ECCN: 3E991

Texas Instruments

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.

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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] (1)

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

$$R_e = R_{e0}\left[1 + \alpha\left(T_v - T_{v0}\right)\right] \quad (2)$$

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

The factorytest application has the following syntax:

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

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
RE_HI                = 7.975
RE_LO                = 6.525
F0_HI                = 924
F0_LO                = 616
Q_HI                 = 1.704
Q_LO                 = 1.136
T_HI                 = 24
T_LO                 = 16

; 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   ; Re0 (ohm)
PPC3_RTV             = 38.2   ; Rtv (K/W)
PPC3_RTM             = 53.8   ; Rtm (K/W)
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)
FS_RATE              = 48000  ; TAS2555 Sample Rate
```

Figure 3. Factory Test and Calibration Configuration File

2.2.1 FTC Settings

Table 1 displays the FTC settings.

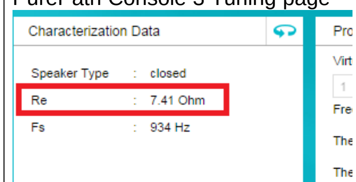
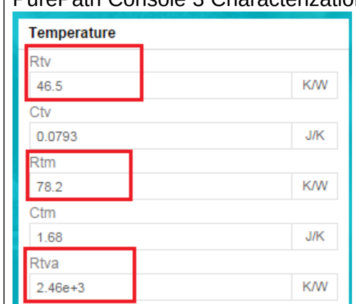
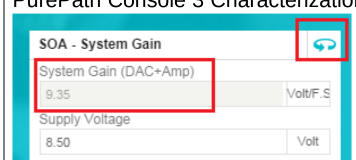
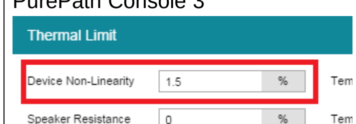
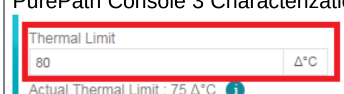
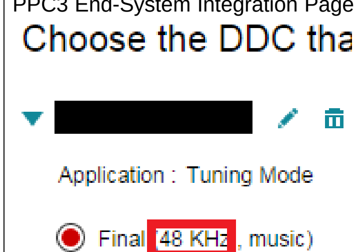
Table 1. FTC Settings

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_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.cfg DragonBoard_combined_configuration_1_voice.cfg DragonBoard_combined_configuration_2_music_0_calibration.cfg 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.

Table 2. FTC Parameters

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 process	PurePath Console 3 Tuning page 
PPC3_RTV PPC3_RTM PPC3_RTVA	Obtained during the characterization process	PurePath Console 3 Characterization page 
PPC3_SYS_GAIN	A function of Class-D gain and DAC gain	PurePath Console 3 Characterization page 
PPC3_DEV_NONLIN_PER	Device non-linearity (percent)	PurePath Console 3 
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 

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.

Table 3. FTC Result

Result	Value
RESULT_PASS	0x00000000
RE_FAIL_HI	0x00000001
RE_FAIL_LO	0x00000010
F0_FAIL_HI	0x00000100
F0_FAIL_LO	0x00001000
Q_FAIL_HI	0x00010000
Q_FAIL_LO	0x00100000
T_FAIL_HI	0x01000000
T_FAIL_LO	0x10000000

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.

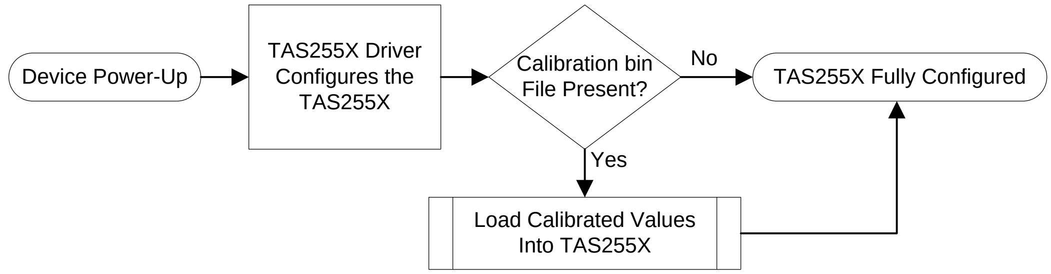


Figure 4. TAS255X Driver During Boot

Figure 5 shows the calibration and verification test process.

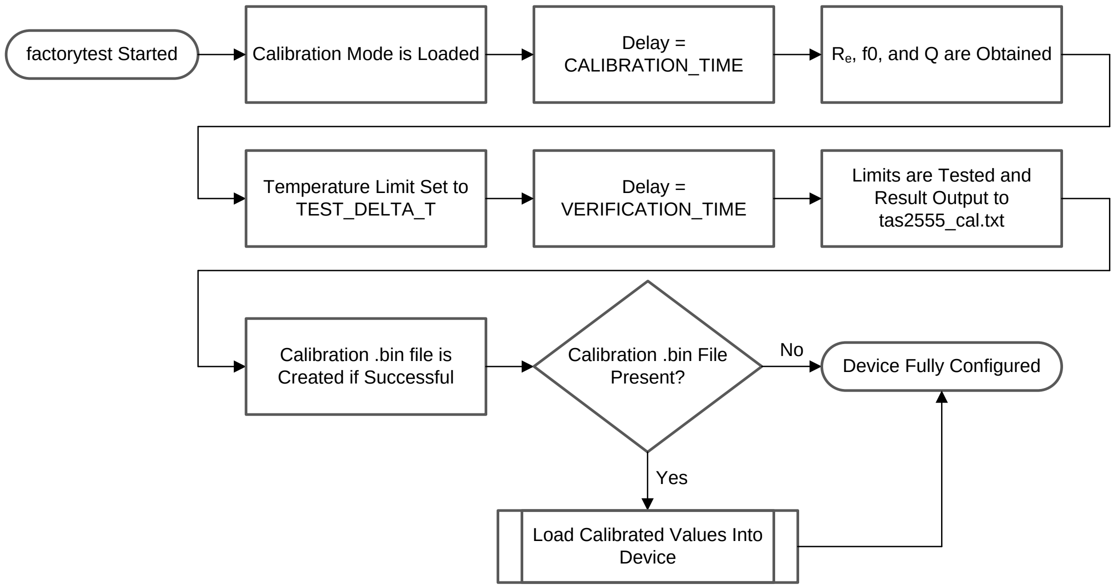


Figure 5. TAS255X Calibration and Verification Process

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.

3.1 Calibration

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:

$$T_v = P\left[R_{tva} \,||\, \left(R_{tv} + R_{tm}\right)\right] + T_a$$

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)

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:

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

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] (4)

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

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

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.

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.

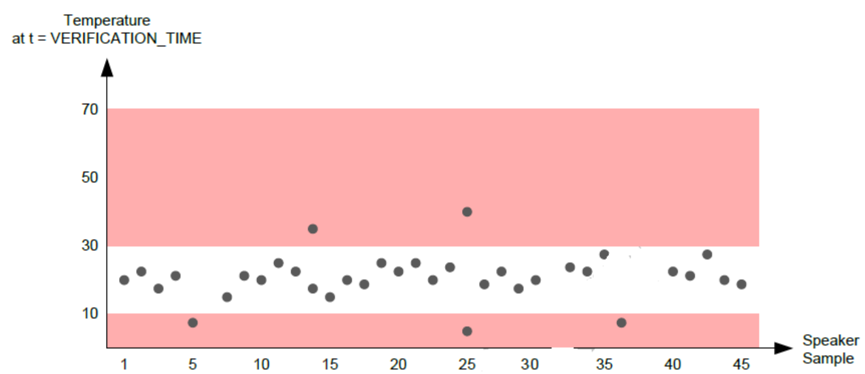


Figure 6. Temperature at Time (t) for Multiple Samples (1 of 2)

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.

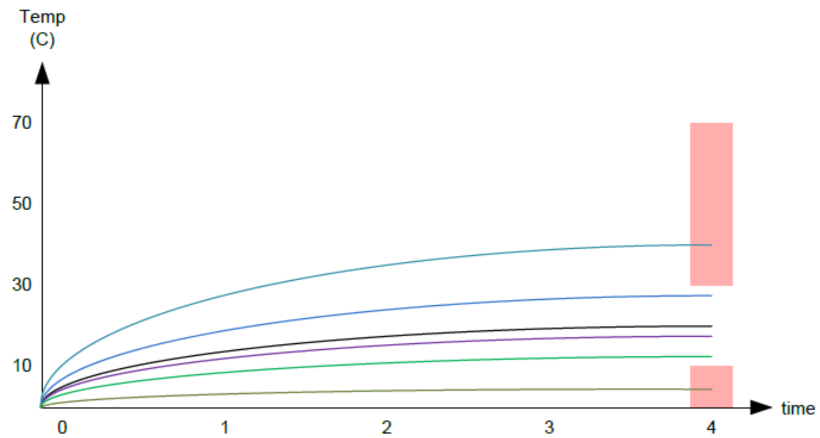


Figure 7. Temperature at Time (t) for Multiple Samples (2 of 2)

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

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Revision History

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

Date	Revision	Description
September 2017	*	Initial release

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