Application Note

Document Number

Reference EVK for Spectral Sensor Calibration

AS7343/AS7352 Evaluation Kit

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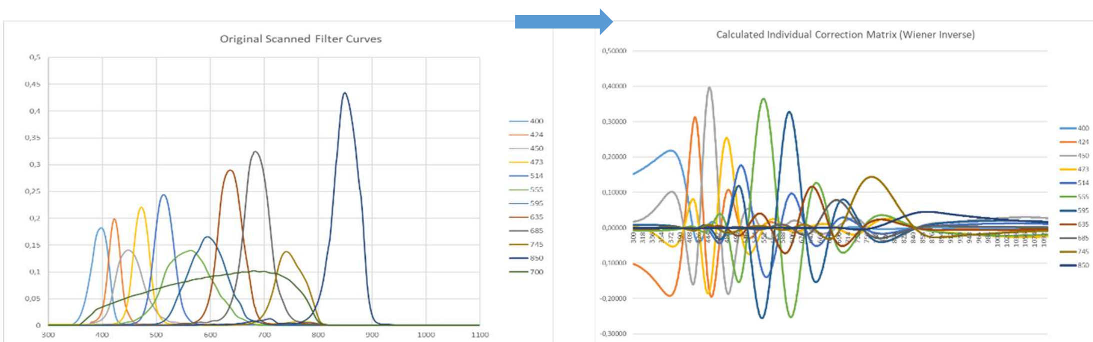
Content Guide

1 Introduction

To correct the sensor deviations of spectral sensors and disturbances in the application, and transfer (match) the sensor signals into an application, (a) the spectral behavior of the sensors must be measured directly[1] or (b) the behavior must be determined directly via measurements in the application[2]. In the case of (b), typical scenarios for the application are measured and compared using the sensor and the reference device. The comparison can be used to determine the deviations and disturbances for (b), and compensate for them later using correction values in the measurements. For (a), the correction can be determined by mathematical methods, in which the known sensor behavior is matched into the application, using functions and parameters.

A sensor behavior in the spectrum can be measured individually and spectrally (a) if the equipment is available for this. This is, for example, a monochromator, which exposes a spectral sensor with monochromatic light and a step size of 1 nm. The sensor response is then measured, and after passing through all the wavelengths, it can be used directly as a real sensor curve for subsequent CM calculations (Figure 1). However, such scanning of the individual sensor response is very time-consuming, but the result is highly accurate.

Figure 1:
Example of an individual CM (right) directly calculated from the sensor's Filter Response (left)



The metrological implementation of (b) involves a setup under the conditions of the application, where different but typical targets are measured using the sensor and a comparison device. The targets must cover the limit values and typical cases of the application. The calculation of the correction function is then done by referencing the sensor and comparison values (Figure 2). Procedures for this are described in [1] with examples. Depending on the number of targets, the procedure is more or less complex and accurate. A trend with more targets and higher accuracy is not unambiguous, but it is correct to some extent. Each application requires several targets with the highest accuracy, which makes a series of measurements necessary and, as an individual calibration, usually exceeds the reasonable effort of a serial calibration. Alternatively, the targets in their number and selection are not the only parameters to determine the accuracy after calibration. All components in the system and the

[1] analyze sensor filter response by direct measuring
[2] infer its behavior by reactions of the sensor in an application

occurrence of faults must be considered and optimized in total. If the calibration is carried out in this way, it promises very good results in the application but is mostly also complex and expensive.

Figure 2 shows an Excel spreadsheet, where an application-specific target is used (here, 24 colors from a color map) to measure Reference data (in CIE1931 XYZ values = Target data's T) and sensor data (= Sensor matrix S in basic corrected counts). The blue tables in Figure 2 are the calculations to get a target-based calibration matrix CM in the orange table.

Figure 2:
Result of a target calibration from comparing Sensor And Reference Data

TARGET DATA T

Reference values	1	2	3	4	5	6	7	8	9	10	11	12
	Dark Skin	ight Skin	Blue Sky	Foliage	e Flower	sh Green	e Yellow	w Green	Purple	rate Red	lish Blue	Orange
X	11,55	38	18,02	10,72	24,65	30,3	45,84	34,38	8,82	28,72	14,08	38,75
Y	10,57	35,03	19,12	13,4	22,96	41,93	43,05	45,2	6,67	19,27	12,16	30,91
Z	7,55	25,66	35,01	7,18	43,02	44,77	8,07	11,62	14,92	13,74	40,48	6,35

Sensor Matrix S

	1	2	3	4	5	6	7	8	9	10	11	12
	Dark Skin	ight Skin	Blue Sky	Foliage	e Flower	sh Green	e Yellow	w Green	Purple	rate Red	lish Blue	Orange
400	0,07106	0,16588	0,25598	0,06611	0,31499	0,26210	0,08530	0,07559	0,16423	0,14061	0,25313	0,07172
424	0,06910	0,17729	0,25875	0,06485	0,32981	0,28788	0,09658	0,08629	0,14872	0,13466	0,30326	0,08202
450	0,15860	0,49436	0,62471	0,16252	0,76774	0,89702	0,19525	0,27442	0,27359	0,27561	0,76358	0,15775
473	0,15123	0,54285	0,56189	0,15322	0,67198	0,95896	0,18328	0,31492	0,21319	0,25128	0,65321	0,15438
514	0,22290	0,71617	0,56679	0,38968	0,61255	1,34883	0,61936	1,06285	0,17621	0,26275	0,38660	0,35779
555	0,37117	1,05944	0,57256	0,44628	0,70590	1,26383	1,41366	1,30361	0,24884	0,70430	0,38372	1,04754
546	0,09480	0,23760	0,16823	0,14913	0,19090	0,41663	0,40505	0,43798	0,06146	0,10448	0,10050	0,22581
595	0,38925	1,15003	0,40787	0,33385	0,59478	0,75739	1,51812	0,99210	0,27186	1,02436	0,27394	1,31483
635	0,52568	1,63927	0,44231	0,36006	0,81396	0,58766	1,81305	0,90554	0,54430	1,65233	0,34743	1,69410
685	0,38160	1,34255	0,30558	0,24731	0,63024	0,44979	1,27461	0,70848	0,75107	1,13617	0,49952	1,24810
745	0,07888	0,20865	0,08382	0,04163	0,12205	0,07212	0,17616	0,11010	0,16917	0,15355	0,14986	0,18019

Sensor Matrix corr offset

S' = S - offset

	Dark Skin	ight Skin	Blue Sky	Foliage	e Flower	sh Green	e Yellow	w Green	Purple	rate Red	lish Blue	Orange
400	0,06681	0,16163	0,25173	0,06186	0,31074	0,25785	0,08105	0,07134	0,15999	0,13636	0,24888	0,06747
424	0,06496	0,17315	0,25462	0,06072	0,32567	0,28375	0,09244	0,08215	0,14459	0,13053	0,29913	0,07789
450	0,14939	0,48514	0,61550	0,15331	0,75853	0,88780	0,18604	0,26521	0,26438	0,26639	0,75436	0,14854
473	0,14188	0,53350	0,55254	0,14388	0,66263	0,94961	0,17394	0,30557	0,20385	0,24194	0,64386	0,14504
514	0,21243	0,70570	0,55632	0,37921	0,60208	1,33836	0,60889	1,05238	0,16574	0,25228	0,37613	0,34732
555	0,35800	1,04627	0,55940	0,43311	0,69273	1,25067	1,40049	1,29044	0,23567	0,69113	0,37055	1,03437
546	0,09083	0,23362	0,16426	0,14515	0,18693	0,41266	0,40107	0,43401	0,05748	0,10050	0,09653	0,22184
595	0,37833	1,13910	0,39694	0,32292	0,58385	0,74646	1,50719	0,98118	0,26093	1,01344	0,26302	1,30391
635	0,51466	1,62825	0,43129	0,34904	0,80293	0,57664	1,80203	0,89451	0,53328	1,64131	0,33640	1,68308
685	0,37391	1,33486	0,29789	0,23962	0,62255	0,44210	1,26692	0,70079	0,74338	1,12848	0,49183	1,24041
745	0,07770	0,20748	0,08264	0,04046	0,12088	0,07095	0,17498	0,10893	0,16799	0,15237	0,14868	0,17901

calculation:
matrix for linear transformation CM

	400	424	450	473	514	555	546	595	635	685	745
A = T * S'_trans	142,5177	163,2143	410,4609	393,1663	582,4636	816,665	228,9099	754,7851	904,3754	654,5415	96,84877
	145,4349	167,4864	428,822	414,3827	626,9071	849,2707	243,5794	759,0558	878,2706	633,4448	93,86426
	167,2429	190,8926	487,152	460,3641	561,9948	690,0651	195,8271	585,1666	681,2461	501,3504	79,75564
	180,7118	-428,668	215,3315	-114,861	-24,0697	39,44455	-16,4092	-20,7301	-8,0364	29,74944	-104,46
	-428,668	2303,911	-1688,91	1061,428	140,0555	-623,681	683,0566	400,4745	-12,9371	-171,942	563,9014
	215,3315	-1688,91	1414,982	-963,108	-61,9822	534,7456	-727,251	-317,341	-3,80139	149,0717	-475,202
	-114,861	1061,428	-963,108	720,7381	120,0141	-811,723	1035,097	497,766	-33,7553	-100,283	326,8643
	-24,0697	140,0555	-61,9822	120,0141	572,3402	-2134,85	2050,233	1465,131	-239,393	10,86543	32,35221
B = [S' * S'_trans]^-1	39,44455	-623,681	534,7456	-811,723	-2134,85	8558,352	-8652,76	-5772,34	901,0318	-11,8476	-201,845
	-16,4092	683,0566	-727,251	1035,097	2050,233	-8652,76	9077,549	5744,224	-855,915	-15,9823	263,6993
	-20,7301	400,4745	-317,341	497,766	1465,131	-5772,34	5744,224	3926,663	-630,175	20,46656	110,2934
	-8,0364	-12,9371	-3,80139	-33,7553	-239,393	901,0318	-855,915	-630,175	119,8456	-30,6599	50,97516
	29,74944	-171,942	149,0717	-100,283	10,86543	-11,8476	-15,9823	20,46656	-30,6599	55,35498	-153,697
	-104,46	563,9014	-475,202	326,8643	32,35221	-201,845	263,6993	110,2934	50,97516	-153,697	477,841
CM = A * B	106,763	264,0092	-112,898	60,23206	6,208266	0,828751	-8,7215	33,75812	-5,37536	-1,99021	3,154893
==> Device Calibration	-113,08	267,1864	-123,162	65,94365	27,52857	-32,685	47,6374	46,19491	-11,6796	0,537424	-1,25876
	128,412	388,3724	-146,35	109,2606	12,3867	-37,8635	28,47036	25,13567	-2,49406	-8,66411	11,79338

In the document [1], different procedures are briefly described, which differ according to the source and the use of the calibration data.

The *individual calibration* is done by using the correction data at the sensor, where they were measured for calibration. This promises the highest accuracy with the highest effort since it considers all individual deviations and disturbances.

In *batch calibrat*ion, a typical sample of a batch (or lot or type) is declared a Golden Device and used for calibration. The resulting correction is applied to all the sensors in the batch. Thus, batch-by-batch deviations are considered, but individual ones are ignored. When a new batch is produced, the Golden Device and the calibration must be updated. In the batch calibration, the selection of the Golden Device is done once at the beginning. Here, batch deviations and production, drift over time are not considered. However, the least amount of effort is involved. Each manufacturer must decide for himself, based on his products, which variant is optimal for him.

There are still procedures to minimize inaccuracies in the series when using Golden Devices in batch calibrations. This is described, for example, in the documents [1] and [**Error! Reference source not found.**] as *balancing*, where the sensor raw values can be adjusted to the behavior of the Golden Device using one or n-targets (like White balancing in cameras). Using more than one target for balancing can increase accuracy after calibration but it is depending on the target selection.

Note that the document [**Error! Reference source not found.**] considers a commercially available light source, which a customer can use as a reference to align their device with the Golden Device, and subsequently use the correction of the Golden Device matrix. However, the deviations between the light sources are not considered, which can lead to inaccuracies.

Figure 3:
Comparison of the calibration results: Individual Calibration, and Golden Device + Balance

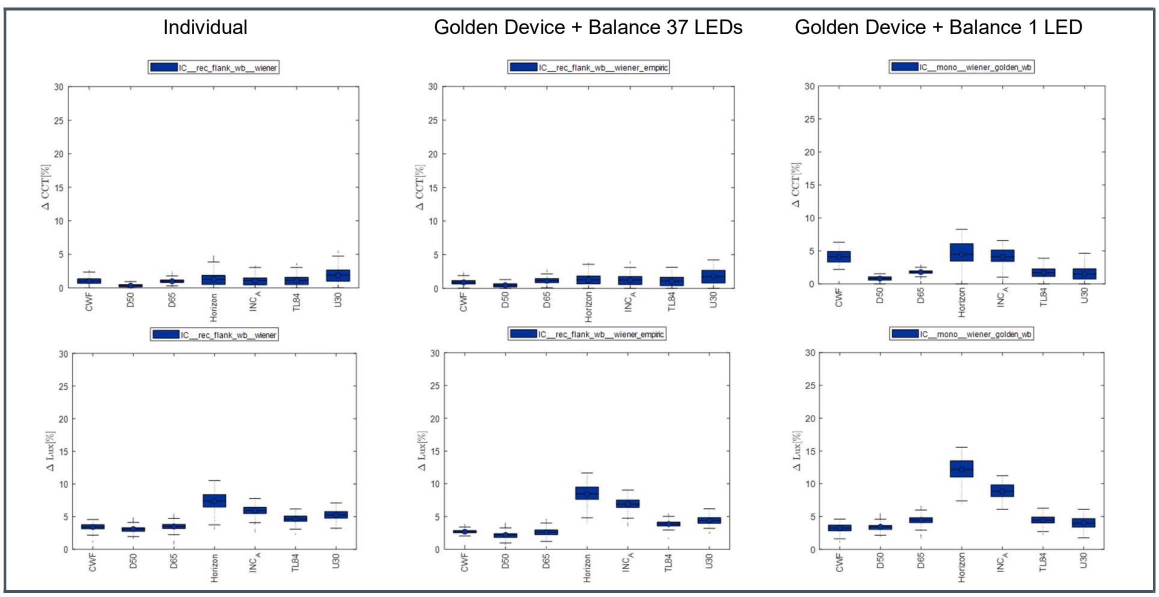


Figure 3 shows exemplary results (mean error) of a comparison between an Individual and Golden Matrix. It also includes Balance-corrected and calibrated sensor results of 85 x AS7343 EVK's after measuring alternative light sources from a light box, whereby 37 LEDs or only 1 LED were (was) used for balancing. The results in CCT and Lux (mean error) in the diagram become better from left to the right, which also corresponds to an increase in effort.

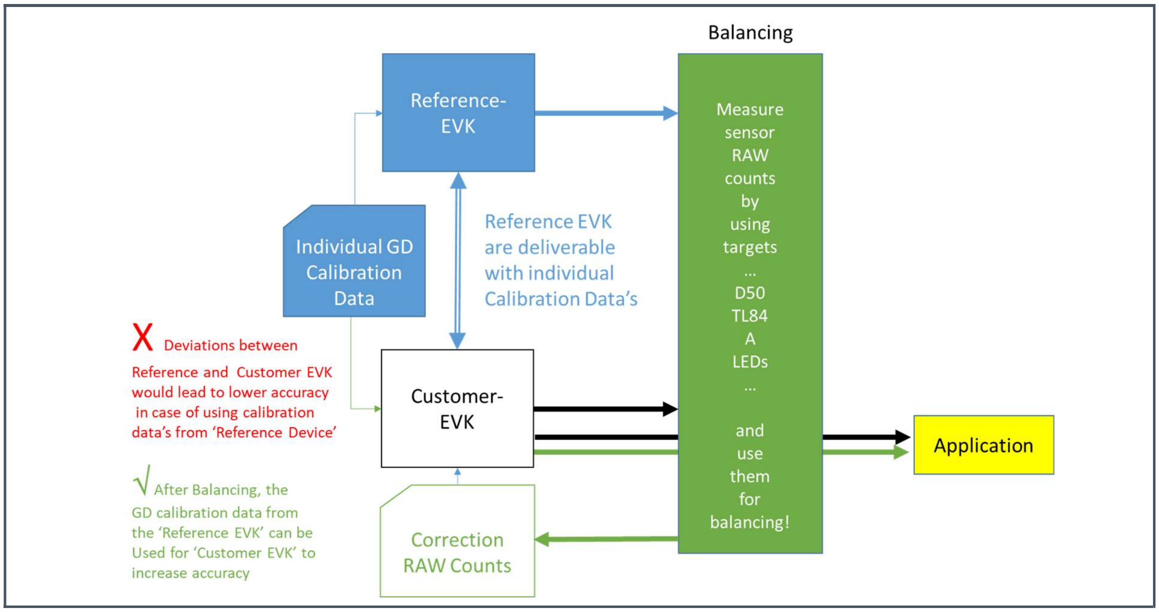
Figure 4:
Exemplary results of different Calibration Methods

Method	Kind of Calibration	Max CCT Error (%)	Max Lux Eror (%)
General CM	Lot / Type	22.5	20.8
General CM + single light source white balancing	Lot / Type	8.3	15.3
Individual CM	Individual	5.6	10.3
General CM + calibrated data with 37 LED’s	Lot / Type	4.3	11.2
Individual CM Individual 3x10 xyzMatrix	Individual	5.6	10.3

Figure 4 shows the results in the table for all variants of the realized calibrations, as maximum values. The accuracy and efforts become higher from top to bottom. A similar procedure to the document [**Error! Reference source not found.**], is described in this application note.

This document refers to users of the AS7343 Evaluation Kit (hereafter named AS7343 EVK ALS or just EVK) supplied by **ams**, with a Golden correction matrix for the EVK’s. That is, a typical device from the first Lot has been spectrally measured with a monochromator, and its sensitivity is calculated to “1” and negated (Wiener Inverse). The result for this Golden Device is a correction matrix spectrally in 1 nm steps, or directly to XYZ values (CIE1931 standard observer – see Figure 1). The matrix considers all the deviations of the filters from the Golden Device in transmission and rest transmission, and represents an individual calibration. The raw values of the Golden Device multiplied by the matrix result in the reconstructed spectrum of the light source, from which the raw values originate. Of course, there are still residual errors resulting from measurement errors in the calibration, as well as disturbances and noise in the sensor detection. However, they are tiny compared to other calibration methods. This matrix of the Golden Device is now used for all “Standard-EVK”, to correct the raw values of a reconstructed spectrum. According to the deviations of the raw values to the Golden Device, the spectra also deviate as a result, since individual drifts are not considered. However, field tests have shown that most of these deviations measured in CCT and Lux (CIE1931 based) do not exceed the 10% limitation. If this accuracy is not sufficient, the accuracy can be increased with a Reference-EVK.

Figure 5:
Using a Reference-EVK and its individual calibration



A Reference-EVK corresponds to the Standard-EVK of **ams** in hardware and software. However, it is supplied with individual correction values. These consist of the correction matrices, factors for gain correction, and the raw values of the kit in a standard light box (calibrated), with various light sources for checking. Using the Reference-EVK, a customer can measure and compare any EVK (=Customer-EVK), with the Reference-EVK at different light sources under laboratory conditions and using single or multiple references as a matrix or average, to balance the Customer-EVK to the Reference-EVK. With the use of the balance data, the use of the calibration matrix of the Reference Kit with the Customer-EVK is possible, which should lead to a higher accuracy than the use of the type-generated matrix of the Golden Device.

Information

The method is not only possible in connection with the Customer-EVK, but it also lends itself to feasibilities and series products if the same sensor type is used in a similar optical stack. Then the Golden Matrix of the Reference-EVK could be used as a series correction matrix for the sensor products, provided that the device is corrected and aligned to the Reference-EVK in the raw values in the final series test. Of course, this method does not replace an individual calibration and is only an estimate that each customer has to check for quality before use in feasibilities and series.

In the following, the details for ordering such Reference–EVK and their uses are described.

1.1 Ordering Information

Ordering Code	Description
AS7343 EVK ALS Reference	The standard AS7343 EVK ALS is delivered with the Reference (Individual Correction) data plus RAW counts for simulations.

2 Out of the Box

2.1 AS7343 EVK ALS

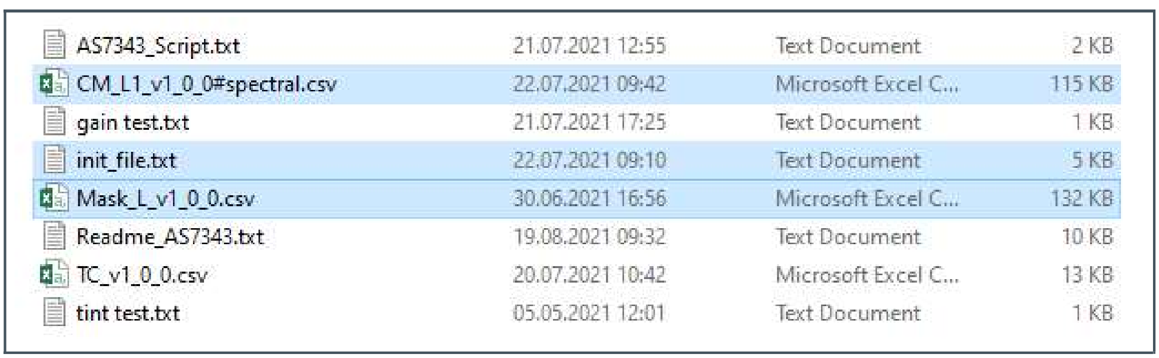
The differences between the AS7343 EVK ALS and the AS7343 EVK ALS Reference are the data for the individual correction and calibration. The data will be described in the following chapters. All other details for the AS7343 EVK ALS, GUI, its installation, and operation are included in [3].

2.2 AS7343 EVK ALS Reference Data's

The setup of the AS7343 EVK ALS Reference installs the standard correction data as described in [3]. These data are located in a separate directory for the EVK-Data (replace \xxxx\ *as user directory* in the following path with your defined subdirectory): "*C:\Users\xxxx\AppData\Roaming\ams-OSRAM\AS7343 Demo ALS*". The data represent general corrections data, which are used for all AS7343 EVK's ALS as a Golden Device-based calibration. With this, these data are not individual calibration data but can be changed by individual ones.

Figure 6 shows the standard files after installation in the defined path. The blue marked files include the correction data for the EVK. They are described in [3].

Figure 6:
Marked Files with (General) Correction data for the AS7343 EVK ALS after the GUI Installation



AS7343_Script.txt	21.07.2021 12:55	Text Document	2 KB
CM_L1_v1_0_0#spectral.csv	22.07.2021 09:42	Microsoft Excel C...	115 KB
gain test.txt	21.07.2021 17:25	Text Document	1 KB
init_file.txt	22.07.2021 09:10	Text Document	5 KB
Mask_L_v1_0_0.csv	30.06.2021 16:56	Microsoft Excel C...	132 KB
Readme_AS7343.txt	19.08.2021 09:32	Text Document	10 KB
TC_v1_0_0.csv	20.07.2021 10:42	Microsoft Excel C...	13 KB
tint test.txt	05.05.2021 12:01	Text Document	1 KB

In addition to the standard data, the USB stick for the Reference-EVK contains additional individual correction data in a separated directory \Reference data.

All files are named with the <device_name> as file name but differ in extension. The following table gives an overview of the files in the reference directory, their contents, and each adequate file(s) used by the AS7343 EVK ALS GUI where parameters must be copied – in the case of using the Reference data in EVK processing.

Figure 7:
Overview of the Reference Files in the Reference Directory with Contents And Parallel

File	Content (Individual data's for each EVK)	Adequate File GUI (see Figure 6) [3] [4]
<device_name>.C	Gain Correction Matrix [13:13] XYZ Calibration Matrix [3:13]	init_file.txt CM_L1_v1_0_0.csv
<device_name>.CSV	Gain Correction Matrix [13:13] Spectral Calibration Matrix [700:13]	init_file.txt CM_L1_v1_0_0.csv
<device_name>.XLSX	for CWF, D50, D65, Horizon, INC_A, TL84, U30: CCT, Lux, TINT, Gain and measured Sensor Basic Values	None - only for individual simulations
<device_name>.XML	Gain Correction Matrix [13:13] Calibration_Vector_Lux [1:13] XYZ Calibration Matrix [3:13] Spectral Calibration Matrix [700:13]	init_file.txt CM_L1_v1_0_0.csv

The Reference Data is processed according to the next steps.

Attention

The Reference data represent results of the individual calibration for the EVK of the AS7343 EVK ALS Reference Package. In principle, they are only valid for this hardware and optical stack. However, a method is presented here where the Reference Data can be applied in conjunction with a similar AS7343 EVK ALS with the same optical stack after EVK's balancing to increase the accuracy with this EVK.

[3] Name ini_file.txt is fix. The GUI expects such a file with this name as initialization file.
[4] Name is defined in initialization file init_file.txt as parameter 'LightDetectionCalibrationMatrixFile= xxx.csv' and free selectable.

3 Working with Reference Data

Golden Device calibration, in combination with balancing, is a proven method and a good compromise between individual calibration and Golden Device calibration alone. Figure 8Error! Reference source not found. shows a comparison of results after Golden Device calibration for (A) based on simulation data, (B) based on measured sensor data, and (C) measured sensor data including balancing.

Figure 8:
Comparison of Different Calibration Methods A-C for Different Light Sources

		Target	Measured	Target	Measured	Target	Measured	Target	Measured	Target	Measured	Target	Measured
(A) General Calibration)based on design data's)		*D65*		*U30*		*TL84*		*CWF*		*Ind A*		*HZ*	
	CCT absolute	6514	7068	2898	3329	3922	4539	4040	4379	2884	3519	2365	3488
	Error abs and %	**554**	**9%**	**431**	**15%**	**617**	**16%**	**339**	**8%**	**635**	**22%**	**1123**	**47%**
	Lux absolute	1083	1057	1568	1550	1485	1175	1146	937	1802	1900	1124	1343
	Error abs and %	**26**	**2%**	**18**	**1%**	**310**	**21%**	**209**	**18%**	**98**	**5%**	**219**	**19%**
		D65		*U30*		*TL84*		*CWF*		*Ind A*		*HZ*	
(B) Golden Device Calibrated	CCT absolute	6514	7056	2898	3225	3922	4311	4040	4227	2884	2880	2365	2296
	Error abs and %	**542**	**8%**	**327**	**11%**	**389**	**10%**	**187**	**5%**	**4**	**0,14%**	**69**	**3%**
	Lux absolute	1083	1039	1568	1260	1485	1185	1146	963	1802	1710	1124	1050
	Error abs and %	**44**	**4%**	**308**	**20%**	**300**	**20%**	**183**	**16%**	**92**	**5%**	**74**	**7%**
		D65		*U30*		*TL84*		*CWF*		*Ind A*		*HZ(CT*	
(C) Golden Device Calibrated plus Device Balance	CCT absolute	6514	6787	2898	2835	3922	3836	4040	4180	2884	2837	2365	2238
	Error abs and %	**273**	**4%**	**63**	**2%**	**86**	**2%**	**140**	**3%**	**47**	**2%**	**127**	**5%**
	Lux absolute**1	1083	1072	1568	1445	1485	1365	1146	1041	1802	1752	1124	1035
	Error abs and %	**11**	**1%**	**123**	**8%**	**120**	**8%**	**105**	**9%**	**50**	**3%**	**89**	**8%**

Remember that the design data from the simulations are only considered typical model parameters (the worst performance is highlighted in yellow in Figure 8Error! Reference source not found.), while the measured data are based on real conditions but do not include individual deviations (the medium performance is highlighted in grey in Figure 8Error! Reference source not found.). Here, double deviations of all system components can have a dramatic effect if the shift is in the opposite direction. Balancing tries to counteract this by adjusting the raw counts and is as good as the target(s) can compensate for this drift across all applications (the best performance is highlighted in green in Figure 8Error! Reference source not found.).

An example is shown in Figure 8**Error! Reference source not found.** in the green table. The balancing was done with light source A because this light source is homogenous over VIS (but characterized by a high NIR and a weak signal in short wavelengths). Nevertheless, the balancing using light source A provides good but different results for the single light sources. Another good method is to measure (balance) over several light sources and take the average of the calculated correction values as a correction vector (or use a matrix with multiple light sources and corrections per filter).

Information

Balancing can increase the accuracy for another device in case of using a Golden Device Calibration Matrix from a lot calibration - if one or more targets can be used to make RAW counts closer to the Golden Device for all applications in the use case. The target and the method should be simulated to be generally applicable and accurate.

The Reference Data can be used for the EVK of the reference package as well as for identical EVKs of the same sensor type. For this purpose, the contents of the Reference Data must be transferred to the initialization files of the GUI. Figure 7 shows the contents from the file that must be transferred into the specified initialization file. The following is to be considered.

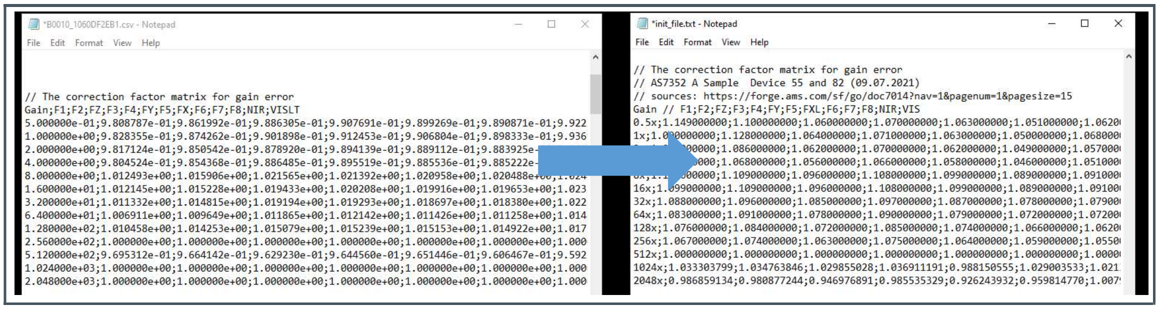
The "*Init_file.txt*" cannot not be renamed. The name is fixed. Other names for other files are agreed on in the file "*Init_file.txt*", i.e. the calibration file and the mask file can deviate in the name from the model, however, they are to be entered in the "Init_file.txt".

The "*Init_file.txt*" file also includes all the parameters for the Main Tab of the GUI (to control the sensor and get the ADC results from the RAW counts up to the Corrected Counts). On the other side, all data in the calibration file CM*.CSV are valid for the ALS Ambient Light Sensing function, which can be started from the Main Tab. ALS calculations are done by the sensor results but can be made by special application-specific parameters like Gain_Correction, which are listed in the CM*.CSV. It means data like Gain_Correction may be listed in two files. In this case, they are valid for the Main Tab and the ALS function separately. Then, the data must be copied twice. More details for the GUI, ALS, and initialization files are given in [3].

As seen in chapter 2.2, when the initialization data of the Reference package is used in combination with an AS7343 EVK, then the initialization files must be changed with the Reference data. Sources and targets for the copy and/or changing process are shown in Figure 7. In practical terms, the following steps are necessary:

- Copy from "*USB:\Reference Datas\<name>.CSV*" to "*C:\Users\xxx\AppData\Roaming\ams-OSRAM\AS7343 Demo ALS*".
- Edit the file "*init_file.txt*" and set the parameter LightDetectionCalibrationMatrixFile= to <name>.CSV.
- Edit "*init_file.txt*" and copy the gain values from the Reference data into the "*init_file.txt*".

Figure 9:
Copying Parameters from Reference Data to the GUI Initialization File



Afterward, start the GUI on the PC after connecting the EVK via USB. The GUI will read the parameters from the "*init_file.txt*" and their specified files. Check the syntax and formal parameters of all the initialization files and list errors in the status windows in case of issues. Follow the instructions of the GUI or see for more details in our manual for the GUI the document [3].

3.1 Working with the Sensor from the AS7343 EVK ALS Reference

The Reference data were generated as individual calibration, with the sensor, hardware, and optical stack from the Reference Kit. The kit and calibration data are tuned for each other and with each other. Therefore, high accuracy measurements can be started with the Reference Kit after copying the initialization data into the initialization files of the GUI (see chapter 3). Compared to a reference device (e.g. spectrometer) and standard light sources, the results should not have a deviation greater than 5% mean CCT or Lux.

The following example shows the results of measuring CWF in a lightbox with an AS7343 EVK ALS Reference Kit (Protocol File with RAW Counts and Target values) and its results after using individual calibration matrix and corrections.

Figure 10:
Part of Test Protocol + Target Reference – CWF Light Source were measured ten times

Device: B0010_1060DF2EB1
Calibration Method: IC__rec_flank_wb__wiener

											Mean
Reference CCT [K]	4041,944631	4040,699513	4038,885171	4044,049501	4041,092184	4043,887417	4042,637366	4039,755486	4040,367789	4040,199864	4041,352
Calculated CCT [K]	4015,903115	4027,869371	4028,064412	4009,925227	4020,001461	4011,728191	4019,806253	4019,432373	4009,918966	4028,216728	4019,087
Deviation CCT [%]	-0,644281856	-0,317522783	-0,267914481	-0,843814462	-0,521906511	-0,79525524	-0,564757891	-0,503077795	-0,753615133	-0,296597605	-0,55087
Reference Lux [lx]	222,9637395	223,1823231	223,1458496	222,9038916	223,1683626	222,8015771	222,8707577	223,00318	223,0720944	222,9580252	223,007
Calculated Lux [lx]	224,1630152	224,5010491	224,5012082	224,1416497	224,1611506	223,8213453	224,1609914	224,1633306	224,1415083	224,5019662	224,2257
Deviation Lux [%]	0,537879276	0,590873863	0,607386889	0,555287777	0,444860543	0,457702416	0,578915655	0,520239511	0,479402825	0,692480602	0,546503
Integration time [ms]	256	256	256	256	256	256	256	256	256	256	
Gain	50,04	50,04	50,04	50,04	50,04	50,04	50,04	50,04	50,04	50,04	
Raw counts											
F1	85	85	85	85	85	85	85	85	85	85	
F2	143	143	143	143	143	143	143	143	143	144	
FZ	218	219	219	219	219	219	219	219	219	219	
F3	187	187	187	187	187	187	187	186	187	187	
F4	284	284	284	284	284	284	284	283	284	284	
FY	703	704	704	703	703	702	703	703	703	704	
F5	193	193	193	193	193	193	193	193	193	193	
FX	676	676	676	677	676	676	676	676	677	676	
F6	402	402	403	402	403	402	402	402	402	403	
F7	157	157	157	157	157	157	157	157	158	157	
F8	24	24	24	24	24	24	24	24	24	24	
NIR	32	32	31	31	31	31	32	32	32	31	
VISLT	366	366	366	366	366	365	366	366	366	366	

Figure 11:
CWF (Dev<1%) Reference Kit after using Individual Correction (Spectral plus XYZ Direct)

User Measured Data plus corrections

Measured Sensor's Channel Data's

AS7352 Channel	Channel Wavelength (WV)	Basic Counts from protocol file	Basic Counts Gain Corrected	Corr Sensor Factor	Offset as Corr BasicC	Corrected Sensor Data's
F1	400	0,006588	0,006588	1,000000	0,00	0,006588
F2	424	0,011083	0,011083	1,000000	0,00	0,011083
FZ	450	0,016896	0,016896	1,000000	0,00	0,016896
F3	473	0,014493	0,014493	1,000000	0,00	0,014493
F4	514	0,022011	0,022011	1,000000	0,00	0,022011
FY	555	0,054486	0,054486	1,000000	0,00	0,054486
F5	547	0,014958	0,014958	1,000000	0,00	0,014958
FXL	595	0,052393	0,052393	1,000000	0,00	0,052393
F6	635	0,031157	0,031157	1,000000	0,00	0,031157
F7	685	0,012168	0,012168	1,000000	0,00	0,012168
F8	745	0,001860	0,001860	1,000000	0,00	0,001860
NIR	850	0,002480	0,002480	1,000000	0,00	0,002480

by using Tint and Gain 50,4 / 256

Results based on XYZ Calibration			Results based on Spectral Calibration		
CIE1931 based on Golden Unit XYZ Calibration Matrix			CIE1931 based on Golden Unit Spectral Calibration Matrix		
X	0,3178		X	0,3178	
Y	0,3259		Y	0,3259	
Z	0,1827		Z	0,1827	
x	0,3846		x	0,3846	
y	0,3943		y	0,3944	
z	0,2211		z	0,2211	
Lx	223	lx	Lx	223	lx
L	2,94		L	2,94	
u'	0,2209	***	u'	0,2209	***
v'	0,5097	***	v'	0,5097	***
CCT	4009	K	CCT	4009	K
CCT inside			CCT inside		

3.2 Working with other AS7343 EVK ALS Kits

When correcting another, but identical, AS7343 EVK ALS (named here Alternative-EVK) with the reference data of the Reference-EVK (Golden Device), higher deviations result - since the system is now no longer individually adjusted. The problem of the non-adjustment of individual deviations has already been explained here several times. The following figures show the protocol and result of the case.

Figure 12:
Part of Test Protocol + Target Alternative – CWF Light Source were measured ten times

Device: B0011_1060DF2E87											Mean
Calibration Method: IC__rec_flank_wb__wiener											
Reference CCT [K]	4042,411919	4041,170302	4043,471339	4043,262781	4040,00196	4043,055395	4041,148217	4043,202811	4042,112022	4046,06296	4042,59
Calculated CCT [K]	3993,615577	4001,720925	3991,983154	3983,848374	3983,507021	3983,974617	3993,426008	3989,546204	3993,615577	3980,138003	3989,538
Deviation CCT [%]	-1,207109574	-0,976186952	-1,273365881	-1,469466862	-1,398388904	-1,461290341	-1,180907165	-1,327081775	-1,199779821	-1,629360626	-1,31229
Reference Lux [lx]	223,0040767	222,7372135	222,7313706	222,7201393	222,8146701	222,7858199	222,862841	222,8196562	222,8515483	222,7251361	222,8052
Calculated Lux [lx]	223,1265287	223,4615552	223,439796	223,1047695	223,1022874	223,107209	223,1257791	223,1261592	223,1265287	223,1066109	223,1827
Deviation Lux [%]	0,0549102	0,325200157	0,318062709	0,172696657	0,129083628	0,144259222	0,117982024	0,137556543	0,12339175	0,171276028	0,169442
Integration time [ms]	256	256	256	256	256	256	256	256	256	256	
Gain	50,04	50,04	50,04	50,04	50,04	50,04	50,04	50,04	50,04	50,04	
Raw counts											
F1	90	90	90	90	90	89	90	90	90	90	
F2	151	151	151	151	151	151	150	151	151	151	
FZ	231	231	231	231	231	231	231	230	231	230	
F3	190	190	190	190	189	190	190	189	190	190	
F4	296	296	296	296	296	296	296	296	296	296	
FY	715	716	716	715	715	715	715	715	715	715	
F5	201	200	200	201	200	201	200	201	200	201	
FX	701	701	702	702	702	702	701	701	701	702	
F6	404	404	404	404	404	404	404	404	404	404	
F7	157	157	157	157	156	157	157	157	157	157	
F8	24	24	24	24	24	24	24	24	24	24	
NIR	31	31	31	31	31	31	31	31	31	31	
VISLT	370	370	370	370	369	369	370	370	370	370	

Figure 13:
CWF (Dev<3%) Reference Kit after using Individual Correction from Reference

User Measured Data plus corrections						
Measured Sensor's Channel Data's						
AS7352 Channel	Channel Wavelength (WV)	Basic Counts from protocol file	Basic Counts Gain Corrected	Corr Sensor Factor	Offset as Corr BasicC	Corrected Sensor Data's
F1	400	0,006975	0,006975	1,000000	0,00	0,006975
F2	424	0,011703	0,011703	1,000000	0,00	0,011703
FZ	450	0,017904	0,017904	1,000000	0,00	0,017904
F3	473	0,014726	0,014726	1,000000	0,00	0,014726
F4	514	0,022941	0,022941	1,000000	0,00	0,022941
FY	555	0,055416	0,055416	1,000000	0,00	0,055416
F5	547	0,015578	0,015578	1,000000	0,00	0,015578
FXL	595	0,054331	0,054331	1,000000	0,00	0,054331
F6	635	0,031312	0,031312	1,000000	0,00	0,031312
F7	685	0,012168	0,012168	1,000000	0,00	0,012168
F8	745	0,001860	0,001860	1,000000	0,00	0,001860
NIR	850	0,002403	0,002403	1,000000	0,00	0,002403
by using Tint and Gain	50,4 / 256					

Results based on XYZ Calibration		
CIE1931 based on Golden Unit XYZ Calibration Matrix		
X	0,3307	
Y	0,3310	
Z	0,1946	
x	0,3862	
y	0,3865	
z	0,2272	
Lx	226	lx
L	2,99	
u'	0,2250	***
v'	0,5067	***
CCT	3918	K
CCT inside		

Results based on Spectral Calibration		
CIE1931 based on Golden Unit Spectral Calibration Matrix		
X	0,3307	
Y	0,3310	
Z	0,1945	
x	0,3862	
y	0,3865	
z	0,2272	
Lx	226	lx
L	2,99	
u'	0,2250	***
v'	0,5067	***
CCT	3917	K
CCT inside		

The deviations become higher than the individual calibration (see Figure 11 and Figure 13) and increase from 1% to 3% for the specific light source CWF. The deviation of other light sources may be higher or lower. This must be tested or simulated for all or typical targets of the application, and a decision must be made based on the mean or maximum limit parameters. If it is decided that the deviations are too large with the Golden Device calibration, a reduction of the deviation can be attempted through balancing. This procedure was also explained in this document.

Figure 14 shows test results of both EVKs with different light sources, measured in a standard light box in Basic_Counts, the average of the results per EVK, and the Correction_Factor for the Alternative-EVK, to make the Basic_Counts similar to the Reference-EVK. The Correction_Factor was calculated as a ratio of the Average per channel of both columns in Figure 14.

Figure 14:
Test Results of the Reference and Alternative EVK with the Average And Correction Factor

Measured with Reference Device								
	CWF	D50	D65	Horizon	INC_A	TL84	U30	Average
F1	0,006635	0,016698	0,014082	0,015238	0,016112	0,004293	0,003747	0,010972
F2	0,011171	0,021358	0,017783	0,017634	0,020398	0,010172	0,007549	0,015152
FZ	0,017088	0,032607	0,026291	0,015503	0,025386	0,017088	0,011397	0,020766
F3	0,01459	0,038961	0,029656	0,034527	0,044472	0,016916	0,011342	0,027209
F4	0,022162	0,047962	0,032966	0,034355	0,054293	0,020921	0,01765	0,032901
FY	0,054894	0,066509	0,04192	0,060264	0,092754	0,056065	0,056658	0,061295
F5	0,015066	0,018259	0,011873	0,016034	0,023911	0,020507	0,018969	0,017803
FX	0,052786	0,061568	0,036143	0,075736	0,106165	0,056111	0,065128	0,064805
F6	0,031405	0,071092	0,039055	0,129904	0,16077	0,039695	0,05206	0,074854
F7	0,012264	0,089015	0,054495	0,210441	0,233602	0,013349	0,017478	0,090092
F8	0,001874	0,04697	0,03128	0,15401	0,149779	0,001717	0,002264	0,055413
NIR	0,002459	0,155922	0,107149	0,73506	0,594657	0,001788	0,002264	0,228471
VISLT	0,028563	0,066259	0,042895	0,115189	0,135345	0,030359	0,032084	0,064385

Measured with Alternative Device										
	CWF	D50	D65	Horizon	INC_A	TL84	U30	Average		CorrVal
F1	0,007018	0,017041	0,014434	0,013528	0,015058	0,004606	0,003981	0,010809		1,015062
F2	0,01178	0,021811	0,018173	0,016362	0,019539	0,010695	0,007884	0,015178		0,99831
FZ	0,018017	0,034293	0,027548	0,015613	0,026065	0,018134	0,0121	0,021681		0,957772
F3	0,014816	0,038742	0,029484	0,032006	0,042326	0,017025	0,011397	0,026542		1,025125
F4	0,023107	0,049445	0,033825	0,034574	0,055073	0,021545	0,018392	0,033709		0,976048
FY	0,05583	0,067711	0,042607	0,061217	0,093293	0,057524	0,058484	0,062381		0,982588
F5	0,015652	0,018758	0,012178	0,016198	0,024207	0,021155	0,019516	0,018238		0,976153
FX	0,054761	0,063722	0,037298	0,078492	0,108866	0,058563	0,067813	0,067074		0,966182
F6	0,031537	0,071177	0,039023	0,130177	0,159669	0,039578	0,051849	0,074716		1,001851
F7	0,012248	0,09003	0,055214	0,214336	0,23489	0,013435	0,017627	0,091111		0,988813
F8	0,001874	0,04576	0,030437	0,150567	0,145001	0,001717	0,002186	0,053935		1,027417
NIR	0,00242	0,146289	0,100318	0,691283	0,55451	0,001795	0,002264	0,214126		1,066997
VISLT	0,028868	0,066244	0,042817	0,114697	0,13376	0,030601	0,032255	0,064177		1,003232

If these Correction-Factors are applied to the Basic_Counts of the Alternative-EVK, the values are adjusted to the Reference-EVK, before the values are then offset with the correction matrix of the Reference-EVK. The result should have a lower deviation, but this will vary from one light source to another.

Figure 15:
CWF (Dev<3%) Reference Kit after using Balancing and Individual Correction from the Reference

Measured Sensor's Channel Data's						
AS7352 Channel	Channel Wavelength (WV)	Basic Counts from protocol file	Basic Counts Gain Corrected	Corr Sensor Factor	Offset as Corr BasicC	Corrected Sensor Data's
F1	400	0,006975	0,006975	1,015062	0,00	0,007081
F2	424	0,011703	0,011703	0,998310	0,00	0,011683
FZ	450	0,017904	0,017904	0,957772	0,00	0,017148
F3	473	0,014726	0,014726	1,025125	0,00	0,015096
F4	514	0,022941	0,022941	0,976048	0,00	0,022392
FY	555	0,055416	0,055416	0,982588	0,00	0,054451
F5	547	0,015578	0,015578	0,976153	0,00	0,015207
FXL	595	0,054331	0,054331	0,966182	0,00	0,052494
F6	635	0,031312	0,031312	1,001851	0,00	0,031370
F7	685	0,012168	0,012168	0,988813	0,00	0,012032
F8	745	0,001860	0,001860	1,027417	0,00	0,001911
NIR	850	0,002403	0,002403	1,066997	0,00	0,002564
by using Tint and Gain		50,4 / 256				

CIE1931 based on Golden Unit XYZ Calibration Matrix		
X	0,3186	
Y	0,3256	
Z	0,1853	
x	0,3841	
y	0,3925	
z	0,2234	
Lx	222	lx
L	2,94	
u'	0,2213	***
v'	0,5089	***
CCT	4010	K
CCT inside		

CIE1931 based on Golden Unit Spectral Calibration Matrix		
X	0,3186	
Y	0,3256	
Z	0,1853	
x	0,3841	
y	0,3925	
z	0,2234	
Lx	222	lx
L	2,94	
u'	0,2213	***
v'	0,5089	***
CCT	4010	K
CCT inside		

Despite the use of the reference correction data, i.e. batch calibration, the accuracy of the results could be increased, or the deviations reduced, by balancing the raw data. However, it is to be expected that the success will not always be as positive as in this example, based on the successful test for a light source and on the basis of laboratory data.

Figure 16 shows the success of balancing, for example, CWF light source. Despite the use of the reference correction data, i.e. batch calibration, the accuracy of the results could be increased, or the deviations reduced, by balancing the raw data. However, it is to be expected that the success will not always be as positive as in this example, based on the successful test for a light source and on the basis of laboratory data.

Figure 16:
Comparing CWF using Reference-EVK and an Alternative EVK with/without Balancing

CWF	LighBox - Target	Reference EVK with Individual Calibration	Alternative EVK with Refernce Matrix	Alternative EVK with Refernce Matrix plus Balancing before
CCT	4042	4009	3918	4010
Diff CCT		33	124	32
in %		*0,8%*	*3,1%*	*0,8%*
Lux	222	223	226	222
		1	4	0
		0,02%	*0,10%*	*0,00%*

Therefore, the results of the balancing depend on many factors. The setup for the measurements should be stable over all the measurements, free from disturbances, and always used under the same conditions. The sensor and optical stack of both systems in balancing should be very comparable. The targets for balancing should correspond later to the application and be typical. It may be necessary to use several targets as an average or as a matrix, i.e. linear combination. The full process of balancing, as well as calibration and matching must be verified very carefully and can be simulated in the feasibility of a project before starting the final product design.

4 Additional Documents

The following list includes a selection of available documents with more technical details for the sensor AS7343 and its Evaluation Kit. This list is not fixed and it is constantly changing. Ask us for new details.

For further information, please refer to the following documents:

1. ams AG, *Spectral Sensor Calibration*, application note.
2. ams AG, *AS7341 Spectral Balance and Calibration*, (QG000139), quickstart guide.
3. ams AG, *Manual AS7343 EVK*, (UG001009), user guide.

5 Revision Information

Changes from previous version to current revision v0-01	Page
Initial version	all

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.

6 Legal Information

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