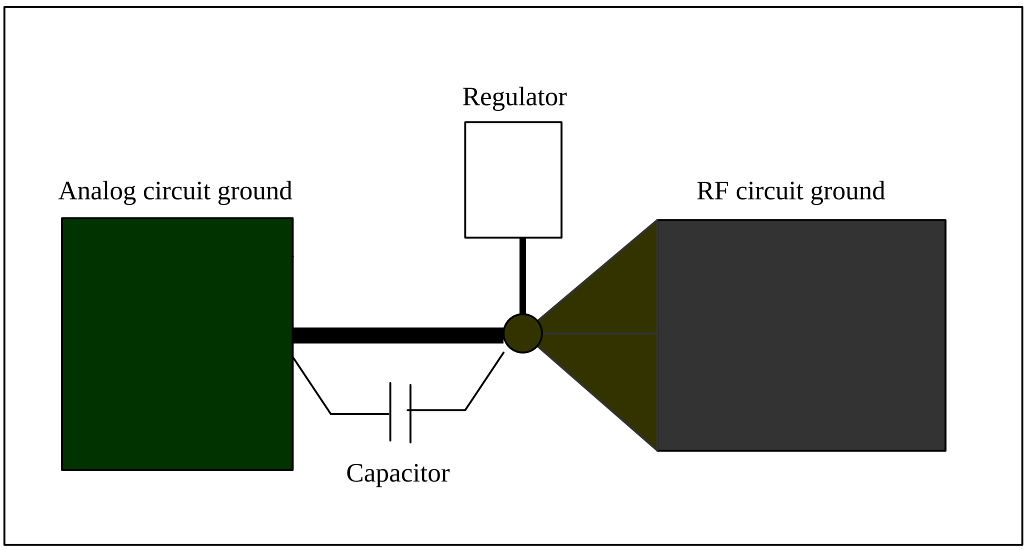
During TX / RX transitions, the ground current coming out of the RF section fluctuates with more than 100mA swing. This is because TX circuit consumes more current than RX circuits. Furthermore, if the antenna is not well matched to the input impedance of the

[2] This is only relevant in very high frequency operations.

20111 Stevens Creek Blvd., #260
Cupertino, CA 95014. U.S.A.
Tel: 408.253.3883
Fax: 408.253.6630

power amp then the reflected energy will add to ground current fluctuations. There are 2 design points to minimizing this effect:

a. Match the antenna well. This will not only lessen ground current fluctuation but also produce a longer range. However, the matching has to be applied across a wider frequency band (quite unlike narrow band analog 900MHz phones) so the antenna matching network should be a 3 to 4 element (or a load line) to widen the Q value, minimizing reflection variations across different RF frequency channels.
b. Separate the RF ground from the analog ground plane in the PCB layout. Only connect them at the power regulator ground pin WITH A NARROW BRIDGE copper trace. The diagram below illustrates several more subtle layout and decoupling suggestions:




The RF ground plane should avoid sharp edges to reduce field leakage. Its contact to the regulator ground pin should be TRIANGULAR, minimizing self inductance (this is important because RF ground current fluctuation is on the order of 100mA.) The analog circuit ground, on the other hand, should be a narrow trace (so there is some residual self inductance. This amount does not produce ground shift since the analog ground current change, if exist at all, is on the order of several mA and seldom fluctuates.) And for maximum isolation effect, this self inductance can be used in parallel with a shorting capacitor between the actual ground plane to the regulator ground pin. This capacitance, together with the parallel parasitic inductor, forms a highly leaky, frequency selective blocking circuit between the two ground planes. As the noise source is convey by the 900MHz, or 2.4GHz carrier wave, the capacitance should be chosen to ensure a rejection range in this carrier band. Its actual value is dependent on the ground wire bridge trace geometry, ferrite beads used, and PCB material. It should be added only if necessary to avoid some other possible side effects which is not elaborated here.

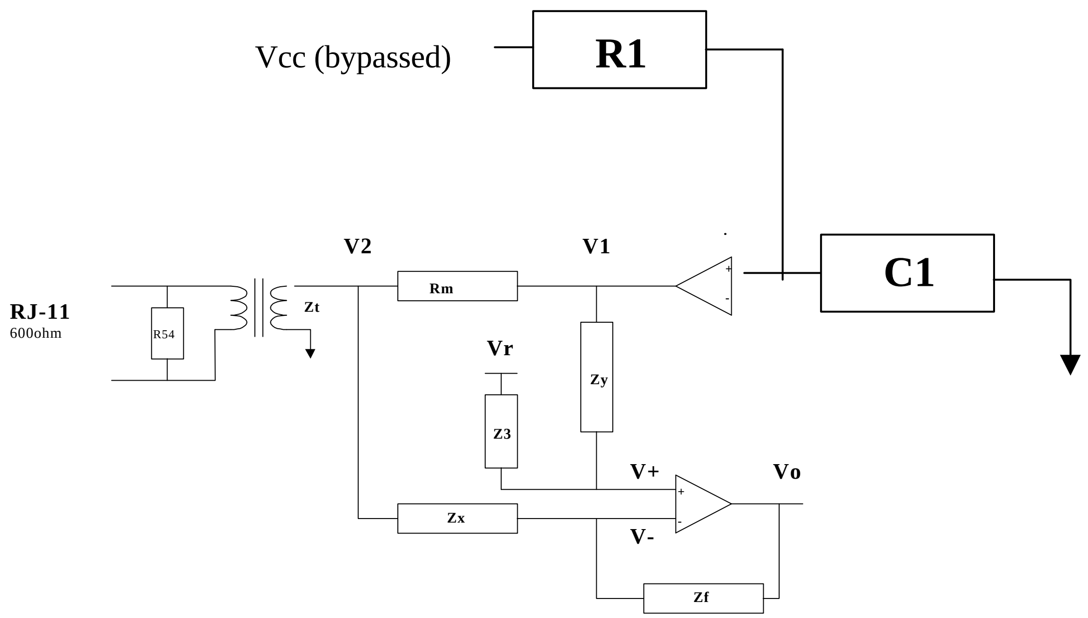
*20111 Stevens Creek Blvd., #260*
*Cupertino, CA 95014. U.S.A.*
*Tel: 408.253.3883*
*Fax: 408.253.6630*

## 3. RF Vcc Noise

Fluctuations in RF TX/RX current requirement produce Vcc fluctuations from the internal resistance of the battery, or the power regulator. This requires a significant by pass capacitor (47uF, in parallel with a 1uF) as in normal by pass circuit designs close to the power regulator Vcc output.

The small amount of Vcc fluctuation after Vcc bypass would still affect certain sensitive audio circuits that derive a reference voltage point, or bias shift point, from the Vcc. Among others, this problem will affect the Telephone hybrid interface reference, and the Microphone bias generator.

The telephone hybrid interface circuit require a reference level at one half of Vcc. This reference signal is usually connected to the high impedance input of the telco interface op amp. (See circuit below.)




The 2 components R1 and C1 forms a low pass filter, in addition to Vcc bypass, further reducing Vcc noise. This is applicable when the op amp chosen has a low input offset current, or drift current. The RC values should be chosen to provide low pass filtering at around 1Hz.

Similarly, the bias voltage supplied to certain types of microphone will also require such extra bypass. The circuit configuration is similar to the above and is not repeated here.

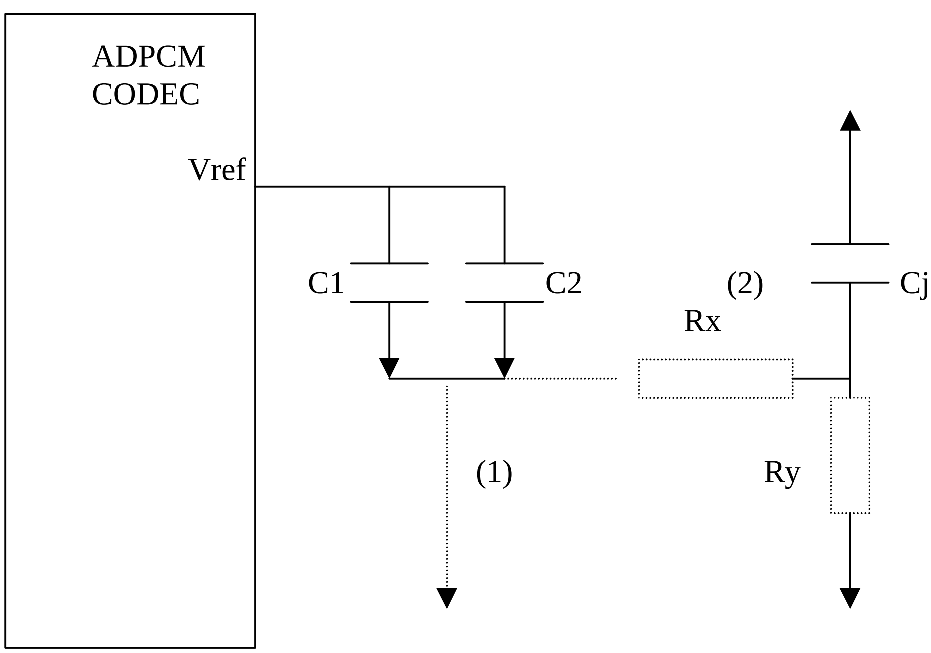
20111 Stevens Creek Blvd., #260
Cupertino, CA 95014. U.S.A.
Tel: 408.253.3883
Fax: 408.253.6630

This bypass technique may apply to other reference circuits that affects the audio band noise. Its improvement is most noticeable when the reference voltage is interfaced to a high impedance load that draws little current.

## 4. Analog Vref noise

Most ADPCM codec require an external Vref capacitor to stabilize its internal reference. This Vref voltage is generated inside the codec and carries very little current (typically a band gap regulator design on silicon, supplying a mid Vcc reference to its internal analog circuits.) Externally this pin is required to be de coupled to analog ground through two series capacitors (high at 22uF, low at 0.1uF).

The noise sensitivity of the codec output due to noise at this input pin is dependent on the exact codec chip. (Some codec vendors has better internal design than others.) However, any noise in the audible range presented at this pin will be reproduced, and sometimes amplified, by the internal circuit of the codec. As such this pin should be properly shielded (frank by ground) and minimized in trace length. In addition, and depending on the internal equivalent circuit of this pin (usually can be obtained from the codec chip supplier) a double by pass circuit need be employed to adequately reduce Vref noise. The idea is similar to the telephone hybrid reference de coupling circuit described in 3.




The values of Ry and Cj in the second circuit is determined by setting the low pass corner frequency at around 1Hz, while keeping the combined Rx and Ry low enough to not produce any fluctuations at Vref during CODEC operation.

**Discussion**

Finally, it should be emphasized that the audio noise are generated ONLY before the ADC going into the codec inputs, or after the DAC output from the codec chip on the receive side. The voice data is processed digitally in between and is not subject to interference of this nature. Therefore all wire traces (and components) that interfaces to the analog world that is close to the RF antenna should be shielded by a ground plane whenever possible. All improvement suggestions mentioned in this technical note should be used in conjunction with proper shielding and not meant to replace it.

If multi layer PCB design is used, most of the problems described in (1) will be resolved. However, the other three problems will still require attention.

The ideal outcome of the audible sound quality at the ear piece is limited only by the in-band spurious and cross talk residual specification of the CODEC chips, which is typically in the minus -50dB to -80dB level and is very quiet. The challenge is in the PCB design and in taking the above circuit precautions.

In summary, the following is a 10 point check list to reduce layout noise in a SATURN digital cordless phone design:

1. AM pickup at the microphone input trace to ADPCM codec.
2. AM pickup at the telco input to the base station ADPCM codec.
3. Minimize intermediate gain setting component traces at handset.
4. Intermediate gain setting traces involving external speaker mixing.
5. Match antenna with wide band load line, or 3 to 4 element matching network to minimize RF signal leakage to ground.
6. Separate RF ground from Analog ground planes. Pay attention to geometry design and at the regulator junction to minimize inductive pulling.
7. Add shorting capacitor in parallel with analog ground plane bridge to create carrier frequency blocking network.
8. Secondary Vcc decoupling low pass filter for telco voltage reference input.
9. Secondary Vcc decoupling low pass filter for microphone bias generator.
10. Secondary Vref decoupling for ADPCM external reference voltage pin.

For further details, or assistance, please contact your local Lanwave representative or directly contact Lanwave technical support at:

Tel: (408)-253-3883
Fax: (408)-253-6630
Email: techsupport@lanwave.com

**- END -**