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# i2i Transmitter/Receiver

Reviewed by Chuck Hansen

**Aerielle, Inc.**
625 Ellis St., Suite 206
Mountain View, CA 94043
650-967-4047
www.aerielle.com
List Price One Pair $120 US
(Street price $90)
Dimensions: 1.25″ W × 5/8″ D × 2.5″ H for each module
Warranty: 1-year limited warranty parts and labor on the i2i Stream.

The i2i® Stream is a wireless digital audio device that allows you to broadcast your favorite music to friends who also have i2i Streams. i2i Streams can send or receive "CD quality" sound up to 30′ wirelessly. You can plug any MP3 player into one end of the i2i Stream and your favorite earphones into the other end and choose one of seven RF channels to start broadcasting. The i2i Stream is said to be universally compatible with iPod®, MP3 and media players, and 32Ω or higher impedance earphones, headphones, and portable speakers.

## OPERATION

The Aerielle i2i Stream consists of two or more identical battery-powered modules that can function either as a transmitter or receiver (**Photo 1**). You recharge the modules by plugging them into an active USB port, or by means of an optional AC powered adapter. Charging is indicated by a flashing red LED. When the LED stops blinking and stays on, the battery is charged. Initial charge time for me was about five hours, and the units are said to operate 5-7 hours per charge.

The unit on the right in **Photo 2** shows the on-off switch/volume control on the top and the mini-USB input port for the battery charger. The unit comes with two pairs of mini-phone jack I/O cords (12″ and 28″) and two USB-mini USB battery charge cords. I would invest in the optional AC powered battery charger if you do not want to tie up your computer to charge the batteries. The computer USB ports on my desktop are only powered after Windows XP starts.


PHOTO 1: i2i Stream display box.


PHOTO 2: i2i Stream modules.

I found the i2i units quite easy to operate. You insert the smaller plug of the audio I/O cable into the small jack at the bottom of the unit you select to be the master transmitter. Then you plug the larger plug of the audio I/O cable into the output jack of an iPod or any other analog audio source. The i2i passes the original audio source through to its own headphone output jack whether the i2i is powered or not, making it easy to set the transmitter input level.

You insert another stereo headphone plug into the larger jack at the top of the i2i unit you want to be the receiver. You can add as many i2i receivers as you want. To power up each unit you press the square nub on the volume control inward and hold it until the large center "i2i" Channel Select button lights. A small battery indicator LED near the volume control will flash one to four times to indicate the relative battery charge power level.

There are seven RF channels available. Set each i2i unit to the same channel color by pressing the large center channel button until they all match. I used red for my testing with no sign of interference from any other nearby i2i units. (I cycled through the other six colors to check for any external interference and found none.)

Finally, you must select the transmitter mode by pressing the Send button above the Channel Select button, which will flash to indicate it is an active transmitter. You select the receive mode by pressing the Receive button below the Channel Select button, which remains lighted. I found this phase of the operation a bit quirky because the button you must activate is on the opposite end from the audio jack you use in that mode.

With the audio source to the transmitter active, everyone with an i2i receiver should hear the same music source and can set their headphone level independently. They can switch sources by having another person assume the "transmitter" role. You can hang the i2i from either the supplied neck lanyards or pocket clips.

## AUDITION

I auditioned the i2i Stream units with an iPod Nano and a Creative Nomad II MP3 player. The Nomad is limited to 128k sampled CD tracks, while the iPod played a mix of 128k through lossless AIFF/WAV file CD tracks.

The iPod Nano itself is a pretty good audio source with lossless WAV or AIFF music. With its 128k sampled audio, the older Nomad is less so. The i2i was equal to the Nomad in sound quality, while it couldn't quite compare to the iPod at its higher sampling rates. Remember, the i2i needs analog input signals, so it must re-process the converted analog audio signals of the other players, which is never as good as doing the original D-A conversion.

I found that the range of the 2.4GHz transmitter with fully charged batteries (four LED flashes) was 36′. Beyond that distance the number and duration of dropouts increases.

The i2i is not aimed at high-end audio enthusiasts, so for its target market (who probably use the lowest bit rate in order to store the most songs) it will do quite well. The midrange was nearly equal to the sources, with a bit edgier treble and more noticeable and less controlled bass. The bass seemed louder than the iPod source, so some added LF emphasis may be in play at lower volume levels.

## MEASUREMENTS

Measurement data depended on the battery conditions of both transmitter and receiver. I maintained the battery charge between three LED flashes and fully charged four LED flashes, recharging when necessary. As a result, the data repeatability is somewhat variable.

The i2i Stream inverts polarity somewhere between the transmitter input and receiver output, because the passed-through signal has the same polarity. The input impedance with the transmitter power off measured 935Ω at 1kHz, 2k7 at 20Hz, and 866Ω at 20kHz. With the transmitter powered, these numbers dropped to 674Ω at 1kHz, 2k5 at 20Hz, and 648Ω at 20kHz. Your audio source will need to be no less than 65Ω to avoid altering the frequency response. The iPod Nano output is rated for 32Ω.

When starting the receiving unit, there is a beep whose loudness represents the volume setting. The unit powers up at the same volume as that which was set at shutdown. When the receiver is shut down, there is another beep. There is no indication in the receiver that the transmitter is shut down, just loss of audio. There is a very low level of hiss in the receiver unit phones at maximum volume with the transmitter off.

I recorded the response for loads of 47k, 60Ω, and 32Ω for **Fig. 1**. The capacitive coupled output rolls the low frequency off –3dB at $f = 1/2\pi RC$. At 47k, this –3dB point is 3Hz, but it increases to 21Hz with a 32Ω load. The high-frequency response was flat out to 22kHz, where it dropped rapidly due to the steep digital LP filter. A-weighted hum and noise (maximum receiver volume, transmitter active with its input shorted) measured -76dB relative to the maximum undistorted 1kHz output level of 384mV RMS. DC offset at the receiver output was less than 1μV.

**Figure 2** shows the maximum volume receiver output voltage versus transmitter input voltage. Gain at 1kHz is about 22dB up to the point where compression is inserted to limit the output voltage. There is more compression imposed at 20Hz than at the higher frequencies.

The i2i Stream THD versus frequency is shown in **Fig. 3**. I maintained the transmitter input at the point just below where output compression occurs and set the receiver volume to what I considered to be the maximum comfortable music listening level of 100mV pp (313mW into 32Ω). I used the distortion test set steep 22kHz LP filter to remove out-of-band noise and digital artifacts. The distortion rises rapidly below 50Hz, and there is a bit of a notch at 60Hz indicating some pickup of the 60Hz line frequency somewhere in the transmit-receive audio chain.

**Figure 4** shows the THD+N versus transmitter input voltage with the receiver volume at maximum. Output level compression causes the steep increase in 1kHz THD at about 1.26V in RMS. The 20Hz trace shows this increase occurs at lower input levels,

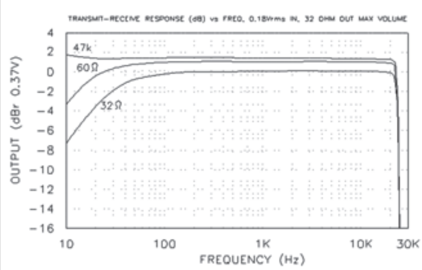

**FIGURE 1: Frequency response.**

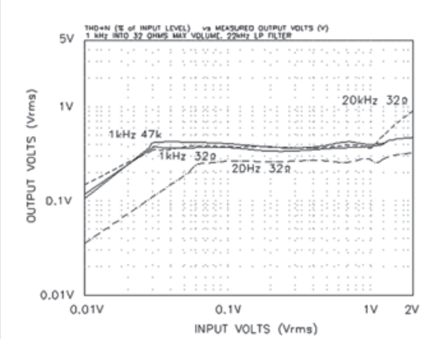

**FIGURE 2: Output vs. input.**

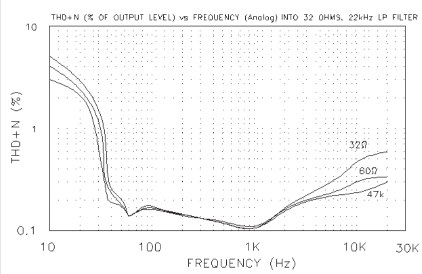

**FIGURE 3: THD+N vs. frequency.**

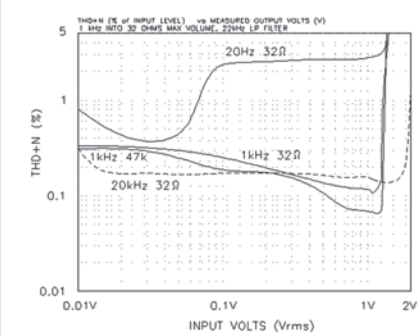

**FIGURE 4: THD+N vs. input voltage.**

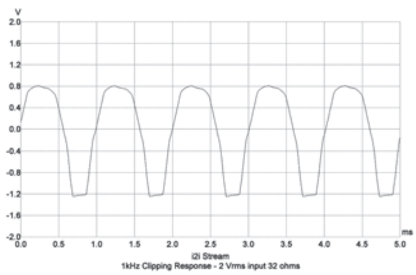


FIGURE 5: Clipping response.

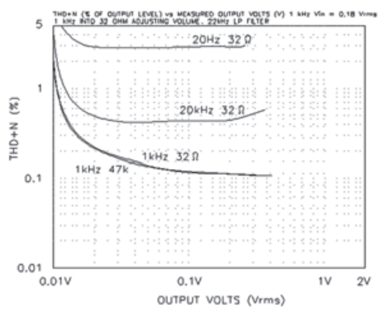


FIGURE 6: THD+N vs. output voltage.

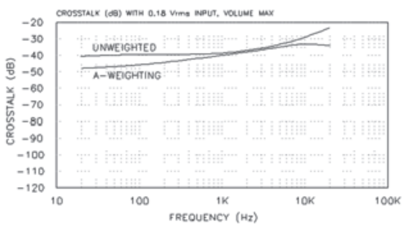


FIGURE 7: Crosstalk.

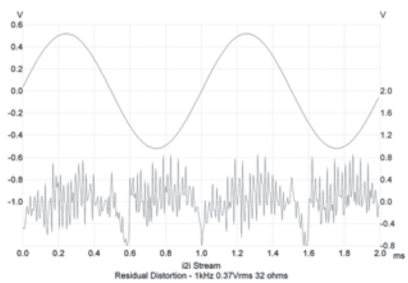


FIGURE 8: Residual distortion 1kHz.

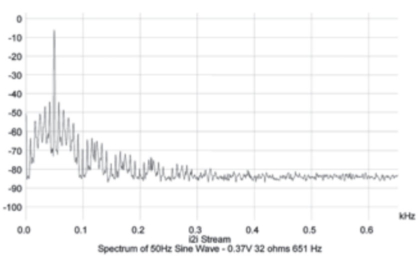


FIGURE 9: Spectrum of 50Hz.

and the i2i Stream compression seems to relax the compression somewhat at 20kHz allowing for more undistorted input voltage. You can also see this in **Fig. 2** with 2V RMS into the transmitter. The upper peaks of the waveform are softly compressed with increasing voltage while the lower peaks become hard clipped as shown in **Fig. 5**.

For the graph of THD+N versus output voltage in **Fig. 6**, I held the transmitter input to 180mV RMS and adjusted the receiver volume control to increase the output. This produces the more usual distortion characteristics with distortion decreasing with output. The low 180mV input signal does not allow output clipping at any of the test frequencies.

Crosstalk performance is shown in **Fig. 7**. There is quite a bit of coupling between the two channels, whose test setup includes the supplied 12″ input cables and simulated headphone wires.

The distortion waveform for 370mV RMS into 32Ω at 1kHz is shown in **Fig. 8**. The upper waveform is the receiver output signal, and the lower waveform is the monitor output (after the THD test set notch filter), not to scale. This distortion residual signal shows mainly the 2nd harmonic, with quite a bit of high-frequency noise and output stage crossover distortion. I don't know whether the headphone amplifier is a linear amp or a battery-saving Class-D switching amp. The THD+N at this point is the lowest of the testing, at 0.108%.

The spectrum of a 50Hz sine wave at 370mV RMS into 32Ω is shown in **Fig. 9**, from zero to 651Hz. The THD+N measures 0.185%. 60Hz line frequency pickup has caused intermodulation of the 50Hz fundamental waveform so that the spectrum is filled with peaks every 10Hz, which is the 60Hz-50Hz IMD product. Note the minimums that occur at the location of each harmonic of 50Hz (100, 150, 200, and so on). Without a chassis ground on the i2i module, I could not attempt to eliminate the 60Hz pickup with the usual manipulation of ground connections.

Increasing the test signal to 1kHz produces the spectrum in **Fig. 10**, which shows mainly the 2nd and 4th harmonics projecting above the rather high noise floor.

**Figure 11** shows the i2i Stream output spectrum reproducing a combined 10kHz + 11kHz intermodulation distortion (IMD) signal at -12dB below peak output into 32Ω. There are significant products at 1kHz, 2kHz, 8kHz, 9kHz, 12kHz, and 13kHz. The peaks around 20kHz and the more prominent peak at 21kHz are probably artifacts of the DAC/digital filter conversion.

## SQUARE WAVE TESTS

I viewed the response of the i2i Stream to three square wave test frequencies on an analog scope at 1.5Vpp using a 32Ω load. I recorded the responses with my 16-bit digital scope. The response at 40Hz (**Fig. 12**) showed a large amount of tilt due to the limited LF response and phase shift.

The 1kHz square wave (**Fig. 13**) exhibits the Gibbs phenomenon ringing associated with the steep digital filters used in the i2i Stream. No clipping is evident on the highest peaks of the ringing, but there is still a noticeable tilt to the horizontal portions of the square wave.

Finally, the 10kHz square wave appears as a sine wave in my scope capture of **Fig. 14**.

## CONCLUSION

I can't really compare my measured data to the manufacturer's data because there wasn't any provided. The audition was hampered somewhat by having to reconvert the analog output of a digital audio device. Its low input impedance would not lend itself to transmitting line-level analog signals. While the measured results do not exhibit high-end performance, the i2i Stream works quite well at its intended function, especially with the lossless iPod audio files.

**Manufacturer's Response:**

The i2i Stream wireless music streaming device digitally transports and reconstructs an audio stream that effortlessly exceeds the quality of 128Kbps MP3 tracks. In fact, its 16-bit, stereo, 48kHz uncompressed digital medium rivals the quality of similarly sampled lossless recordings.

While it's true that some audio quality is lost in digitizing and then reconstructing the analog audio signal, this is an inevitable condition of any analog-interfaced wireless audio device, and certainly any wireless device which can mate with iPods. Direct digital streaming would not only require integration within the player, but raises issues of copyright infringement with the direct distribution of digital content.

If the goal of the high-end audio enthusiast is to realize digital content with the highest possible fidelity, they will embrace wired speakers or wired headphones. But for the convenience and freedom of a wireless device, our measurements show that the i2i Stream provides excellent reconstruction of the source material within the restrictions of going through an interim analog medium. For the benefit of going wireless, it may still be enjoyed by the enthusiast with this understanding.

Note that the i2i Stream does not compress the instantaneous dynamic range of the audio. Rather, it has an Automatic Level Control circuit (ALC) which acts over longer periods to improve the overall experience in a one-to-many broadcast scenario. When multiple listeners or several simultaneous streaming destinations are involved (such as multi-room audio), all recipients need to be able to customize their listening levels, and keep those levels consistent across changes in source material and manipulation of source devices by the person who is transmitting.

For this reason, we use ALC to normalize the input level. Almost all cases of actual source material have mixtures of frequencies, so that the ALC attenuation engages and maintains an average level of attenuation, and avoids the distortion artifacts possible with certain pure tones especially at low frequencies.

The i2i Stream is intended primarily for use with music players with headphone outputs. We recommend setting the player volume at halfway, which in most players is enough to engage the ALC attenuation at an average level while staying clear of saturation. Our audio tests are performed under these actual operating input conditions, and perform quite well under audio analysis.

We have found that under real-world conditions, the user will adjust the input volume of a complex source to optimize subjective clarity and minimize distortion to which the ALC may contribute under sub-optimal input conditions.

The i2i Stream system maintains a consistent signal polarity from the source, to the transmitter pass-through, to the receiver output. No inversion of signal occurs. There is a small amount of fixed digital-channel latency which may appear as an inversion with pure sine waves at certain fixed frequencies.

Notwithstanding the differences in impedance, our tests show flat frequency response (within 3dB) from 20Hz to 20kHz with an unloaded iPod source, with an iPod source loaded with earbud headphones, and with a CD player line-output source. Adaptation to the line output is possible with a passive attenuator accessory in a home-audio accessory kit.

The i2i Stream has excellent Signal-to-Noise Ratio, better than 75dB below the reference signal. This spec is borne out by 3rd-party testing as well as our own.

We performed Stereo Separation (Crosstalk) tests with standard i2i cables and standard iPod headphones, with nominal input levels at mid-ALC engagement as previously stated.

In the unloaded-transmitter test, which is equivalent to the simple remote listening scenario, our result was -75dB at 1kHz, and it was no worse than -50dB all across the band. In the test where the transmitter is loaded with the iPod headphones, equivalent to the music-sharing scenario, the result was a solid -45dB across the band.

If the Stereo Separation tests are performed at the lower threshold of ALC operation, or up near the saturation of the codec, it could have unpredictable results. Significantly poorer results could also be due to defective cables or crosstalk in nonstandard cabling in the test apparatus.

Thank you for your interest and for the review. In certain cases where your findings and the test conditions deviate from ours, we are pleased to have had the opportunity to add our comments.

*John R. Haggis*
*VP Engineering*
*Aerielle, Inc.*
*aX*

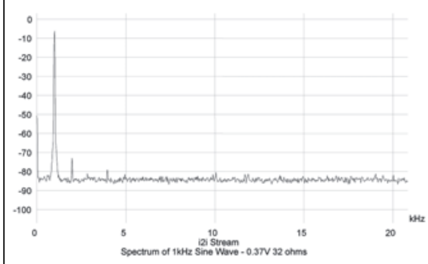

**FIGURE 10: Spectrum of 1kHz.**

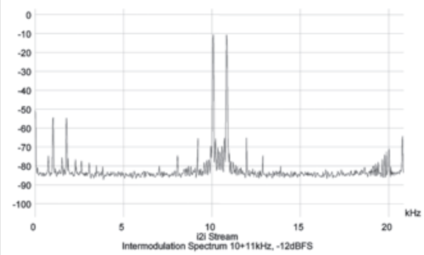

**FIGURE 11: Intermodulation spectrum 10kHz + 11kHz.**

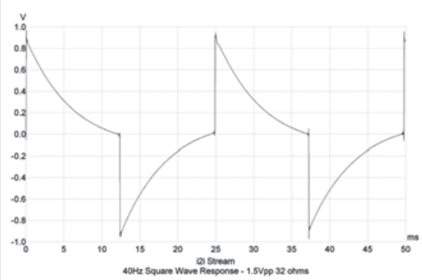

**FIGURE 12: 40Hz square wave.**

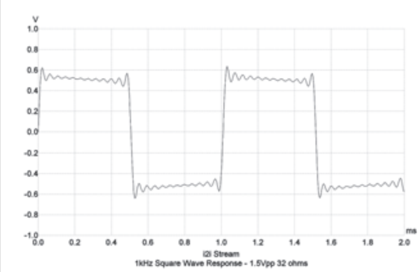

**FIGURE 13: 1kHz square wave.**

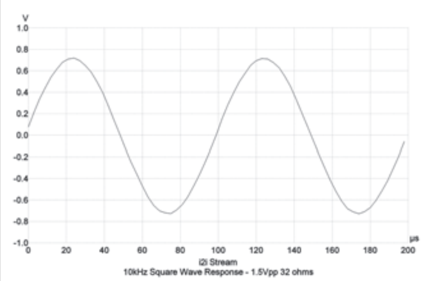

**FIGURE 14: 20kHz square wave.**

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"Soldering" letter by Keith Levkoff (*aX* 10/08).
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PCBs from J.R. Laughlin's "An Automated Level Control (*aX* 10/08).

**Articles from Past Issues:**

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"A Graphical Evaluation of Harmonic Distortion in Valves," by Pierre Touzelet (*aX* 7/08).
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"An On-Peak Power Supply, Pt. 1," by Ed Simon (*aX* 8/08).
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## CONTRIBUTORS

**George Danavaras** ("The Reflection Loudspeaker," p. 5) graduated from National Technical University of Athens, Greece in 1986 with a degree in Electronic Engineering. He currently works in the R & D division for a Greek Telecommunication company. His hobbies include design and manufacturing of audio crossovers, amplifiers, and loudspeakers.

**Jan Didden** ("The Borbely Annals," p. 12) built his first OTL amp with 807 tubes 35 years ago. He has built speakers, preamps, and tape recorders, but is most interested in power amps, especially using error correction as discussed by Hawksford. Many of his projects have been published by *audioXpress*. Now retired from a career with the Netherlands Airforce and NATO, he tries to complete all those half-finished projects accumulated for lack of time. He now also has the time to travel to interesting audio events and interview audio luminaries. His projects are documented on his Linear Audio website.

**Rich Johnson** ("Designing a Midrange Horn," p. 20) resides in Newark, N.J.

**Bill Fitzmaurice** ("Building the Occam Audio MTM 4 Kit," p. 30) has been a professional musician since 1966 and has been constructing instruments, amplifiers, and speakers for just as long. Vice president of DeltaSounds Loudspeakers Inc., Fitzmaurice is the author of *Speaker Builder's Loudspeakers for Musicians* and over 30 magazine articles dealing with speakers and electric instruments, as well as the action-adventure novel *Operation: Sergeant York*. Bill and his wife of over 30 years reside in Laconia, N.H.

**Rudy Godmaire** ("Vg1 Correlations," p. 32) works as a sales consultant for Bell Canada. DIY audio has become a passion ever since his first attempt in 1998. He deeply enjoys sharing his passion with other DIYers and especially with friends François and Pierre. Above all, listening to music and attending classical concerts and opera with his beloved wife Elaine remains among the most fulfilling activities he cherishes. Readers may visit his personal website at www3.sympatico.ca/r.godmaire.

**Chuck Hansen** ("Review: i2i Transmitter/Receiver," p. 34) is an electrical engineer and holds five patents in his field of engineering. He began building vacuum-tube audio equipment in college. He plays jazz guitar and enjoys modifying guitar amplifiers and effects to reduce noise and distortion, as well as building and restoring audio test equipment. He enjoys sailing and has over 150 magazine articles to his credit.

**John Shand** ("Jazz Track," p. 46) is a CD reviewer for *Australian HiFi and Home Theatre Technology*.

*Continued from page 33*

where : $\mathbf{Vg1_{T/U}}$ is the value of Vg1 in the triode or ultralinear mode for a specific plate voltage Va.

This formula enables the prediction of any value of $Vg1_{T/U}$ for high tensions ranging between 350V and 500V. As you can see in **Table 2**, this relation seems to be highly significant because it exhibits a standard deviation $\sigma$ of only 1.6%. Based on the data I collected, the statistical meaning of this is that 95% of the time, the real value of Vg1 will be within the calculated value of $Vg1_{T/U}$ $\pm 2\sigma$ or $Vg1_{T/U}$ ±3.2%. As a general rule of thumb, I can more conservatively state that this model will predict any value of $Vg1_{T/U}$ with an accuracy ±5%, which will be true 99% of the time.

## FURTHER THOUGHTS

The development of this mathematical model was made strictly from published datasheets. Though my personal measurements tend to confirm the correlations, exhaustive evaluation with empirical data would be required to further validate and perhaps refine the model. Nevertheless, with an accuracy of ±5%, it fully answers my needs and exceeds my expectations.

The model was designed on the basis of maximum bias current, but behaves equally well for lower values. In fact, the aforementioned levels of accuracy remain the same for bias currents set anywhere between 80% and 100% of the maximum current bias admissible. You only need to carefully determine the value of $Vg1_{P425V}$ with the desired current bias and apply this value in equation 3.

## CONCLUSION

Tube technology is certainly one that is very mature. Still, there seem to remain little secrets that are there for us to discover. This is at least what these correlations suggest. With this mathematical model in my toolbox, I can now design and optimize driver stages well before I start building my amplifiers.

For your convenience, I have prepared an Excel application that enables fast calculation of $\mathbf{Vg1_{T/U}}$. You can download this file from the *audioXpress* website. I wish this model will be as useful for you as it is for me. *aX*