CALL PROGRESS DETECTOR
Data Sheet

The Data contained in the document is preliminary and is subject to change.

Summary

Call Progress (CP) tones are different in most country. Currently, there is no standard that covers CP tone detection since they are designed for human recognition. This algorithm detects tones derived from the standard North American set of tones (350, 440, 480, 620 Hz) and 400 Hz tone. The tones may come in a pair (any with any) or as a single tone.

CP detector (CPD) only reports the onset and removal of a tone. The analysis of timing (if required) shall be responsibility of a higher-level application due to uncontrollable variability of those parameters from country to country.

- Low MIPS: TDB on C55x, 0.6 MIPS on C54x.
- Designed as a telecom system component rather than a stand-alone algorithm.
- Can be configured on the fly, and such parameters as twists, maximal frequency deviation, spectrum cleanness, and signal duration thresholds can be altered during a call. The granularity of each parameter is about 0.25 dB (and 0.5 Hz for frequency acceptance margins).
- Provides estimates on the frequency and energy for detected tones, which ease the identification of the PSTN interfacing problems for the given country / administration / LEC.
  - typical error of frequency estimation is 0.2 Hz RMS
  - typical error of energy estimation is 1 dB RMS
- Wide dynamic range: down to –40 dBm for typical setting, wider in special configurations.
- High noise immunity:
  - 15 dB AWGN SNR for a typical configuration setting,
  - 5 dB AWGN SNR with a special configuration.
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The CP detector design provides for extendibility when and if required by Licensee.

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1 Theory of operations

The proposed "Express DSP" compliant C55x /C54x CP detector is based on multi-rate signal processing and modern complex domain applied spectral analysis methods and approaches. Frequency content analysis is optimized for short signals, and it provides reliable results. It takes advantage of C55x architecture with high degree of parallelism, dual MAC, and three simultaneous data read paths.

The frame size of 5 ms is too low for CP tone detection because of their close spacing. Thus MIPS figure can be lowered if several instances are running simultaneously. The feature will be implemented in a subsequent release.

The further details are beyond the scope of this document.

2 API

2.1 Data structures

2.1.1 Data base

Database is an object that keeps data, which should be preserved between calls to process incoming data. It should be properly initialized and shall not be overwritten by any other application. It may be moved into another location without limitations. The 'best' placement for database is internal DARAM, but performance shall not suffer drastically even if the database is placed in external RAM. If any performance problem arises, the object may be copied via DMA (in and out) into a temporary location in internal RAM.

Database size:

- 182 Words (16 bit), long word (32 bit) alignment

The content and meaning of particular fields of the database are undisclosed in this document.

2.1.2 Scratch pad

Scratch pad is an object that is used during calls to process incoming data. It does not need to be initialized. It may be overwritten by any other application. It may reside in a new place each time a processing function is called: i.e. it may be moved into another location without limitations. The 'best' placement for database is internal DARAM. Performance will suffer drastically even if the database is placed in internal SARAM.

Scratch pad size:

- 368 Words, long word alignment

The content and meaning of particular fields of the scratch pad are undisclosed in this document.

2.1.3 Configuration

Configuration is an object, which contain important decision making parameters and it is referenced each time an input processing functions is called. The data there is READ-ONLY by CPD functions. Many instances of CP detector may refer to the same instance of configuration data. The configuration data may be altered by external application on the fly. It is preferable that no associated CP detector is active (processes a valid CP signal) at the time of change.

Note that `Int` is defined in TI's supplied `ialg.h` file as 16 bit signed word.

```
typedef struct ICPD_tCfg {
    Int sNormShift;
    Int sNoiseThr;
    Int sMinEnThr;
    Int sStableThr;
    Int sTwistThr;
    Int sCleanThr;
    Int sMaxFreqDevThr;
    Int sMinToneDuration;
    Int sMinEndDuration;
    Int sAbortTimeout;
} ICPD_tCfg;
```

All relevant parameters are expressed in dB, scaled up with a coefficient, so that 3.0103 dB corresponds to 512. Thus 1 dB will correspond to approximately 170.083 ~ 170 = ICPD_1DB. The same definition is applied to Frequency deviation, but here 1% of frequency deviation corresponds to 170.083 (the same value).

The fields of configuration have the following meaning:

Parameter	Description	Recommended Range
NormShift	'Normalization': number of left shifts to align data so that 0dbm0 corresponds to 2048 DC. If right shifts are required, use negative values	0
NoiseThr	Maximum frame energy of background noise relative to signal level. '	6…15 dB
MinEnThr	Minimum frame energy to count a frame as valid.	-35…–25 dBm
StableThr	Amount that the current frame energy for either low frequency or high frequency is allowed to differ from its average value.	1…3 dB
TwistThr	Difference in energy between tones in a dual CP tone. This value has approximately 0.5dB of headroom, but allow for more headroom in very noisy conditions.	3…5 dB
CleanThr	Amount that the energy of maximum components in the band can be higher than any other components. Values above 40 dB are invalid.	25…35 dB
MaxFreqDevThr	Maximum allowed deviation of an instantaneous frame frequency from the standardized value. It is calculated as: -10*log10(sin(2*pi*F*dlt/400)); where F = max of all frequencies (620 Hz); dlt = max allowed freq offset (0.005 for 0.5%); pi = 3.14159265..., 15 dB corresponds to 5 Hz	10…15 dB
MinToneDuration	Number of good frames before START event is sent. The mapping to tone duration (approximate): duration ~ sMinToneDuration*5 + 25ms.	2…10 (10…50 ms)
MinEndDuration	Number of silent frames before END event is sent.	3…6 (15…30 ms)
AbortTimeout	Number of 5 ms frames in which a signal is to be ignored if a faulty tone occurs.	3…6 (15…30 ms)

2.1.4 CP signal measurements

CP detector provides following statistics of the incoming signal:

Parameter	Description	Precision
LoEn	Average energy of the lowest frequency component in the pair, or of the single tone.	~1 dB
HiEn	Average energy of the highest frequency component in the pair, or it shall be ignored for the single tone case.	~1 dB
LoFreqDev	Average deviation of the frequency from the standard values, in Hz.	~0.2Hz
HiFreqDev	Average deviation of the frequency from the standard values, in Hz.	~0.2Hz

The CP detector keeps this data until next tone is about to be detected. If required, the user can retrieve this data beforehand. The data may be used to identify faulty equipment and adjust thresholds.

Data precision depends on noise and tone duration. If used in low-noise conditions with long digits (in excess of 200 ms), the energies are correct with precision of 0.5 dB. The numbers provided in the above table are for a case of AWGN 15dB SNR, 50 ms digits, and a frequency deviation of less than 2%.

The signal measurements are reported within ICPD_Status structure:

```
typedef struct ICPD_Status {
    Int size;           /* sizeof the whole parameter struct */
    ICPD_tCfg *pCfg;   /* in: ptr to cfg to update.*/
                        /* used if and only if CMD_CFG indicated */
    Int sLoEn;          /* out: statistics */
    Int sHiEn;
    Int sLoFreqDev;
```

```
    Int sHiFreqDev;
} ICPD_Status;
```

2.2 IALG API

XDAIS compliant IALG interface is fully supported.

2.3 Vendor specific API

2.3.1 Initialization

```
extern void CPD_MIKET_init_db (void *pDb, ICPD_tCfg *pCfg);
```

pDb shall refer to the user-allocated properly aligned memory block.
PCfg shall refer to a valid configuration structure.

2.3.2 Control

```
extern void CPD_MIKET_control
(void *pDb, Int Cmd, ICPD_Status *pStatus );
```

Cmd can constructed by OR-ed flags:

```
#define ICPD_CMD_OFF      (1)       // disable detector from running.
                                    // function CPD_process will return almost immediately.
#define ICPD_CMD_RESET    (2)       // reset database variables, data saving buffers, statistics, etc.
                                    // preserves pointer to configuration data.
                                    // If RESET is not or-ed with OFF, the detector starts running.
#define ICPD_CMD_CFG   (4)          // update pointer to configuration data to be used.
                                    // pCfg in pStatus can point to the same configuration data
                                    // for any number of CPD detector instances.
#define ICPD_CMD_GET_STTS  (8)      // request statistics structure to be filled
```

It is not recommended to apply OFF without RESET due to the obvious consequences of calling _control(pDb, 0); afterwards.

Asynchronous calling _control() and _process() from different tasks is not recommended.

All other flags will be ignored.

2.3.3 Process

```
extern Int CPD_MIKET_process(void *pDb, void *pSc, Int *pIn);
```

Returns report word: MSByte as event and LSByte as tone ID.

Event	Value	Meaning
ICPD_EV_NONE	0	No changes happened this frame
ICPD_EV_START	(3<<8)	The tone was OK for prescribed MinToneDuration. That's a tone for sure, we can say now.
ICPD_EV_END	(4<<8)	The tone is over now. Clean and clear finish. The tone was followed by a relative 'silence' with the power level less than

		the threshold
ICPD_EV_ABORT	(5<<8)	Something is wrong with this tone. It started Ok, went on ok for several frames, but something went wrong afterwards. As the result, it did not end properly

Normally, user shall get a sequence of
- EV_START,
- EV_END.

LSByte of Report: Tone Id is constructed as a bit mask, where
- bit 0 corresponds to 350 Hz
- bit 1 corresponds to 400 Hz
- bit 2 corresponds to 440 Hz
- bit 3 corresponds to 480 Hz
- bit 4 corresponds to 620 Hz

Note that:
- pDb must point to initialized database.
- pSc must point to scratch pad. pSc shall point to DARAM if max speed is required, otherwise MIPS will nearly double.
- pIn shall point to a frame (40 samples) of continuous, LSB aligned data.
- If CPD is turned off, then pSc and pIn can point anywhere.

3 Specifications

3.1 General

Parameter	C54x version	C55x version
MIPS / Instance	0.6 MIPS	TBD MHz
Algorithm Memory (DARAM & SARAM), words	1.9 kW	TBD kW
Instance Memory (SARAM), words	182 W	182 W

3.2 Performance characterization

There may be no warranty given that it will operate perfectly under all and any life circumstances. Note that CP detector operates with real-world data, it can be ‘close to perfect’, but it cannot ever possibly be absolutely perfect.

Note that the performance of CP detector fully depends on the configuration parameter settings. If those are set inappropriate, the performance will be degraded or even CP detector may become dysfunctional. Ensure that a user understands the meaning of parameters and consequences of wrong settings before any changes applied.

There are numberless variations of test conditions, and only some of them may be of particular interest to a Licensee. The demo program provided is a bit-exact simulation of CP detector. It may be used to characterize the performance of CP detector in conditions of particular interest, if different from test cases provided.

3.2.1 Default configuration

The following table shows the default CP detector’s settings.

Parameter	Value
TwistThr	4.0 dB
NormShift	-3
MinEnThr	-25.0 dBm
NoiseThr	15 dB
StableThr	3.0 dB
CleanThr	30 dB
MaxFreqDevThr	5 Hz
MinToneDuration	15
MinEndDuration	2
AbortTimeout	4

3.2.2 Noise immunity test

All possible combinations of tones, both single and dual, were cycled through a bit-exact simulation with AWGN. For each tone, each frequency was varied from –9 to +9 Hz off the nominal. For each frequency deviation, the tone was repeated 100 times.

The level of CP tones was set at –16 dBm. The tone duration was set to 195 ms. The silence between tones was set to 140ms.

The 3 curves on the figures below reflect the maximum, average and minimum acceptance ratio.

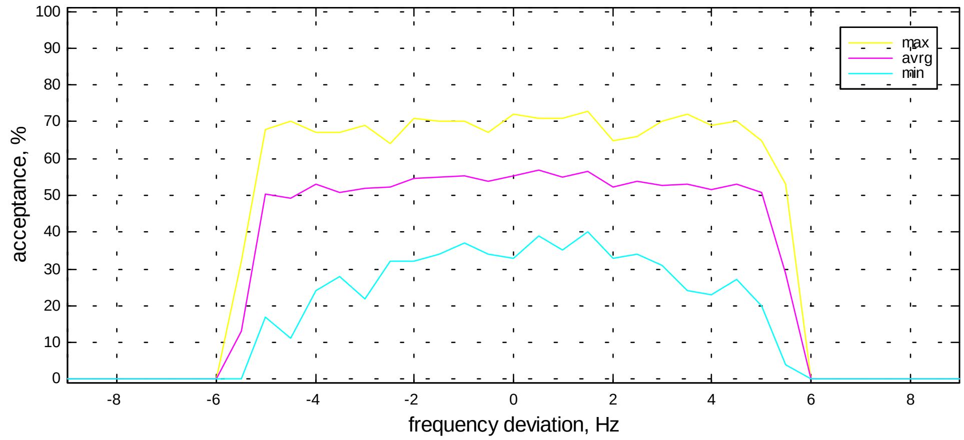

Figure 3.1. Acceptance curves for AWGN SNR of 10 dB.

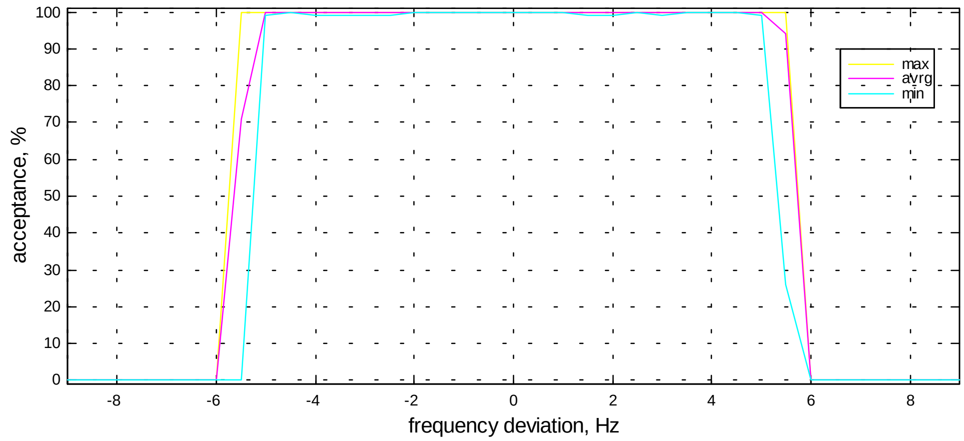

Figure 3.2 Acceptance curves for AWGN SNR of 15 dB.

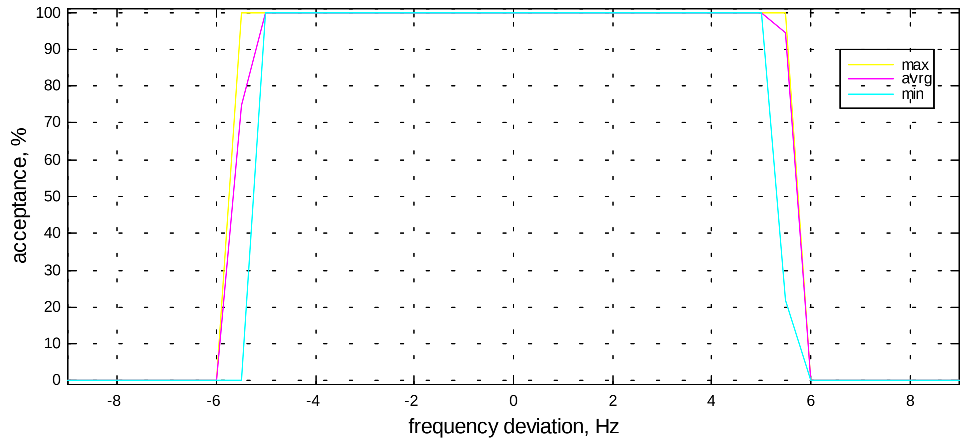

Figure 3.3 Acceptance curves for AWGN SNR of 20 dB.

3.2.3 Twist sensitivity test

The results are essentially the same for all dual tones. The SNR for this case is 25 dB.

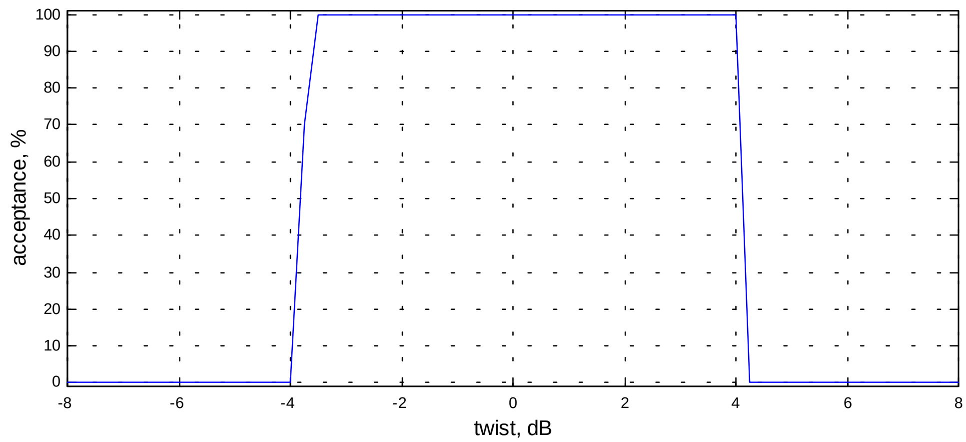

Figure 3.4. The acceptance curve for twist (low frequency level relative to higher frequency level) variations.

3.2.4 Minimum energy sensitivity test.

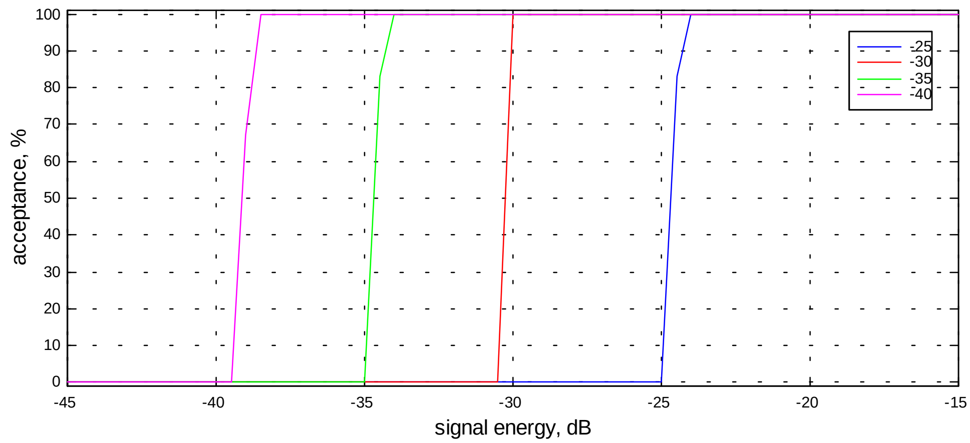

Figure 3.5. The acceptance curves for different pCfg->sMinEnThr settings.

The minimal energy the CPD works with is –39 dBm for the given pCfg->sShift (=-3).

3.2.5 Frequency deviation measurement error

The AWGN SNR was set to 20 dB for this test. For each frequency, $\sigma \approx 0.07$ Hz, bias is less than 0.06 Hz.

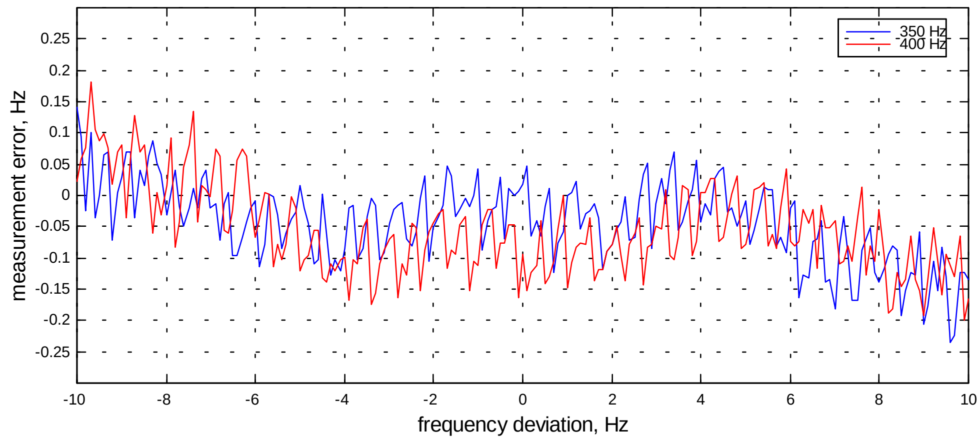

Figure 3.6. The error of frequency measurement for some of the tones.

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