ADPCM and Echo Controller on BBSP4CH

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ABSTRACT

- Full G726 (incl. G721) ADPCM Voice Coding
- Supports A-Law and μ-Law
- Echo Control Software for DECT
- >24dB Echo Cancellation for Normal DECT signal levels
- 0 - 24 dB User Programmable Echo Suppression

The Texas Instruments BBSP4CH ADPCM + Echo Controller is a flexible multi-channel full G726 32KBPS ADPCM voice coder with DECT Echo Control functions. It is programmable for use in a wide variety of DECT based PABX systems ranging from small 4 line PABX's for high street businesses right up to large multi-cell PABX's with hand-over between cells and maybe thousands of telephone lines.

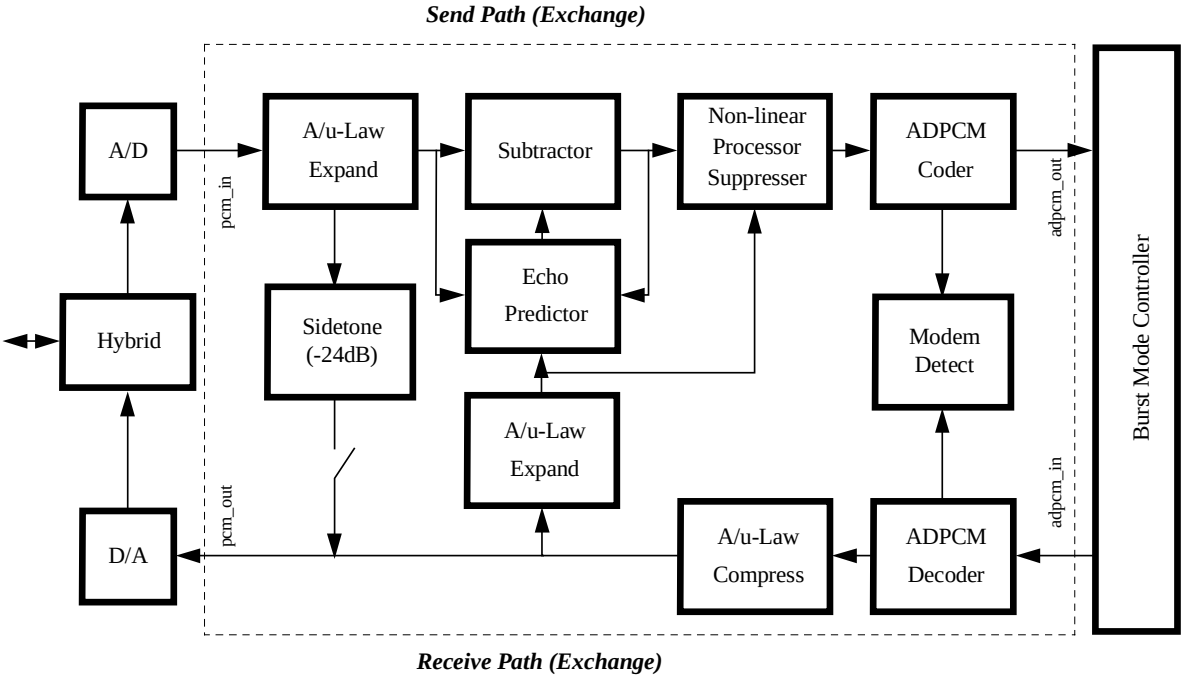

Figure 1: Block Diagram of ADPCM and Echo Control Function

1. Algorithm

1.1 Description

The Texas Instruments Echo control software on the BBSP4CH is based on the ETSI 300 175-8 transmission requirements for DECT specification.

This specification itself refers to the CCITT standard G165 and, where echo control parameters are not specified for DECT, the values in the G165 recommendation have been used.

1.2 DECT Echo Control Requirements

1.2.1 Echo Canceller

The DECT specification recommends that for the specified signal levels an overall echo reduction be made of >34dB of which >24dB must be obtained by cancellation and a further 9-12dB must be obtained by suppression. The gain plan for DECT specifies (in section 6 of ETSI 300 175-8) that the transmitted signal level of the digital line interface will be 0dBr and that this corresponds to an acoustic power level of -10dBm0. For a standard telephone hybrid the near end echo is -13±5dB, the receive path echo will therefore be at -23±5dBm0. The DECT echo canceller is required to reduce this by >24dB, the echo after echo cancellation must therefore be -47±5dBm0 depending on the characteristics of the line hybrid. All valid signal levels are cancelled by at least 28dB subject to a quantization noise floor on the cancelled output of around -60dBm0. Reduction below -60dbm0 requires the use of the Echo Suppresser. Echo Cancellation is required by DECT for echoes of 0-4ms after transmission and the BBSP4CH easily meets this requirement by cancelling echoes 0-8ms after transmission.

1.2.2 Echo Suppresser

The receive path is suppressed by the echo suppression constant 0-24dB when a speech level which is greater than the background noise is detected. The background noise is measured by an adaptive technique where the log term signal is averaged over a long period of time. This average is limited in range from -21.2 to -32.5dBm0 so signals above -21.2dBm0 are always treated as speech and signals below -32.5dBm0 are always treated as background noise. The receive path is suppressed by the echo suppression constant 0-24dB when a speech level which is greater than the measured background is transmitted, the suppression is soft switched in over 6ms (DECT requires <10ms) if the transmitted signal falls below this threshold before the end of the switch on period then suppression will be returned to zero within 30ms. Once 6ms of signal above the background average + suppresser margin has been received, suppression will continue for 70ms after the transmitted signal falls below the measured background noise, it will then soft switch out over 30ms. The echo suppression constant can be programmed to be off, 3, 6, 9, 12, 15, 18 or 24dB. Only echo suppression of off, 9 and 12dB are valid for use in a DECT system. The amount of signal above the background noise that is required to trigger the Echo Suppression is also programmable between 2.4, 3.5 and 4.5dB. This is to stop minor variations in the background noise from triggering the Echo Suppresser. The quantization noise floor of the suppresser is below -67DBm0.

1.3 Details of Texas Instruments Echo Controller

1.3.1 Signal Delay

The Echo Canceller will cancel echoes up to 8ms after the original output.

1.3.2 Group Delay

The group delay of the echo-canceller is 125µs in each direction.

1.3.3 Minimum Echo Loss

The Echo canceller requires that the minimum echo loss from R_{out} to S_{in} is 6dB. Echoes at levels greater than these are taken as a double-talk situation. Provision is made in the echo canceller to program it to compensate for gains in the PABX between the echo canceller and the hybrid of up to 12dB.

1.3.4 Echo Canceller Update

The update of the echo canceller estimator can be suppressed by the controller. If it is not suppressed by the controller, then the estimator will be updated when speech is detected on the transmit side and not on the receive side. Transmit speech is detected when the short term averaged signal level is greater than -30.5dBm0. Receive speech is detected when the averaged receive level is at a level greater then the averaged transmit level-6dB after PABX gain compensation.

1.3.5 Convergence Time

The echo canceller is designed in such a way that it will have converged onto the echo after being supplied with 500ms of white noise at suitable input levels, as specified above.

1.3.6 Artificial Echoes

Some echo-less digital systems produce artificial echoes of -24±2dBm, echoes produced by these systems will be cancelled like ordinary network echoes.

1.3.7 Residual Echo

After passing through a converged Echo Canceller the residual echo will be cancelled by more than 28dB or quantization limited to -60DBm0. Some typical performance data for the echo canceller after 125ms and 500ms of convergence with white noise is shown in the table below. (Due to spectral differences is speech signals all echo cancellers take longer to converge with real speech than with white noise, typically the convergence time is doubled.)

$_{in}$(dBm0)	$S_{in}=R_{in}$-6dB (Echo)	$S_{in}=R_{in}$-12dB (Echo)	$S_{in}=R_{in}$-18dB (Echo)	$S_{in}=R_{in}$-24dB (Echo)
0.0	**-25.8**	**-40.7**	**-42.5**	**-42.5**
-6.0	**-33.8**	**-47.2**	**-48.8**	**-49.8**
-12.0	**-42.6**	**-53.7**	**-55.1**	**-56.0**
-18.0	**-53.1**	**-59.9**	**-61.0**	**-61.2**
-24.0	**-62.1**	**-64.1**	**-63.7**	**-63.6**
-30.0	**-42.3**	**-48.4**	**-54.1**	**-59.6**

The same data produces the following performance after 500ms of convergence.

R_{in}(dBm0)	$S_{in}=R_{in}$-6dB (Echo)	$S_{in}=R_{in}$-12dB (Echo)	$S_{in}=R_{in}$-18dB (Echo)	$S_{in}=R_{in}$-24dB (Echo)
0.0	**-45.1**	**-47.2**	**-47.3**	**-47.3**
-6.0	**-51.6**	**-53.7**	**-53.9**	**-53.8**
-12.0	**-58.3**	**-59.5**	**-59.7**	**-59.5**
-18.0	**-63.1**	**-63.0**	**-62.8**	**-62.3**
-24.0	**-64.4**	**-64.1**	**-63.8**	**-63.6**
-30.0	**-54.3**	**-60.0**	**-62.2**	**-63.7**

These Figures are shown in the graphs in Figure 2 and Figure 3 below respectively for 125ms and 500ms.

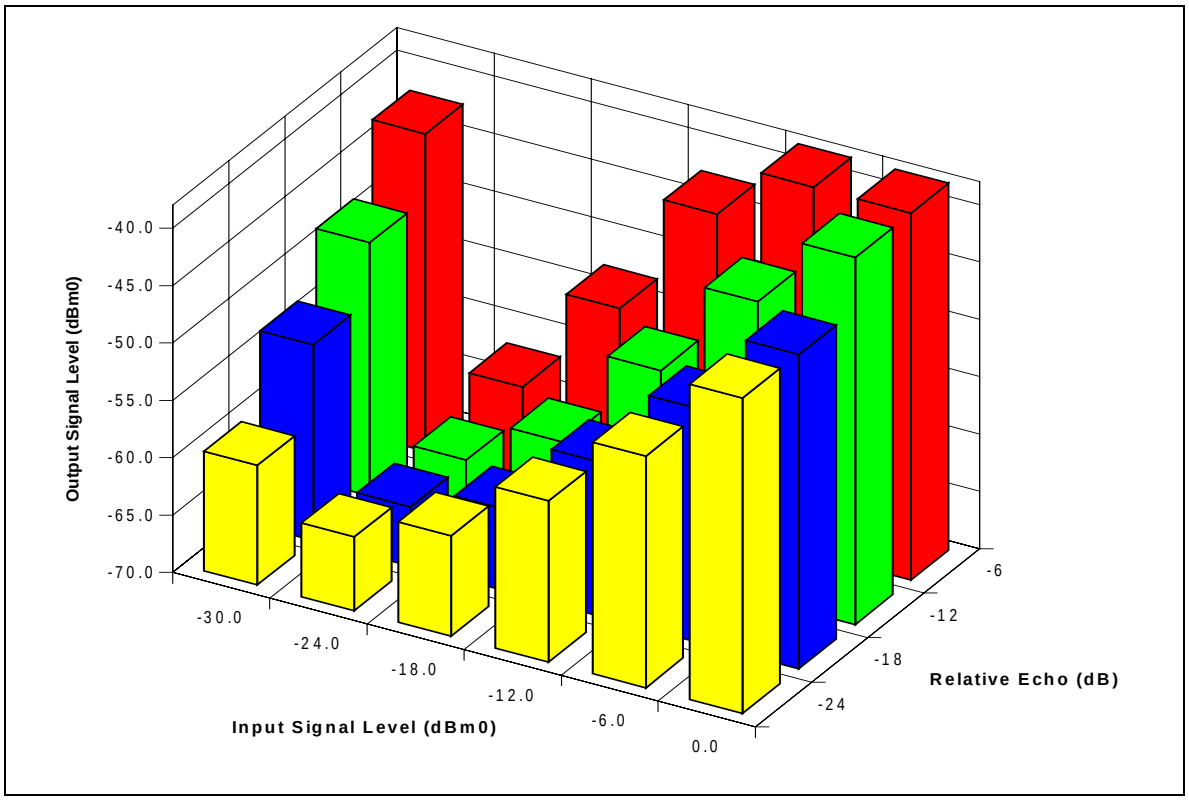

Figure 2: Residual Echo after 125ms

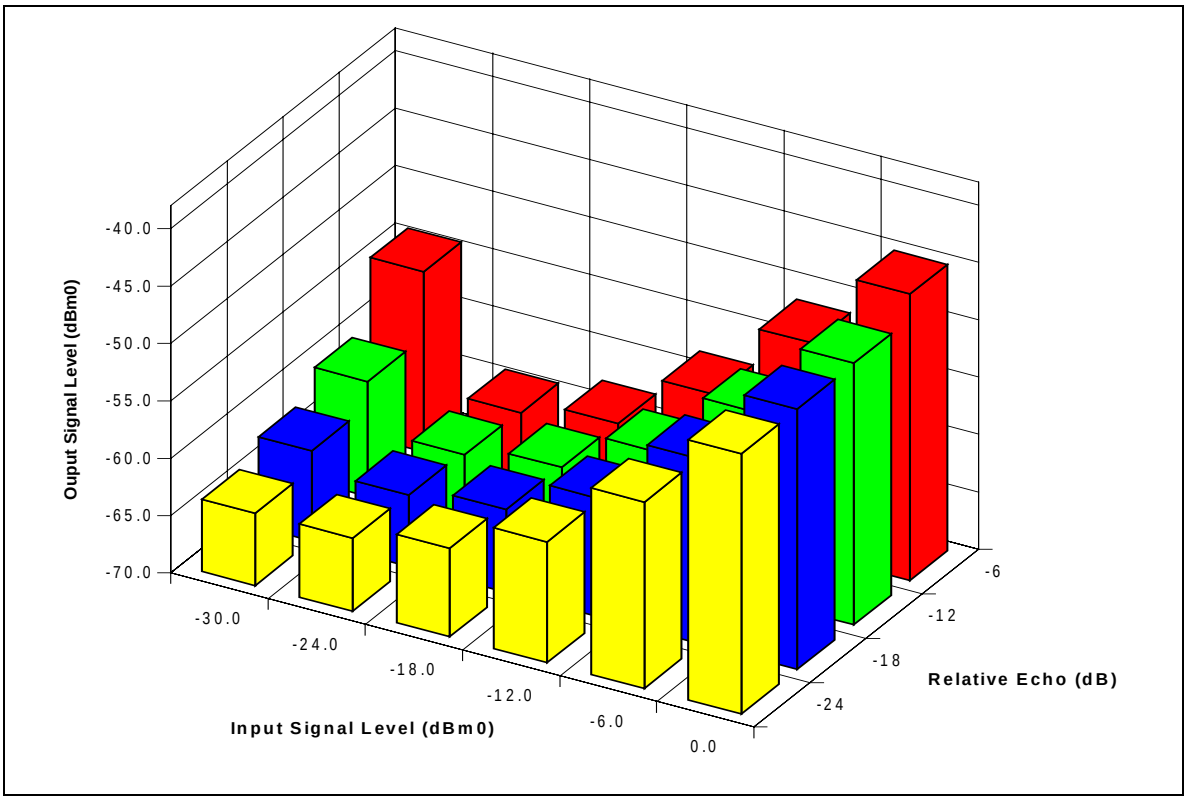

Figure 3: Residual Echo After 500ms

1.3.8 Echo Suppression

As well as echo cancellation the echo control software also contains a non-linear processor Echo Suppresser, this gives an additional echo suppression of 0,3,6,9,12,15,18 or 24dB. It is recommended that the echo suppresser is set to 9dB. The performance of the Echo Suppresser with time for a sample of speech is shown in Figure 4 below. Transmit speech is detected when the short term transmission level is more than 3.5dB (programmable) above the long term averaged transmission level (Limited between -32.5 and -21.2dB).

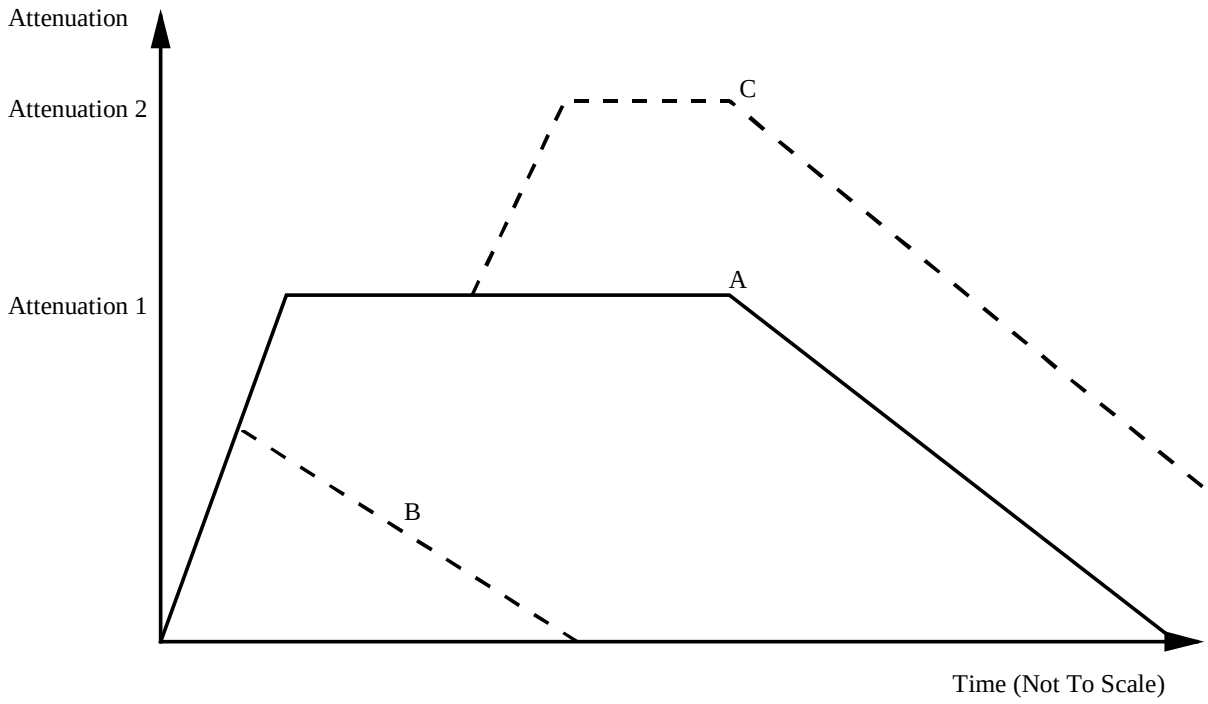

Figure 4: Echo Suppresser Performance vs. Time for a Speech Sample

2. Command Description

2.1 Settings

The BBSP4CH ADPCM + Echo Controller can be programmed for a variety of different applications. Below is a list of features, which can be programmed to customize the device for a given application:

2.1.1 Suppresser Commands

Suppresser Level
Suppresser Average
Suppresser Margin

2.1.2 Canceller Commands

Cancel Time
Dead Time
PABX Gain Adjust
Echo Canceller Mode

2.1.3 Other Channel Commands

Mute
Channel State
Sidetone
Reset Channel

2.1.4 Global Commands

Reset All
SYNCP Master
PCM Loop back
ADPCM Loop back
Direct Loop back
Loop back Off
NOP

The BBSP4CH uses "Last Look Logic" on its input commands to reduce susceptibility to noise and data resynchronizations on the telecommunications line. Commands are not executed until they have been received on 2 successive frames.

2.2 Suppresser Level

This programs the amount that the far end signal is attenuated in the echo suppresser during near end speech. It can be disabled or programmed to a variety of levels between 3dB and 24dB. Only values of 9 and 12dB may be used in a DECT application.

2.3 Suppresser Average

This programs the 1/2 time of the background noise filter, which is used to detect near end speech for the echo suppresser. The Echo Suppresser is activated when the near end signal is greater than the background average by the Suppresser Margin. the background average is limited between -21.2 and -32.5dB. Normally this value is programmed to 4Sec but in some noisy environments where the noise level is variable it may be necessary to program to a lower value so that the background noise level can be tracked.

2.4 Suppresser Margin

This programs the margin by which the near end signal must be above the measured (or limited) near end background signal for the echo suppresser to be activated. A value of 3.5dB is the default for this mode. In some quiet environments 2.4dB may be sufficient. Conversely, if operating in a noisy environment it may be beneficial to operate at the higher margin of 4.5dB.

2.5 Canceller Time

This programs the time period over which near end echoes are cancelled by the echo canceller, it can be programmed in 1ms steps from 3ms to 8ms. The echo canceller time does not start until after the Dead Time. The total of this and the Dead Time must be between 4 and 8ms. 4ms worth of echo cancellation is required by DECT though, in some large distributed networks where the “near end” may actually be at another location, a higher value may be needed.

2.6 Canceller Dead-Time

This programs the time period before which near end echoes are cancelled by the echo canceller. It can be programmed in 0.5ms steps from 0ms to 1ms. The echo canceller time does not start until after this time. This parameter allows the user to accommodate digital echo-less delays in the system between the canceller and the hybrid. The total of this and the Cancel Time must be between 4 and 8ms. If there are known to be digital delays within the PABX before the hybrid, these may be compensated for by programming the dead-time to 0.5 or 1.0ms. In this period samples are delayed without cancellation as there can be no echo in the time delay of the digital signal before the hybrid.

2.7 Canceller PABX Gain Adjust

Normally the echo canceller expects there to be at least a 6dB loss in the hybrid, however with digital gains between the echo canceller and the hybrid this may not be the case; any gains can be compensated for by programming this value to 6 or 12dB gain adjust. If, after adjustment, the echo is greater than -6dB, the canceller will falsely detect a double talk situation during near end speech.

2.8 Canceller Mode

This allows the echo canceller to be programmed into 1 of 3 states:

1) Enabled: The echo canceller updates its coefficients and cancels the echo. This mode should be used with 2 wire analogue lines.
2) Frozen: The echo canceller cancels the echo with the stored coefficients without updating them. This mode should not be used until the echo canceller has stabilized onto the line characteristics.
3) Disabled: The echo canceller does not cancel the echo or update the stored coefficients. This mode should be used with digital or 4 wire analogue "echo-less" lines.

2.9 Mute

To allow for muting of the receive channel during burst error on the DECT receive path each individual channel may be muted by forcing the ADPCM input value. Mute may be disabled or the input may be forced to F or 0. These values correspond to + and - zero in ADPCM. ADPCM itself uses F for zero and it is therefore recommended that this value is used for muting the receive channel. Typically the mute would be controlled by the radio receiver, which would mute the ADPCM input value during periods of signal drop-out over the radio to prevent the user from hearing “squawks” and other irritating noise when the received signal falls below the background noise level.

2.10 Power Down

When a channel is powered down, the output data for that channel is not written to the output port so any data that was input in those slots in the previous frame will be output in the following frame. Power down mode and direct loop back mode are actually the same state.

2.11 Sidetone

This allows the device to be programmed to provide the far end with an artificial echo to cancel when connected via a 4 wire analogue or digital connection to the main exchange.

2.12 Modem Answer Tone Detection

This allows the device to automatically detect the 2100Hz modem answer tones transmitted from either end and disable internal echo control so that the DECT and

Modem Echo cancellers do not fight each other. The device may be programmed to either detect and disable or detect and ignore these signals, the default is to detect and ignore (for compatibility with older SW releases).

2.13 Reset Channel (A or µ-Law)

This allows an individual channel to be reset to the default configuration. All channels can be reset simultaneously with the Reset All command. Two versions of this command are provided one for A-Law and one for µ-Law.

2.14 Reset All Channels (A or µ-Law)

This command performs a software reset of all channels on the chip. Individual channels can also be reset with the Reset Channel command. Two versions of this command are provided; one for A-Law and one for µ-Law. At hardware reset all channels are reset to A-Law.

2.15 SYNCP Master/Slave

Sending the master version of this command to the BBSP4CH puts it in the mode where it generates SYNCP markers. Sending the slave version puts it in the mode where it repeats the frame synchronization markers.

2.16 PCM Loop Back

This command puts all 4 channels into the PCM loop back mode. All 4 channels are looped back in both directions at the PCM software I/O point; input PCM values are output directly on the same slot in the following frame, input ADPCM values are decoded and recoded before being output on the following frame.

All channels can be removed from this mode with the Loop back Off command or channels can be individually reset or powered down with the Reset Channel and Channel State commands respectively.

2.17 ADPCM Loop Back

This command puts all 4 channels into the ADPCM loop back mode. All 4 channels are looped back in both directions at the ADPCM software I/O point; input PCM values are coded and then decoded and output on the same slot in the following frame, input ADPCM values are output directly on the following frame.

All channels can be removed from this mode with the Loop back Off command or channels can be individually reset or powered down with the Reset Channel and Channel State commands respectively.

2.18 Direct Loop Back

This command puts all 4 channels into the direct loop back mode in which all channels are powered down. No data is written by the core to the output slots in this mode, so all values are re-output on the following frame unmodified.

All channels can be removed from this mode with the Loop back Off command or channels can be individually reset or powered down with the Reset Channel and Channel State commands respectively.

2.19 Loop Back Off

This command removes all channels from any of the loop back modes and powers up all channels.

2.20 NOP

No Change in Operation; this command can be sent to the BBSP4CH when there is no need for any changes to the device. All unused op-codes are guaranteed not to damage the device though some are used by Texas Instruments for test purposes and may affect output values. These other codes may also be used in future versions of the device and control software should not use them.

3. Examples

An example of an application using the BBSP4CH along with other Texas Instruments DECT components is shown in Figure 5 below. This application consists of a BBSP4CH on a PABX supporting a wide variety of phones from DECT hand-set to wire lines, with both ISDN and analogue hybrid connections to external exchanges. The BBSP4CH connects to the exchange along with a multi-channel DECT time switch controller, conversations between DECT hand-sets or between DECT hand-sets and ADPCM lines may be switched directly by the time switch controller and/or PABX while the BBSP4CH is used to connect up to 4 hand-sets to traditional analogue phones, ISDN phones or varieties of non ADPCM external lines.

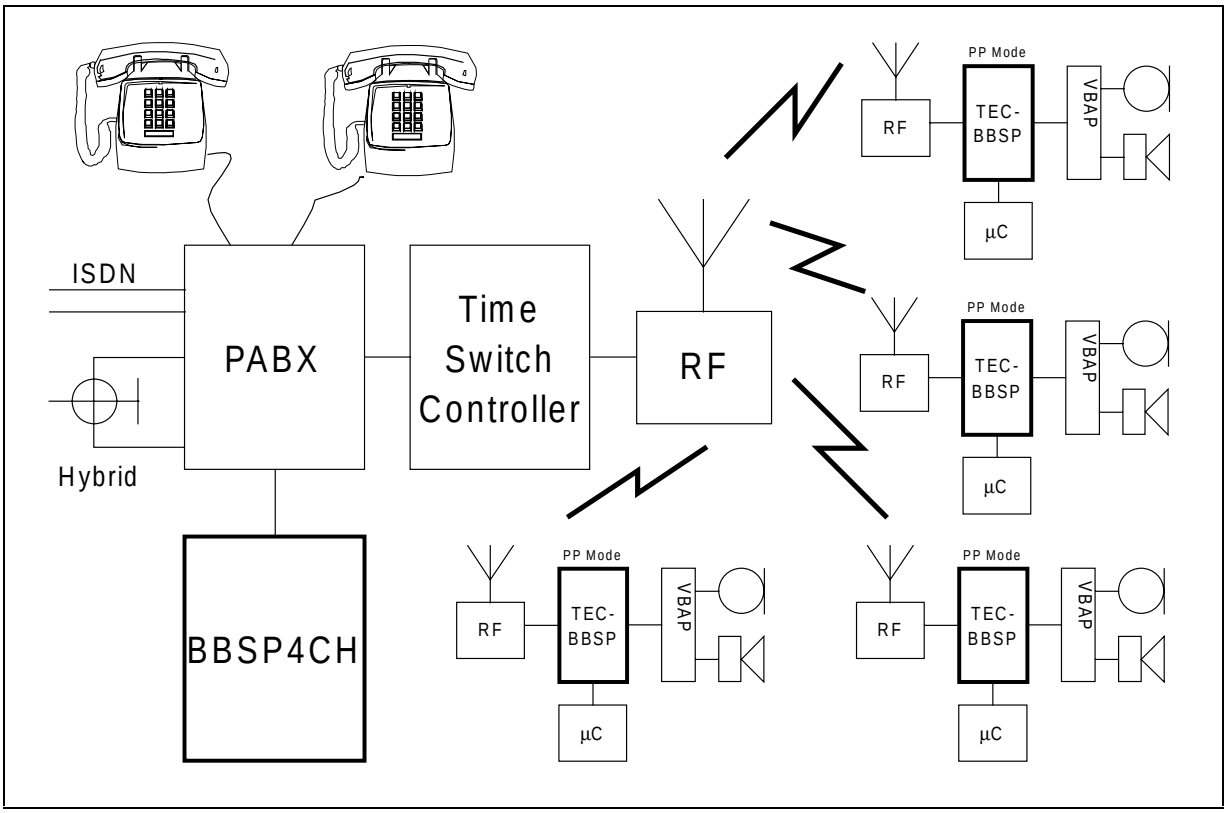

Figure 5: Example BBSP4CH Application

3.1 Small Stand Alone DECT PABX with Digital Connections

This application will typically be an ISDN or other digital linked telephone line such as is found in small offices like Estate Agencies and Solicitors The total number of input lines is less than one DECT channel's worth. As there is no hybrid at the near end there is no need to perform echo cancellation and a simple echo suppresser is all that is required. Switching is performed using the Time Slot Controller.

3.1.1 Suppresser Commands

Suppresser Level	9dB
Suppresser Average	4Sec
Suppresser Margin	3.5dB

3.1.2 Canceller Commands

Cancel Time	4ms
Dead Time	0ms
PABX Gain Adjust	0dB
Echo Canceller Mode	Disabled

3.2 Small Stand Alone DECT PABX with Analogue Connections

This application is similar to the one above except that in this case connection is by means of standard analogue telephone lines instead of by digital ISDN lines. As there is a 2 wire hybrid in the base station it is now necessary to perform echo cancellation.

3.2.1 Suppresser Commands

Suppresser Level	9dB
Suppresser Average	4Sec
Suppresser Margin	3.5dB

3.2.2 Canceller Commands

Cancel Time	4ms
Dead Time	0ms
PABX Gain Adjust	0dB
Echo Canceller Mode	Enabled

3.3 Small Digitally Networked DECT PABX's

This is the situation were a multiple outlet such as a bank has a large number of small PABX's distributed throughout a large geographical area but all of these PABX's are networked together with leased digital lines from a network provider. In this situation there is no echo cancellation from the network and so the far end echo needs to be cancelled by the near end echo canceller; hence there is a need for a longer echo cancellation. The exact delay is unknown as communication can be between branches at various distances apart so the canceller has to cope with both short and long delays.

3.3.1 Suppresser Commands

Suppresser Level	9dB
Suppresser Average	4Sec
Suppresser Margin	3.5dB

3.3.2 Canceller Commands

Cancel Time	8ms
Dead Time	0ms
PABX Gain Adjust	0dB
Echo Canceller Mode	Disabled

3.4 Large PABX with Digital Connections

This application is similar to the first application for the small PABX except that there are now too many lines for switching in the Time Slot Controller or there are now multiple cells with hand-overs between Time Slot Controllers; so switching is now performed on the PCM data between the Echo Canceller and the hybrid. To allow for the delays in the switching elements the Dead Time is now programmed to 1ms.

3.4.1 Suppresser Commands

Suppresser Level	9dB
Suppresser Average	4Sec
Suppresser Margin	3.5dB

3.4.2 Canceller Commands

Cancel Time	4ms
Dead Time	1ms
PABX Gain Adjust	0dB
Echo Canceller Mode	Disabled

3.5 Large PABX with Analogue Connections

Like its counterpart for the small PABX, the large PABX may also need to be connected to the main telephone network using analogue lines, in which case it is necessary to cancel the echo on the 2 wire interface between the PABX and the main exchange.

3.5.1 Suppresser Commands

Suppresser Level	9dB
Suppresser Average	4Sec
Suppresser Margin	3.5dB

3.5.2 Canceller Commands

Cancel Time	4ms
Dead Time	1ms
PABX Gain Adjust	0dB (Depends on levels for countries analogue network)
Echo Canceller Mode	Enabled

3.6 Large Digitally Networked PABX's

This is the head office version of the small Networked PABX's described above, the basic parameters are the same except that, again, there is hand-over between cells and/or large numbers of lines leading to switching delays in the PCM data path.

3.6.1 Suppresser Commands

Suppresser Level	9dB
Suppresser Average	4Sec
Suppresser Margin	3.5dB

3.6.2 Canceller Commands

Cancel Time	7ms
Dead Time	1ms
PABX Gain Adjust	0dB
Echo Canceller Mode	Disabled

4. Other Products

Texas Instruments produce a range of solutions for supporting DECT applications other solutions and products include:

4.1 Available/Sampling

8 Channel ADPCM vocoder without Echo Control
Burst Mode Controllers for DECT Hand-sets
Time Switch Controllers for DECT Base Stations
5V Single Rail Combos for A/D/A functions

4.2 Soon

TEC-BBSP based ADPCM coders with Burst Mode Controllers or Echo Cancellers
3V Single Rail Combos for A/D/A functions.