ECCN: 3E991



Application Report SLAA779–September 2017

TAS2555, TAS2557, and TAS2559 Factory Test and Calibration Guide

ABSTRACT

This document explains how to test and calibrate the TAS2555, TAS2557, and TAS2559 to account for speaker parameter variations.

Contents

| 1 | Introduction | . 2 |
|---|--------------------------------------|-----|
| 2 | Factory Test Application | . 2 |
| 3 | Test and Calibration Process | . 7 |
| 4 | Calibration Wave File Specification | 10 |
| 5 | Verification Wave File Specification | 10 |
| 6 | Export Control Notice | 10 |

List of Figures

| 1 | Factory Test Syntax | 2 |
|---|---|---|
| 2 | Factory Test Examples | 3 |
| 3 | Factory Test and Calibration Configuration File | 3 |
| 4 | TAS255X Driver During Boot | 7 |
| 5 | TAS255X Calibration and Verification Process | 7 |
| 6 | Temperature at Time (t) for Multiple Samples (1 of 2) | 9 |
| 7 | Temperature at Time (t) for Multiple Samples (2 of 2) | 9 |
| | | |

List of Tables

| 1 | FTC Settings | 4 |
|---|----------------|---|
| 2 | FTC Parameters | 5 |
| 3 | FTC Result | 6 |

Trademarks

All trademarks are the property of their respective owners.



1 Introduction

With Texas Instruments' integrated Smart Amp devices (TAS2555, TAS2557, and TAS2559, referred to as TAS255X) it is possible to calibrate the Smart Amp algorithm to account for variations in the speaker voice coil resistance (R_e). The R_e value is important because it is used to derive the temperature of the speaker voice coil. The voice coil temperature is determined as follows:

$$T_{v} = \frac{\left(\frac{R_{e}}{R_{e0}} - 1\right)}{\alpha} + T_{v0}$$

where

- T_v Voice coil temperature [°C]
- T_{v0} Calibration temperature [°C]
- R_e Measured voice coil DC resistance [ohm]
- R_{e0} Voice coil DC resistance obtained during calibration at T_{v0} [ohm]
- α Temperature coefficient of resistance [1/°C]

As Equation 2 shows, the Re value increases as the voice coil temperature is increased:

 $R_{e} = R_{e0} \left[1 + \alpha \left(T_{v} - T_{v0} \right) \right]$

(2)

(1)

If the R_{e0} variation from speaker to speaker is too large, it can affect the amount of headroom available for the thermal protection algorithm. Calibrating for each speaker in the production line ensures a constant headroom across speakers for better consistency.

TI provides an ARM and Linux user space application, called **factorytest**, that performs the following:

- Obtains R_{e0}, f0 and Q (with ambient temperature as input)
- Verifies thermal limiter accuracy
- Compares measured parameters against pass/fail limits
- Saves the result into a text file
- Creates a calibration bin file which is used by the TAS255X driver during boot-up

2 Factory Test Application

For installation and detailed usage, please refer to factorytest_readme.txt.

2.1 Usage

2

The factorytest application has the following syntax:

factorytest [-t ambienttemperature] [-c configurationfile] [-v]

Copyright © 2017, Texas Instruments Incorporated

Figure 1. Factory Test Syntax



Figure 2 shows how to use a custom configuration file, change the ambient temperature used during characterization, and place the tool in verbose mode.

```
# Uses the default values:
factorytest
# Uses a custom-defined configuration file (ftcfg):
factorytest -c +<mySpeaker>.ftcfg
# Assumes 25C ambient temperature during test:
factorytest -t 25
# Verbose:
factorytest -v
# Uses the configuration file, 27C ambient, verbose:
factorytest -t 27 -c DV1_spk.ftcfg -v
```

Figure 2. Factory Test Examples

2.2 Custom-Defined Factory Test Configuration File (ftcfg)

The user can configure the FTC settings and parameters by using the factorytest –c option. These parameters are stored in a ftcfg file.

```
; TAS255XFactory Test and Calibration Configuration File
; Project: TBD
; Version: TBD
; FTC Settings
FTC_BYPASS = 0
                             ;
TEST_DELTA_T = 20
                            ; Verification Temperature
CALIBRATION_TIME = 5000
VERIFICATION_TIME = 5000
NFS = 0.0004
CONFIGURATION = 0
CONFIGURATION_CALIBRATION = 2 ;
; Pass/Fail Limits
                    = 7.975
RE_HI
RE_LO
                   = 6.525
                    = 924
FO_HI
F0_LO
                    = 616
                    = 1.704
Q_HI
Q_LO
                    = 1.136
T_HI
                     = 24
                     = 16
T_LO
; Obtained from Speaker Manufacturer
SPK_T_MAX = 100 ; Speaker Maximum Temperature (C)
SPK_RE_TOL_PER = 10 ; Re +/- tolerance (%)
SPK_RE_ALPHA
                   = 0.0034 ; Temperature coefficient alpha (1/K)
; Obtained from PurePath Console 3 (PPC3)
PPC3_RE0 = 7.25
                             ; ReO (ohm)
                             ; Rtv (K/W)
                    = 38.2
PPC3_RTV
                = 53.8 ; Rtm (K/W)
PPC3 RTM
PPC3_RTVA

        PPC3_RTVA
        = 2530 ; Rtva (K/W)

        PPC3_SYSGAIN
        = 9.35 ; System Gain (V/FS)

PPC3_DEV_NONLIN_PER = 1.5 ; Device Non-linearity (%)
PPC3_DELTA_T_LIMIT = 90 ; Delta Thermal Limit (C)
                    = 48000 ; TAS2555 Sample Rate
FS_RATE
```

Figure 3. Factory Test and Calibration Configuration File

Copyright © 2017, Texas Instruments Incorporated



Factory Test Application

4

www.ti.com

2.2.1 **FTC Settings**

Table 1 displays the FTC settings.

Table 1. FTC Settings

| Setting | Description | Typical values |
|---------------------------|--|--|
| FTC_BYPASS | For future implementation. Currently, the FTC is bypassed by deleting the calibration output bin file. | 0 |
| TEST_DELTA_T | Delta T limit setting used during the verification test. Used in conjunction with T_HI and T_LO. | 20 |
| CALIBRATION_TIME | Duration (in ms) of calibration phase (where $R_{\rm e},$ f0 and Q are obtained) | 5000 |
| VERIFICATION_TIME | Duration (in ms) of the verification phase (where the temperature limit is verified) | 5000 |
| NFS | Trade-off between f0–Q accuracy and tracking speed | 0.0004 for quicker tracking. |
| CONFIGURATION | Default configuration | Set this to the default configuration number from the firmware .bin file (typically 0). |
| CONFIGURATION_CALIBRATION | Configuration within the tas255X_ucDSP.bin file that is used for the calibration test | This value is obtained from the in-system tuning output files by looking at the calibration file name. |
| | | DragonBoard.bin |
| | | DragonBoard.ftcfg |
| | | DragonBoard.json |
| | | DragonBoard_combined_configuration_0_music_0.ctg |
| | | DragonBoard_combined_configuration_1_voice.crg |
| | | DragonBoard combined configuration 3 rom mode2.cfg |
| | | DragonBoard_configuration_0_music_0.cfg |



2.2.2 FTC Parameters

Each speaker model and version requires adjusting the FTC parameters based on the characterization information obtained from PurePath Console 3 (PPC3) and the speaker manufacturer. Pass/Fail limits are defined by the user, based on the project requirements.

| Parameter | Description | Where to Obtain Parameter |
|-----------------------------------|---|---|
| SPK_T_MAX | Voice coil maximum temperature | Speaker manufacturer |
| SPK_RE_TOL_PER | Percent R _e tolerance | Speaker manufacturer |
| SPK_RE_ALPHA | Thermal coefficient for the speaker | Speaker manufacturer |
| PPC3_RE0 | R_{e0} obtained during the characterization | PurePath Console 3 Tuning page |
| | process | Characterization Data Prc Speaker Type : closed Re : 7.41 Ohm Fs : 934 Hz The |
| | | The |
| PPC3_RTV PPC3_RTM PPC3_RTVA | Obtained during the characterization process | Rtv K/W Ctv J/K Rtm J/K Rtm J/K Rtm J/K Rtm J/K Rtm J/K Rtm K/W Ctr Liss J/K J/K |
| PPC3_SYS_GAIN | A function of Class-D gain and DAC gain | SUA - System Gain System Gain (DAC+Amp) 9.35 Volt/F.S Supply Voltage 8.50 Volt |
| PPC3_DEV_NONLIN_PER | Device non-linearity (percent) | PurePath Console 3 Thermal Limit Device Non-Linearity 1.5 Speaker Resistance 0 % Terr |
| PPC3_DELTA_T_LIMIT | Thermal limit parameter (delta C) | PurePath Console 3 Characterization page |
| FS_RATE | Sample rate during calibration | PPC3 End-System Integration Page Choose the DDC tha Choose the D |
| | | Final 48 KHz , music) |

Table 2. FTC Parameters



2.2.3 Pass/Fail Limits

These limits are defined by the user to determine pass/fail criteria for R_e, f0, and Q. TI recommends obtaining these values from the speaker manufacturer. The T_HI and T_LO parameters should be derived from the TEST_DELTA_T parameter.

The result from the factory test is provided in the TAS255X_CAL.txt file that the factorytest application outputs.

| Result | Value |
|-------------|------------|
| RESULT_PASS | 0x0000000 |
| RE_FAIL_HI | 0x0000001 |
| RE_FAIL_LO | 0x0000010 |
| F0_FAIL_HI | 0x0000100 |
| F0_FAIL_LO | 0x00001000 |
| Q_FAIL_HI | 0x00010000 |
| Q_FAIL_LO | 0x00100000 |
| T_FAIL_HI | 0x0100000 |
| T_FAIL_LO | 0x1000000 |

Table 3. FTC Result

Copyright © 2017, Texas Instruments Incorporated



3 Test and Calibration Process

The factorytest tool automatically outputs a calibration bin file once the process completes.

As Figure 4 shows, after power up the TAS255X driver loads the Smart Amp program into the TAS255X. If the calibration bin file, tas255x_cal.bin, is present, the driver automatically loads the calibrated values into the TAS255X.



Figure 4. TAS255X Driver During Boot

Figure 5 shows the calibration and verification test process.



Figure 5. TAS255X Calibration and Verification Process

At the end of the process, if the verification is successful, the factorytest tool creates a calibration bin file (tas255x_cal.bin) and loads the newly calibrated settings into the TAS255X.



In order to obtain the calibration data, a filtered white noise signal (provided by TI) is automatically played during the calibration test (refer to Section 4). This white noise results in a small voice coil temperature increase. The voice coil temperature as a function of power is described by the following equation:

$$\mathbf{T}_{\mathbf{v}} = \mathbf{P} \Big[\mathbf{R}_{tva} \mid \mid \left(\mathbf{R}_{tv} + \mathbf{R}_{tm} \right) \Big] + \mathbf{T}_{a}$$

where

- T_v Voice coil temperature [°C]
- T_a Ambient temperature [°C]
- P Power delivered to the voice coil R_e as heat [W]
- R_{tva} Thermal resistance from voice coil to air gap [°C/W]
- R_{tv} Thermal resistance from voice coil to magnet [°C/W]
- R_{tm} Thermal resistance from magnet to ambient air [°C/W]

(3)

(4)

The worst-case change in temperature occurs when the back-emf is not present. (that is, blocked impedance) and the magnet temperature has stabilized, as Equation 4 shows:

$$\Delta T_{v} = \frac{\left(10^{S_{db}/20} \times G_{sys}\right)^{2}}{R_{e}} \times \left[R_{tva} \mid | (R_{tv} + R_{tm})\right]$$

where

- ΔT_v Change in voice coil temperature minus ambient temperature T_v T_a [delta °C]
- S_{dB} Input RMS signal level [dBFS]
- G_{sys} System gain as described in Section 2.2.2 [V/FFS]
- R_e Voice coil DC resistance [Ω]

Equation 5 is an example for a typical 8- Ω speaker when excited by the white noise signal mentioned in Section 4.

$$\Delta T_{v} = \frac{\left(10^{-30/20} \times 9.35\right)^{2}}{8} \times \left[2630 \parallel (38.2 + 53.8)\right] = 1.5 \,\text{delta}^{\circ}\text{C}$$
(5)

Again, this is a worst case number assuming no back-emf and a stabilized magnet temperature. If a cold magnet is assumed, this number becomes 0.65°C. Since a real speaker has back-emf, its mechanical resistance will reduce the power delivered to the voice coil close to resonance, and consequently, reduce this change in temperature even further.

Copyright © 2017, Texas Instruments Incorporated



3.2 Temperature Verification

The purpose of temperature verification is to help identify speaker failures (out of specification speakers or loose connections). During the verification phase a signal is played for a determined time, based on the VERIFICATION_TIME setting, to heat up the voice coil. After this time, t, the speaker under test will heat up to a temperature determined by its thermal parameters R_{tva} , R_{tv} , R_{tm} , C_{tv} , C_{tm} . Most good speakers will fall on a narrow temperature range, however, the spread depends on the variations of the parameters previously mentioned. The customer decides the limits in which a speaker is considered a failure based on statistical analysis of the calibration files (tas255x_cal.txt). Figure 6 shows an example of five rejects when the T_HI parameter I set to 30 and T_LO set to 10.



Figure 6. Temperature at Time (t) for Multiple Samples (1 of 2)

Figure 7 shows an example time domain plot of several speakers. This assumes a VERIFICATION_TIME equal to 4000 ms. Notice the two rejects in this example.



Figure 7. Temperature at Time (t) for Multiple Samples (2 of 2)



4 Calibration Wave File Specification

The calibration wave file, TAS255X_cal_m28dB.wav, is provided by TI (see Calibration and Verification Wave Files).

Pre-filtered specification:

- RMS Level: –16 dB
- Peak to Average Ratio: 2
- Signal type: white noise

Post-filter specification:

- Filter Type: Forth-Order Butterworth LPF, fc = 1500 Hz.
- RMS Level: -28 dB.

5 Verification Wave File Specification

The verification wave file, TAS2555_verify_m06dB.wav, is provided by TI (see Calibration and Verification Wave Files).

Specification:

- RMS Level: –6 dB
- Peak to Average Ratio: 2
- Signal type: white noise

6 Export Control Notice

Recipient agrees to not knowingly export or re-export, directly or indirectly, any product or technical data (as defined by the U.S., EU, and other Export Administration Regulations) including software, or any controlled product restricted by other applicable national regulations, received from disclosing party under nondisclosure obligations (if any), or any direct product of such technology, to any destination to which such export or re-export is restricted or prohibited by U.S. or other applicable laws, without obtaining prior authorization from U.S. Department of Commerce and other competent Government authorities to the extent required by those laws.



Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Date | Revision | Description |
|----------------|----------|-----------------|
| September 2017 | * | Initial release |

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your noncompliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/stdterms.htm), evaluation

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2017, Texas Instruments Incorporated