

Audio Analysis Testing Using a KPCI-3108 Board with LabWindows/CVI 5.0.1

Introduction

Manufacturers of cellular and cordless telephones employ a variety of methods to test the audio quality of their products during production. These tests may be as simple as measuring the Vrms of a sinewave input signal that is passed through the analog microphone and speaker circuits. In this case, a DMM usually offers sufficient measurement capability.

More detailed testing of the analog microphone and speaker circuit typically involves total harmonic distortion measurements, frequency response analysis, and noise measurements. For this scenario, a more specialized instrument is required for these audio measurements.

Some manufacturers make audio measurements through the complete phone circuit, including the digital encoder/decoder (CODEC) circuit and the RF circuitry. In this case, a communication analyzer is needed to receive and transmit the modulated RF signal from the phone under test (DUT). Speech CODECs are designed to process the multi-frequency content of human speech, so most of them do not recognize single frequency tones. Therefore, testing the complete path for audio signals in digital cellular phones usually requires a source capable of generating multiple frequencies or tones.

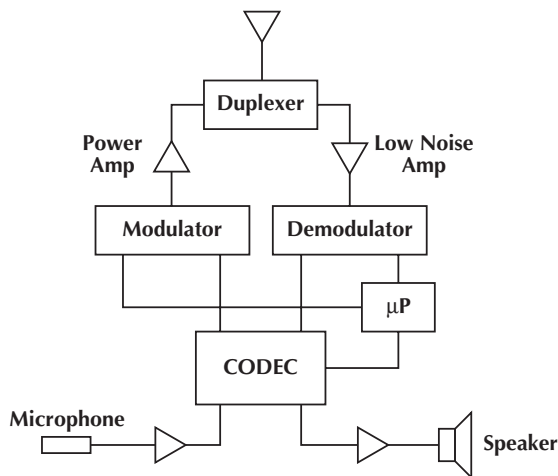


Figure 1. Block Diagram of a Cellular Phone

To qualify the audio circuit of a portable phone fully, an artificial “mouth” and an artificial “ear” are placed in front of the microphone and speaker of the wireless phone. The use of an artificial mouth and an artificial ear is a standard technique in design evaluation laboratories. Some manufacturers use these test system components in production. The mouth is connected

to a multi-tone sinewave function generator. The ear receives the signal produced by the speaker. The output of the ear is acquired and is compared to the signal produced by the generator. The power spectrum and total harmonic distortion of this signal are computed. The frequency and amplitude of each harmonic of the output is compared to its counterpart in the generated wave. These tests are most often performed while the phone is in the RF transmission state.

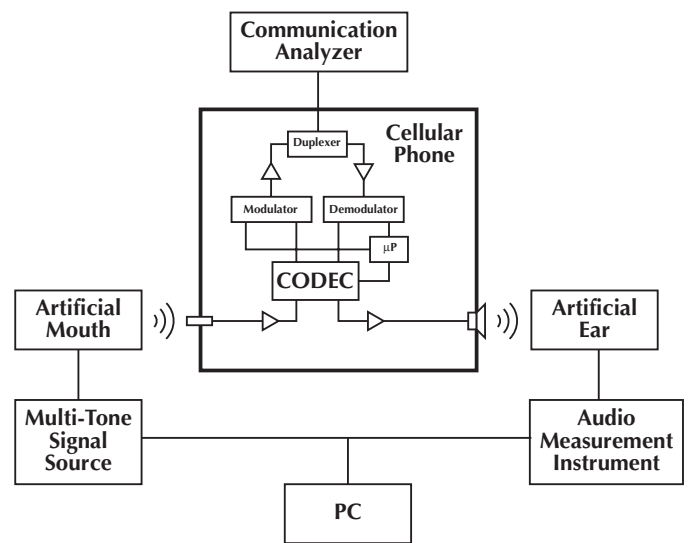


Figure 2. Audio Circuit Test System

Data Acquisition Approach

Basically, this application requires signal generation and measurement equipment, as well as software to control the hardware and perform the signal processing. A high performance data acquisition board offers a compact solution for sourcing and measurement. However, the data acquisition board must meet some important criteria:

- It must be able to acquire and generate signals simultaneously. Note that while these operations must be simultaneous, they do not necessarily need to be synchronized.
- It must have high A/D resolution and a high gain amplifier because the signal amplitudes are in the range of 100mV.
- The board must have an analog output capable of generating complex waveforms.

While Keithley offers a variety of data acquisition products that are suitable for this application, the KPCI-3108 High-Resolution Analog and Digital I/O Board is an excellent choice. It provides two waveform-quality analog outputs, allowing it to generate a two-tone waveform that simulates speech. The board's A/D converter samples signals at 100ksamples/sec with 16-bit resolution to provide accurate measurements in the audio band. In addition, the KPCI-3108 has 12 programmable gains, which yields resolution down to microvolts. Other good choices include the KPCI-3116 250kS/s Analog and Digital I/O Board or any of the ADwin Windows-based real-time measurement and control systems.

On the software side, data acquisition packages such as TestPoint™, LabVIEW, LabWindows/CVI, HP-VEE, etc., or applications created in programming languages such as Visual Basic, Visual C++, or Delphi provide the necessary power for audio analysis. However, it's important to note that, when a language is used, a mathematics library is necessary to compute the power spectrum. This library is available from companies such as Quinn-Curtis, Inc and AccuSoft Corporation. The data acquisition packages already include a mathematics library for performing the computations.

This application note outlines a solution for use in conjunction with the LabWindows CVI package, which is widely used in the telecommunications market.

While a DriverLINX® board driver can be used to control the KPCI-3108 board, a special LabWindows/CVI library has been designed to perform all the functions necessary to complete the tasks. The library can initialize the board, compute the waveform to be generated, acquire the signal, and compute the power spectrum and THD values.

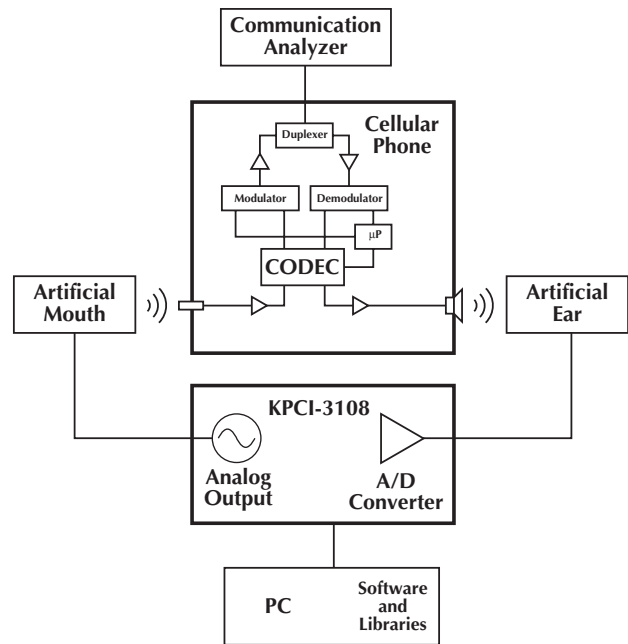


Figure 3. Audio Circuit Test System Using KPCI-3108

The Library

The KPCI-3108 LabWindows/CVI library for THD measurements supports all the functions necessary for the user to program the application without the need to work with the DriverLINX driver. The end user program must be linked with the regular DRVLINX32.LIB file that comes with the board. In order to use the library, the compiler must have the following constants defined or undefined:

```
/DWIN32_LEAN_AND_MEAN /D_MSC_VER=0
```

The library supports the following functions:

```

/*****/
/* Function : Init */
/* Purpose : This function must be called before any other functions in */
/* the library. It is used to load the driver, init the driver, test the */
/* board and initialize the hardware */
/* Parameters : */
/* nInitMethod : This parameter can take any of the following */
/* values : */
/* KPCI3108_INIT_WITH_CVI_WIN_HWND: */
/* The DLINX messages are sent to the main CVI window */
/* KPCI3108_INIT_WITH_CVI_THR_HWND: */
/* The DLINX messages are sent to the main CVI window for the */
/* current thread. */
/* KPCI3108_INIT_WITH_HIDDEN_PANEL: */
/* The Dlinx messages are sent to a hidden private window that */
/* is created and deleted internally by this library */
/* Return value : */
/* Any of the possible library error codes. The function has */
/* been successful only when the returned value is */
/* KPCI3108_NO_ERROR */
/*****/

```

```

int KPCI3108_Init (int nInitMethod);
/*****
/* Function : Close
/* Purpose : This function must be called during program termination to
/* close the driver.
/* Parameters :
/* None
/* Return value :
/* Any of the possible library error codes. The function has
/* been successful only when the returned value is
/* KPCI3108_NO_ERROR
*****/
int KPCI3108_Close (void);

/*****
/* Function : Start_ADTask
/* Purpose : Starts an acquisition on an analog input channel
/* Parameters :
/* ADChannel : Any AD channel from 0 to 7 in differential mode
/* or from 0 to 15 in single ended mode
/* nSamples : Number of sample to acquire (No limits except
/* available memory).
/* SamplingRate : Acquisition frequency in Hertz. From 1.0 to
/* 100000.0
/* ADRange : Range to be used, can take any of the following
/* constants :
/* KPCI3108_RANGE_10V : +/- 10 V.
/* KPCI3108_RANGE_5V : +/- 5 V.
/* KPCI3108_RANGE_2_5V : +/- 2.5 V.
/* KPCI3108_RANGE_1_25V : +/- 1.25 V.
/* KPCI3108_RANGE_1V : +/- 1 V.
/* KPCI3108_RANGE_500MV : +/- 500 mV.
/* KPCI3108_RANGE_250MV : +/- 250 mV.
/* KPCI3108_RANGE_125MV : +/- 125 mV.
/* KPCI3108_RANGE_100MV : +/- 100 mV.
/* KPCI3108_RANGE_50MV : +/- 50 mV.
/* KPCI3108_RANGE_25MV : +/- 25 mV.
/* KPCI3108_RANGE_12_5MV : +/- 12.5 mV.
/* Return value :
/* Any of the possible library error codes. The function has
/* been successful only when the returned value is
/* KPCI3108_NO_ERROR
*****/
int KPCI3108_Start_ADTask (unsigned int ADChannel,
unsigned long nSamples,
double SamplingRate,
short ADRange);

/*****
/* Function : Acquire_AD
/* Purpose : Starts an acquisition on an analog input channel
/* NOTE THAT THIS FUNCTION RETURN ONLY AFTER FULL COMPLETION OF THE
/* ACQUISITION TASK. DO NOT USE IT FOR LENGTHY ACQUISITIONS (MORE THAN
/* 10 Secs)
/* Parameters :
/* ADChannel : Any AD channel from 0 to 7 in differential mode
/* or from 0 to 15 in singled ended mode
/* nSamples : Number of sample to acquire (No limits except
/* available memory).
/* SamplingRate : Acquisition frequency in Hertz. From 1.0 to
/* 100000.0
/* ADRange : Range to be used, can take any of the following
/* constants :
/* KPCI3108_RANGE_10V : +/- 10 V.
/* KPCI3108_RANGE_5V : +/- 5 V.
/* KPCI3108_RANGE_2_5V : +/- 2.5 V.
/* KPCI3108_RANGE_1_25V : +/- 1.25 V.
/* KPCI3108_RANGE_1V : +/- 1 V.
/* KPCI3108_RANGE_500MV : +/- 500 mV.
/* KPCI3108_RANGE_250MV : +/- 250 mV.
/* KPCI3108_RANGE_125MV : +/- 125 mV.
/* KPCI3108_RANGE_100MV : +/- 100 mV.
/* KPCI3108_RANGE_50MV : +/- 50 mV.
/* KPCI3108_RANGE_25MV : +/- 25 mV.
/* KPCI3108_RANGE_12_5MV : +/- 12.5 mV.
*****/

```



```

        double RefreshRate,
        short DARange);

/*****
/* Function : Stop_DATask
/* Purpose : This function stop the generation of a waveform on any DA
/* Channel
/* Parameters :
/*           None
/* Return value :
/*           Any of the possible library error codes. The function has
/*           been successful only when the returned value is
/*           KPCI3108_NO_ERROR
*****/
int KPCI3108_Stop_DATask(void);

/*****
/* Function : Get_ADTask_Status
/* Purpose : This function return the actual status of a DA task
/* Parameters :
/*           pStatus : On exit hold the actual task status
/*           KPCI3108_TASK_SCHEDULED : Task is about to start
/*           KPCI3108_TASK_ARMED : Task is ready and waaait for trigger*
/*           KPCI3108_TASK_ACTIVE : Task is running
/*           KPCI3108_TASK_INACTIVE : Task is stopped
/*           KPCI3108_TASK_DONE : Task completed
/*           pCurrentBuffer : Actual task buffer under processing
/*           pNextElement : Next buffer element to be processed
/* Return value :
/*           Any of the possible library error codes. The function has
/*           been successful only when the returned value is
/*           KPCI3108_NO_ERROR
*****/
int KPCI3108_Get_DATask_Status(WORD* pStatus,
                              WORD* pCurrentBuffer,
                              DWORD* pNextElement);

/*****
/* Function : OnDLEvent
/* Purpose : This callback function is called by the driver every time a
/* task event is encountered.
/* NOTE : This callback is declared but not defined. It is the job of the
/* library used to define its body.
/* Parameters :
/*           Not relevant to the user, but must be passed without
/*           modifications to the PreProcessDLEvent function so the
/*           following global variables are
/*           updated according to the event :
/*           KPCI3108_wTaskID;
/*           KPCI3108_wMessage;
/*           KPCI3108_wDevice;
/*           KPCI3108_wMode;
/*           KPCI3108_wSubSystem;
/*           KPCI3108_wBufferIndex;
/* Return value :
/*           None
*****/
void CVICALLBACK KPCI3108_OnDLEvent(WinMsgWParam wParam,
                                    WinMsgLParam lParam,
                                    void *callbackData);

/*****
/* Function : PreProcessDLEvent
/* Purpose : This function should be called to update the variables.
/*           KPCI3108_wTaskID;
/*           KPCI3108_wMessage;
/*           KPCI3108_wDevice;
/*           KPCI3108_wMode;
/*           KPCI3108_wSubSystem;
/*           KPCI3108_wBufferIndex;
/*           before processing a DL event
/* Return value :
/*           None
*****/

```


How to Use the Library

The library offers many different techniques to perform the required tasks, so individual users will find a variety of ways to perform the same task. The following approach is just one example of the possibilities.

Generating a multi-tone waveform from one of the analog outputs:

Before any measurements can be made, the board must generate a multi-tone sine wave. The library includes a full set of functions tailored to create the waveform, then output it in continuous mode.

First, we must choose some important values, particularly the generation refresh frequency, which is the duration of one full waveform. In this example, for the sake of simplicity, let's define the duration as one second. Therefore, the frequency (expressed in Hz) and the size of the array holding the waveform must be the same number. If we assume a duration of one second and a refresh frequency of 50kHz, then the waveform size would be 50,000 points.

Step 1: Declare, define, and initialize the array that will hold the waveform:

```
Double *pWaveform;  
pWaveform = malloc( 50000 * sizeof(double) );  
KPCI3108_ResetWaveform( pData, 50000 );
```

Step 2: Add all the harmonics to the waveform array:

To add harmonics to the waveform, a specific function named "AddHarmonicToWaveform" is used.

For this example, we will add three harmonics:

Harmonic 1: 50Hz @ 100mVRMS

Harmonic 2: 217Hz @ 37mVRMS

Harmonic 3: 1kHz @ 25mVRMS

This results in the following piece of code:

```
KPCI3108_AddHarmonicToWaveForm(pWaveform, 50000, 0.1,  
50.0, 50000.0) ;  
KPCI3108_AddHarmonicToWaveForm(pWaveform, 50000,  
0.037, 217.0, 50000.0) ;  
KPCI3108_AddHarmonicToWaveForm(pWaveform, 50000,  
0.025, 1000.0, 50000.0) ;
```

Step 3: Output the signal:

This final step is easy. Just use the "Start_DA" function, and it's done. Use the "Stop_DA" when you want to stop generating the signal, either at the end of the test or if a change in the waveform is required.

```
KPCI3108_Start_DATask (0, pWaveform, pWaveform, 50000,  
50000.0, KPCI3108_RANGE_5V) ;  
.../  
KPCI3108_Stop_DATask ();
```

Acquiring the signal:

Now that the signal is present on the analog output, we can acquire the signal returned by the phone through the artificial ear. To acquire the whole waveform, we will sample the points during one second. In order to use a FFT algorithm to compute the power spectrum and ultimately the THD, the size of the acquisition should be a multiple of 2^n . (The computations of FFT algorithms are optimized for and based on a multiple of 2^n samples.) As explained previously, this implies that the number of samples is equal to the acquisition rate. In this example, we will perform an acquisition of 16,384 samples at a rate of 16,384Hz.

To do this job, we simply have to define and declare an array that will hold the data, then call the "Acquire_AD" function as shown in this example:

```
double* pData;  
pData = (double *)malloc((16384)*sizeof(double));  
ErrCode = KPCI3108_Acquire_AD(0, 16384, 16384.0,  
KPCI3108_RANGE_250MV, pData);
```

Computing the power spectrum and THD:

After completion of the acquisition, all that remains is to compute the power spectrum and the THD. The following is a documented example of how to perform these tasks while taking advantage of the LabWindows CVI math function (AutoPowerSpectrum):

```
// Declare arrays to hold generated frequencies and  
amplitudes  
// These variables should be filled before each calls to  
AddHarmonic  
// In this example, the pFreqs array hold 3 values :  
50,217,1000  
// The pRMS array hold 3 values : 0.1, 0.037, 0.025  
// nFreq take the value 3  
double pFreqs[1024];  
double pRMS[1024];  
WORD nFreq;  
  
// Define variables used for computation  
double* pSpectrum;  
double df;  
unsigned long i_loop;  
unsigned long j_loop;  
  
// Define the pSpectrum array  
pSpectrum = (double *)malloc((16384/2)*sizeof(double));  
  
// Compute the power spectrum  
AutoPowerSpectrum (pData, 16384, 1.0/16384.0 ,pSpectrum ,  
&df);  
for(i_loop = 0; i_loop < (16384/2); i_loop++)  
{  
    *(pSpectrum + i_loop) = sqrt(*(pSpectrum + i_loop));  
}
```

For more information or assistance in implementing this application, contact Alain Lainé, Keithley Instruments France.
Phone: 33-1-60-11-51-55. Fax: laine_alain@keithley.com

```
// Get fundamental and tone harmonics amplitudes
FundamentalAmp = 0.0;
for(i_loop=0;i_loop<nFreq;i_loop++)
{
    HarmonicMax[i_loop]=0.0;
    for(j_loop=(unsigned long)floor(pFreqs[i_loop])-
1;j_loop<(unsigned long)ceil(pFreqs[i_loop])+1;j_loop++)
    {
        HarmonicMax[i_loop] = (HarmonicMax[i_loop] >
*(pSpectrum + j_loop)) ? HarmonicMax[i_loop] : *(pSpectrum +
j_loop);
    }
    FundamentalAmp = (FundamentalAmp >
HarmonicMax[i_loop]) ? FundamentalAmp : HarmonicMax[i_loop];
}

// Compute THD
SumOfHarms=0.0;
for(i_loop=0;i_loop<(ACQ_SIZE/2);i_loop++)
{
    if(*(pSpectrum + i_loop) != FundamentalAmp)
        SumOfHarms+=((*(pSpectrum + i_loop)) * (*(pSpectrum +
i_loop)));
}
THD = sqrt(SumOfHarms) / FundamentalAmp;
```

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