

TigerANC-Wifi-S User Manual

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1. General Description

1.1. Introduction

TigerANC-Wifi-S is a signal processing product equipped with visual interface to help establish an active noise control system. Apart from TigerANC-Wifi-S, users need at least the following equipments to establish a complete active noise control system.

(1) A computer with Wi-Fi

TigerANC-Wifi-S communicate with visual interface via Wi-Fi so that user can accomplish parameter setting, modelling and noise control by operating on the interface.

(2) Sensors and sensor amplifiers

Depending on the control channel number and the control mechanism, no more than two sensors would be needed. For feedforward active noise control, the reference signals are usually picked up by microphones, tachometers or accelerometers, and the error signals are usually picked up by microphones. Since TigerANC-Wifi-S only accepts (analog) line inputs, signal conditioners are usually needed to amplify the signals picked up by the sensors to a reasonable level.

(3) Actuators and power amplifiers

Loudspeakers are usually used as the control sources for active noise control systems. Power amplifiers are needed to drive the loudspeakers before using the signal output from a TigerANC-Wifi-S.

All signal connectors on TigerANC-Wifi-S are in RCA style, and cables and adapter connectors might be needed to connect a TigerANC-Wifi-S and the other equipments. Sometimes one or several more loudspeakers are needed to act as primary noise sources in simulating experiments.

1.2. An illustrating example

To demonstrate the implementation of TigerANC-Wifi-S, a single-channel feedforward active noise control system is described. The schematic diagram of the system is shown in Fig. 1.1. A noise generator drives a loudspeaker through the power amplifier to act as the primary noise source; at the same time the noise signal is also directed to “Input 1” (white) of a TigerANC-Wifi-S as the reference signal. The signal picked up by the error microphone is amplified and then directed to “Input 2” (yellow) of the TigerANC-Wifi-S as the error signal. The control output calculated by the TigerANC-Wifi-S is directed from “Output” to the control source respectively through the power amplifier. In this illustrating example, a 150-Hz sinusoidal signal is expected to be controlled. If the user needs to hear the noise attenuating process, the microphones should be placed near the user’s ear.

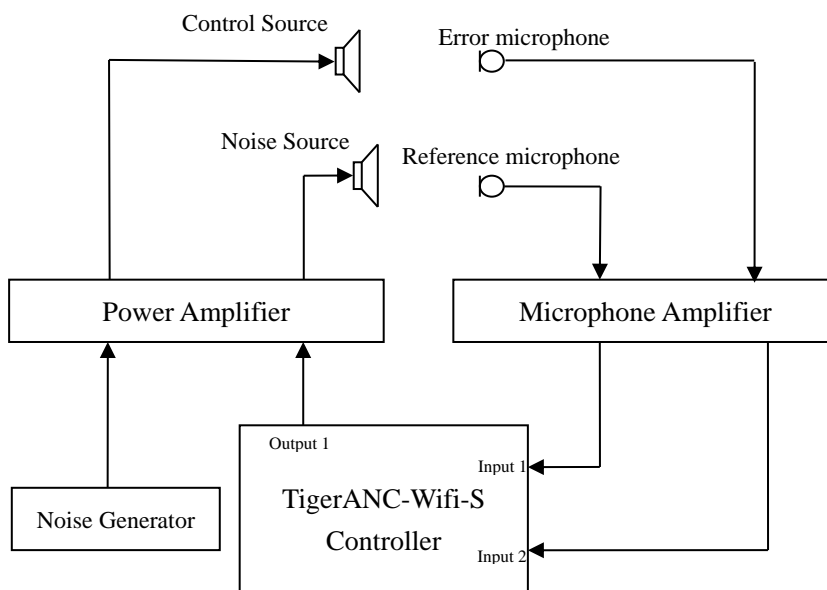


Fig 1.1 Schematic diagram of a single-channel centralized active noise system



Fig 1.2 The main screen of TigerANC-Wifi-S

Power on a TigerANC-Wifi-S, connect to the Wi-Fi named “USR-322” and run the visual interface. The main interface shown in Fig. 1.2 will appear on the computer. Carry out a simple active noise control experiment with the following steps.

(1) Setup the sampling rate and some control parameters

Click the “Parameters” button, click the input box of “Sample Rate”, and then choose “16000 Hz” From the pop-up panel as depicted in Fig. 1.3. The default value of sample rate of the system is 16 kHz.

Click the “Model Taps” and the “Control Taps” input box and set both the “Model Taps” and the “Control Taps” to “1024” respectively.

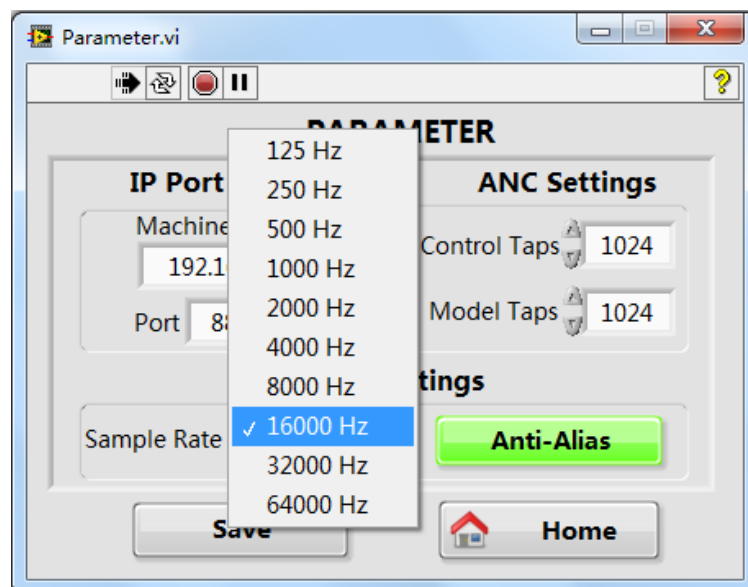


Fig 1.3 Setup the sample rate

(2) Start the modeling process

To increase the accuracy of cancellation path modeling, TigerANC-Wifi-S actuates the control source with white noise and models the cancellation path between the output of the control channel and the input of the input channel from error sensor.

Enter the modeling panel by clicking the “Model” button in the main panel. Set a proper modeling signal level by changing the number in the input box below the “ID SIG Level”. This number can be changed either by clicking the up and down arrow (increasing and decreasing) or by typing a proper value in the input box, as depicted in Fig. 1.4. Note that 0 dB refers to 5 Vpp DA output, and the relation between the “dB” value and the actual DA output is described in Section 4.3.

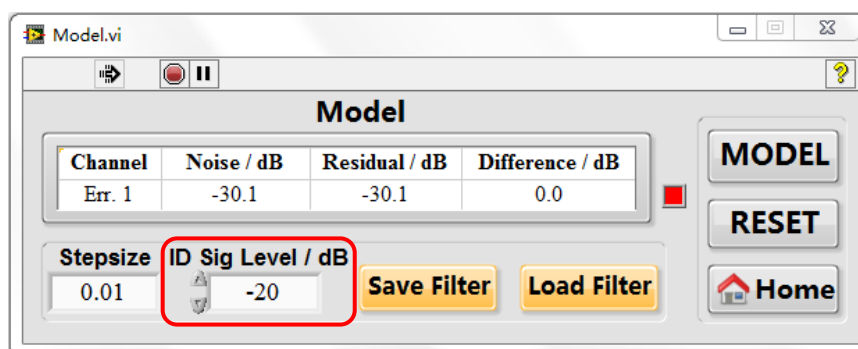


Fig 1.4 The model panel of TigerANC-Wifi-S

Pay attention to the number shown at the “Noise” column of the monitoring window, which indicates the power level of the signal picked up by the error microphone, as shown in Fig. 1.5. The relation between the “dB” value and the actual AD input is described in Section 4.1. Ensure that the level is between -40 dB and -12 dB, otherwise reassign a proper value (larger or smaller) to the “ID SIG Level”.

Adjust the step size for updating the model filter by typing a number in the input box

below the “Stepsize”.

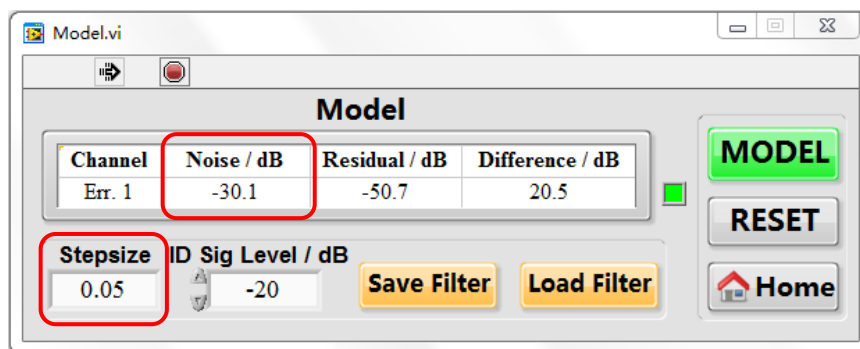


Fig 1.5 Pay attention to the microphone signal level

After that, click the “Model” button, then the modeling process begins. Pay attention to the varying number shown at the “Residual” or “Difference” column of the monitoring window, as depicted Fig. 1.6, which indicates the modeling error power level or the difference between the initial noise level and the residual noise level. If the “Residual” level keeps increasing (or the “Difference” level keeps decreasing), the modeling process suffers from divergence of the model filters. In this case, click the “Model” button again to stop the modeling process, reassign a smaller “Stepsize”, and click the “Reset” button. After that, restart the modeling process by clicking the “Model” button.

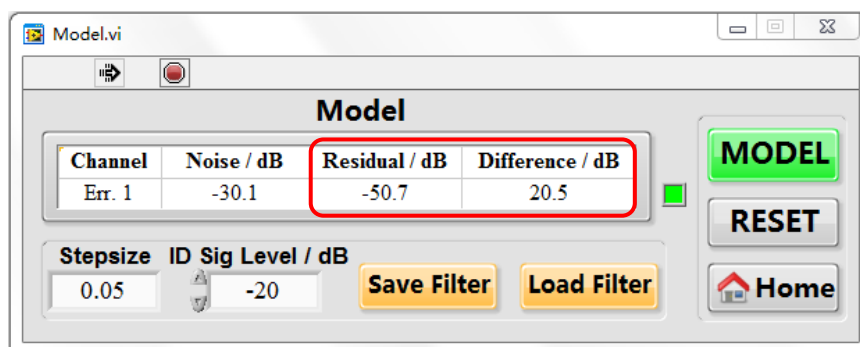


Fig 1.6 Inspect the “Residual” and “Difference” level in modeling

On the other hand, if the “Residual” level keeps unchanged and cannot attenuate for a long time, stop the modeling process and increase the “Stepsize”. After that, restart the modeling process by clicking the “Model” button. Repeat the above process until the “Residual” level decreases quickly to a very small number (or the “Difference” level increases to a large number, e.g. a number higher than 20 dB). Note that the status lights on the right side of the “Difference” column will vary from red to green during a reasonable modeling process. The successful modeling will be indicated by a very stable low “Residual” level or a very stable high “Difference” level. Usually the “Difference” level above 20 dB is expected.

After the modeling process is completed successfully, return to the main panel.

(3) Start the control process

Enter the control panel by clicking the “Control” button in the main panel. Actuate the noise source with a 150 Hz sinusoidal signal, then ensure that the reference signal level and the error signal level are within a reasonable range (range between -40 dB and -12 dB is recommended), as shown in Fig. 1.7. This can be obtained by adjusting the gain of amplifier of the microphones or the power amplifier of the noise source. The relation between the “dB” value and the actual AD input is described in Section 5.1.

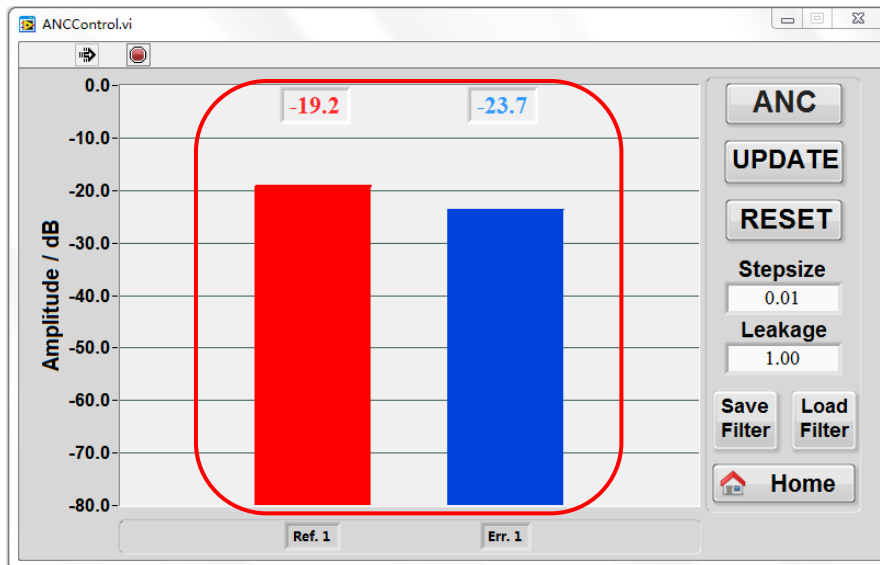


Fig 1.7 Check the reference and error signal power

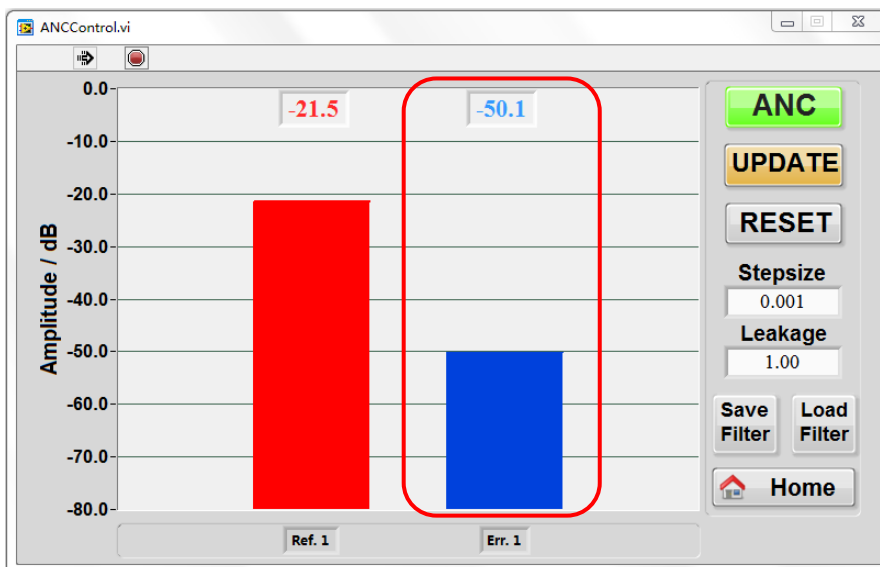


Fig 1.8 Track the performance in control

Assign a proper number to the step size by changing the number in the input box below “Stepsize”. Similar to that in the modeling panel, this number can be changed by typing a proper value in the input box. Set a proper leakage factor by adjusting the number under “Leakage” (1 is recommended in this demonstration). After that, highlight the “ANC” button by clicking it, and make sure that the “Update” button does not grey out (if so, click it to

highlight it). If everything works well, users will find that the error signal level keeps decreasing, as shown in Fig. 1.8. However, sometimes users may find that the error signal level increasing even leading to howling of the control source. When this happens, just click the “ANC” button again to interrupt the control process, and click the “Reset” button to reset the control filters. Then reassign a smaller number to the “Stepsize”. After that, resume the control process by clicking the “ANC” button again. If the error signal level does not attenuate for a long time, click the “ANC” button and reassign a larger number to the “Stepsize”, then restart the control process. Repeat the above steps until the error signal level starts to decrease, which indicates the convergence of the control system.

(4) Tracing the performance of the control process

Although signal level shown by TigerANC-Wifi-S provides a simple method to evaluate the control process, users are highly recommended to use a professional measurement instrument, e.g. PULSE from Bruel & Kjaer, to trace the performance of the whole system. In the scenario described above, if the control process works properly, users can hear a significantly attenuated level of the 150 Hz sinusoid noise.

1.3. Software modules

As can be seen on the main panel of TigerANC-Wifi-S (Fig. 1.2), the software of the controller consists of 6 buttons. Each button is relevant to a basic module of the controller, named as “Control”, “Model”, “Parameters”, “System”, “Filters”, and “About” respectively. The “About” module shows the system information, including the software version, of the TigerANC-Wifi-S. All functions of the other modules will be described in detail in the rest of this manual.

2. System

The system module, as shown in Fig. 2.1, allows users to configure the system parameters.

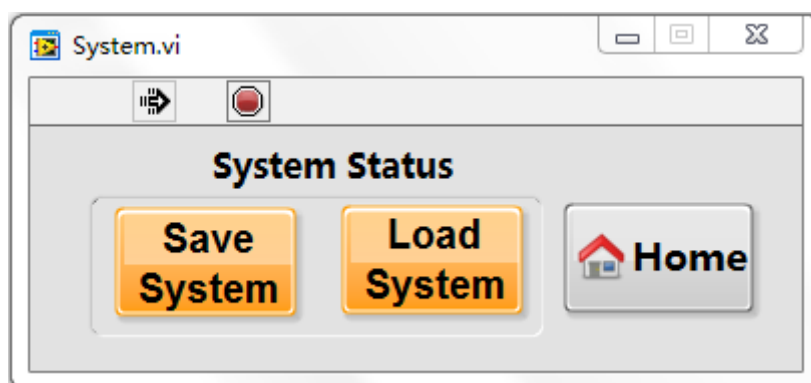


Fig 2.1 The “System” Module

2.1. System data save & load

All system parameters, including those relevant to the modeling process and the control process, together with all model filter coefficients and control filter coefficients, can be saved to or loaded from the txt file in “D:\DSPdata\SaveAndLoad” by clicking the “Data Save” or “Data Load” button (the name of the txt file is “date + time + SystemFilter.txt”).

2.2. System initial status

The default initial configuration of the system is shown in Table 2.1.

Table 2.1 The default initial status

System parameter	Module	Default setting
Sample Rate	Parameters	16000 Hz
Anti-Alias	Parameters	ON
Control Num	Parameters	1
Error Num	Parameters	1
Model Taps	Parameters	1024
Control Taps	Parameters	1024
ID SIG Level	Model	-20 dB
Stepsize Value	Model	0.01
Model filter coefficients	Model	All set to 0
Stepsize Value	Control	0.001
Leakage Value	Control	1
Control filter coefficients	Control	All set to 0

3. Parameters

The “Parameters” module, as shown in Fig. 3.1, allows users to choose the sample rate of the system and set up some parameters relevant to the whole active noise control system.

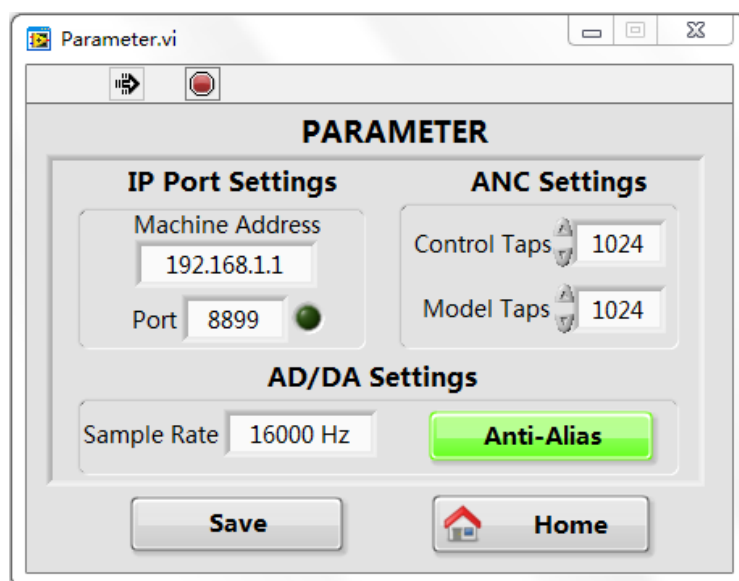


Fig 3.1 The “Parameter” module

3.1. IP Address and port

The IP address and port of TigerANC-Wifi-S can be set in this section, which is used for Wi-Fi connection with interface.

3.2. Sampling rate

The sampling rate of TigerANC-Wifi-S can be varied from 125 Hz to 64 kHz in 10 step level, which can be chosen from the pop-up panel by clicking the “Sample Rate” input box.

3.3. Anti-aliasing low pass filtering

The higher the sampling rate is, the shorter the latency of the controller will be. The analog low-pass filters within the hardware can effectively prevent aliasing for sampling rate not less than 16 kHz. At this setup, the AD/DA time delay is 3 sampling periods for 16 kHz sampling rate, i.e. 187.5 μ s.

However, for sampling rate less than 16 kHz, sometimes aliasing will degrade the performance of the controller. By switching the “Anti-Alias” to “ON” position, TigerANC-Wifi-S will enable pre-defined anti-aliasing low pass digital filter in the system and prevent aliasing for sampling rate less than 16 kHz. Nevertheless, the anti-aliasing digital filters will introduce extra time delay into the system, which might significantly deteriorate the wideband noise control performance of the controller!

3.4. Taps of model filters

Users can type in a reasonable number for the model filter taps in the “Model Taps” input

box. To guarantee the computational efficiency of the DSP chip, the length must be set as an integer multiple of 8. The model filter length has an upper limit due to the computational capacity of the DSP chip used in the system. The filter length will be automatically set to its upper limit if a number larger than the upper limit is typed. Users can check the detail information about the maximum length of the filters in Appendix A.

3.5. Taps of control filters

The taps of control filters can be changed by typing a proper value in the “Control Taps” input box. To guarantee the computational efficiency of the DSP chip, the control filter length should be set as an integer multiple of 8. The control filter length has an upper limit due to the computational capacity of the DSP chip used in the system. The filter length will be automatically set to its upper limit if a number larger than the upper limit is typed. Users can check the detail information about the maximum length of the filters in Appendix A.

3.6. Save

The parameters can be saved in the txt file in D:\DSPdata\SaveAndLoad with the name “ReadConfig.txt” by clicking “Save” button.

4. Model

The purpose of the “Model” module, as depicted in Fig. 4.1, is to allow users identify the cancellation path, i.e. the transfer function between the control output and the error input of the active noise control system.

4.1. Monitoring window

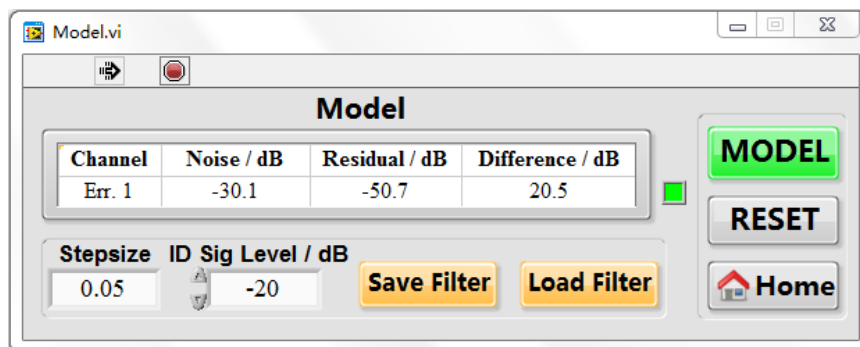


Fig 4.1 The “Model” module

In the middle of the “Model” module interface, there are three columns of varying numbers which enable users to inspect the modeling process. The “Noise” column shows the signal level picked up by the error input, the “Residual” column shows the modeling error signal level, and the “Difference” column shows the difference between the “Noise” column and the “Residual” column. In a proper modeling process, the smaller the “Residual” (or the larger the “Difference”) is, the better the modeling result will be. The signal level is shown in “dB” unit and calculated as the following equation.

$$\text{Signal Level} = 10 \times \log_{10} \left[E \left(\frac{V_{rms}^2}{25} \right) \right], \quad (4.1)$$

where V_{rms} represents root mean square of the input signal amplitude and $E()$ represents the expectation operation. For sinusoidal signal with 10 Vpp (- 5 V ~ 5 V) input, the signal level will be -3 dB.

4.2. Setting the identification signal

TigerANC-Wifi-S uses white noise as the identification signal. The identification signal should be sufficient loud to achieve a reliable modeling result. Users can set the identification signal level by setting a number below the “ID SIG Level” notation. 0 dB “ID SIG Level” refers to 5 Vpp DA output, and the relation between the “dB” value “X” and the actual DA output “Y” in Vpp is described as the Equation (4.2).

$$Y = 5 \times 10^{X/20} \quad (4.2)$$

The “ID SIG Level” can be changed either by clicking the up and down arrow (increasing and decreasing) or by typing a proper value in the input box. Pay attention to the

numbers in the “Noise” column of the monitoring window. A noise level between – 40 dB and – 12 dB is recommended. If the noise level is out of a reasonable range, adjust the “ID SIG Level” correspondingly.

4.3. Start the modeling process

The stepsize for the modeling filter can be set by typing in the “Stepsize” input box. After that, users can model the cancellation path between the control source and the error sensor by clicking the “Model” button. Note that the button will be highlighted in the modeling process.

To trace the performance of the modeling process, users should pay attention to the number shown in the “Residual” and “Difference” columns in the monitoring window. A normal modeling process leads to continuous decreasing of the “Residual” (increasing of the “Difference”) until they reach a comparatively stable level. If the “Residual” keeps increasing (the “Difference” keeps decreasing), users should stop the modeling process by clicking the “Model” button again (the button will grey out) and do the following things before resuming the modeling process.

- (1) reset the model filters by clicking the “Reset” button;
- (2) make sure that the “Noise” level is in a reasonable level (between – 40 dB and – 12 dB).
The signal level can be adjusted by using power amplifiers and the sensor signal amplifiers, or by changing the “ID SIG Level”;
- (3) decrease the step size of the model filter.

If the “Residual” level keeps stable and cannot be attenuated for a long time, click the “Model” button and increase the “Stepsize”. After that, restart the modeling process by clicking the “Model” button again.

Repeat the above process until the “Residual” level decreases quickly to a very small number (or the “Difference” level increases to a large number, e.g. a number higher than 20 dB). Note that the status lights on the right side of the “Difference” column will vary from red to green during a reasonable modeling process. The successful modeling will be indicated by a very stable low “Residual” level or a very stable high “Difference” level. Usually the “Difference” level above 20 dB is expected. Note that sometimes a too short model filter length might lead to an unsuccessful modeling process. In that case, try to increase the model filter length within the range described in Appendix A.

4.4. Stop modeling

The modeling process can be stopped any time by clicking the “Model” button and the button will be grayed out.

4.5. Reset model filters

The model filter coefficients can be reset by clicking the “Reset” button.

4.6. Model filters save & load

The model filter coefficients can be saved to or loaded from the txt file in “D:\DSPdata\SaveAndLoad” by clicking the “Save Filter” or “Load Filter” button respectively (the txt file name is “date + time + ModelFilter.txt”).

5. Control

The “Control” module, as depicted in Fig. 5.1, enables users to carry out active control action and check noise control performance.

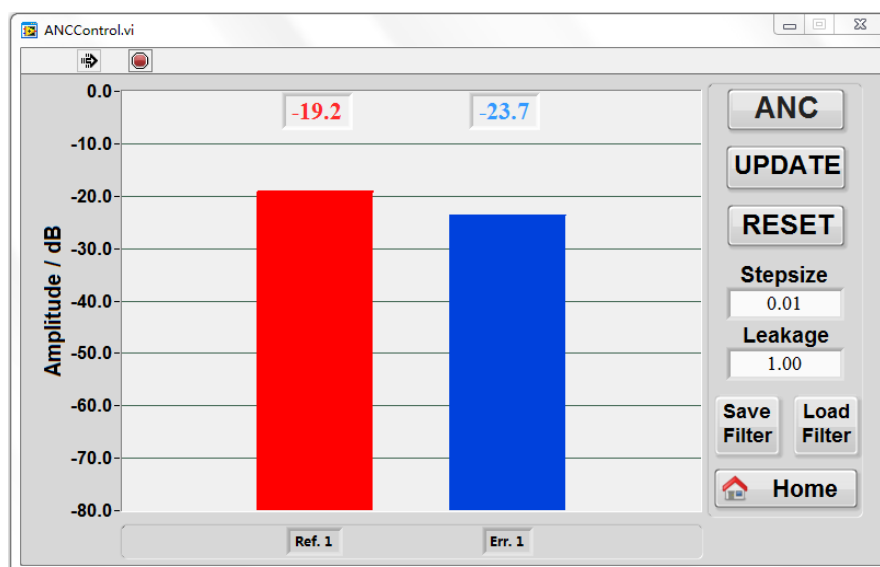


Fig 5.1 The “Control” module

5.1. Monitoring window

There are two bars with varying heights indicating the signal level picked up by the reference sensor and the error sensor. The signal level is shown in “dB” unit and calculated as the following equation

$$\text{Signal Level} = 10 \times \log_{10} \left[E \left(\frac{V_{rms}^2}{25} \right) \right], \quad (5.1)$$

where V_{rms} represents root mean square of the input signal amplitude and $E()$ represents the expectation operation. For sinusoidal signal with 10 Vpp (-5 V – 5 V) input, the signal level will be -3 dB.

5.2. Start the control process

Before the control process starts, actuate the noise source. Make sure that the signal levels shown in the monitoring window are within an appropriate range (-40 dB to -12 dB recommended).

After setting a proper step size and a proper leakage factor for the control filter by adjusting the “Stepsize” and the “Leakage” respectively, click the “ANC” button to start the control process. Note that the button will be highlighted in the control process. If the “Update” button grays out, click it to enable the filter coefficients update.

Users should pay attention to the “ERR.” signal level in the monitoring window which should keep decreasing until reaching a comparatively stable level. If the “ERR.” signal level keeps increasing and even some kind of harsh noise can be heard, stop the control process by clicking the “ANC” button (which makes it grey out), and reset the control filter coefficients by clicking the “Reset” button. The divergence might be caused by the following reasons.

(1) Signal overflow

Adjust the sensor signal amplifier to make sure that the “REF.” signal level and the “ERR.” signal level are below -12 dB before the control process. Some professional measurement equipment is recommended to use for tracking time domain waveform of the input signal, so that users can make sure that the input signal is within the input range (10 Vpp) of TigerANC-Wifi-S.

(2) Cancellation path modeling failure

Check whether the cancellation path is identified successfully by inspecting the plot of the model filter as described in Sec. 6.1.

(3) Too large step size for the control filter

In some cases, the divergence is caused by using a too large step size for control filter. Reduce the step size and retry the control process. Note that when the noise contains sinusoidal signals, the step size should be set significantly smaller than that for controlling wide band noise.

Sometimes the “ERR.” signal level remains stable for a long time after the initialization of the control process, which indicates that the active noise control system is ineffective. The problem might be caused by the following reasons.

(1) Too small signal level

Adjust the sensor signal amplifier to make sure that the “REF.” signal level and the “ERR.” signal level are higher than -40 dB before control process.

(2) Too small step size for the control filter

In most cases, increasing the step size of control filter will increase the convergence speed. However, be careful not to set to a too large step size to avoid divergence of the system.

(3) Weak coherence between the signal picked by the reference sensor and the error sensor

Users should be aware of the coherence between the signal picked by the reference sensor and the error sensor because the noise attenuation level depends significantly on this property.

(4) Too short control filter length

Sometimes the control performance suffers from short control filter length. Users can increase the control filter length within the scope described in Appendix A.

(5) Non-causal control system

For wide band noise control, it is important to check the system’s causality, which is described as follows.

$$T_{\text{sec}} + T_{\text{ref}} + T_{\text{AD/DA}} \leq T_{\text{pri}}, \quad (5.2)$$

where T_{sec} represents the propagation time of the acoustic wave from the control source to the error sensor, T_{ref} represents the propagation time of the acoustic wave from the noise source to the reference sensor, $T_{\text{AD/DA}}$ represents the total latency of AD/DA (including the anti-aliasing filter and other shaping filters) of the controller hardware, and T_{pri} represents the propagation time of the acoustic wave from the noise source to the error sensor. For TigerANC-Wifi-S, $T_{\text{AD/DA}}$ can be as short as $187.5 \mu\text{s}$ at 16 kHz sampling rate. However, when digital anti-aliasing filter is enabled, as described in Section 3.2, extra latency caused by the filter will probably form a threat to the causality of the whole system. If the divergence is caused by the violation of causality constraint, users should either change the physical structure of the whole system

or try to reduce the AD/DA latency by increasing the sampling rate, disabling the anti-aliasing filter and other shaping filters.

Note that when the active noise control is ongoing (the “ANC” button is highlighted), users can only check the parameters and status in other modules, and all operations in other modules are disabled.

5.3. The leakage factor

The leakage factor, denoted as α hereafter, can balance the system between the steady state performance and the stability. The updating process of the control filter coefficients can be described as

$$\mathbf{w}_{\text{new}} = \alpha \mathbf{w}_{\text{old}} - \mu \mathbf{X}_f \mathbf{e} \quad (5.3)$$

where μ represents the step size, \mathbf{w} represents the vector containing control filter coefficients, \mathbf{X}_f represents the matrix formed by the filtered reference signals, and \mathbf{e} represents the vector containing the error signals. Note that when $\alpha = 1$, Equation (5.3) simplifies to the standard multi-channel FXLMS scheme and the best control performance can be achieved. However, the system might face the problem of instability. To improve the robustness of the system, a carefully chosen α smaller than 1 is recommended.

5.4. Stop control

The control process can be stopped any time when the “Control” button is clicked and grays out.

5.5. Filter coefficients freeze & resume

When the “Update” button is clicked grayed out, the control filter stops updating and noise attenuation level will be kept comparatively stable. The control filter will continue updating after the “Update” button is clicked and highlighted.

5.6. Reset control filters

The control filter coefficients can be reset by clicking the “Reset” button.

5.7. Control filters save & load

The control filter coefficients can be saved to or loaded from the txt file in “D:\DSPdata\SaveAndLoad” by clicking the “Save Filter” or “Load Filter” button respectively (the txt file name is “date + time + ControlFilter.txt”).

6. Filters

In the “Filters” module, as depicted in Fig. 6.1, users can plot the coefficients of one of the model filters or the control filters on the screen. The filter can be depicted either in time domain or in frequency domain.

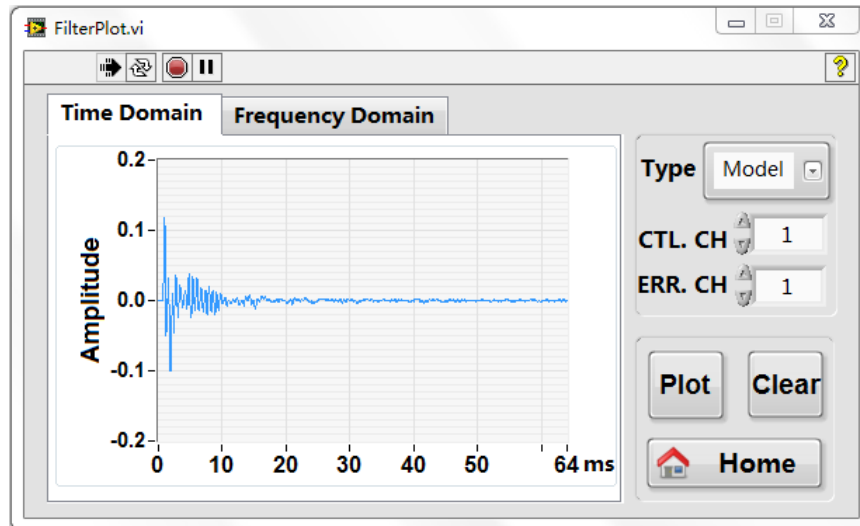


Fig 6.1 The “Filters” module

6.1. Plot filters

If users need to check the cancellation path model filter or control filter, choose “Model” or “Control” in the “Type” input box. Press “Plot” button then the curve of the corresponding filter will be shown.

6.2. Show the filter in frequency domain

The filter can be shown in frequency domain when users click the “Frequency Domain” tab on the screen, as depicted in Fig. 6.2.

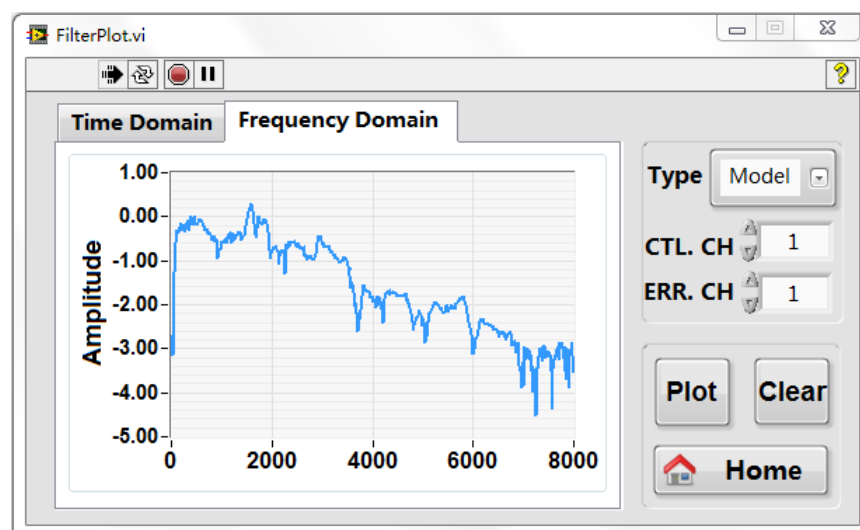


Fig 6.2 Show the filter in frequency domain

Appendix

A. Maximum filter length

The model filter length and the control filter length are restricted by both computational capacity and the maximum on-chip RAM of the hardware. For different Control strategies, users should be aware of the maximum filter length in case that the active noise control fails because of overflow of the computational or storage burden. The maximum filter length in some commonly used configurations is summarized as follows.

Table A Maximum filter taps

Sampling Rate (kHz)	Working channel number (Control channel number equal to Error channel number)	Filter length of both the model filter and the control filter
64	1	720
32	1	1952
≤ 16	1	4096

B. TigerANC-Wifi-S specifications

System Description

TigerANC-Wifi-S is an active controller equipped with a visual interface. The controller communicates with the interface via Wi-Fi. All control parameters can be set through the interface where the control status also can be viewed. The hardware mainly includes a high-end float-point DSP, which is in charge of the core control algorithms. The controller also benefits from the ultra-low latency of AD/DA conversion, which makes it possible to realize a compact ANC system for many latency critical applications.

Number of Channels

- 2 analog input channels (reference and error input)
- 1 analog output channels

Adaptive Algorithms

Gradient descent feed-forward control using the FXLMS algorithm

Control Filter Types

FIR

Maximum Tap Length for Control Filters

Depends on the sampling rate used

Adjustable Algorithm Parameters

- Cancellation path transfer function taps
- Cancellation path identification signal strength
- Cancellation path identification stepsize

- Control filter taps
- Control filter stepsize
- Control filter leakage coefficient

Cancellation Path System Identification

Adaptive FIR model with random noise as the excitation signal

Sampling Rates

There are 10 choices of sampling rates varying from 125 Hz to 64 kHz, with optional anti-aliasing low-pass filter

Output Filtering

The white noise generated by the internal signal generator can be high-pass, low-pass and band-pass filtered with 10 pre-defined different filters. Users can load their own filter parameters through a USB flash disk.

Analog Inputs

- Signal maximum is 10Vpp
- AC coupled inputs

Analog Outputs

- Signal maximum is 5 Vpp
- AC coupled outputs

Saving Data

System data can be saved to “D:\DSPdata”

Signal Display

Software display

- Identification signal level
- Modeling error level
- Reference signal level
- Error signal level
- Cancellation path filters
- Control filters

Hardware

Digital Signal Processor

- Main processor, Texas Instruments (TI) 456MHz TMS320C6748 float-point

Analog Inputs

- 2 analog inputs sampled simultaneously
- 10 V_{pp} input range
- 16 bit precision
- High input impedance
- Selectable analog low-pass filter for each port
- RCA front-panel connectors

Analog Outputs

- 1 analog outputs sampled simultaneously
- 5 V_{pp} output range
- 16 bit precision
- Low output impedance for driving power amplifiers
- Selectable analog low-pass filter for each port
- RCA front-panel connectors

Sampling Rate

- There are 10 choices of sampling rates varying from 125 Hz to 64 kHz, with optional down-sampling low-pass filter

Group Delay

- Minimum of 187.5 μ s with analog low-pass filter @ 16 kHz sampling rate from AD input to DA output

Host Communication

- Visual interface developed by Labview.

Power Supply

- 12V DC power
- Less than 10 Watts power consumption
- IEC power cord connector