Technical Documentation

ES 1.x - API definition

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Important Notice

IMPORTANT NOTICE

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Notes

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Glossary

ES	Echo Suppressor/Suppression
AEC	Acoustic Echo Canceller/Cancellation
TCS	TI's Chipset Solution
DL	Downlink
UL	Uplink
VAD	Voice Activity Detector/Detection
TCL	Terminal Coupling Loss
CNG	Comfort Noise Generator
NFS/NFA	Noise Floor Saturation/Adjustment
CL	Coupling Loss
ABB	Analogical Base Band
PGA	Programmable Gain Amplifier

References

[1] ITU-T Recommendation P340, “Transmission Characteristics and Speech Quality Parameters of Hands-free Terminals”, May 2000.
[2] TI Technical Documentation L1D_AS260, “Echo Suppressor – Overview”

1 Introduction

The purpose of this document is to describe the Application Protocol Interface (API) related to the Echo Suppressor (ES) module. This document applies to ES 1.21 and next releases ES 1.x. A first chapter is dedicated to the ES module overview. A second chapter presents the module API with an explanation of the ES configuration and control parameters. In appendices, some predefined and custom configurations of the ES are proposed in full-duplex (handset mode), partial-duplex (handset/handsfree modes) and half-duplex (handsfree mode) according to the ETSI specification [1](Chap. 8).

2 ES Module overview

The ES suppressor role is to eliminate the residual echo in a speakerphone application, where the Acoustic Echo Canceller (AEC) is unable to cancel the entire echo in the uplink due to non-ideal acoustical environment such as a non-linear loudspeaker response for example (Figure 2.1).

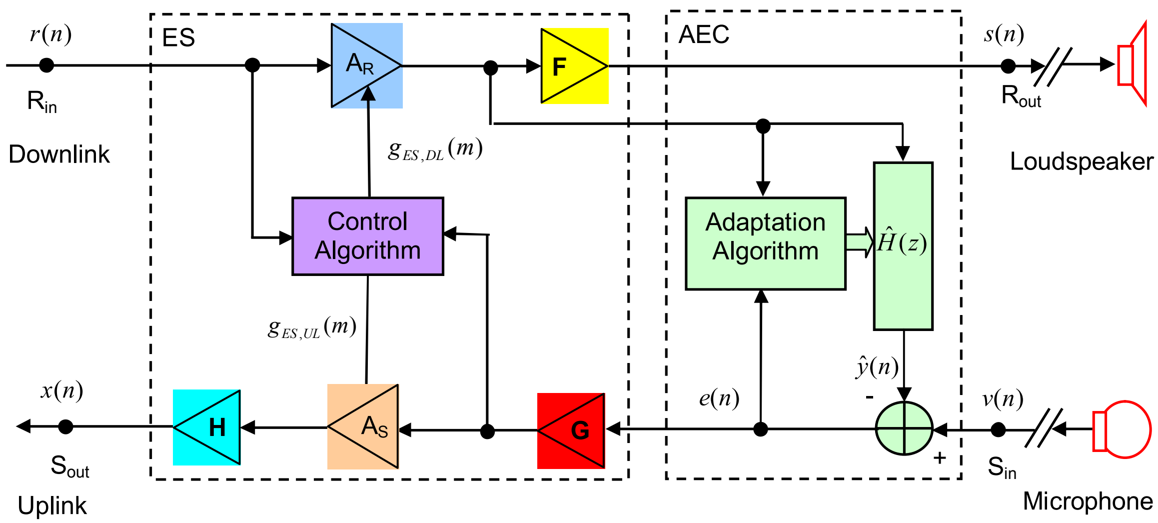

Figure 2.1 The Conventional AEC/ES + Digital Gains Block Diagram

The ES applies variable attenuations in the downlink (A_R) as well as in the uplink (A_s). In the downlink (DL), A_R attenuates the loud signals and so reduces the non-linearity in the loudspeaker while in the uplink (UL), A_s attenuates the residual echo in the AEC output. A_R and A_s are time varying in relation with the communication status: Idle (1), double-talk (2), far-end (3) and near-end (4) as defined below (Table 2.1):

ES State	Communication Status	
	Far-End	Near-End
1 - Idle	Inactive	Inactive
2 - Double-talk	Active	Active
3 - Far-end	Active	Inactive
4 - Near-end	Inactive	Active

Table 2.1 The ES and Communication Status

The ES control algorithm has a state estimator inside which decides from frame to frame (20ms) the current status of the communication. Function to the ES states, a predefined attenuation is applied in the downlink (A_R) and in the uplink (A_s) from vectors through the ES configuration area in the API (3.2.1).

The ES module is designed to be compliant with the ESTI P340 specification [1](Chap. 8) defining handsfree terminal behaviors according to the attenuations to provide in the receiving (A_R) and in the sending (A_S) directions. Those attenuations are conditioning the communication modes (full-duplex, partial-duplex and half-duplex). The dependency between the communication modes the terminal behaviors are presented below (Figure 2.2).

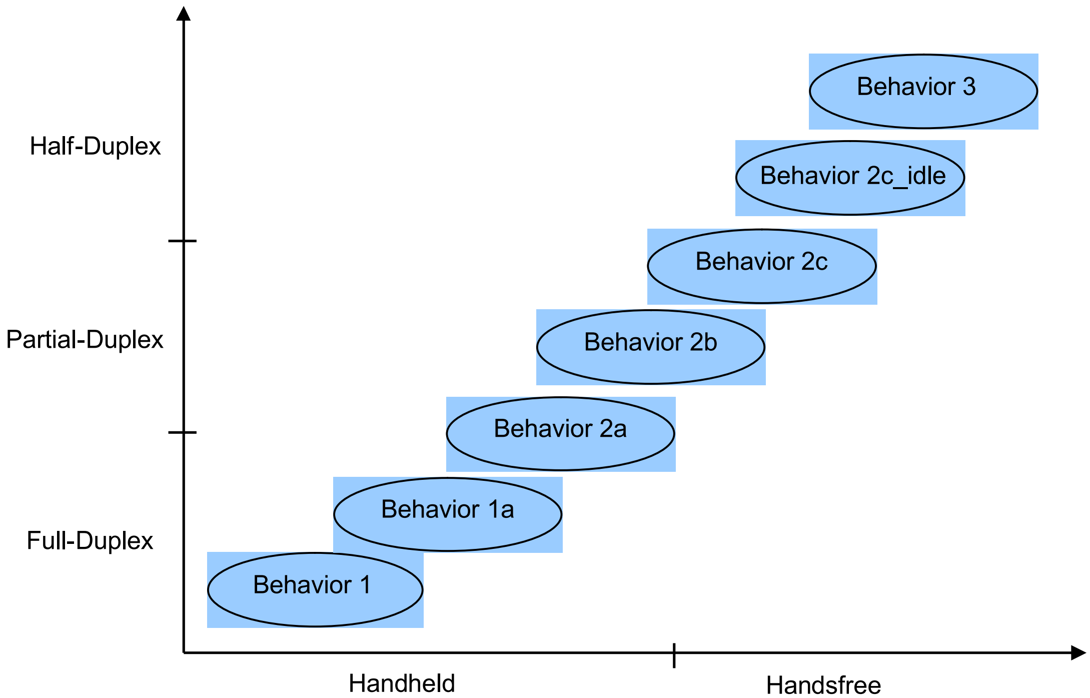

Figure 2.2 The Communication Modes and ES Behavior Dependency

The ES is enabled and disabled through the control area in the API (3.2.2). In case of noisy environment in the near end side, the ES can be enabled with either a Comfort Noise Generator (CNG) or a Noise Floor Saturation/Adjustment (NSF/NFA) options in the aim to avoid the noise frame chopping effect the uplink. The ES control also allows the deactivation of (A_R) and (A_S) independently.

A summary of the ES API is available in (A. Appendix) of the present document. The ES configuration values for the predefined behaviors (1, 1a, …, 3) are listed in (B. Appendix) of the present document. It is recommended to use the predefined configurations for 0dB $\leq$ Coupling Loss (CL).

To help the AEC/ES system to deal with negative coupling loss -24dB < CL < 0dB for loud echo environment, ES allows to apply a digital gain in the downlink (F) and in the uplink (G and H) (Figure 2.1). The digital gains can be enabled through the ES configuration area in the API (3.2.1) in a custom behavior (C. Appendix).

3 ES Module API Description

This chapter describes the parameter interface of the ES module.

3.1 Module Entry Functions

3.1.1 Function f_es_top ()

Prototype:

```
void     f_es_top (T_ES_STATIC_VAR *p_es_data);
```

Description: This ES top level function contains the call of all signal processing functions necessary to perform the ES algorithm. Note this function is used to process the echo suppression on both side (DL and UL). The function parameters are presented below (Table 3.1).

Parameters:

Type	Name	Flow	Description
T_ES_STATIC_VAR	*p_es_data	IN/OUT	Pointer on the ES module static variables

Table 3.1 The ES Top Function Parameters

The *p_es_data structure pointer parameter is used to pass the static variables to the ES top function as well as through the internal signal processing functions. In addition, the ES parameters are passed to the module through a data structure pointer *p_es_param element of *p_es_data.

The d_es_mode parameter element of the structure pointed by *p_es_param is used to pass the functioning mode of the ES module to the top function.

Requirements: The entire signal processing functions code must be mapped on a single DSP page as it does not support extended addressing.

Reentrancy: This API is reentrant.

Return value: None.

3.1.2 Function f_es_init ()

Prototype:

```
void     f_es_init (_ES_STATIC_VAR *p_es_data);
```

Description: This function is used to initialize the ES module. The function parameters are presented below (Table 3.2)

Parameters:

Type	Name	Flow	Description
T_ES_STATIC_VAR	*p_es_data	IN/OUT	Pointer on the ES module static variables

Table 3.2 The ES Initialization Function Parameters

Requirements: The init function code must be mapped on a single DSP page as it does not support extended addressing.

Reentrancy: This API is reentrant.

Return value: None.

3.2 Module Interface

This chapter focuses on the API for ES module on ***Calypso+/Perseus2*** chipset. This area is divided into three parts:

- Configuration area;
- Control area;
- Status area.

3.2.1 ES Configuration Area

The DSP uses the T_ES_PARAM *p_es_param data structure pointer to configure the ES module. *p_es_param is an element of *p_es_data. The data structure is made up by the elements presented below (Table 3.3). Parameters colors are related to the ES block diagram in Appendix A.

&	Type	Parameter Name	Description
+0	T_SINT16	d_es_mode	ES enable/disable and selection CNG, ALS/NSFoptions
+1	T_SINT16	d_es_gain_dl	Digital gain DL to Rout [-66dB; +24dB]
+2	T_SINT16	d_es_gain_ul_1	Digital gain UL from Sin [-66dB; +24dB]
+3	T_SINT16	d_es_gain_ul_2	Digital gain UL to Sout [-66dB; +24dB]
+4	T_SINT16	d_es_tcl_fe_ls_thr	TCL reference threshold in FE mode for loud signal
+5	T_SINT16	d_es_tcl_dt_ls_thr	TCL reference threshold in DT mode for loud signal
+6	T_SINT16	d_es_tcl_fe_ns_thr	TCL reference threshold in FE mode for nominal signal
+7	T_SINT16	d_es_tcl_dt_ns_thr	TCL reference threshold in DT mode for nominal signal
+8	T_SINT16	d_es_tcl_ne_thr	TCL reference threshold in NE mode
+9	T_SINT16	d_es_ref_ls_pwr	Reference power for loud signals in DL
+10	T_SINT16	d_es_switching_time	Switching time index
+11	T_SINT16	d_es_switching_time_dt	Switching time index in DT mode
+12	T_SINT16	d_es_hang_time	Hangover time index
+13	T_SINT16	a_es_gain_lin_dl_vect[0]	Downlink linear attenuation (A_R) per state (1 - Idle)
+14	T_SINT16	a_es_gain_lin_dl_vect[1]	Downlink linear attenuation (A_R) per state (2- Double-talk)
+15	T_SINT16	a_es_gain_lin_dl_vect[2]	Downlink linear attenuation (A_R) per state (3- Far-end)
+16	T_SINT16	a_es_gain_lin_dl_vect[3]	Downlink linear attenuation (A_R) per state (4- Near-end)
+17	T_SINT16	a_es_gain_lin_ul_vect[0]	Uplink linear attenuation (A_S) per state (1 - Idle)
+18	T_SINT16	a_es_gain_lin_ul_vect[1]	Uplink linear attenuation (A_S) per state (2- Double-talk)
+19	T_SINT16	a_es_gain_lin_ul_vect[2]	Uplink linear attenuation (A_S) per state (3- Far-end)
+20	T_SINT16	a_es_gain_lin_ul_vect[3]	Uplink linear attenuation (A_S) per state (4- Near-end)

Table 3.3 The ES Configuration Area

According to the ES expected behavior [1](Chap. 8), the recommended configuration parameters values (7 predefined configurations) are listed in the tables (B. Appendix).

ES parameters are further described in ES custom configuration in Appendix C.

3.2.2 ES Control Area

The ES control area is represented by the T_UINT16 d_es_mode variable from bits 0 to 6 (Table 3.4).

T_UINT16	Bit 15		Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
d_es_mode			HDV Mngt.	ALS UL	ALS DL	NSF	CNG	ES Att. DL	ES Att. UL

Table 3.4 The ES Control Area

According to the d_es_mode bits values, the ES attenuations UL (ES UL) and DL (ES DL) are enabled (1) or disabled (0). In the same way, the ES options such as Comfort Noise Generation (CNG) acting in UL, Noise Floor (NSF) acting in UL, Attenuation Level Smoothing (ALS) acting independently in UL and in DL are enabled (1) or disabled (0). The hangover is managed using bit-6.

The d_es_mode recommended values are listed below (Table 3.5).

Value		Comment
Initial	Handover	
0x0000	0x0000	ES disable
0x0003	0x0043	ES UL enable, DL enable
0x0007	0x0047	ES UL enable, DL enable + CNG
0x000B	0x004B	ES UL enable, DL enable + NSF

Table 3.5 The ES Control Recommended Values

During handover, bit 6 must be set from 0 to 1. So, for each initial value corresponds one hangover value. After hangover, the bit 6 should reset from 1 to 0 and d_es_mode must be reset to its initial value (Table 3.5).

Some full configurations of ES corresponding to recommended control values are presented in (B. Appendix).

3.2.3 Status Area

The DSP uses this area to give some information on the ES module status to the MCU. The ES status area is represented by the T_UINT16 d_es_state variable quantified by the bits 0 to 5 (

T_UINT16	Bit 15		Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
d_es_mode			HDV Mngt.	ALS UL	ALS DL	NSF	CNG	ES Att. DL	ES Att. UL

Table 3.6).

T_UINT16	Bit 15		Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
d_es_mode			HDV Mngt.	ALS UL	ALS DL	NSF	CNG	ES Att. DL	ES Att. UL

Table 3.6 The ES State Area

The d_audio_state variable is the image of d_audio_ctrl variable. Consequently, The d_es_mode possible values are listed in the same table as d_es_mode (Table 3.5).

Appendices

A. Appendix: Summary of ES + Digital Gains API

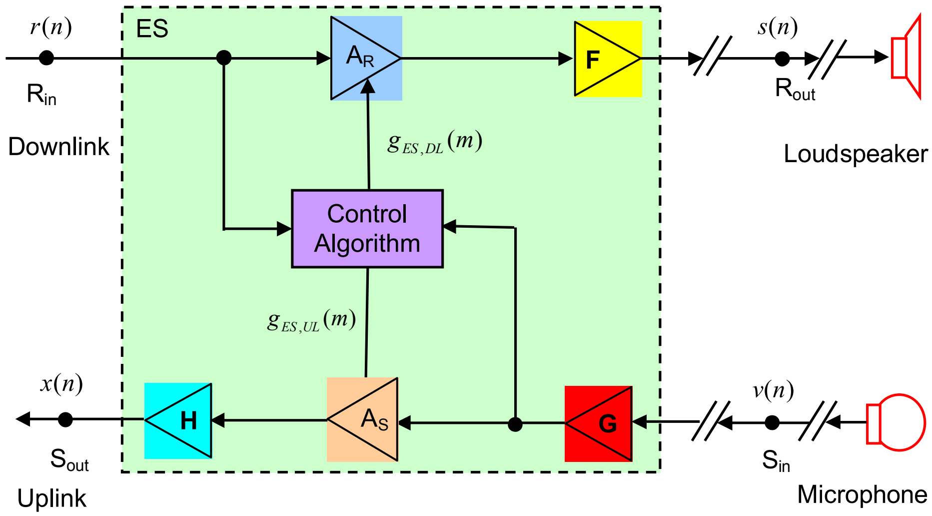

Figure 3.1 The ES + Digital Gains Block Diagram

Rank	Type	Parameter Name	Description
1	T_SINT16	d_es_mode	ES enable/disable and selection CNG, ALS/NSFoptions
2	T_SINT16	d_es_gain_dl	Digital gain DL to Rout [-66dB; +24dB]
3	T_SINT16	d_es_gain_ul_1	Digital gain UL from Sin [-66dB; +24dB]
4	T_SINT16	d_es_gain_ul_2	Digital gain UL to Sout [-66dB; +24dB]
5	T_SINT16	d_es_tcl_fe_ls_thr	TCL reference threshold in FE mode for loud signal
6	T_SINT16	d_es_tcl_dt_ls_thr	TCL reference threshold in DT mode for loud signal
7	T_SINT16	d_es_tcl_fe_ns_thr	TCL reference threshold in FE mode for nominal signal
8	T_SINT16	d_es_tcl_dt_ns_thr	TCL reference threshold in DT mode for nominal signal
9	T_SINT16	d_es_tcl_ne_thr	TCL reference threshold in NE mode
10	T_SINT16	d_es_ref_ls_pwr	Reference power for loud signals in DL
11	T_SINT16	d_es_switching_time	Switching time index
12	T_SINT16	d_es_switching_time_dt	Switching time index in DT mode
13	T_SINT16	d_es_hang_time	Hangover time index
14	T_SINT16	a_es_gain_lin_dl_vect[0]	Downlink linear attenuation (A_R) per state (1 - Idle)
15	T_SINT16	a_es_gain_lin_dl_vect[1]	Downlink linear attenuation (A_R) per state (2- Double-talk)
16	T_SINT16	a_es_gain_lin_dl_vect[2]	Downlink linear attenuation (A_R) per state (3- Far-end)
17	T_SINT16	a_es_gain_lin_dl_vect[3]	Downlink linear attenuation (A_R) per state (4- Near-end)
18	T_SINT16	a_es_gain_lin_ul_vect[0]	Uplink linear attenuation (A_S) per state (1 - Idle)
19	T_SINT16	a_es_gain_lin_ul_vect[1]	Uplink linear attenuation (A_S) per state (2- Double-talk)
20	T_SINT16	a_es_gain_lin_ul_vect[2]	Uplink linear attenuation (A_S) per state (3- Far-end)
21	T_SINT16	a_es_gain_lin_ul_vect[3]	Uplink linear attenuation (A_S) per state (4- Near-end)

Table 3.7 The ES + Digital Gains API

B. Appendix: ES Predefined Configurations

For coupling loss 0dB ≤ CL corresponding to nominal or low echo environment in hands-free/handheld modes, the ES can be enabled in 7 predefined configurations (1, 1a, 2a, 2b, 2c, 2c_idle, 3) as listed below (Table 3.8 - Table 3.14).

Rank	Name	Value	Reference
1	d_es_mode	0x000B	ES UL enable, DL enable + NSF
2	d_es_gain_dl	0x0000	Disabled
3	d_es_gain_ul_1	0x0000	Disabled
4	d_es_gain_ul_2	0x0000	Disabled
5	d_es_tcl_fe_ls_thr	0x1729	6dB
6	d_es_tcl_dt_ls_thr	0x05D1	0dB
7	d_es_tcl_fe_ns_thr	0x5C36	12dB
8	d_es_tcl_dt_ns_thr	0x1729	6dB
9	d_es_tcl_ne_thr	0x05D1	0dB
10	d_es_ref_ls_pwr	0x00BF	70dB
11	d_es_switching_time	0x0005	100ms
12	d_es_switching_time_dt	0x0005	100ms
13	d_es_hang_time	0x0008	150ms
14	a_es_gain_lin_dl_vect[0]	0x5A9D	-3dB
15	a_es_gain_lin_dl_vect[1]	0x5A9D	-3dB
16	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
17	a_es_gain_lin_dl_vect[3]	0x5A9D	-3dB
18	a_es_gain_lin_ul_vect[0]	0x5A9D	-3dB
19	a_es_gain_lin_ul_vect[1]	0x5A9D	-3dB
20	a_es_gain_lin_ul_vect[2]	0x16C2	-15dB
21	a_es_gain_lin_ul_vect[3]	0x7FFF	0dB

Table 3.8 The ES Parameters Values – Behavior 1

Rank	Name	Value	Reference
1	d_es_mode	0x0003	ES UL enable, DL enable
2	d_es_gain_dl	0x0000	Disabled
3	d_es_gain_ul_1	0x0000	Disabled
4	d_es_gain_ul_2	0x0000	Disabled
5	d_es_tcl_fe_ls_thr	0x1729	6dB
6	d_es_tcl_dt_ls_thr	0x05D1	0dB
7	d_es_tcl_fe_ns_thr	0x5C36	12dB
8	d_es_tcl_dt_ns_thr	0x1729	6dB
9	d_es_tcl_ne_thr	0x05D1	0dB
10	d_es_ref_ls_pwr	0x00BF	70dB
11	d_es_switching_time	0x0005	100ms
12	d_es_switching_time_dt	0x0005	100ms
13	d_es_hang_time	0x0008	150ms
14	a_es_gain_lin_dl_vect[0]	0x5A9D	-3dB
15	a_es_gain_lin_dl_vect[1]	0x5A9D	-3dB
16	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
17	a_es_gain_lin_dl_vect[3]	0x5A9D	-3dB
18	a_es_gain_lin_ul_vect[0]	0x5A9D	-3dB
19	a_es_gain_lin_ul_vect[1]	0x5A9D	-3dB
20	a_es_gain_lin_ul_vect[2]	0x4026	-6dB
21	a_es_gain_lin_ul_vect[3]	0x7FFF	0dB

Table 3.9 The ES Parameters Values – Behavior 1a

Rank	Name	Value	Reference
1	d_es_mode	0x000B	ES UL enable, DL enable + NSF
2	d_es_gain_dl	0x0000	Disabled
3	d_es_gain_ul_1	0x0000	Disabled
4	d_es_gain_ul_2	0x0000	Disabled
5	d_es_tcl_fe_ls_thr	0x1729	6dB
6	d_es_tcl_dt_ls_thr	0x05D1	0dB
7	d_es_tcl_fe_ns_thr	0x5C36	12dB
8	d_es_tcl_dt_ns_thr	0x1729	6dB
9	d_es_tcl_ne_thr	0x05D1	0dB
10	d_es_ref_ls_pwr	0x00BF	70dB
11	d_es_switching_time	0x0005	100ms
12	d_es_switching_time_dt	0x0005	100ms
13	d_es_hang_time	0x000A	200ms
14	a_es_gain_lin_dl_vect[0]	0x5A9D	-3dB
15	a_es_gain_lin_dl_vect[1]	0x47FA	-5dB
16	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
17	a_es_gain_lin_dl_vect[3]	0x47FA	-5dB
18	a_es_gain_lin_ul_vect[0]	0x5A9D	-3dB
19	a_es_gain_lin_ul_vect[1]	0x4026	-6dB
20	a_es_gain_lin_ul_vect[2]	0x0813	-24dB
21	a_es_gain_lin_ul_vect[3]	0x7FFF	0dB

Table 3.10 The ES Parameters Values – Behavior 2a

Rank	Name	Value	Reference
1	d_es_mode	0x0007	ES UL enable, DL enable + CNG
2	d_es_gain_dl	0x0000	Disabled
3	d_es_gain_ul_1	0x0000	Disabled
4	d_es_gain_ul_2	0x0000	Disabled
5	d_es_tcl_fe_ls_thr	0x1729	6dB
6	d_es_tcl_dt_ls_thr	0x05D1	0dB
7	d_es_tcl_fe_ns_thr	0x3A2F	10dB
8	d_es_tcl_dt_ns_thr	0x0E9D	4dB
9	d_es_tcl_ne_thr	0x05D1	0dB
10	d_es_ref_ls_pwr	0x00BF	70dB
11	d_es_switching_time	0x0005	100ms
12	d_es_switching_time_dt	0x0005	100ms
13	d_es_hang_time	0x000D	250ms
14	a_es_gain_lin_dl_vect[0]	0x5A9D	-3dB
15	a_es_gain_lin_dl_vect[1]	0x32F4	-8dB
16	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
17	a_es_gain_lin_dl_vect[3]	0x32F4	-8dB
18	a_es_gain_lin_ul_vect[0]	0x5A9D	-3dB
19	a_es_gain_lin_ul_vect[1]	0x2D6A	-9dB
20	a_es_gain_lin_ul_vect[2]	0x0207	-36dB
21	a_es_gain_lin_ul_vect[3]	0x7FFF	0dB

Table 3.11 The ES Parameters Values – Behavior 2b

Rank	Name	Value	Reference
1	d_es_mode	0x0007	ES UL enable, DL enable + CNG
2	d_es_gain_dl	0x0000	Disabled
3	d_es_gain_ul_1	0x0000	Disabled
4	d_es_gain_ul_2	0x0000	Disabled
5	d_es_tcl_fe_ls_thr	0x0176	-6dB
6	d_es_tcl_dt_ls_thr	0x005E	-12dB
7	d_es_tcl_fe_ns_thr	0x05D1	0dB
8	d_es_tcl_dt_ns_thr	0x0176	-6dB
9	d_es_tcl_ne_thr	0x02EA	-3dB
10	d_es_ref_ls_pwr	0x00BF	70dB
11	d_es_switching_time	0x0005	100ms
12	d_es_switching_time_dt	0x0005	100ms
13	d_es_hang_time	0x000D	250ms
14	a_es_gain_lin_dl_vect[0]	0x5A9D	-3dB
15	a_es_gain_lin_dl_vect[1]	0x2879	-10dB
16	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
17	a_es_gain_lin_dl_vect[3]	0x2879	-10dB
18	a_es_gain_lin_ul_vect[0]	0x5A9D	-3dB
19	a_es_gain_lin_ul_vect[1]	0x2026	-12dB
20	a_es_gain_lin_ul_vect[2]	0x0082	-48dB
21	a_es_gain_lin_ul_vect[3]	0x7FFF	0dB

Table 3.12 The ES Parameters Values – Behavior 2c

Rank	Name	Value	Reference
1	d_es_mode	0x0007	ES UL enable, DL enable + CNG
2	d_es_gain_dl	0x0000	Disabled
3	d_es_gain_ul_1	0x0000	Disabled
4	d_es_gain_ul_2	0x0000	Disabled
5	d_es_tcl_fe_ls_thr	0x0176	-6dB
6	d_es_tcl_dt_ls_thr	0x005E	-12dB
7	d_es_tcl_fe_ns_thr	0x05D1	0dB
8	d_es_tcl_dt_ns_thr	0x0176	-6dB
9	d_es_tcl_ne_thr	0x02EA	-3dB
10	d_es_ref_ls_pwr	0x00BF	70dB
11	d_es_switching_time	0x0005	100ms
12	d_es_switching_time_dt	0x0005	100ms
13	d_es_hang_time	0x000D	250ms
14	a_es_gain_lin_dl_vect[0]	0x5A9D	-3dB
15	a_es_gain_lin_dl_vect[1]	0x2879	-10dB
16	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
17	a_es_gain_lin_dl_vect[3]	0x2879	-10dB
18	a_es_gain_lin_ul_vect[0]	0x2026	-12dB
19	a_es_gain_lin_ul_vect[1]	0x2026	-12dB
20	a_es_gain_lin_ul_vect[2]	0x0082	-48dB
21	a_es_gain_lin_ul_vect[3]	0x7FFF	0dB

Table 3.13 The ES Parameters Values – Behavior 2c_idle

Rank	Name	Value	Reference
1	d_es_mode	0x0007	ES UL enable, DL enable + CNG
2	d_es_gain_dl	0x0000	Disabled
3	d_es_gain_ul_1	0x0000	Disabled
4	d_es_gain_ul_2	0x0000	Disabled
5	d_es_tcl_fe_ls_thr	0x0004	-26dB
6	d_es_tcl_dt_ls_thr	0x0001	-32dB
7	d_es_tcl_fe_ns_thr	0x000F	-20dB
8	d_es_tcl_dt_ns_thr	0x0004	-26dB
9	d_es_tcl_ne_thr	0x000F	-20dB
10	d_es_ref_ls_pwr	0x00BF	70 dB
11	d_es_switching_time	0x0005	100 ms
12	d_es_switching_time_dt	0x0005	100 ms
13	d_es_hang_time	0x0014	400 ms
14	a_es_gain_lin_dl_vect[0]	0x5A9D	-3 dB
15	a_es_gain_lin_dl_vect[1]	0x1449	-16 dB
16	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
17	a_es_gain_lin_dl_vect[3]	0x0B68	-21dB
18	a_es_gain_lin_ul_vect[0]	0x0E5D	-19dB
19	a_es_gain_lin_ul_vect[1]	0x0E5D	-19dB
20	a_es_gain_lin_ul_vect[2]	0x0010	-66dB
21	a_es_gain_lin_ul_vect[3]	0x7FFF	0 dB

Table 3.14 The ES Parameters Values – Behavior 3

C. Appendix: ES Custom Configuration

For coupling loss -24dB < CL < 0dB corresponding to loud echo environment in handsfree mode (low distance between the loudspeaker and the microphone, high volume in the uplink), the ES can be enabled in a custom configuration.

Digital gains

In loud echo environment, the coupling loss must be compensated using the digital gain G while the near end propagation loss must be compensated using the digital gain H. Consequently, the ES configuration is dependant to the Analogical Base Band (ABB) settings as presented below (Figure 3.2);

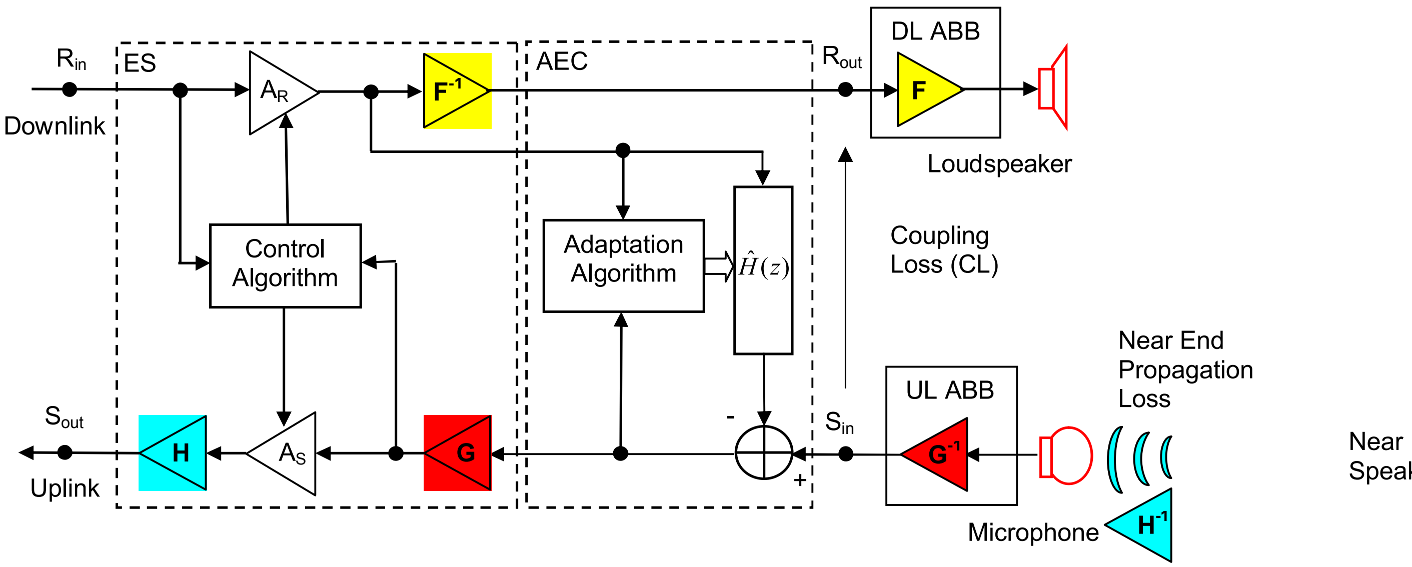

Figure 3.2 The AEC/ES and ABB Dependencies in Loud Echo Environment

When the coupling loss is -24dB < CL < 0dB, the AEC risks to diverges due overflow in the adaptive impulse response and to the strong non-linearity as clipping in the ABB. To help the AEC converging, the strategy is to move the CL closer to 0dB. For that, the ABB PGA UL is set to reduce the CL by G^{-1} while the digital gain uplink is set to compensate by G after AEC in the UL. The digital gain H is set to compensate the near end propagation loss H^{-1} as post processing after ES to provide enough loudness in the UL.

The calculation of the digital gain parameters from their specification in dB to the hexadecimal values to be set through the ES API is done according to the next formulae:

$$\mathrm{d\_es\_gain\_dl} = 2^{11} * 10^{\frac{F_{dB}}{20}}, \quad \text{(C.1)}$$

$$\mathrm{d\_es\_gain\_ul\_1} = 2^{11} * 10^{\frac{G_{dB}}{20}}, \quad \text{(C.2)}$$

$$\mathrm{d\_es\_gain\_ul\_2} = 2^{11} * 10^{\frac{H_{dB}}{20}}. \quad \text{(C.3)}$$

For example, using (C.3), H = +14dB leads to: d_es_gain_ul_2 ; 10264 ≡0x2818.

For example, considering a measured CL = -12dB, we have G^{-1} = -12dB, G = 12dB. H is depending on the microphone sensitivity and on the distance with the near ends speaker. So, H has to be set according to acoustic lab. measurements. It is also recommended to keep F^{-1} = 0dB except if AEC divergence is noticed due to loudness in the DL. The corresponding custom configuration based on behavior 2c is proposed below (Table 3.15).

Rank	Name	Value	Reference
22	d_es_mode	0x0007	ES UL enable, DL enable + CNG
23	d_es_gain_dl	0x0000	Disabled
24	d_es_gain_ul_1	0x1FD9	+12dB
25	d_es_gain_ul_2	0x2818	+14dB
26	d_es_tcl_fe_ls_thr	0x0176	-6dB
27	d_es_tcl_dt_ls_thr	0x005E	-12dB
28	d_es_tcl_fe_ns_thr	0x05D1	0dB
29	d_es_tcl_dt_ns_thr	0x0176	-6dB
30	d_es_tcl_ne_thr	0x02EA	-3dB
31	d_es_ref_ls_pwr	0x00BF	70dB
32	d_es_switching_time	0x0005	100ms
33	d_es_switching_time_dt	0x0005	100ms
34	d_es_hang_time	0x000D	250ms
35	a_es_gain_lin_dl_vect[0]	0x5A9D	-3dB
36	a_es_gain_lin_dl_vect[1]	0x2879	-10dB
37	a_es_gain_lin_dl_vect[2]	0x7FFF	0dB
38	a_es_gain_lin_dl_vect[3]	0x2879	-10dB
39	a_es_gain_lin_ul_vect[0]	0x5A9D	-3dB
40	a_es_gain_lin_ul_vect[1]	0x2026	-12dB
41	a_es_gain_lin_ul_vect[2]	0x0082	-48dB
42	a_es_gain_lin_ul_vect[3]	0x7FFF	0dB

Table 3.15 The ES Parameters Values – Custom Behavior 2c + Digital Gains

Attenuation vectors

The attenuation levels per state in DL ($A_{R,i}$) and in UL ($A_{S,i}$) are computed using the next relations ($1 \le i \le 4$):

$$\text{a\_es\_gain\_lin\_dl\_vect}[i-1] = 32768 * 10^{\frac{(A_{R,i})_{dB}}{20}}, \quad \text{(C.4)}$$

$$\text{a\_es\_gain\_lin\_ul\_vect}[i-1] = 32768 * 10^{\frac{(A_{S,i})_{dB}}{20}}. \quad \text{(C.5)}$$

For example, using (C.5), $A_{S,3} = -48\text{dB}$, leads to: $\text{a\_es\_gain\_lin\_ul\_vect}[2] \;;\; 130 \equiv 0x0082$.

TCL Thresholds

ES system is based on four states: Idle (1), Double-talk (2), Far-end (3) and Near-end (4).

The ES control algorithm performs a state estimation on the current 20-ms frame from the UL and DL VAD decisions and the TCL estimation [2]Table 3.12.

For each input frame, the ES state is determined in order to compute the attenuations to be applied in downlink and in uplink.

TCL estimation is the ratio in dB of the smoothed frame power estimations of the DL input ES signal and the UL output AEC signal.

TCL estimate is compared to dynamic thresholds.

The TCL dynamic thresholds $\Gamma_{TCL,FE}(m)$ and $\Gamma_{TCL,DT}(m)$ are computed in the current frame m using the reference thresholds $\Gamma_{TCL,FE,L}$, $\Gamma_{TCL,DT,L}$, $\Gamma_{TCL,FE,N}$, $\Gamma_{TCL,DT,N}$, $\Gamma_{TCL,NE,0}$ and the power threshold for loud signal in the downlink Γ_{Loud}.

Parameters	Notation	Description
d_es_tcl_fe_ls_thr	$\Gamma_{TCL,FE,L}$	TCL reference threshold in far-end mode for loud signals
d_es_tcl_dt_ls_thr	$\Gamma_{TCL,DT,L}$	TCL reference threshold in double-talk mode for loud signals
d_es_tcl_fe_ns_thr	$\Gamma_{TCL,FE,N}$	TCL reference threshold in far-end mode for nominal signals
d_es_tcl_dt_ns_thr	$\Gamma_{TCL,DT,N}$	TCL reference threshold in double-talk for nominal signals
d_es_tcl_ne_thr	$\Gamma_{TCL,NE,0}$	TCL reference threshold in near-end mode
d_es_ref_ls_pwr	Γ_{Loud}	loud signal reference power

Table 3-16: The ES TCL thresholds parameters

Downlink signal frame power estimate, $\hat{p}_{S_N}(m)$, is compared to reference power threshold of loud signal in order to choose TCL reference thresholds between nominal and loud far-end conditions.

This strategy allows the ES to deal with loud signals in the downlink. When a loud signal resides in the downlink, the TCL Far-end threshold is decreased that favor the ES state in the Far-end mode.

$$\begin{cases}\Gamma_{TCL,FE}(m) = \Gamma_{TCL,FE,L}, \\ \Gamma_{TCL,DT}(m) = \Gamma_{TCL,DT,L},\end{cases} \text{if } 10\log_{10}(\hat{p}_{s_N}(m)) > \Gamma_{Loud}, \tag{C.6}$$

$$\begin{cases}\Gamma_{TCL,FE}(m) = \Gamma_{TCL,FE,N}, \\ \Gamma_{TCL,DT}(m) = \Gamma_{TCL,DT,N},\end{cases} \text{if } 10\log_{10}(\hat{p}_{s_N}(m)) \le \Gamma_{Loud}, \tag{C.7}$$

$$\Gamma_{TCL,NE}(m) = \Gamma_{TCL,NE,0}, \forall m. \tag{C.8}$$

The TCL reference thresholds for loud signals in far-end and double-talk modes are calculated as follow:

$$\text{d\_es\_tcl\_fe\_ls\_thr} = \text{round}\left\{\frac{32768}{\alpha_{TCL}} 10^{\frac{\Gamma_{TCL,FE,L}}{10}}\right\}, \tag{C.9}$$

$$\text{d\_es\_tcl\_dt\_ls\_thr} = \text{round}\left\{\frac{32768}{\alpha_{TCL}} 10^{\frac{\Gamma_{TCL,DT,L}}{10}}\right\}. \tag{C.10}$$

$\alpha_{TCL} = 22,$ Using (C.9) and (C.10), for instance with $\Gamma_{TCL,FE,L} = 6dB$ and $\Gamma_{TCL,DT,L} = 0dB$ we have $\text{d\_es\_tcl\_fe\_ls\_thr} \;;\; 0.18095 \equiv 0\text{x}1729$ and $\text{d\_es\_tcl\_dt\_ls\_thr} \;;\; 0.04545 \equiv 0\text{x}05\text{D}1$.

In the same way, the TCL reference thresholds for nominal signals are computed as follow:

$$\text{d\_es\_tcl\_fe\_ns\_thr} = \text{round}\left\{\frac{32768}{\alpha_{TCL}} 10^{\frac{\Gamma_{TCL,FE,N}}{10}}\right\}, \tag{C.11}$$

$$\text{d\_es\_tcl\_dt\_ns\_thr} = \text{round}\left\{\frac{32768}{\alpha_{TCL}} 10^{\frac{\Gamma_{TCL,DT,N}}{10}}\right\}. \tag{C.12}$$

$\alpha_{TCL} = 22,$ Using (C.11) and (C.12), for instance with $\Gamma_{TCL,FE,N} = 12dB$ and $\Gamma_{TCL,DT,N} = 6dB$ we have $\text{d\_es\_tcl\_fe\_ns\_thr} \;;\; 0.72040 \equiv 0\text{x}5\text{C}36$ and $\text{d\_es\_tcl\_dt\_ns\_thr} \;;\; 0.18095 \equiv 0\text{x}1729$.

The TCL reference threshold in near-end mode is computed using the next rule:

$$\text{d\_es\_tcl\_ne\_thr} = \text{round}\left\{\frac{32768}{\alpha_{TCL}} 10^{\frac{\Gamma_{TCL,NE,0}}{10}}\right\}. \tag{C.13}$$

$\alpha_{TCL} = 22,$ Using (C.13), for instance with $\Gamma_{TCL,NE,0} = 0dB$ we have $\text{d\_es\_tcl\_ne\_thr} \;;\; 0.04545 \equiv 0\text{x}05\text{D}1$.

Reference power for loud signals is computed using the following formula:

$$\text{d\_es\_ref\_ls\_pwr} = \text{round}\left\{32768 \frac{N}{\alpha_{ENE}} 10^{\frac{\Gamma_{Loud} - 90.3}{10}}\right\}. \tag{C.14}$$

$\alpha_{ENE} = 256$, *N* is the ES processing frame size, $N = 160$, Using (C.14), with $\Gamma_{Loud} = 70dB$ we have and $\text{d\_es\_tcl\_ls\_pwr} \;;\; 0.00582 \equiv 0\text{x}00\text{BF}$.

ES includes UL and DL VAD [2]. To improve the VAD reliability, the decision is done according 3 states: Inactive (IA), Marginally Active (MA) and Strongly Active (SA) corresponding respectively to “no-speech”, “noise or speech” and “speech”.

Then, ES state $\eta_{ES}(m)$ is determined using the VAD decisions $d_{VAD,DL}(m)$, $d_{VAD,UL}(m)$ and the TCL estimate $\hat{T}CL(m)$ compared to the thresholds $\Gamma_{TCL,DT}(m)$ and $\Gamma_{TCL,NE}(m)$ according to the rules below (Table 3-17):

Far-end VAD $d_{VAD,\,DL}(m)$	1 or 2 (MA/SA)		0 (IA)	0 (IA)	otherwise
Near-end VAD $d_{VAD,UL}(m)$	-	0 (IA)	1 or 2 (MA/SA)	0 (IA)	
TCL Estima-tion $\hat{T}CL(m)$	H $\hat{T}CL(m) > \Gamma_{TCL,FE}(m)$	-	L $\hat{T}CL(m) < \Gamma_{TCL,NE}(m)$	-	
ES State $\eta_{ES}(m)$	3 (FE)		4 (NE)	1 (IDLE)	2 (DT)

Table 3-17: ES state computation

Depending on ES states, attenuations are applied in the DL and in the UL according to the ITU P340 [1] performances guidelines for attenuations levels in sending and receiving directions for full-duplex, half-duplex and partial-duplex terminals.

Switching times and hangover time

These time parameters are used in the ES control algorithm to perform smooth switching in ES states and DL and UL attenuations. Their values shouldn't be modified.