STIMULUS SETUP INSTRUCTIONS

MULTI-MASTER V1A*

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*The stimuli incorporated in to MULTI-MASTER V1a have been described in a series of publications to come out of the laboratory of Dr. Terry Picton. For access to published articles as well as those which are in-press please go to http://www.hearing.cjb.net

STIMULUS	MODE	CARRIER TYPE	DESCRIPTION OF STIMULI
MASTER (RMS) / SMF	0	1	AM, FM or MM pure tone stimuli. Exponential envelopes are also possible for AM. The RMS is compensated for different amounts of amplitude modulation so that a constant RMS is maintained (see John et al, 2000). RMS is not maintained for Exponential envelopes
MASTER (P-P)	1	1	AM, FM or MM pure tone stimuli. Exponential envelopes are also possible for AM. The p-p limits are maintained for different amounts of amplitude modulation so that RMS is decreased with greater mod depth (see John et al, 2000)
NOISE STIMULI BBN / HPN / LPN / COMPLEX	2	0/1	AM noise can be created when carrier type is in mode 0. Up to 4 AM noises can be created per ear. Each amplitude modulated stimulus is created with a different noise series so that the noise is not correlated. AM noise can be used for rapid universal newborn hearing screening (John et al, 2003). Calibration of instrument is performed when carrier type is set to 1. (see MASTER tutorial, www.hearing.cjb.net).
INVERSE ENVELOPE	3	1	Inverse envelopes can be used to create gaps in continuous tones. The higher the exponential, the smaller the gap. This may be used to study gap detection using ASSRs. We have not yet tried this stimulus. The implementation of gaps in noise or narrow band noise has not yet been incorporated into the software so only mode 1 can be used.
FM EXPONENTIAL ENV.	4	1	This allows for exponential modulation of FM to occur. Exponential FM was not found to be better than conventional FM (John et al, 2002).
CHANGE IN PHASE OF AM	5	1	In this mode one can change the phase of the AM stimulus. This is accomplished by defining the values in the "phase FM" fields of the PA1 screen. Obviously one can not use %FM in this mode.
CHANGE PHASE OF AM & INV CARRIER	6	1	This mode allows one to change the phase of the AM, and the phase of the carrier is now 180 rather than 0. This Mode can be used to compensate some types of artifacts that may occur at higher intensities (e.g., above 40 dB SPL) in bone conduction ASSR.
125 uSEC CLICK (+)	7/8	1	These modes permit ASSRs to be recorded in response to "+" or "–" clicks. These can be used for rapid universal newborn hearing screening (John et al, 2003).
1 MSEC BURST (BN/LPN/HPN)	9	1	This mode allows for 1 msec bursts to be created using broadband or narrow-band noise.

Key:

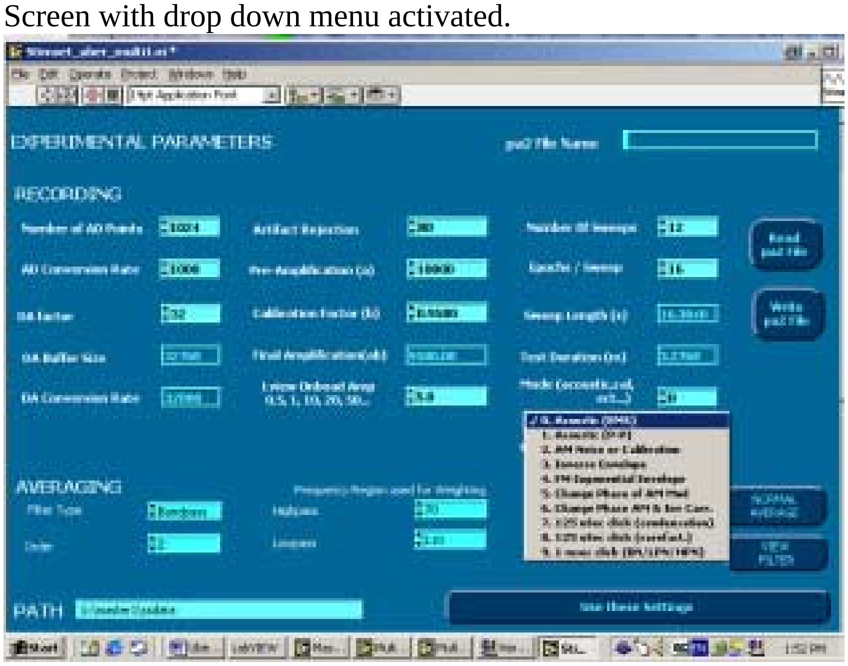
BBN	Broadband Noise
LPN	Low Pass Noise
HPN	High Pass Noise
COMPLEX	Both Low-pass or High-Pass Noise
EXPONENTIAL	Exponential Envelope function can be derived using exponentials from 1 to 100. Increasing the exponent will increase the rise slope.
INVERSE	Inverse Envelope. The Inverse of EXPONENTIAL Envlope. Can be used for Gap Detection experiments.
RMS	Root Mean Square energy measure (is maintained for different modulation depths).
P-P	Peak SPL levels (are maintained for different modulation depths).

SETTING THE MODE AND STIMULUS TYPE:

The Experimental Parameters or “PA2” screen allows one to define the recording parameters which will be used during the MASTER test. The two controls which are most important for determining how the stimulus parameters will be implemented are the “Mode” Control and the “Carrier Type” control which are both on the middle, right hand section of the screen. Both of these controls are “drop down menus” which means that in order to change the value of these controls, the user must place the computer mouse over the control and then click the left mouse button. The two figures on this page show what occurs when the user selects these controls.

Experimental Parameters or “PA2” Screen:

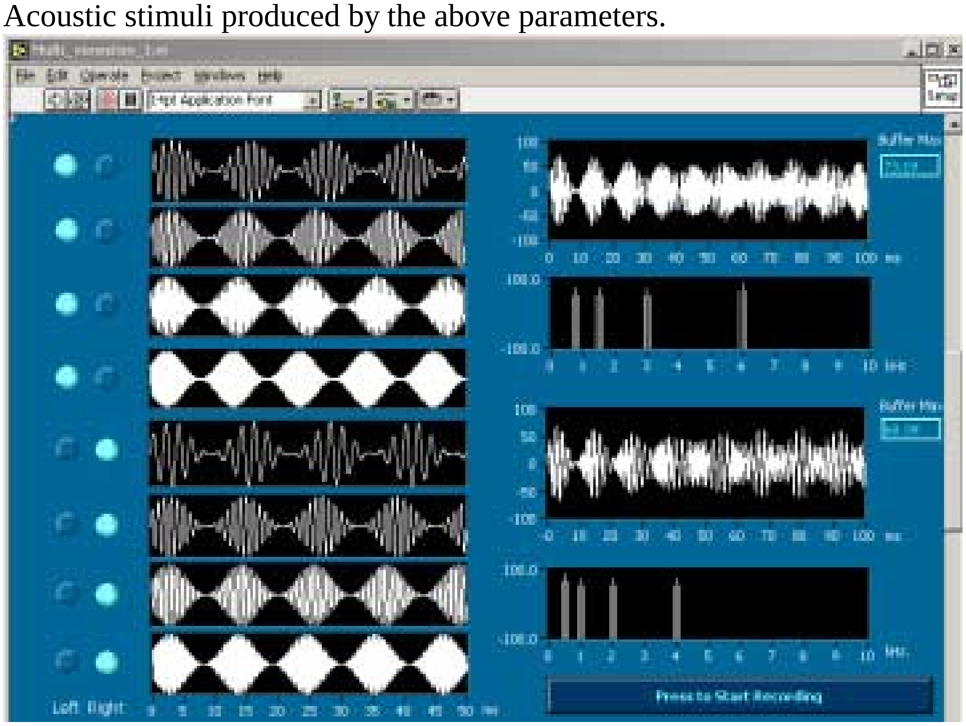
Screen with drop down menu activated.



CONVENTIONAL MASTER STIMULI: MODE=0, CARRIER TYPE=1.

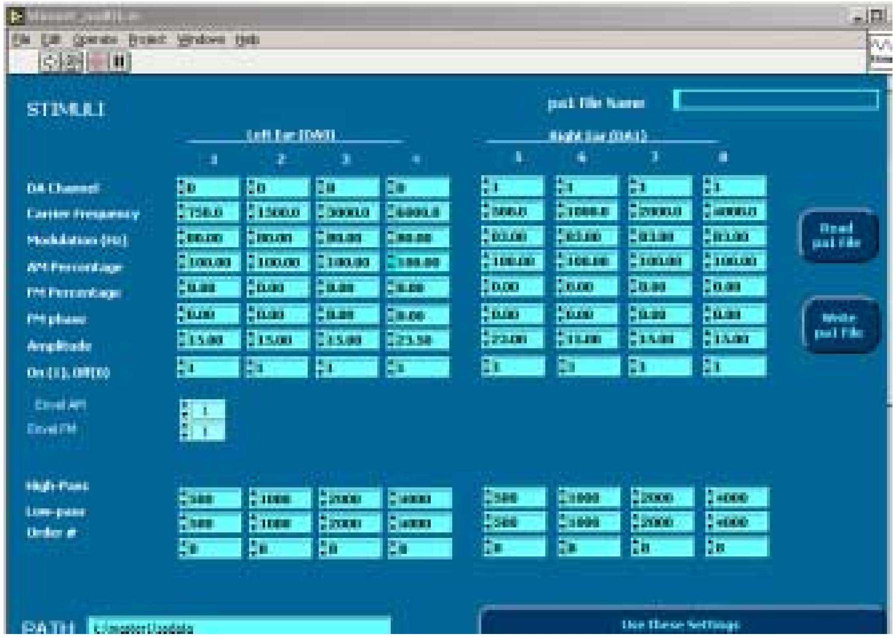
Here we see the Define Stimuli or "PA1" screen with conventional master stimuli. The top of the screen defines 8 AM stimuli, 4 for each ear. Below this are 2 fields where the envelope's exponents have been set to 1. The bottom of the screen enables the user to define 4 band-pass noises, however, since the user will choose Mode 0 on the Experimental Parameters or "PA2" screen, these values will be functionally ignored by the software. The user can load stored values from disk by choosing "read pa1 file".

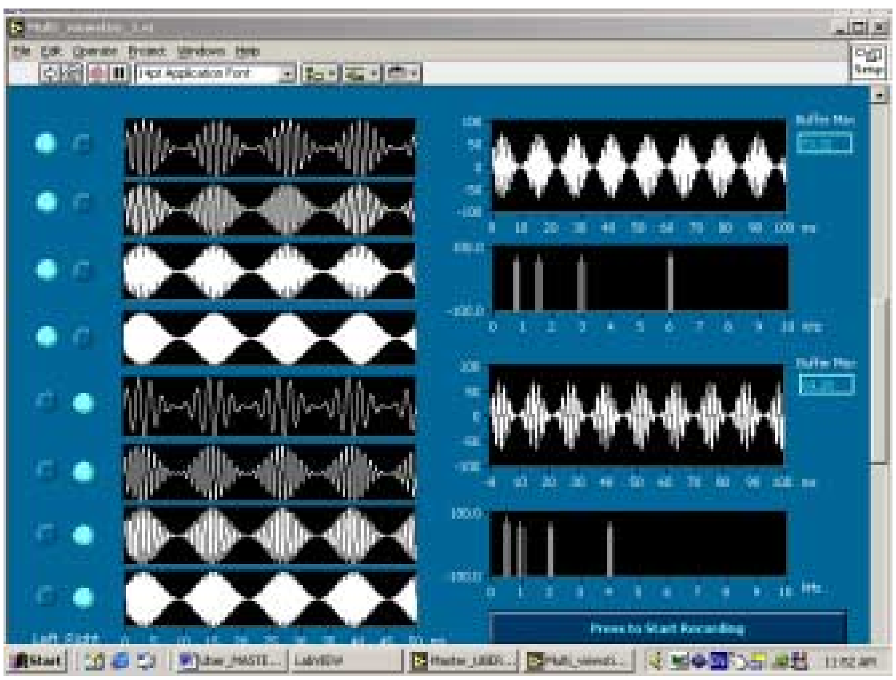
Acoustic stimuli produced by the above parameters.



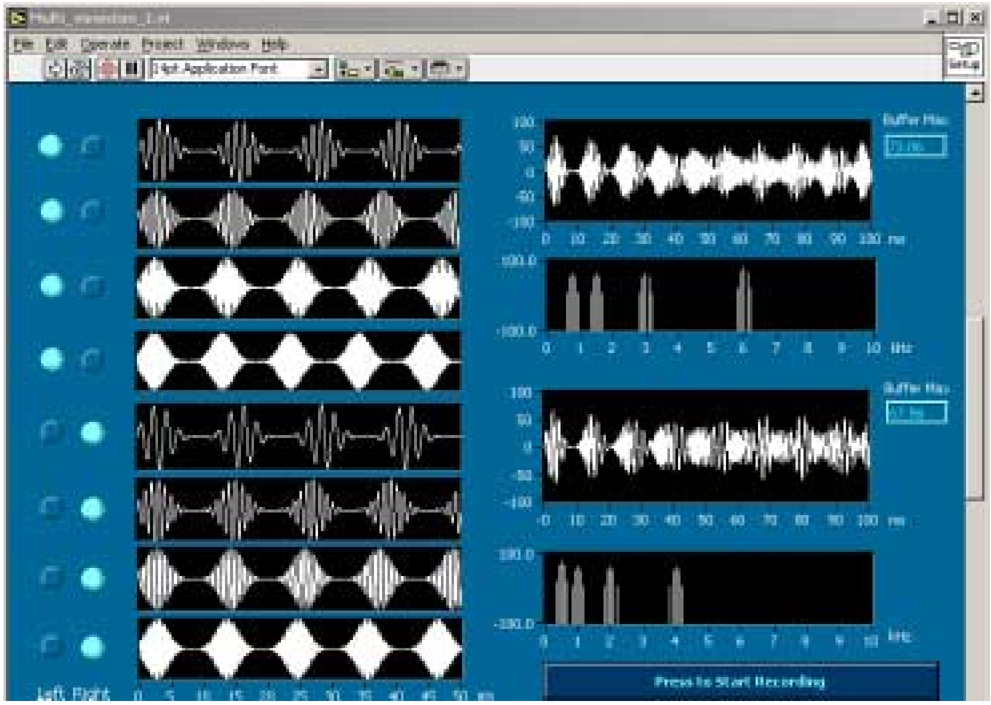
SINGLE MODULATION FREQUENCY (SMF) MASTER STIMULI: MODE=0, CARRIER TYPE=1.

By modulating all the carrier frequencies for an ear at the same rate (i.e., 80 for left ear and 83 for right) a Single Modulation Frequency stimulus is created. While not frequency specific, this stimulus will produce a large response which can be used in screening applications of the MASTER technique (John et al 2003). Since all the carriers are modulated at the same rate, the time waveform shows discrete bursts of activity.

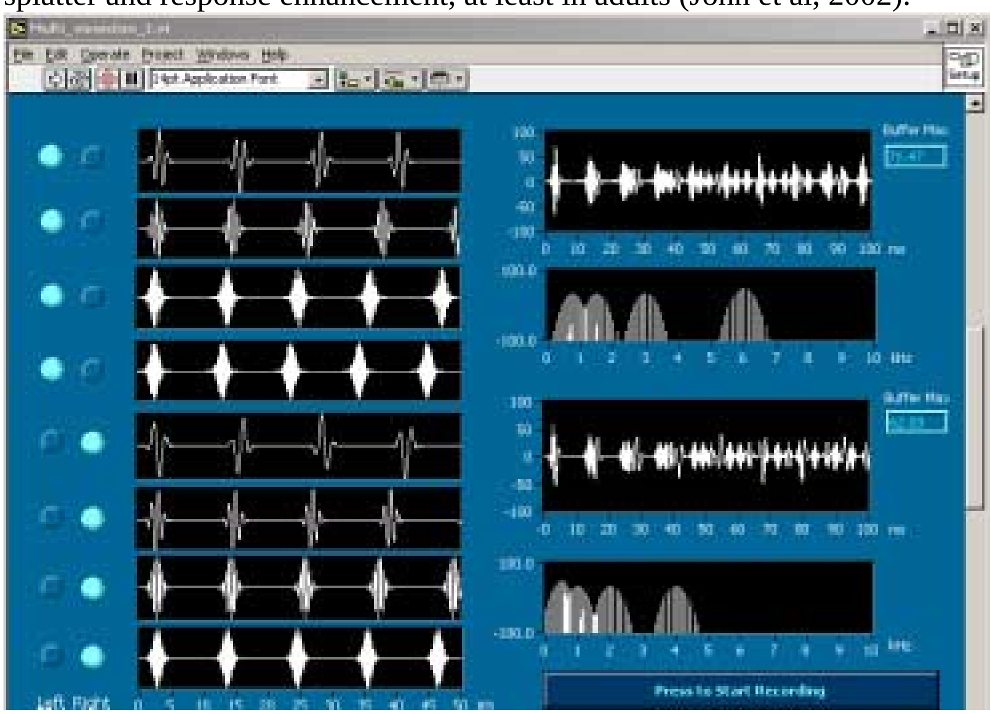




EXPONENTIAL MASTER STIMULI: MODE=0, CARRIER TYPE=1.
With exponential= 2.



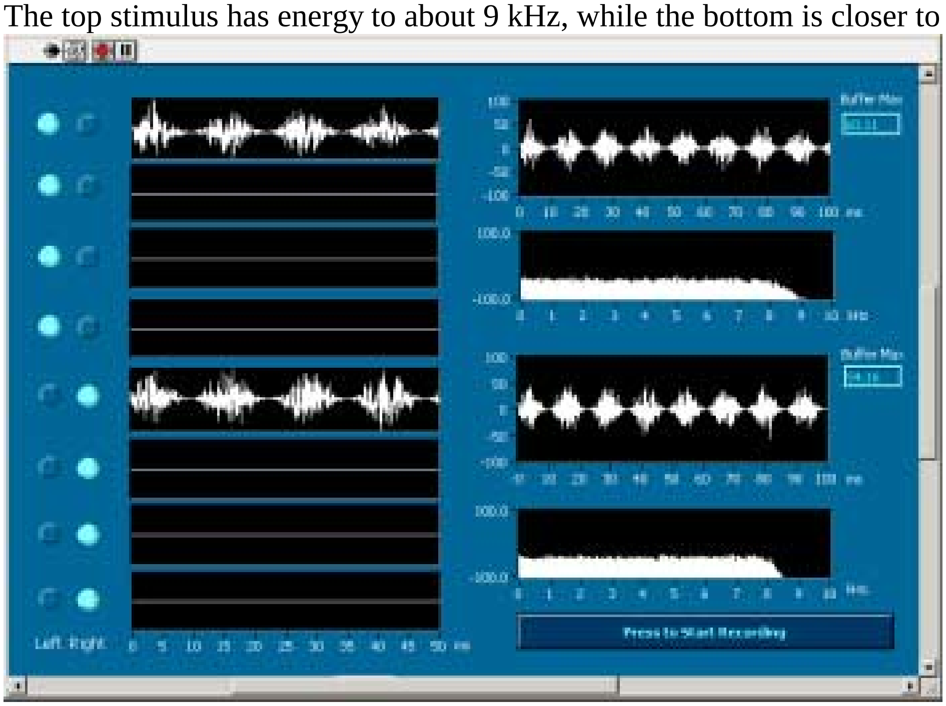
With exponential= 15. The rise/fall slopes have become more rapid, and there is therefore more spectral splatter apparent in the amplitude spectra of the stimuli. Stimuli created with the exponential set to 2 are probably the best compromise between spectral splatter and response enhancement, at least in adults (John et al, 2002).



MASTER NOISE STIMULI: MODE=2, CARRIER TYPE=0.

This shows the PA1 screen for setting up Noise stimuli. The DA channel (row 1) which signifies the ear of presentation, the modulation frequency (row 3), the Amplitude (Row 7), and the on/off (row 8) are used. The Envel AM and Envel FM are ignored. The high-pass, low-pass, and order number (# of poles in the filter) are used to define the noise. Here the user has defined a single AM noise stimulus for both the left and right ears. The noise is defined as spanning from 1 to 8000 Hz. The order # for the left filter (8) is less than for the right (20) causing the left stimulus to have a slower falloff.

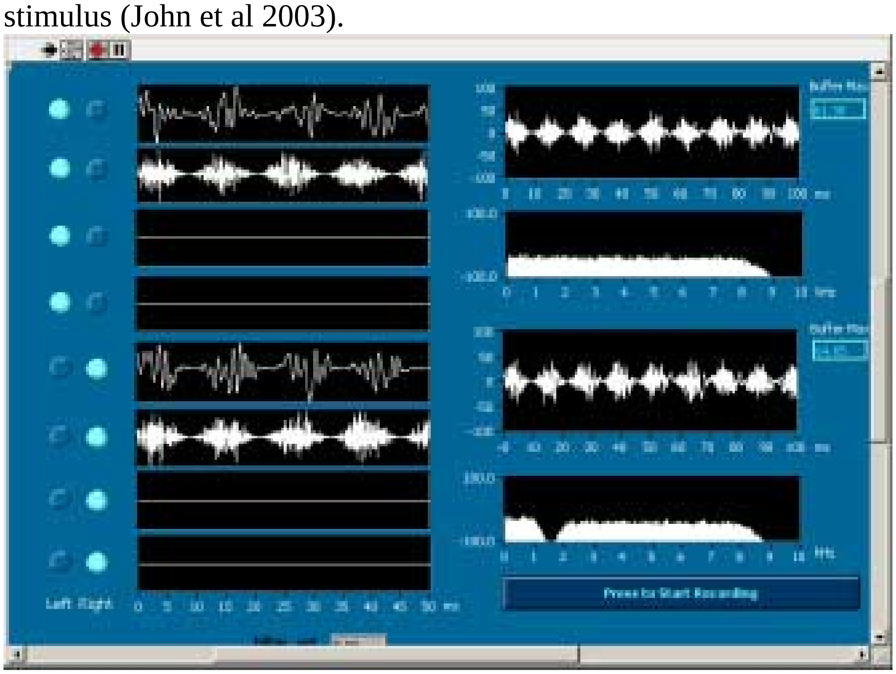
The top stimulus has energy to about 9 kHz, while the bottom is closer to 8 kHz.



MASTER COMPLEX NOISE STIMULI: MODE=2, CARRIER TYPE=0.

Complex noise stimuli are created by modulating a lowpass noise and a highpass noise at 2 different modulation rates. Issues of masking and enhancement can be investigated by using these types of stimuli (John et al, 2003). In the figures below, the left ear stimulus has energy from 1Hz - 1kHz, modulated at one rate (80Hz) and 1kHz-8kHz modulated at another rate (85 Hz).

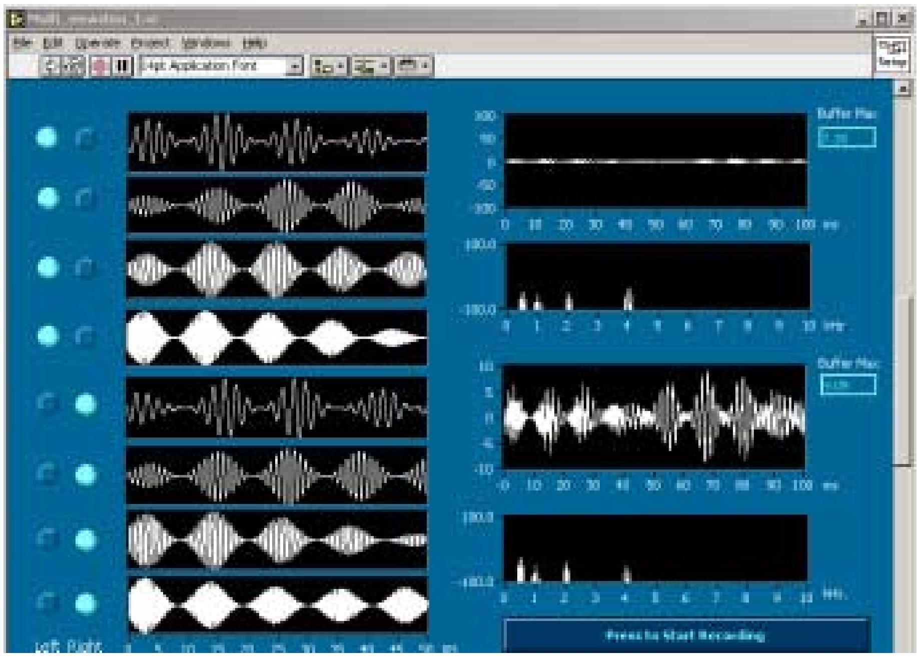
The spectra for the top stimulus looks the same as the spectra for the amplitude modulated noise, where the noise spanned from 1Hz to 8kHz, shown on the previous page, although here, 2 modulation rates are used. On the bottom a notch has been defined for the stimulus, and the lower stimulus acts to enhance the response to the higher stimulus (John et al 2003).



MASTER NARROWBAND NOISE STIMULI: MODE=2, CARRIER TYPE=0.
This shows the PA1 screen for setting up Narrowband Noise stimuli and is much like the previous figure except 4 stimuli are used in each ear, and the noise is much more frequency specific. The low-pass and high-pass are set at the same frequency using an 8^{th} order filter.

MASTER NARROWBAND NOISE STIMULI….CONTINUED

The 4 narrow band noises will each look almost like amplitude modulated tones, except their amplitude spectra will have more sidebands. Notice that in the time waveform of the complex stimulus, which is on the right side of the figure, that the stimulus looks very small. Since the filtering for the stimuli is very tight, there is significant attenuation of the amplitude of the noise series. On the lower graph, the y-axis has been changed from the normal default of +/-100 to +/- 10.

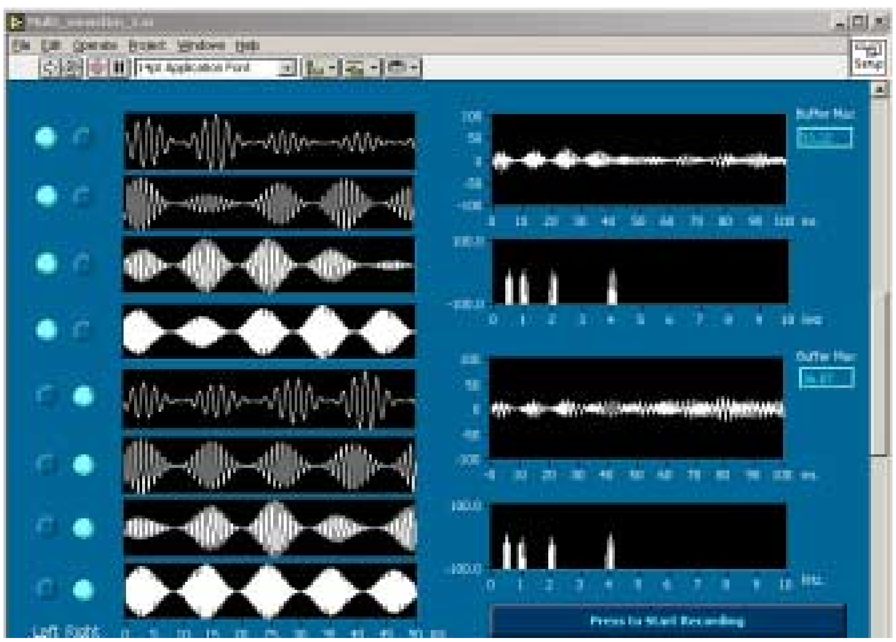


Changing an axis value can be done by using the left button of the mouse to "click on" the axis values, and then entering different values. While the amplitude of the stimulus for the left ear is the same magnitude as that for the right, the bottom stimulus looks bigger merely due to a change of the scale of the graph. Changing the scale on the graph allows the user to see the stimulus clearly, but since the stimulus amplitudes are small they do not take advantage of the full resolution of the digital-to-analogue buffer. In other words, this is shown for demonstration purposes only. In practice, in order to compensate for the attenuation produced by the sharp filtering, one can increase the size of the modulation envelope. Since the filtered noise is multiplied with the modulation envelope to produce the amplitude-modulated noise, increasing the size of the envelope will enhance the size of the stimuli.

The amplitude on the Pa1 screen is normally set below 25 for each of the 4 stimuli. The D/A buffer is +/- 10 volts. Setting each stimulus near, but less than 25, will use almost 100% of the buffer. Each stimulus will require about 2.5 volts or 25% of the total buffer. The reason that the user sets the values below 25% rather than at 25% exactly is because RMS is normally maintained under mode 0, which means that the stimuli will be larger than 25% after they are amplitude modulated (for full discussion see John et al 2000). In any case, since the filters attenuate the carrier signal, this problem can be overcome by setting the amplitudes of the stimuli at 75 or above. This is shown on the next page.

MASTER NARROWBAND NOISE STIMULI….CONTINUED

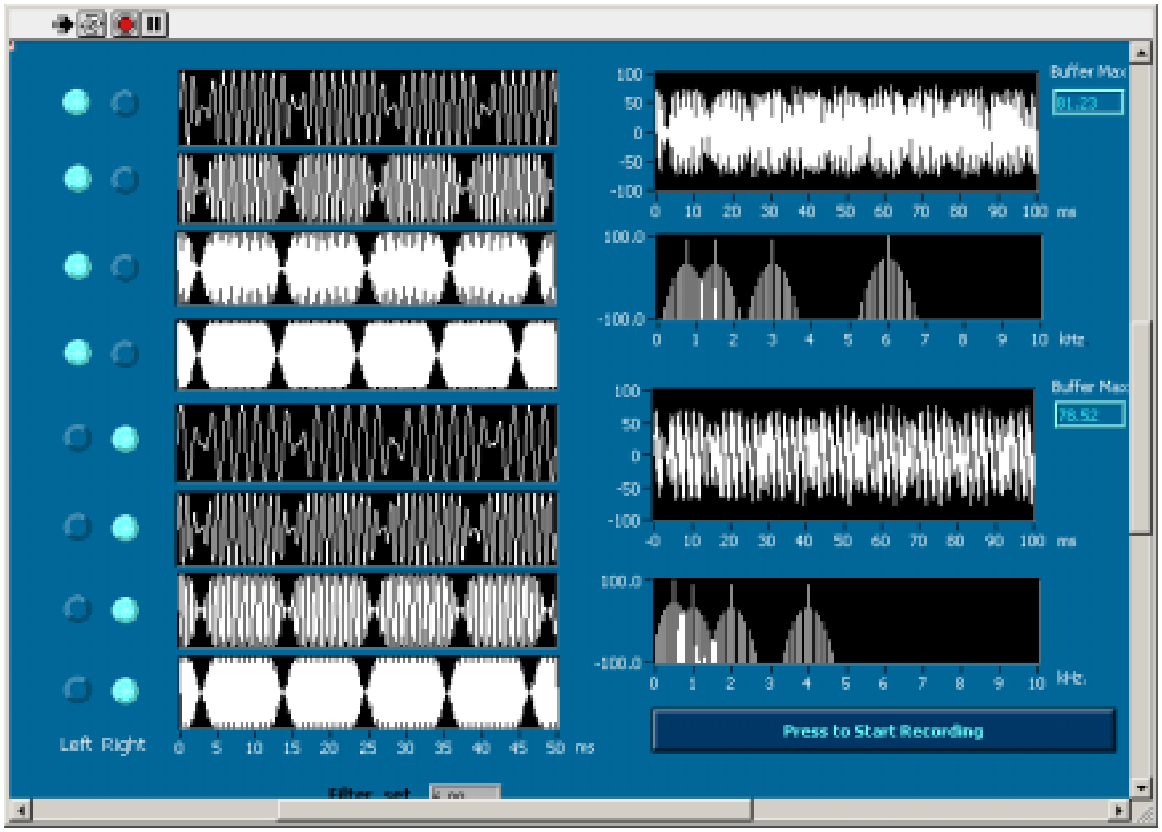
In the figures below the stimuli have been set with amplitudes of 75 or more. This does not exceed the buffer because the narrowband noise carrier signals are considerably below +/-1 volt due to the tight filtering.



It is important to note that the noise stimuli for each of the bandpass noise series show considerable variability with respect to the amplitude of each of the individual modulations. In the top stimulus (left hand side) the first 2 bursts are much larger than the second two. This is because the noise of the random time series will have different frequencies, and when these are filtered, the residual band-pass noise will necessarily have differing amounts of energy. The functional implications of these characteristics for the signal and response may be quite complex.

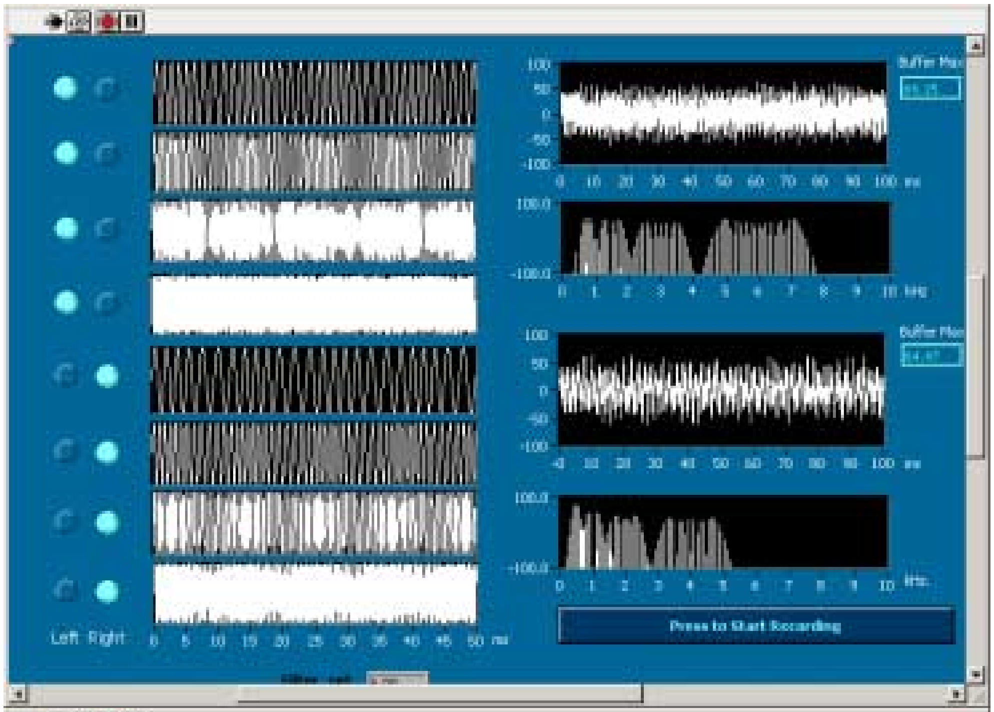
INVERSE MASTER STIMULI: MODE=3, CARRIER TYPE=1.

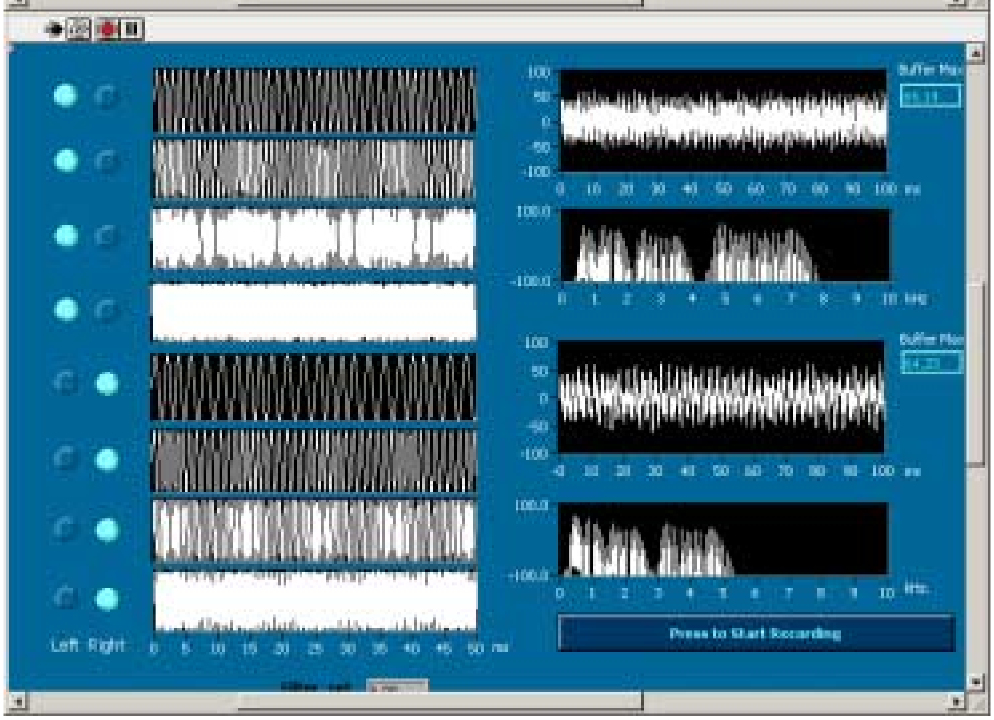
This shows inverse stimuli with exponential=15. These stimuli may prove to be useful in ASSR correlates gap detection. We have not tried these yet and do not wish to promote or dissuade users from incorporating these into experiments.



FM EXPONENTIAL MASTER STIMULI: MODE=4, CARRIER TYPE=1.

The use of exponential FM has not been found to increase response size, but may be used for investigational purposes. The top figure shows exponential envelope set at 2. The lower figure shows an increase in the power spectra distribution when the exponent is increased further.

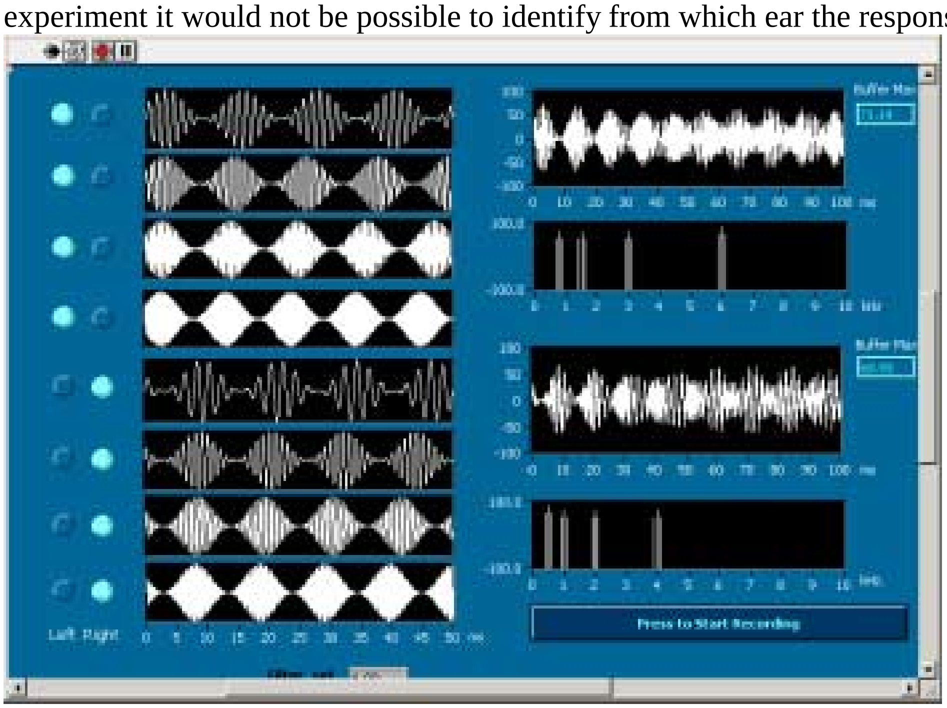




AM PHASE CHANGE WITH MASTER STIMULI: MODE=5, CARRIER TYPE=1.

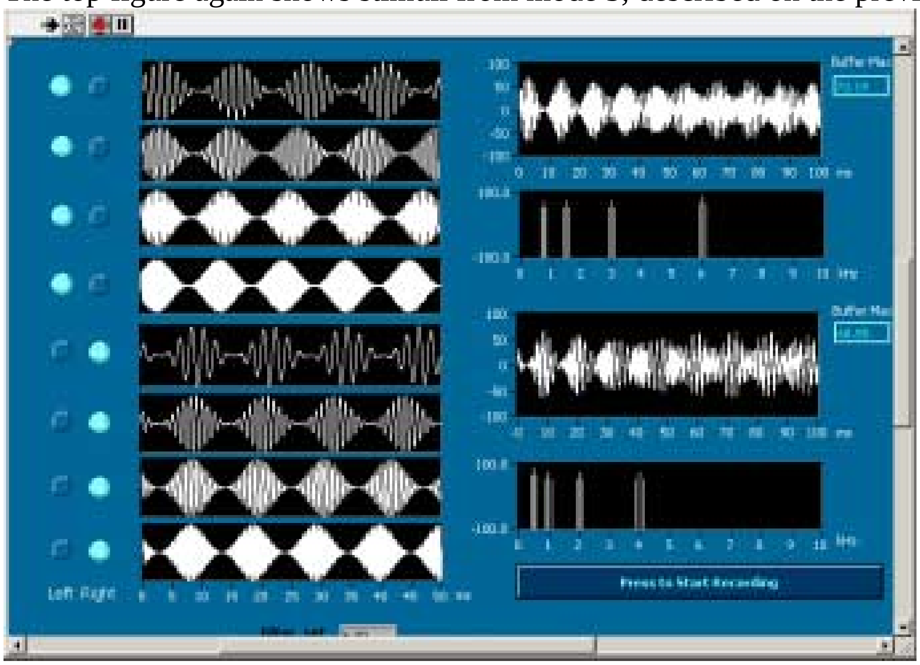
The phase of AM envelope is 0 for the left ear and is switched to 180 for the right ear. This is accomplished by changing the fields for the phase of the FM which in this mode are used to define the phase of the AM, <u>only when in Mode 5.</u> Note that the phase of the responses will still be defined as if the stimuli had an onset phase of zero!

The phase of the 500 Hz left ear stimulus (row 1, on left) is 0 deg, while the phase of the 500 Hz right ear stimulus (row 5) is 180 degrees. This is also true for the 1000, 2000, and 4000 Hz stimuli. For demonstration purposes, the modulation rates are identical for the left and right ears for demonstration purposes only. If these rates were used in an experiment it would not be possible to identify from which ear the response was elicited.

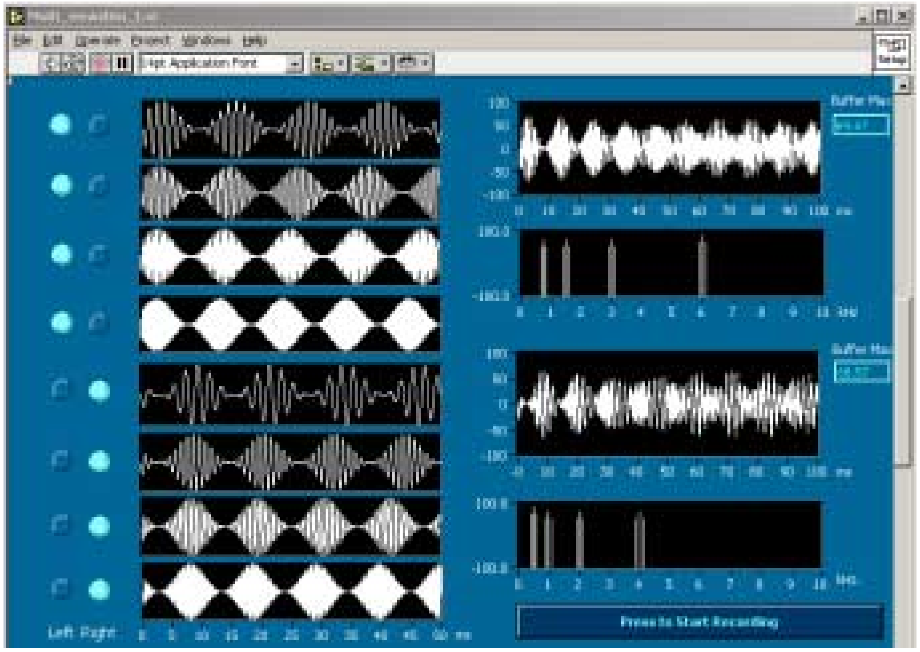


AM PHASE CHANGE WITH MASTER STIMULI=180 DEG: MODE=6, CARRIER TYPE=1.
Mode 6 set the phases of the carrier frequencies to 180 degrees, rather than 0 degrees. This type of stimulus can be used to cancel out artifact produced by bone conduction experiments. By collecting data at 0 degrees which is then averaged with data collected at 180 degrees, the problems of artifacts can be compensated. (Mode 6 also allows for the phase of AM to be changed as well.)

The top figure again shows stimuli from mode 5, described on the previous page.



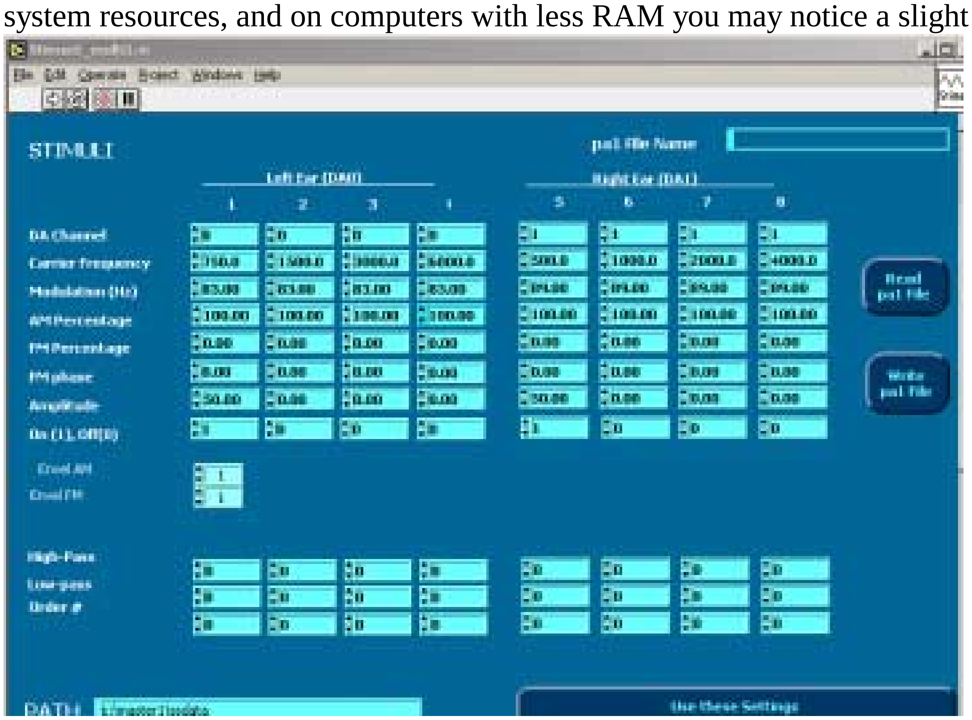
Using mode six, the carrier frequencies are 180 degrees out of phase. Comparing the peaks of the individual carriers shown in the top and bottom figures, shows that the individual waves are vertically flipped


Press to Start Recording
Left Right
Buffer Max
Setup

MASTER CLICK STIMULI: MODE=7, CARRIER TYPE=1.

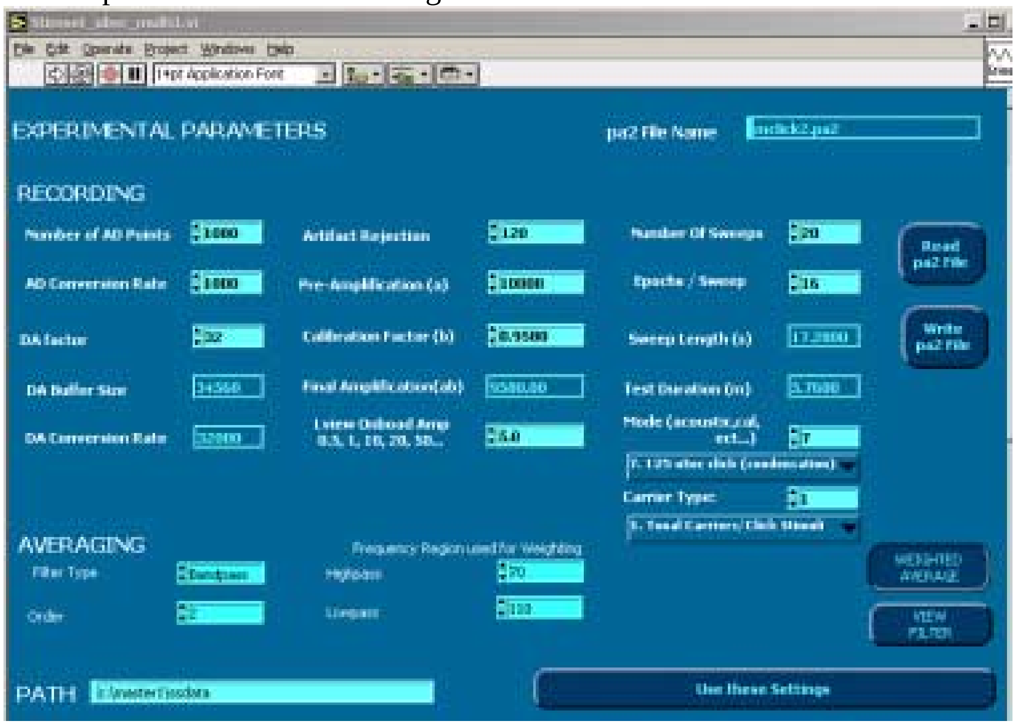
Multi-MASTER v1 also allows one to record auditory steady-steady state responses to click stimuli. The responses evoked by click stimuli become significant very rapidly and therefore can be used in universal newborn hearing screening. As in the case of the modulation rate used to produce modulated tones or modulated noise, the repetition rate of the transient stimuli must be a sub-harmonic (integer sub-multiple) of the epoch length. When both ears are tested at the same time, both rates must meet this criteria. Further, the repetition rates (or more accurately, 1/repetition rates) must be submultiples of the clock tick rate (John et al 2003). Failure to follow these guidelines will cause the ASSR to occur at a modulation rate that is not an integer of the epoch length and the steady-state response will not be localized to a single bin.

In the PA1 screen below a click stimulus has been defined for each ear. The stimuli take up 50% of the buffer. The stimuli in each ear must occur at different rates. Accordingly, the # of points in the DA buffer was made equal to the product of the integer numbers of cycles of the two stimuli which occur within a single epoch multiplied by a power of 2 (giving approx. 32,000 points). A further proviso that the AD buffer was exactly 1/32 of the DA buffer was ensured by choosing the 2 rates so that the final # of DA-buffer points was divisible by 32. We chose the 2 modulation rates to be 90 and 96 cycles per epoch which resulted in a product of 8640. This value was then multiplied by 4 to give 34,560 points. This result was then divided by 32 to obtain the # of points (1080) for each AD buffer. Because the A/D rate was set at 1000 Hz and the A/D buffer was 1080, the epoch duration was 1080 ms and the actual frequencies for the 2 stimuli were 83.33 Hz [i.e., 90*(1000/1080))] and 88.89 Hz, respectively. Both the A/D rate of 1000 Hz and the D/A rate of 32,000 Hz were acceptable since these are both integer submultiples of the 20 MHz clock used by the MASTER system. Because the sweep length is not (necessarily) a power of 2, the program automatically uses a discrete FFT. This will require additional system resources, and on computers with less RAM you may notice a slight delay.

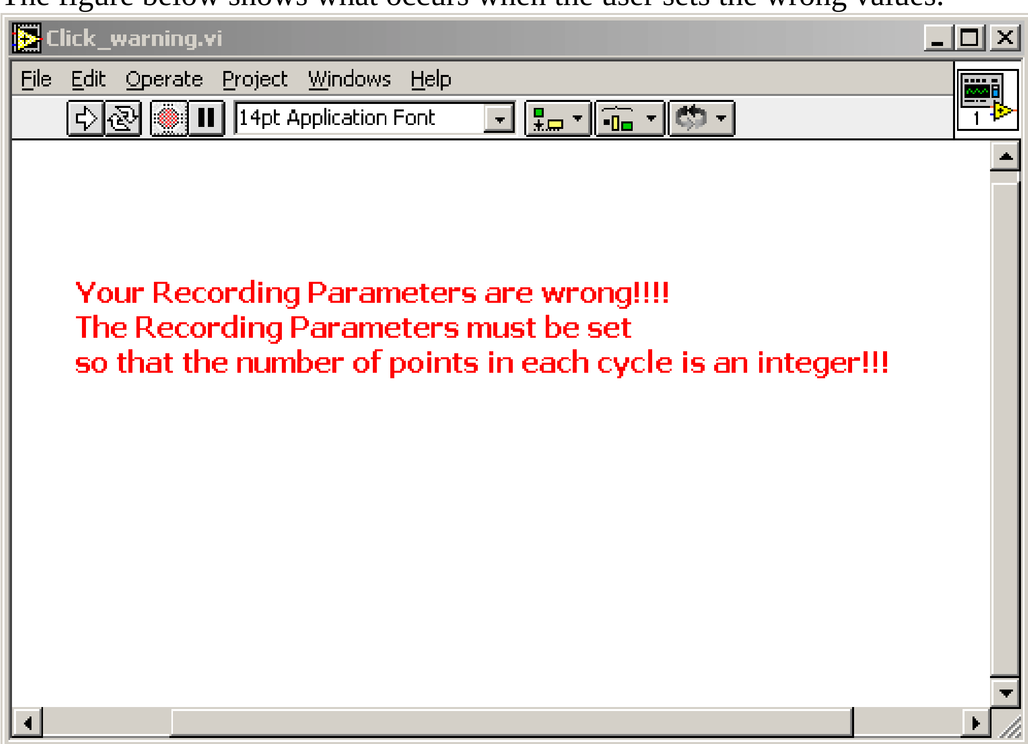


MASTER CLICK STIMULI….CONTINUED…

The Experimental Parameters screen shows that the number of AD points has been set to 1080 rather than the usual 1024 points. The values for the 1st column on the left side of the figure are all correct. If a user defines these values incorrectly, a warning will flash and keep the user from continuing.

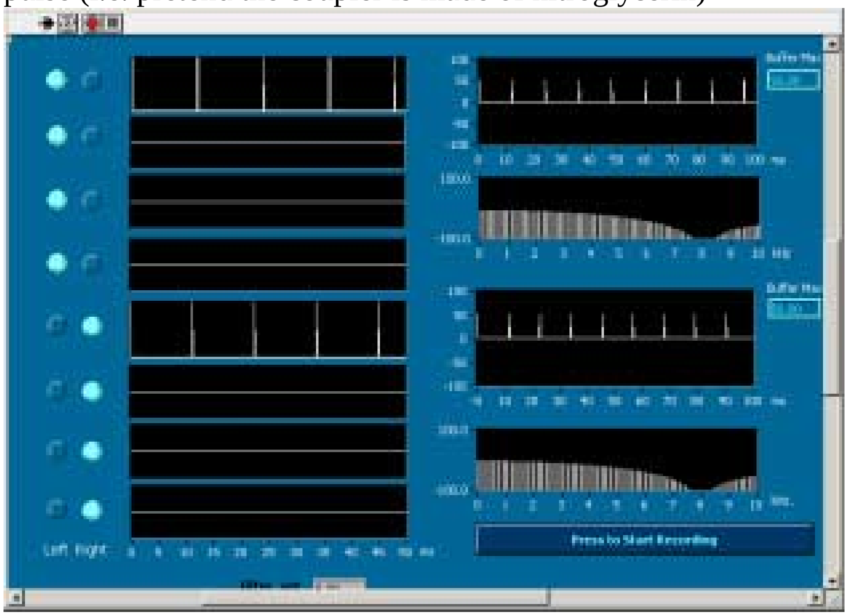


The figure below shows what occurs when the user sets the wrong values.

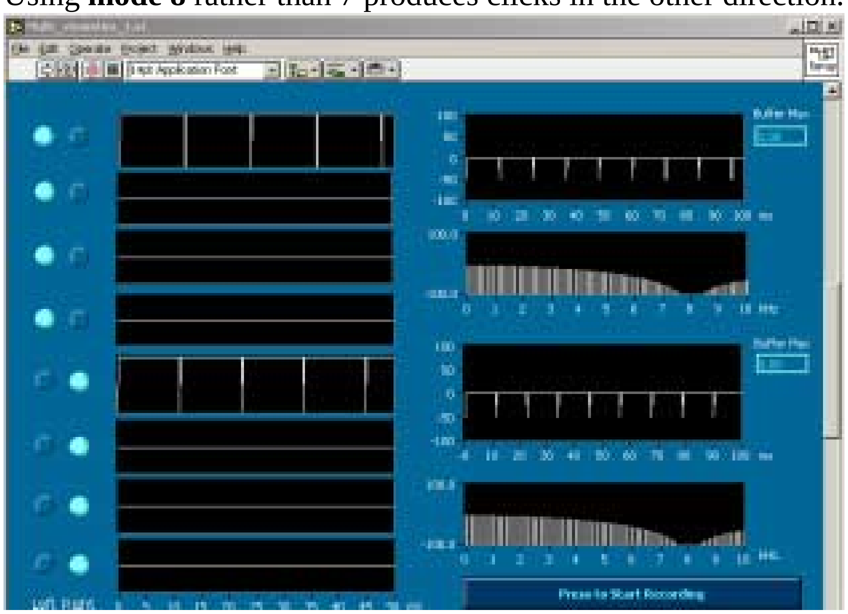


MASTER CLICK STIMULI….CONTINUED…

The figure below shows the time series and amplitude spectra for the click stimuli. There is a dip at the 8 kHz region due to the duration of the click (1000 msec/.125 msec=8,000) or, in this case, 8 kHz. While these clicks are pointing upwards, they are not necessarily condensation (+) clicks. The actual click polarity depends upon the configuration of the transducers with respect to the output signal. Some SPL meters may indicate whether a pulse is characterized as condensation or rarefaction. However, if this is not the case then this may be determined empirically by examining the output of the SPL meter on an oscilloscope. Determine if the initial trace of the stimulus is positive or negative on your scope. After this step, disconnect the transducer from the SPL meter and VERY GENTLY tap the top of the acoustic coupler in order to mimic a positive air pressure pulse (i.e. pretend the coupler is made of nitroglycerin)

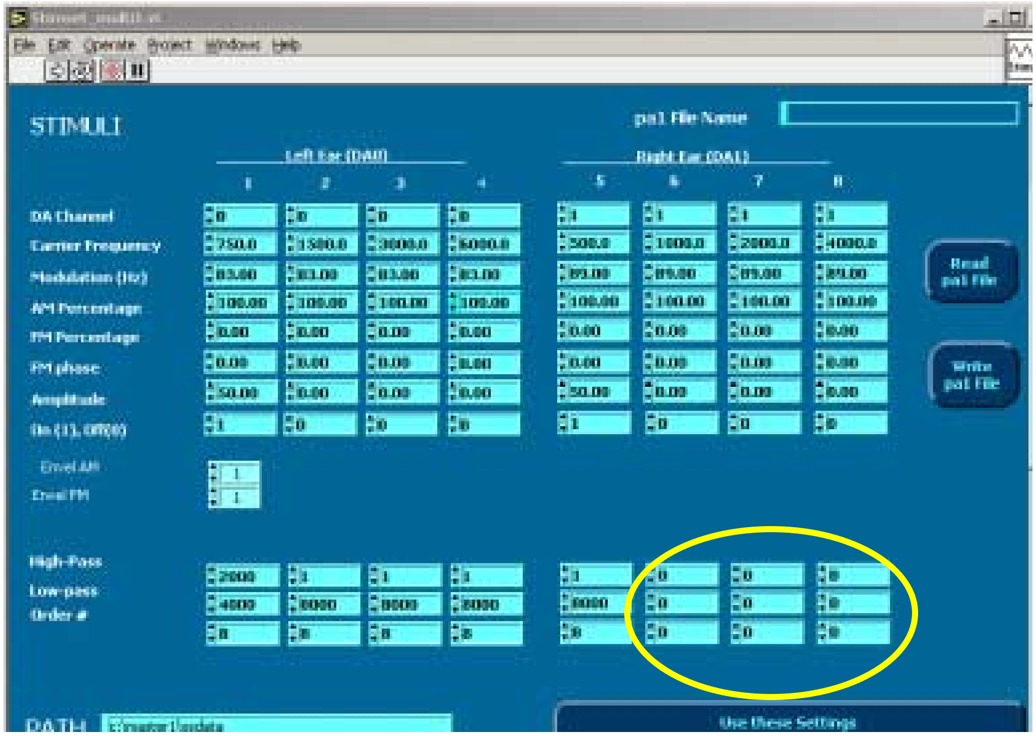


Using **mode 8** rather than 7 produces clicks in the other direction.



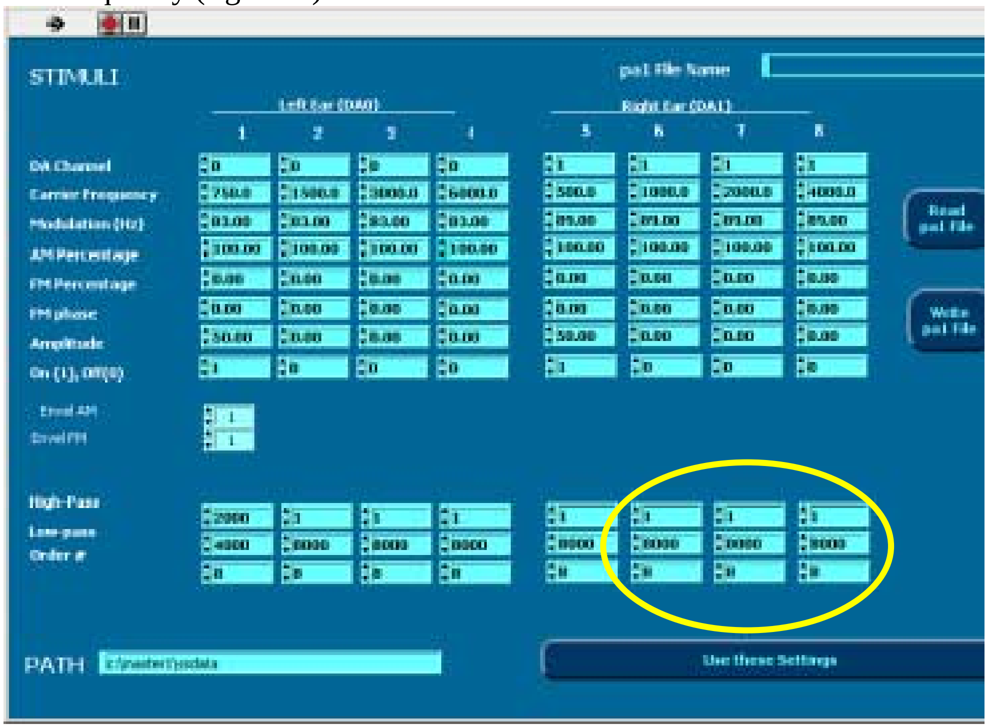
MASTER NOISE BURST STIMULI: MODE=9, CARRIER TYPE=0.
Choosing mode 9 will enable the creating of noise burst stimuli. In this mode, the modulation rate fields are again used to determine the repetition rates. And again, the discrete stimuli must be presented at a rate that is a sub-multiple of the epoch duration. Each 1 msec click is multiplied with a noise carrier to produce a brief noise pulse. Because the noise routine is accessed even when stimuli are not activated (by setting on/off field to 1), it is important that the user ensure that the high-pass and lo-pass filters are defined for all stimuli, whether they are activated or not. Otherwise the program will send zeros to the filter subroutine and the program will get stuck.

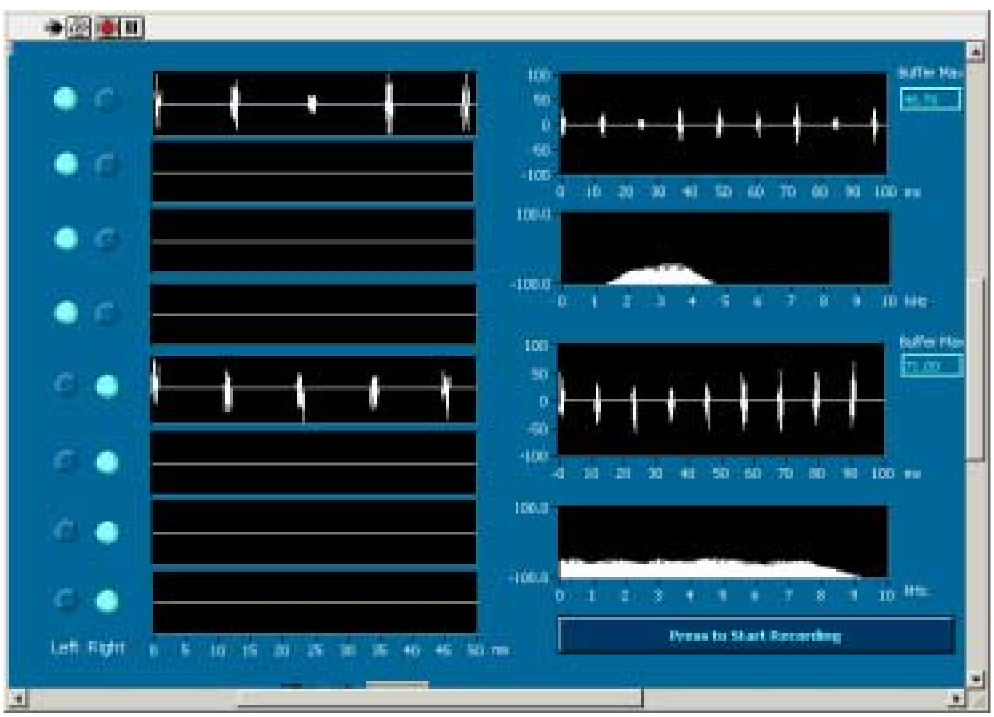
Incorrect Pa1 file which will cause errors is shown below.



MASTER NOISE BURST STIMULI…CONTINUED…

Correct configuration is shown below to make noise burst of high frequency (left ear) and broad frequency (right ear)





Notes and References:

Stimulus Calibration:

<u>Amplitude Modulated Tones</u>

The reader will notice in many of the stimuli which are defined on pages 1-15 that for some frequencies the amplitudes are defined as 15, while other frequencies have an amplitude of 23. Each amplitude modulated pure tone or noise must be calibrated to a desired sound level prior to its being combined with other stimuli that are to be presented simultaneously. Normally, using our ER3A transducers from Etymotic Research the 500 Hz and 6000 Hz would be lower than the other frequencies if we simply set all stimululus amplitudes to 15, since the ER3A's are not as responsive at those frequencies. By increasing the amplitudes to 23, for the 500 and 6000 Hz stimuli, the stimuli are all presented at about the same dB SPL level.

Normally, each stimulus should be calibrated separately, and the combined should also be calibrated to ensure that not much intensity has been added to the combined stimulus (only 3-5 dB with pure tone stimuli). If each of the stimuli are calibrated to 50 dB RMS SPL, the combination of 4 stimuli should be between 53 and 56 dB RMS SPL depending upon how the chosen modulation frequencies and carrier frequencies superimpose. It is probably the case that in the ear, where the individual carrier frequencies are sensed by their tonotopically appropriate areas of the cochlea, the functional intensity is again 50, even though the combined stimulus is presented slightly higher.

<u>Amplitude Modulated Noise</u>

Due to the random nature of the time series, the noise stimuli will vary within 3-5 dB across consecutive trials. For any modulation rate a novel noise times series is used. The only manner of obtaining the same time series for several recordings is to choose the "Run Experiment" option from the "Main Menu" screen of the software program. Every time the "Load New Protocol" option is chosen, new stimuli are created.

Noise Floor Estimate:

The Multi-Master v1a software contains a new row in its data table labeled "NF". NF stands for Noise floor, and the values in each column of this row are the size of the 95% confidence limits of the noise multiplied by 1000 (i.e. nanovolts).

These estimates can be related to the value of the noise floor in the following manner.
A good noise estimate "N" of background levels of noise is the root mean square of the 120 adjacent amplitude spectra bins which are above and below the frequency of modulation. This can be computed as
N=sqrt(sum(a^2)/120)
Where "a" is each of the adjacent 120 noise bins which are summed together.

The circle radius on the Multi-Master v1 program is computed as CR=N * 1.74, or the .95% confidence levels for the noise (1.74 is sqrt of F value 3.04, at .05 for 2, 240).

In the software amplitude CR is multiplied by 1000 and reported in Nanovolts in the tables.

The CR is available in the header info of the .dat and .avg files.

The CR value can be converted to the value “N” by multiplying it by 0.574 (1/1.74), and dividing by 1000 to get the value into microvolts.

While the Noise Floor estimates are in Nanovolts, the amplitude of the stimuli are reported in uVolts!

Signal Detection:
The Multi-Master v1a software uses only the 1st harmonic in its analysis of the signal. Since the time series data may be stored by the user, other types of analysis using, different statistical criteria or higher number of harmonics may perform differently (Picton et al, 2003) and can be tested by the users offline using MATLAB. For M-files see our website.

References:

John M. S., Dimitrijevic, A., and Picton, T. W. (2003). Efficient Stimuli for Evoking Auditory Steady-State Responses, Ear and Hearing, In Press.

John M. S., Dimitrijevic, A., and Picton, T. W. (2002). Auditory steady-state responses to exponential modulation envelopes. Ear and Hearing,23(2):106-17.

John, M. S., & Picton, T. W. (2000). MASTER: a Windows program for recording multiple auditory steady-state responses. Computer Methods and Programs in Biomedicine, 61, 125-150.

Picton TW., John MS, Dimitrijevic A, and Purcell DW. Human Auditory Steady-State Responses. International Journanl of Audiology. In Press

To obtain any references for the MASTER technique please go to www.hearing.cjb.net