

# **Clarity CVC-HFK-Sys4.0.5 Software Integration, Testing, and Validation**

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Texas Instruments  
Clarity Technologies

*HFK DP Software Applications*

## **ABSTRACT**

This document describes a test procedure used to validate that the Clarity Clear-Voice Capture Hands-Free Kit (CVC-HFK®) software has been correctly installed and the hardware is functioning correctly. This document assumes you have built your own or are using one of the sample projects provided with the TI – HFK reference design.

This interface references a wired hands-free product. For Bluetooth™ integration, the resulting tuned levels delivered to the DSP and codec should be similar.

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## 1 Application Overview – CVC-HFK

One of the most important software elements necessary to make a pleasant full-duplex, hands-free call within and automobile is the acoustic echo canceller (AEC). Acoustic echo is caused when the signal from the in-vehicle loudspeaker is coupled to the far field hands-free microphone. When sound comes out of the loudspeaker, these sounds reflect off objects within the vehicle and get directed back to the hands-free microphone. Without a mechanism to cancel this acoustic echo, people talking from the far-end to the hands-free user at the near-end will hear an echo of their voice.

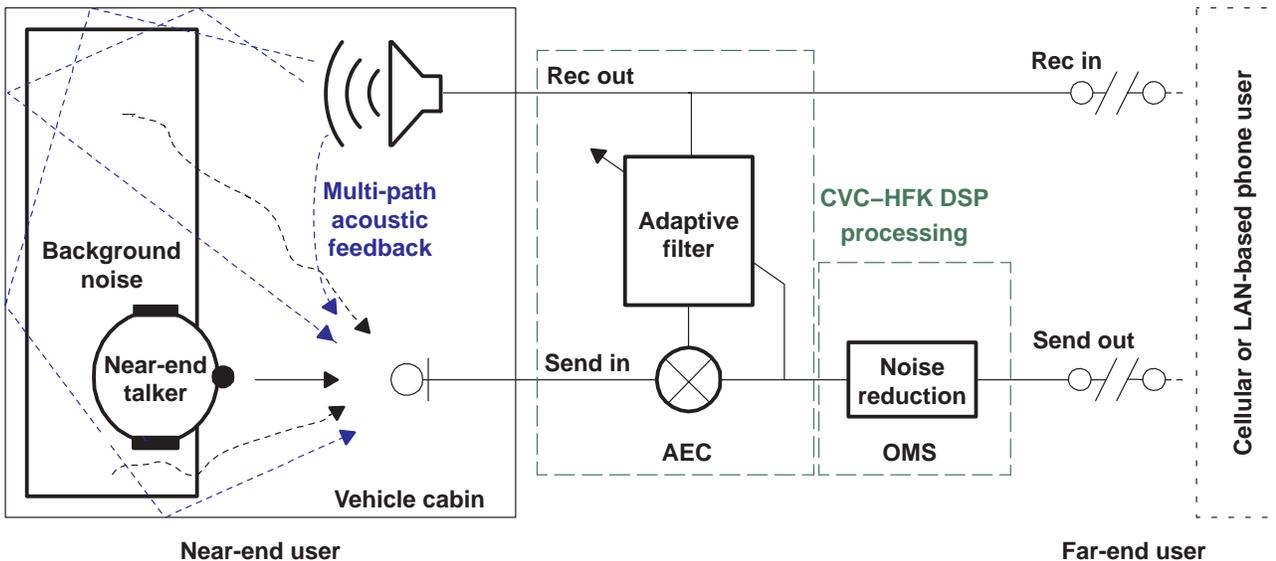


Figure 1. HFK Overview Illustration

The Clarity Clear Voice Capture – Hands-Free Kit (CVC-HFK) software suite contains an AEC algorithm subsystem that runs in the TI C54xx DSP. The AEC has the ability to perform adaptive acoustic echo cancellation. Refer to Figure 1 for a pictorial depiction of the application. The Clarity AEC algorithm works in hands-free mode by attempting to estimate the acoustic echo coupled to the microphone and remove it before it is transmitted back to the remote far-end user telephone. The AEC algorithm must monitor the reference signal at the near-end loudspeaker (rec-in), determine how it is transformed as it returns through the send path (adaptive filter), and subtract that transformed signal from the near-side microphone signal. The algorithm is adaptive to compensate for changes in the acoustic environment during a phone call.

In addition to handling acoustic echo cancellation, the Clarity CVC-HFK provides an integrated one-microphone solution (OMS) noise reduction algorithm. When used in the hands-free mode, stationary ambient noise that is present in automotive situations is a major problem for hands free systems. The OMS solution supports an adaptive noise cancellation function that attenuates the ambient noise of the microphone (send-in) signal, extracts the voice of interest, and transmits the cleaned speech (send-out) to the far-end user.

## 2 Hardware Platform Requirements

In addition to hardware, software, and tools included with the TI-HFK reference design package, additional test equipment is required in order to test and validate the performance of the integrated product.

### 2.1 Mandatory List

These mandatory items are the minimum required in order to test the software integration, and to perform validation by listening to the results. This type of testing is subjective, but is a good start.

- CD player with adjustable volume control
- Oscilloscope or digital RMS voltmeter
- Assorted cables
- Stereo headphones

### 2.2 Suggested List

For a more complete test, it is recommended that you use a PC with the correct software that enables you to view, play, record, and analyze sound files.

- PC with sound card and CD drive
- PC player and recording software
  - Suggest Adobe Audition (former Cool Edit Pro, Syntrillium Software)  
<http://www.adobe.com/products/audition/>
- Amplified Directional Electret-Microphone
  - Peiker Acoustic Inc., Part # M015-VR-034-2.5 <http://www.peiker.com>
- Amplified external speaker
  - Portable 12 VDC amplified loudspeaker (Sony Speaker SRSA27)
  - PC speaker (AC and battery powered)

### 3 Integrating the TI-HFK Reference Design Board

#### 3.1 Test and Validation Overview

Tests will be performed using analog stereo audio files (.wav) that will be played by an external player into the board using input jack JP4 (2.5 mm jack). The input signals will undergo processing; the result can be recorded or listened too via headphones, heard from a radio driven from the boards FM transmitter, or routed to an external amplified speaker.

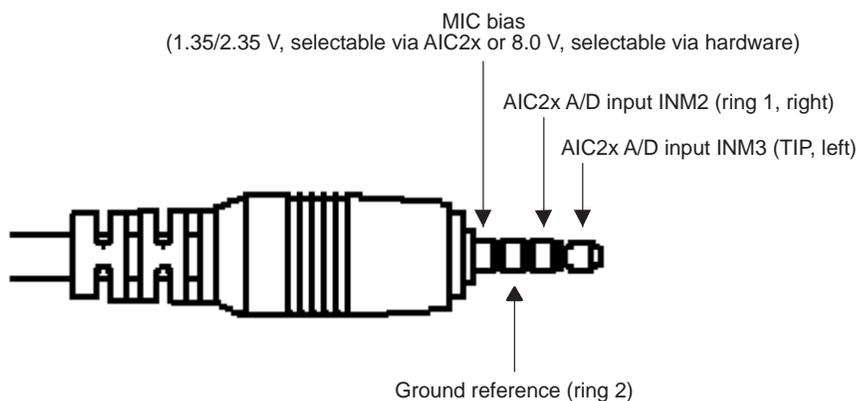
#### 3.2 Custom Interface Cable-to-Audio Player

Before the board can be connected to either a PC a CD player, the proper cables will be required to interface each device. The audio player stereo files will simulate a hands-free call and provide both the send-in (microphone) and the rec-in (speaker reference) signals. A cable will need to be built such that the output from the audio player will match the pin definition of the TI-HFK reference design board input connector, JP4. Typically, on the audio players, a stereo 3.5 mm (1/8 inch) round audio plug connector is used. When audio tracks are played, the outputs on the 3.5-mm plug that are typically configured with the TIP (left balance) will be the send-in microphone signal, and the ring (right balance) will be the reference signal and the sleeve (ground).

The input definition to the TI board is shown in Table 1.

**Table 1. JP4 (2.5-mm Jack) Pin Definition**

Signal Identifier	Connector Pinout	Signal Description
AIC2x A/D input INM3	Connector TIP	Send-in (microphone)
AIC2x A/D input INM2	Connector ring1 (collar1)	Rec-in (reference)
GND	Connector ring2 (collar2)	Signal ground reference
MIC bias	Sleeve	User selectable DC MicBias



**Figure 2. 2.5 mm Audio Input Connector to the TI-HFK**

**NOTE:** The board has two on-board electret microphones, M1 and M2, which will be automatically disconnected when the plug is inserted into the JP4 jack. This plug allows the external microphone and loudspeaker reference signal to be connected to the board inputs.

### 3.3 Calibrating the Audio Player (PC or CD Player)

Calibration is required to set up the audio player for the correct input sensitivity to the board.

#### 3.3.1 Calibration Process

The calibration process is as follows:

1. Plug in your custom audio cable into the audio player.
2. Using the other end of your cable (2.5-mm plug) attach your oscilloscope or digital voltmeter.
3. Ground reference your measurement device to the “Sleeve” position of the connector.
4. Adjust the output balance to the center (equal parts left and right).
5. Play the calibration track. (Note: the track is 60 seconds; if the time expires, replay the track).
6. Adjust the volume control until 500 mVolt RMS (1.414 Volt pk-pk) is measured at both the left and right outputs (TIP and RING1).

**NOTE:** Once the calibration is performed, the audio player selection must be maintained.

Figure 3 illustrates the calibration waveform. Waveform characteristics are sinusoidal, 1 kHz, 500 mVrms, stereo, and 60 seconds in duration.

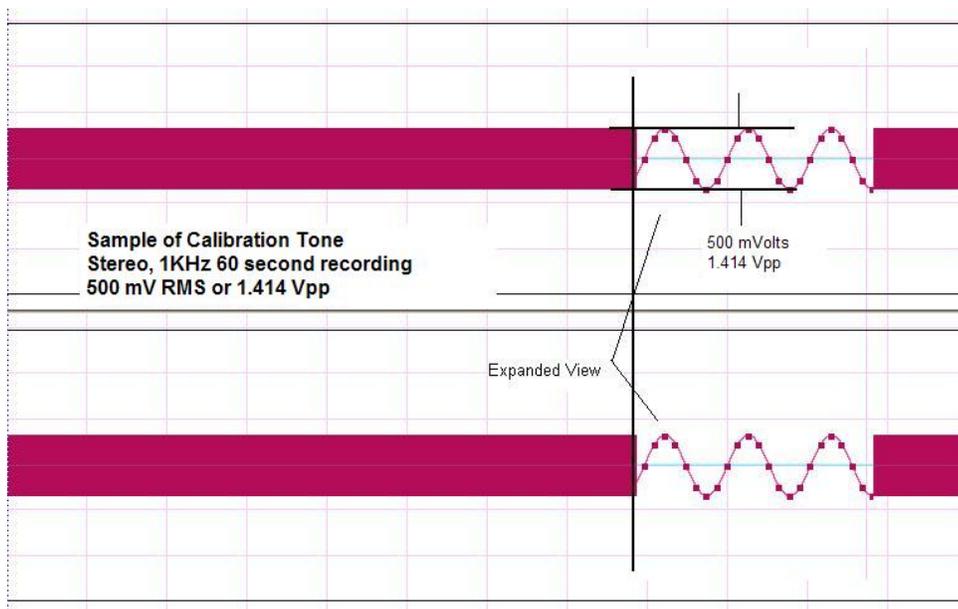
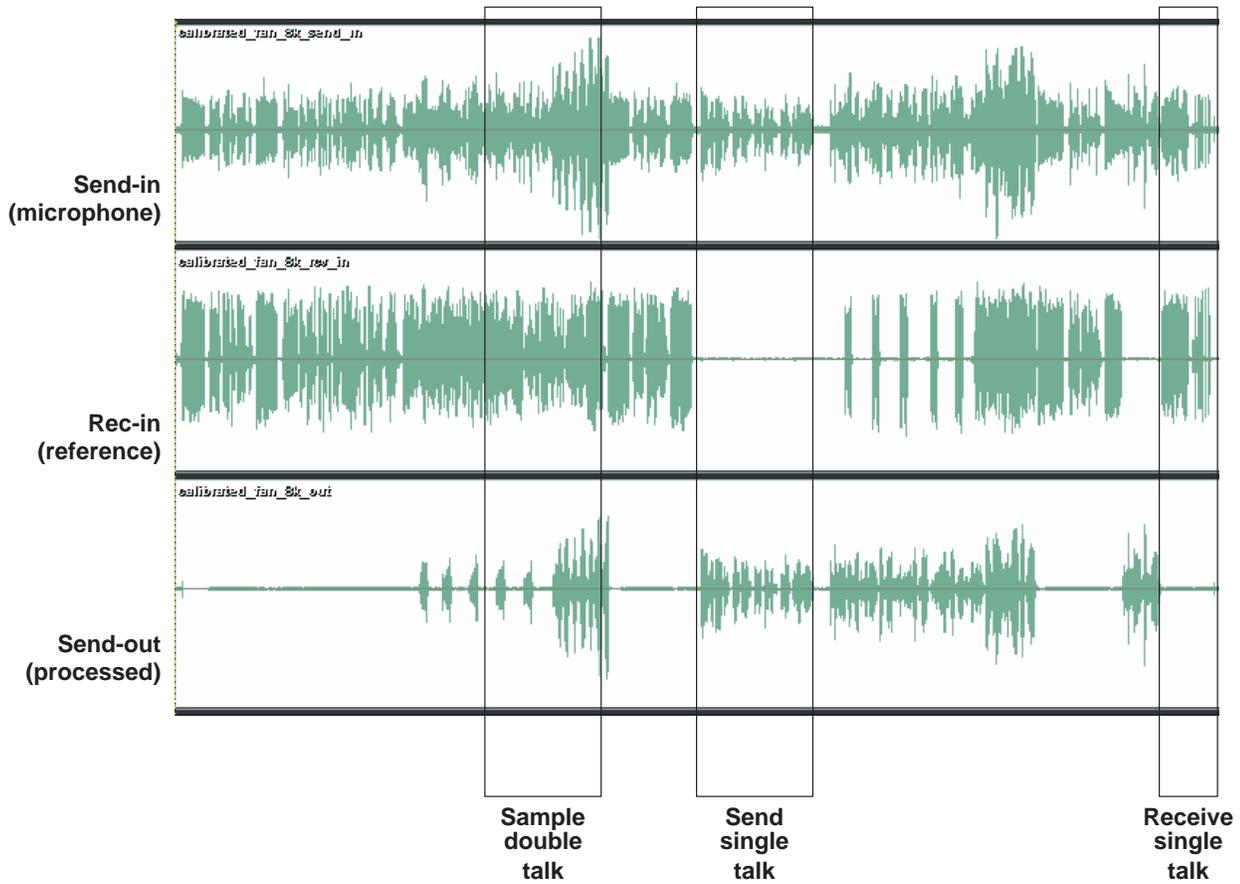


Figure 3. Sample Calibration Tone

### 3.4 Playing HFK TEST File

To validate that correct performance of the software, a test recording has been prepared that tests several modes that are encountered during a typical hands-free communication. Within the test file, all modes of talk conditions are included with the single file. Figure 4 is an illustration of the test file.

**NOTE:** When playing this test file, ensure that the audio player’s volume and balance are not altered from the calibrated settings (see section 6.3).

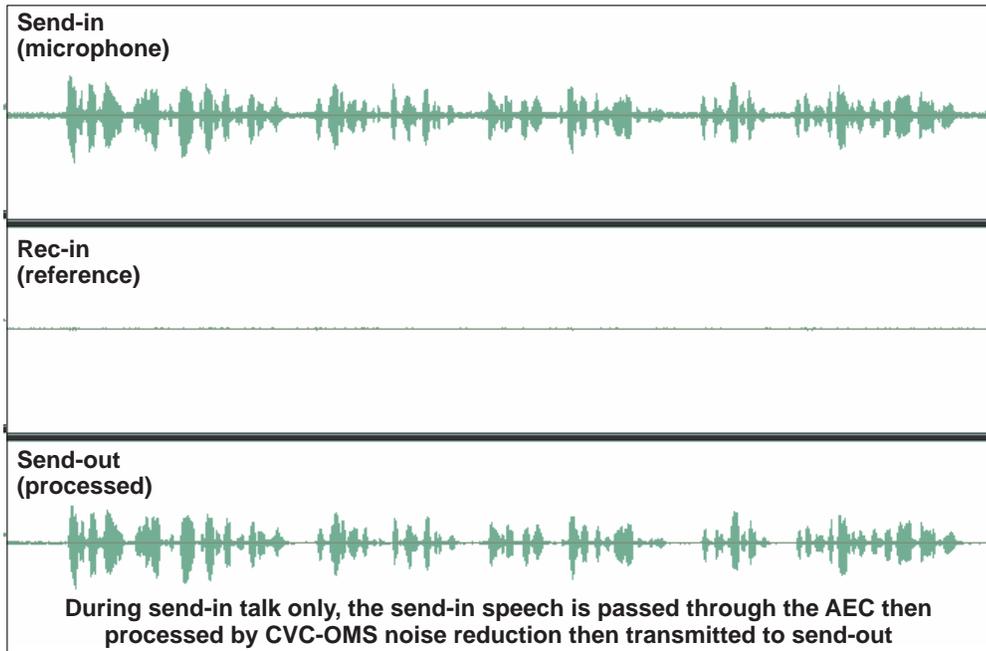


NOTE: The highlighted selections: double talk, send talk, and receive talk, will be reviewed below.

**Figure 4. Sample Test Wav File**

### 3.4.1 Send Single Talk

Send talk is defined as the near-end user (in-vehicle) talking to the far-end listener. Figure 5 shows the resultant two inputs and the processed speech (send-out). The AEC detects the near speech that allows it to pass and is cleaned by the OMS noise reduction before being transmitted to send-out.



**Figure 5. Sample Send Single Talk**

### 3.4.2 Receive Single Talk

Receive talk is defined as the far-end user talking to the near-end (in-vehicle) user. Figure 6 shows that the CVC-HFK does not process this signal. The received signal is used as the reference signal to the AEC adaptive filter. This signal, along with the send-in, provides the AEC the required information to calculate correlation, and subtracts the echo from the send-in as part of the AEC function.

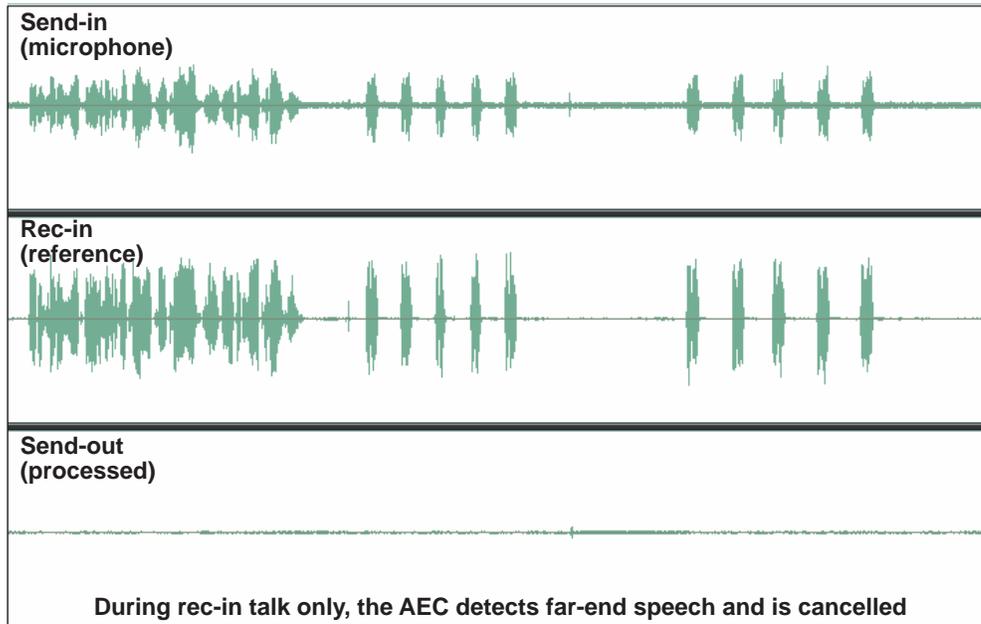
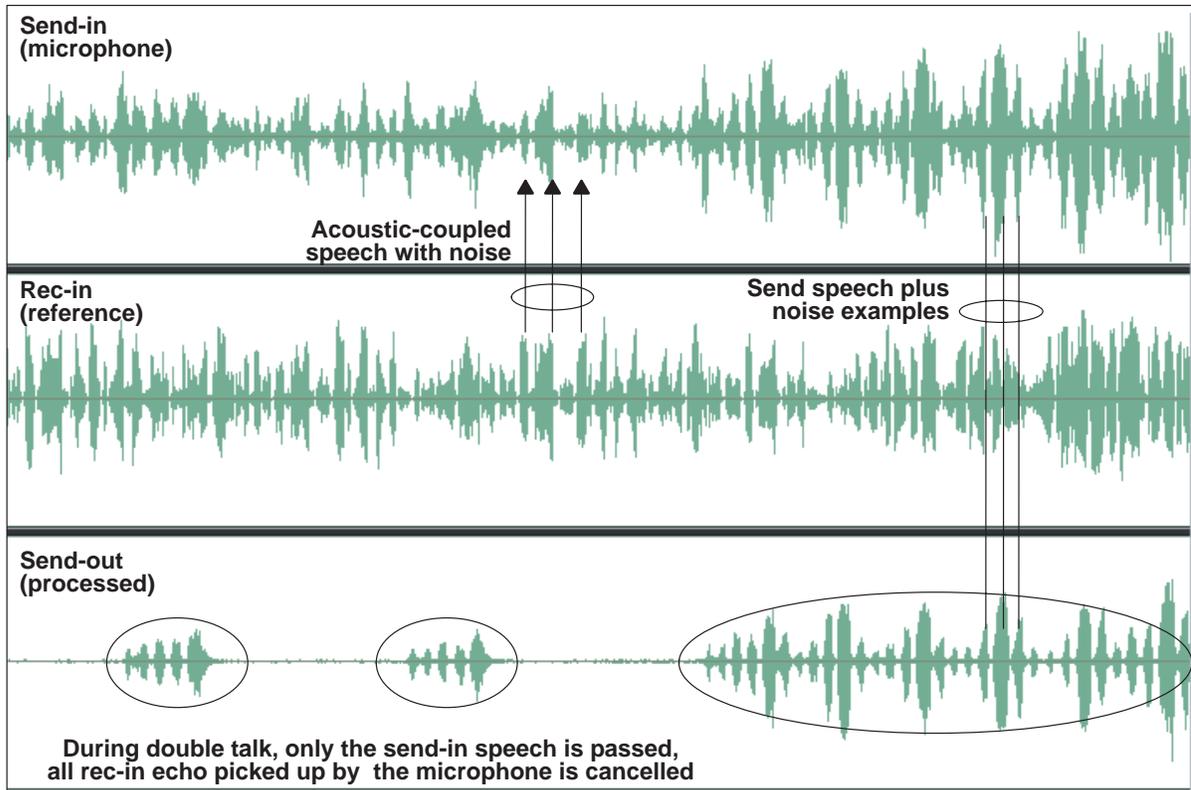


Figure 6. Sample Receive Single Talk

### 3.4.3 Double Talk

Double talk occurs when both the near-end user (in-vehicle) and the far-end user are talking concurrently. As illustrated in Figure 7, the AEC has cancelled all far-end speech, allowing only near-end speech to pass. This ensures that the far-end speaker does not hear an echo when he/she talks, but is still able to participate in a full two-way communication.

The send-in is a mixed signal comprised of the near-end user's speech plus noise, and is mixed with the acoustic-coupled signals that have been passed through the loudspeaker(s) and picked up by the microphone.

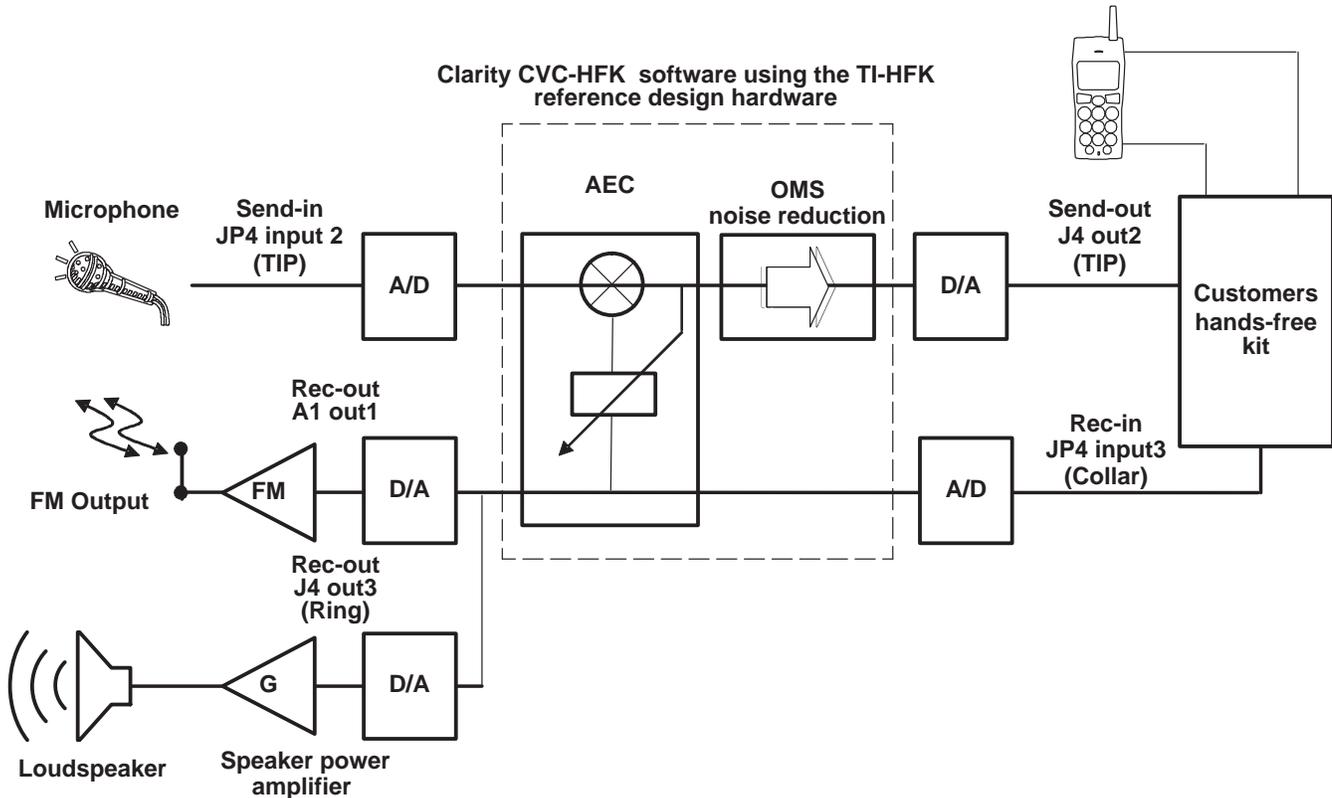


**Figure 7. Sample Double Talk**

You can examine the results by utilizing a PC with proper audio software to play and simultaneously record the output. Statistics can be measured to determine the effectiveness of the CVC-HFK, e.g., echo return loss estimate (ERLE), residual echo, delay, and noise reduction.

## 4 Adding the TI-HFK Reference Design Board into an HFK

When integrating the TI-HFK board with a cellular hands-free kit, several components and proper interfaces will be required before good cellular calls can be achieved.



**Figure 8. Integration Connections**

You must select components that are compatible with both the CVC-HFK application software and board hardware to get good performance. Many different microphones, speakers, and car audio systems will be supported by the HFK; however, to limit the variation of the application note, we have selected specific industry standard components that should lead to a successful setup.

In addition to the board's DC power requirement, three connections are required from the TI-HFK board to the cellular kit for integration:

- Microphone input the TI HFK board
- Send-out, processed audio output
- Rec-in, received in signal from the cellular kit

The following sections provide a detailed discussion of each connection.

## 4.1 Microphone Input (Send-In)

The TI-HFK board has programmable analog input amplifiers internal to the codec. Input gains are under program control from 0 to 42 dB in 1.5 dB steps. For our test application, the program input gain has been set to 0 dB gain, since we are recommending the use of an OEM approved amplified microphone. The microphone recommended has special shielding to reduce noise caused by both Bluetooth™ and GSM communication; Peiker Acoustic Inc.

part no. M015-VR-034-2.5. This microphone is a two-wire device that utilizes a voltage bias (signal) and ground. To facilitate this microphone you are required to configure the board such that the MicBias voltage to 8 volts (see Table 2–1, MICBIAS Options, of the *Hands-Free Kit Development Platform User's Guide* (SPRU703) for details).

The microphone will use input AIC2x A/D Input 3 on the JP4 connector (left channel, TIP). General recommendations are for the send-in *loud speech* — maximum scale input, defined as 100 SPL @ the microphone — during far talk peaking out at 60% of full-scale codec input, or 1.2  $V_{p-p}$  at the codec input. Then test loud speech from the near end into the microphone, ensure < 75% of full scale codec input, or 1.5  $V_{p-p}$  at the codec input. Adjust your loud speaker volume or microphone position and adjust your analog circuitry not to exceed the both targets. For different microphone sensitivities, gain adjustments to the application software will be required.

## 4.2 Reference Signal (Rec-In)

In order for the echo canceller to function properly, speaker reference signal AIC2x A/D Input 2, on the JP4 connector (right channel, Collar1), is a requirement. You can also use this signal to drive an amplified speaker if the FM Modular is not used. General recommendations are for the reference signal (Rec-In) *loud speech* — maximum scale input received from the hands-free kit; setting this maximum is a combination of the phone volume setting + the volume on the loudspeaker before distortion occurs + Far-End loud speech — peaking out at 80% of full scale, or 1.6  $V_{p-p}$  at the inputs to the codec.

Adjust your analog circuitry not to exceed the 80% target. If you need analog gain to reach the desired levels, the programmable codec amplifiers can be used with an adjustment to the application software.

**NOTE:** IMPORTANT: For proper operation of the HFK, the Rec-In > Send-In.

## 4.3 Processed Out (Send-Out)

Similar to the inputs, the codec contains programmable analog output attenuators. Output attenuators are under program control from 0 to –42 dB in 1.5 dB steps. For the test application, only channel OUT2 is used for the Send-Out signal (J4, TIP, 3.5mm plug). The program output attenuation has been set to 0 dB gain, since we are trying to match the sensitivity characteristics of the input microphone. For different output sensitivities, attenuation adjustments will be required to the application software.

**NOTE:** The second channel output is reserved for the FM modulator.

### 4.3.1 Output Electrical Characteristics

Stereo outputs are provided on the design at near line level. That is, the outputs are designed to drive a 150 Ohm load with a peak voltage of approximately 2 Vpp. The line level outputs are driven from the AIC2x codec with a DC offset of approximately 1.35V. These outputs are AC-coupled with 0.1  $\mu$ F caps in RC1 and RC2. Both outputs are available on port J4, a 3.5-mm (1/8-inch) jack, wired in the standard L/R configuration. Table 2 defines the output channel mapping for the audio subsection.

**Table 2. Audio Subsection Output Channel Mapping**

J4.pin	AIC2x Output	Channel
Tip	OUT2	Left (processed out)
Collar	OUT3	Right
Shield	GND	N/A

## 5 Recommendations for Speaker and Microphone Placement

### 5.1 Microphone Position and Orientation Determination

In order to achieve the best overall microphone performance, a few critical variables need to be understood before final installation into the vehicle.

- Maintain the recommended distance of 18 inches (46 cm) between the microphone to the in-vehicle users mouth. The recommended distance range is from 12 to 22 inches (30–56 cm).
- Minimize the microphone exposure to wind currents (windows and fan blowers).
- Consider the microphone size and mounting scheme in an effort to aim the front of the microphone toward the vehicle user's mouth.

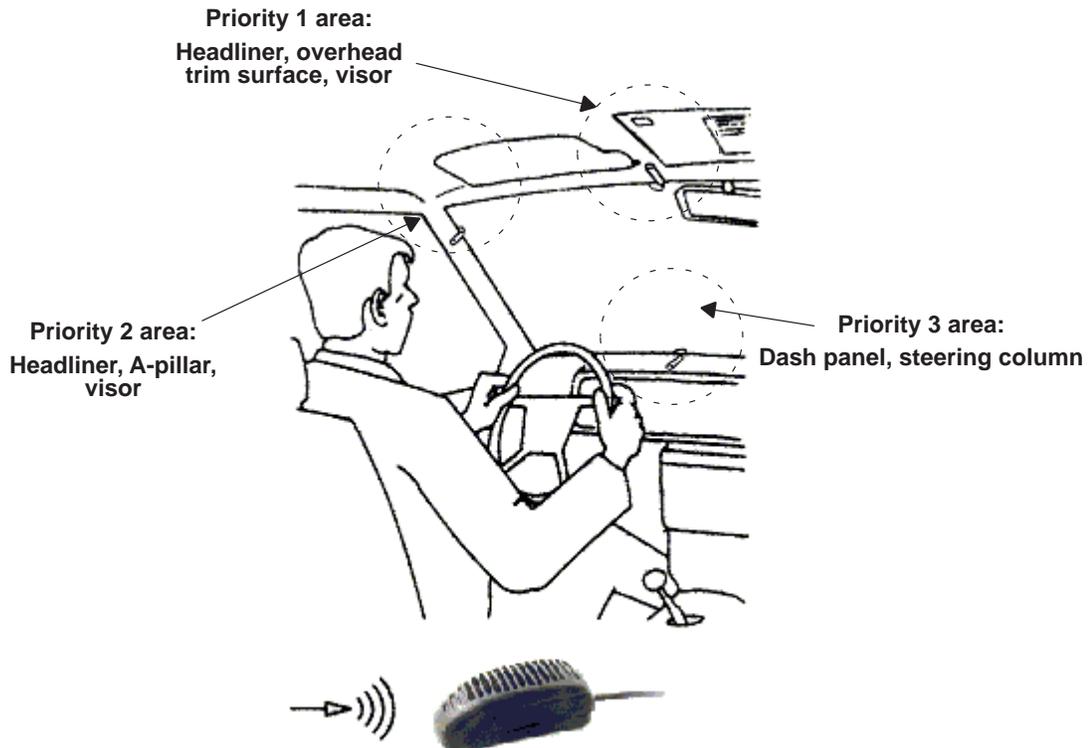
Based on the aforementioned considerations and with the assistance of Figure 9, you are able to choose the best possible microphone location. First, follow the Priority 1, 2, and 3 area suggestions. Once determined, you can secure the microphone using the metal plate or a Velcro strip and route the cable back to the electronics for termination. Then, ensure the cable is hidden from view, secured and NOT pinched or knotted. Finally, avoid parallel cable routing with the antenna lead and other noisy cables.

### 5.2 Loudspeaker Location Suggestion

It is suggested that you mount the loudspeaker in an appropriate location to provide good acoustical performance without interfering with the microphone pickup field. The pickup field is described as a  $\pm 30$  degree cone as measured from the front face of the microphone, projecting outward toward the vehicle operator.

The loudspeaker should be placed at least 3 ft. (1 meter) from the microphone. The loudspeaker should be directed away from the microphone's pickup field to reduce the potential of echo feedback. Ideally, the loudspeaker would be located behind or positioned 90 degrees from the front orientation of the microphone.

The level of sound distortion from the loudspeaker will have a direct adverse effect on echo events.



**Figure 9. Microphone Placement**

### 5.3 Requirements for Radio Settings and FM Modulator

The TI-HFK reference design board is equipped with an FM modulator used to transmit the Rec-In signal received from the cellular phone, to be broadcast as an FM station received by the car radio. The car radio will then amplify the signal to be heard during the telephone call.

To achieve maximum performance from the radio, we recommend the following:

- All DSP functions, including independent volume control, should be disabled during a hands-free call.
- Before all vehicle loudspeakers are used, start the adjusting the balance and fade functions to enable only the front speakers.
- Once benchmarking has been deemed acceptable, begin to add all other speakers to achieve similar echo performance.
- Set a station preset in the FM band to 90 MHz.

Any time the audio from the hands-free kit wants to be heard on the car radio, the preset channel must be selected. The volume is primarily controlled by the radio controls and the phone volume will also provide some adjustment features.

## 6 Related Documents

The following documents provide additional background information on some of the features and functions of the hands-free kit development platform.

1. *TMS320C54x DSP Reference Set, Volume 2: Mnemonic Instruction Set* (literature number SPRU172)
2. *Implementing a Software UART on the TMS320C54x with the McBSP and DMA* (literature number SPRA661)
3. *DSP/BIOS Device Driver Developer's Guide* (literature number SPRU616)
4. *TMS320C6000 Board Support Library API Reference Guide* (literature number SPRU432)
5. *TMS320C54x Assembly Language Tools User's Guide* (literature number SPRU102)
6. *TMS320C54x DSP Programmer's Guide* (literature number SPRU538)
7. *TMS320C54x DSP/BIOS User's Guide* (literature number SPRU326)
8. *XDS560 Emulator Reference Guide* (literature number SPRU589)
9. *Code Composer Studio Getting Started Guide* (literature number SPRU509)
10. *TLV320AIC20 Low Power, Highly-Integrated Programmable 16-bit 26-KSPS Dual Channel Codec Data Manual* (literature number SLAS363)
11. *TLV320AIC24 Low Power, Highly-Integrated Programmable 16-bit 26-KSPS Dual Channel Codec Data Manual* (literature number SLAS366)
12. *Texas Instruments Hands-Free Kit Development Platform User's Guide* (literature number SPRU703)
13. *Clarity Clear Voice Capture (CVC) – Hands-Free Kit Suite of Application Notes* (literature number SPRA960)
14. *Hands-Free Kit: Integration of the AIC24 Driver in Reference Framework 3* (literature number SPRA966)
15. *Hands-Free Kit: Integration of the Clarity Acoustic Echo Cancellation (AEC) Algorithm in RF3* (literature number SPRA969)
16. *Hands-Free Kit: Integration of the Stonestreet One Bluetooth Stack with the Clarity AEC Algorithm in RF3* (literature number SPRA973)

The Texas Instruments documentation listed above is available for download from <http://www.ti.com>.

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