Application Note

AN000660

AS7341 Demo for Fast Measurement Using Unicom Board

Quick Start Guide for Fast Measurement with AS7341 Spectral Sensor

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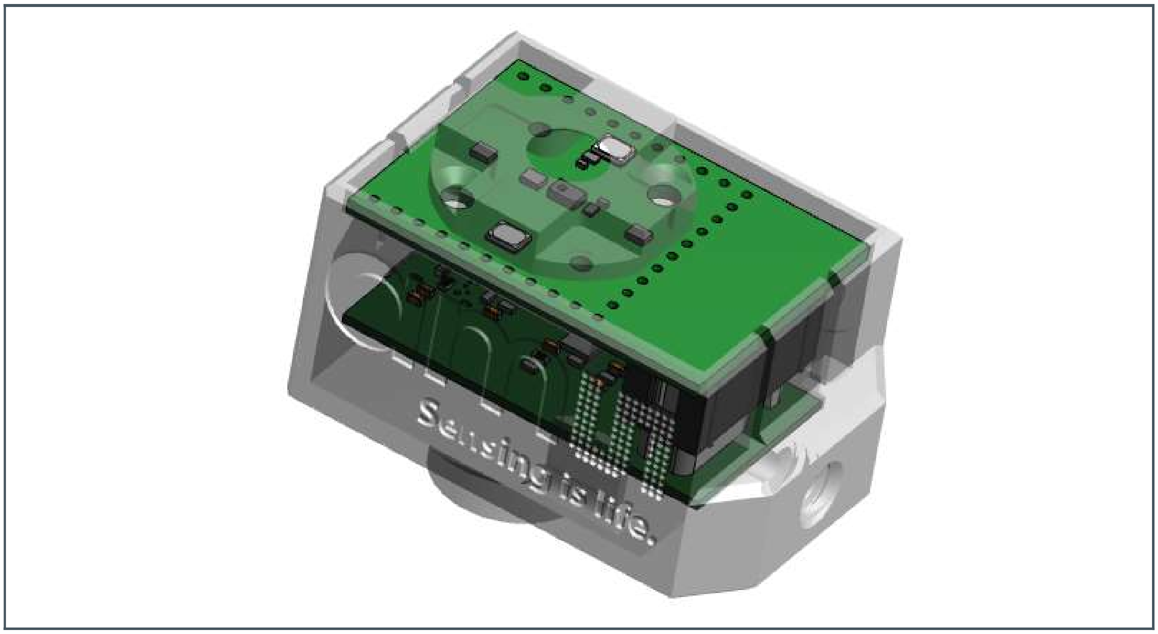
Content Guide

1 Introduction

The AS7341 EVK Fast Demo demonstrates high-speed flicker and spectral measurement capabilities in reflection mode.

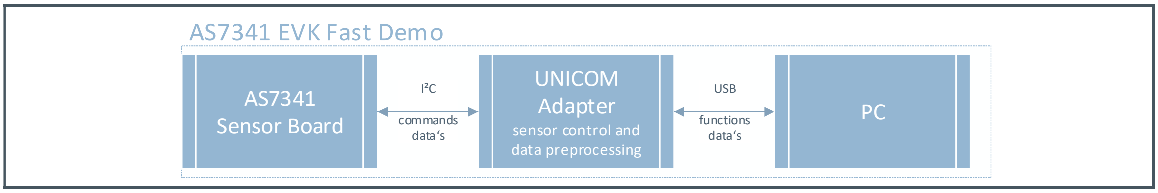
Figure 1:
Front and Back side of AS7341 EVK Fast Demo in Plastic Housing



The sensor board collects data from the sensor on the I²C level, logs them, and transfers them via a digital interface board (called Unicom board), as data packets in the GUI and the log files to the PC. The interface board and PC are connected via a standard USB 3.0 cable.

The software for Fast Demo consists of firmware and PC test software as GUI. The firmware implements the sensor control, data logging, and transfer to the PC. The GUI represents the user interface.

Figure 2:
Block Diagram AS73xx EVK Fast Demo



The Windows-oriented Fast Demo supports two different applications.

The first is a spectral measurement with selectable channels for measurements in reflection mode. The sensor results can be saved directly to a log file and/or displayed as a line graph on the screen. For this purpose, an LED on the sensor board is used, which can be switched on/off via the GUI. For the measurement in reflection, the sensor board is equipped with an adapter, which realizes a measurement geometry of 0°/45° degrees. The sensor board must be placed directly on a target to measure reflection.

The second application is called FIFO (flicker), where the sensor logs detected counts of light frequencies, which are converted by FFT into evaluable flicker frequencies, ~index, and ~factor. The results are printed out on the screen or in selectable log files, separated according to the sensor and FFT results. The test results for the demo showed a sampling frequency of up to 18 kHz. With LED illumination, a flicker between 10 Hz and 1 kHz can be detected, with an average accuracy of 1% and a duty cycle between 10% and 90%.

1.1 Kit Content

The Fast Demo consists of the following items, shown in Figure 3.

Figure 3
Kit Content of EVK Variant ALS

Item 1 **USB 3.0 Cable**	**Item 2** **Sensor Hardware and Interface in Plastic Housing with Front Adapter** **(front and back side)**	**Item 3** **USB Stick**
	 	

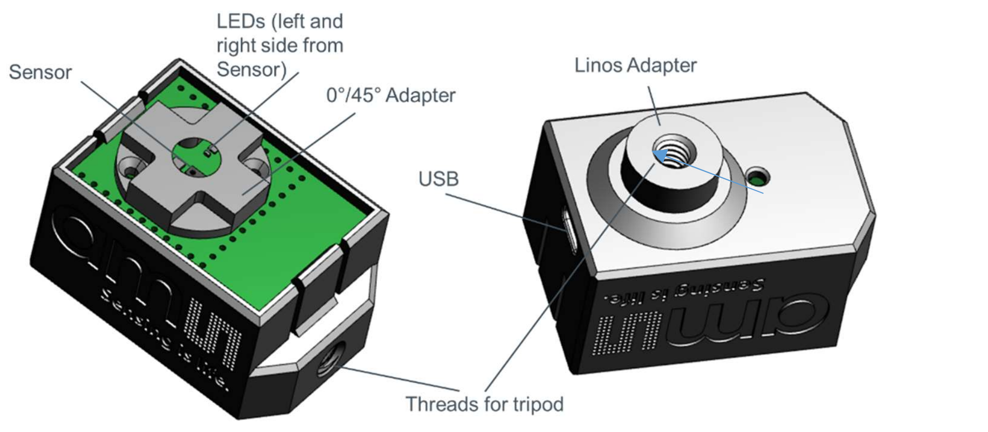
Item No.:	**Item**	**Comment**
1	USB 3.0 Cable	
2	990601119	AS7341 EVK Fast Demo Hardware in Plastic Housing with 0°/45° Front Adapter, V2.0.
3	USB Data Stick	Documents, software, firmware and drivers.

2 AS73xx EVK Fast Demo - Hardware

The hardware consists of a sensor and interface card, a front adapter, and housing where all components are mounted. A USB 3.0 cable connects the Fast Demo hardware to the PC. The manual for the AS7341 EVK (UG000400) describes all the hardware components and the adapter. All details for the sensor chip are included in the datasheet.

Figure 4 describes the Fast Demo interfaces.

Figure 4:
Fast Demo Interfaces



The Unicom board is the interface from the sensor board to the GUI. It controls the sensor and logs sensor data before it is transferred as data packets. It is derived from the microcontroller STM32F413 that provides generic interfaces like USB to I²C, SPI, and UART, etc. The I²C (inter-integrated circuit) bus interface handles communications between the microcontroller and the serial I²C bus. It supports Standard-mode (Sm), Fast-mode (Fm), and Fast-mode Plus (Fm+). The Unicom board supports the connection with AS73xx via the I²C bus.

The firmware is configured, coded, and uploaded for Fast-mode (which supports up to 400 kHz clock frequency) connection with the AS73xx sensor board (part of the AS73xx EVK).

The following figures show the front and bottom side of Unicom (Tiny version[1]), namely the schematic and position of components on the board. If a new firmware has to be loaded on the Unicom Board, the boards have to be removed carefully from the housing. To set the Unicom Board to program mode, use the S1 Push Button (see Figure 5, program mode). The process is described later.

[1]The low size variant of the Unicom is standard for demo applications = lower interfaces and smaller size.

Figure 5:
Front and Bottom View Unicom (Tiny version) with S1 Push Button

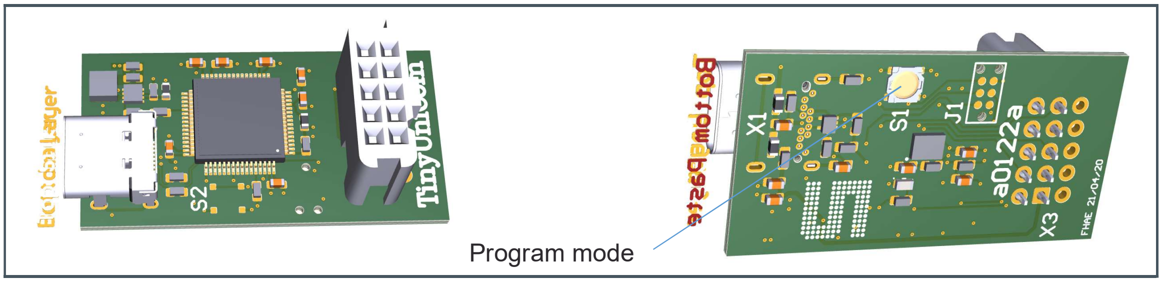
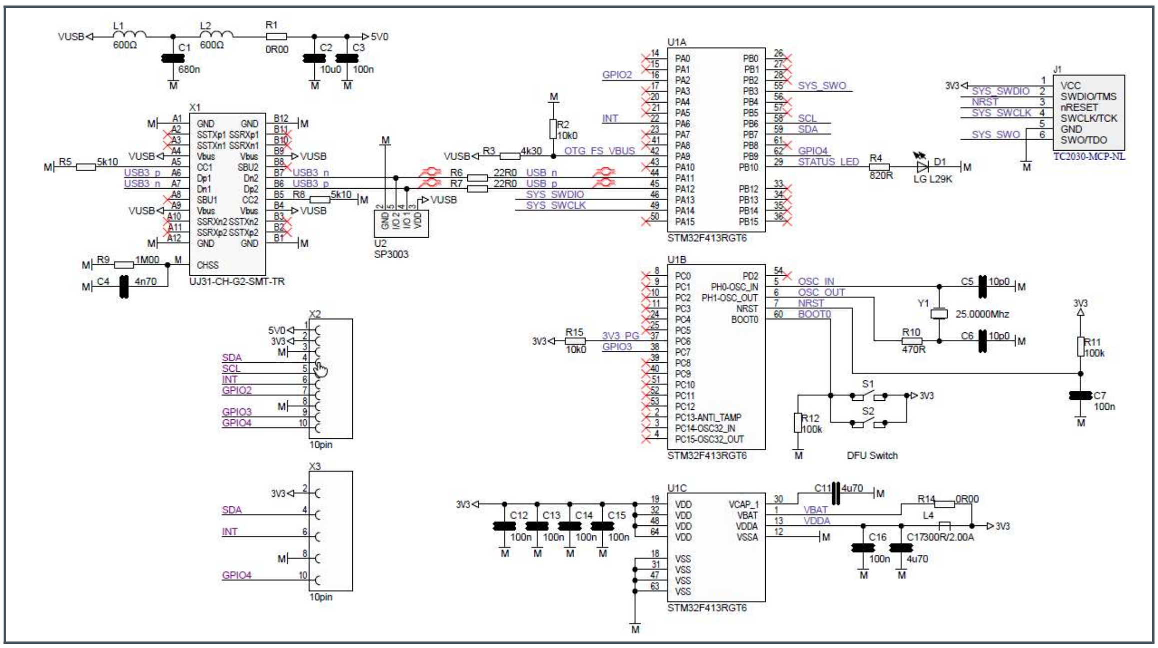


Figure 6:
Schematic Unicom (Tiny version)



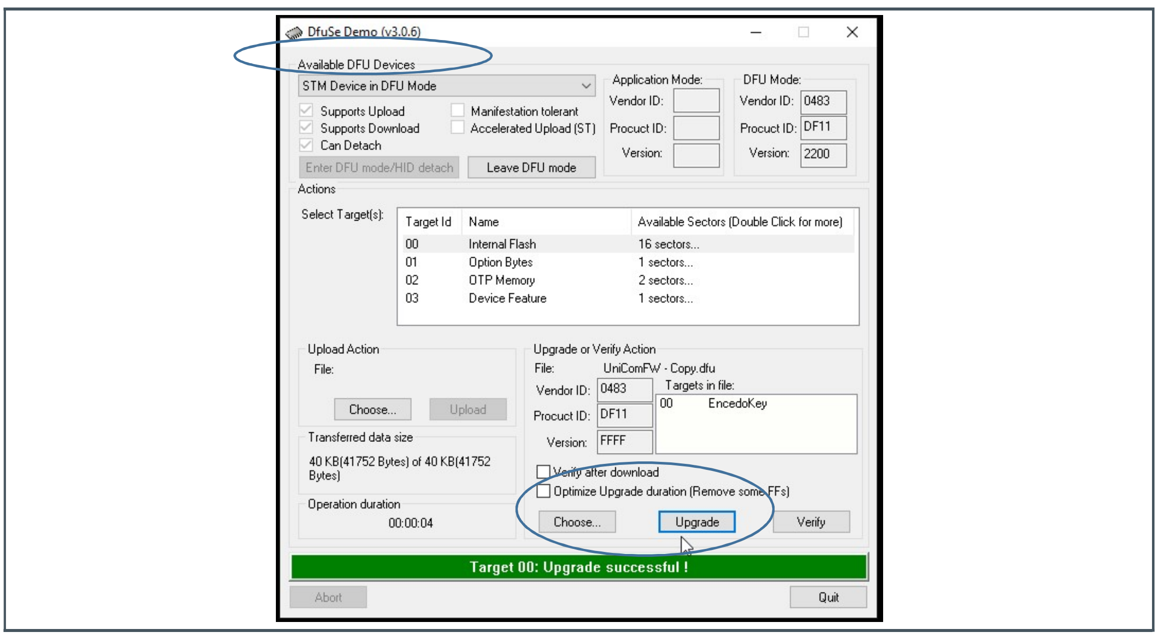
3 AS73xx EVK Fast Demo – Firmware

The Unicom interface board includes the required firmware for the AS7341 EVK Fast Demo. Firmware version v0.6.0.0 or higher is required. In case an upgrade or upload is necessary, please follow these steps:

1. Install "DfuSeDemo" (https://stmicroelectronics-dfuse.software.informer.com/3.0/)
2. Press and hold the DFU button to set the Unicom board to program mode (see Figure 5) while connecting the Unicom board (without sensor board) directly to a laptop (no hub) via USB. Once connected, release the button.
3. Start "DfuSeDemo". If the Unicom board is in the correct mode, you should see an 'STM Device in DFU Mode' as an available DFU-Device (see Figure 7).
4. Click on the "Choose" button and select desired DFU file. Click on the "Upgrade" button to start the upload process. Within seconds, you should see a message from the software: "Upgrade successful".

More details for the software are described in the DfuSeDemo manual (UM4012.pdf), which is installed in the Windows Start Directory "STM32 directory".

Figure 7:
DfuSeDemo Software – Main Window after Successful Firmware Upgrade



4 AS73xx EVK Fast Demo – GUI

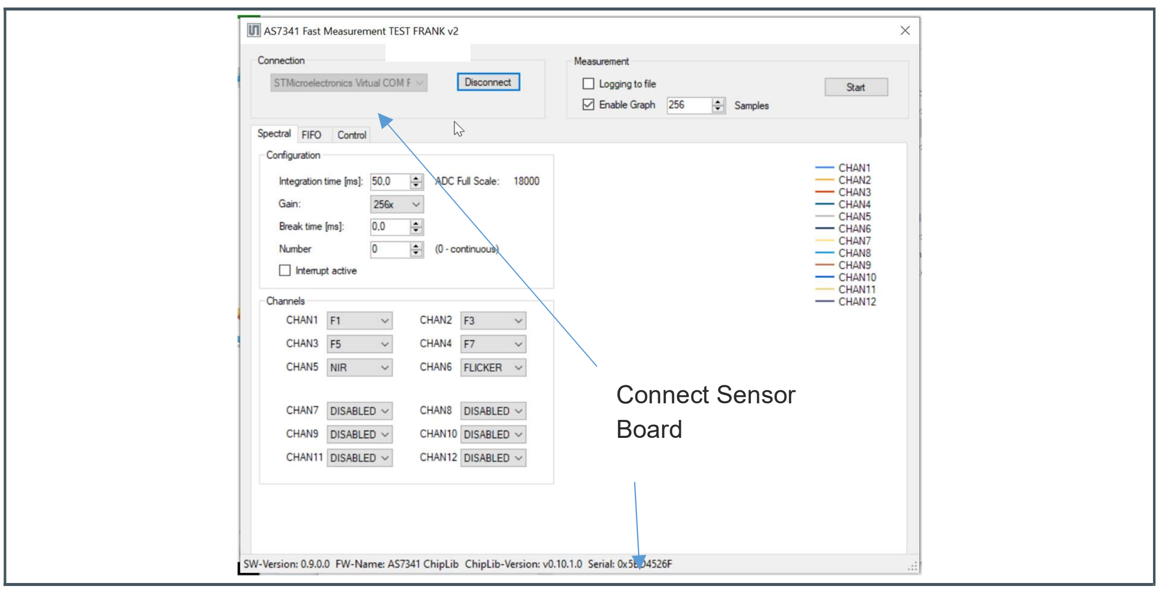
The AS73xx GUI for Fast measurement is for Windows 10 based systems, where .NET Framework 4.5.2 or later versions are preinstalled.

Start the software application by clicking on the file “AS73xx_FastMeasurement” and double-clicking the “.exe” icon.

An application window will pop up as shown in Figure 8. This window contains the basic setup functions and three tabs with specific functions for alternative use cases or setups. The basic functions are to connect the sensor, enable/disable the log file/graph, and start/stop the measurements. The tabs are Detections of Spectral, FIFO (Flicker), and Control.

The connection box is filled with the COM port of the connected Unicom board. Pressing the “Connect” button adjacent to the list box initiates the connection of the AS73xx sensor. The serial number of the detected board is displayed in the footnote if the sensor board was successfully detected (see blue arrow in Figure 8).

Figure 8:
AS73xx Fast Measurement GUI



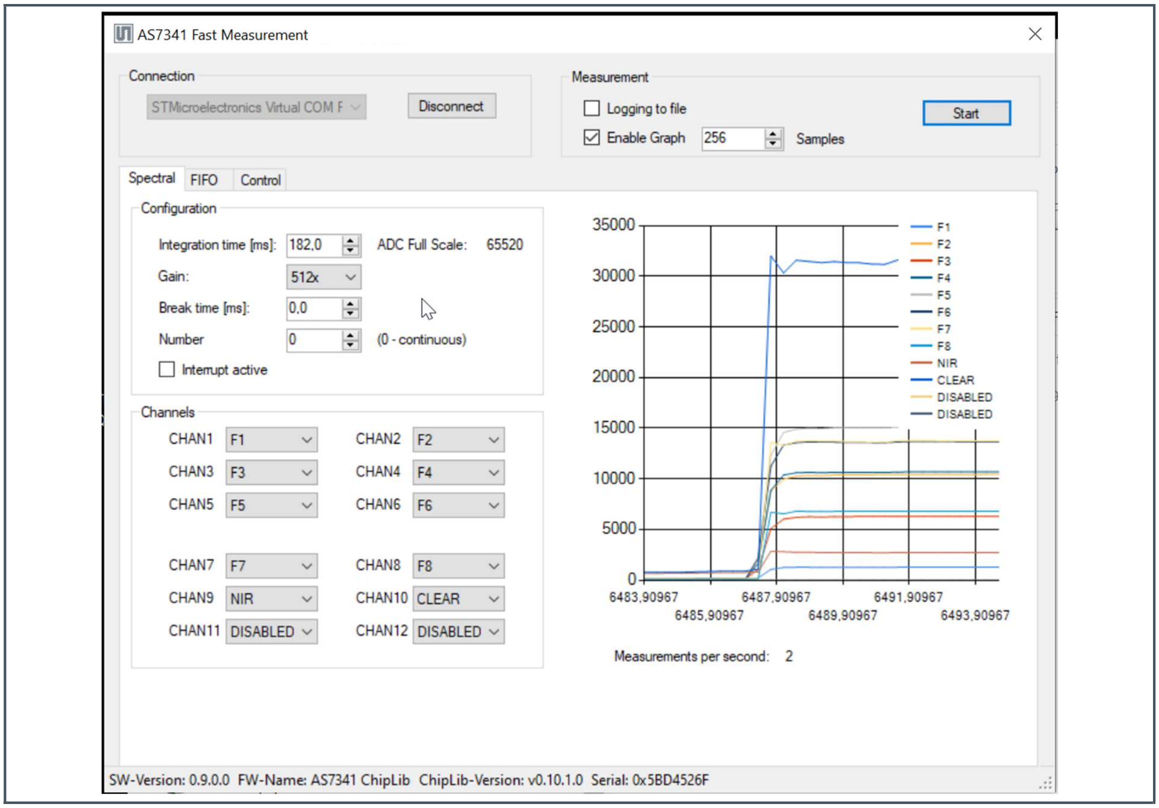
Once the connection is successful, there is possibility to navigate to three of the operational tabs - *Spectral, FIFO, and Control*.

The Control tab is only used to activate/deactivate the function or components of the demo. In the current GUI version, the LED selection is placed in the Control tab.

4.1 Spectral Tab

In the Spectral tab, most of the parameters are selectable in limited but variable ranges. The setups for the parameters: **Integration Time, Break Time, Gain,** and **Channel configuration,** can be set based on the specific application requirements.

Figure 9:
Spectral Measurement Tab



Channels - Channel Configuration: The AS73xx has eight optical channels that cover the visible spectrum. One channel is used to measure near-infrared light, and another channel is a photodiode without a filter ("clear"). The device also integrates a dedicated channel to detect ambient light flicker. On the other side, the AS73xx contains only a limited number of ADC channels, and the number of optical channels is higher than the ADC channels on-chip. Therefore, select in the *Channel configuration* the right channel for the test setup, based on the application-specific requirements. The Spectral tab considers all these channels. Their counts as results are in the log file and diagram. The Channel Configuration is realized by an on-chip integrated multiplexer (SMUX) and a mapping of available photodiodes to one of the six available ADC converters (ADC0 to ADC5). The operator can select six ADC channels with any of the 11 available channels: F1, F2, F3, F4, F5, F6, F7, F8, Clear, NIR, and Flicker.

Integration Time (TINT) and ADC Value: The Integration Time is set using ATIME (0x81) and ASTEP (0xCA, 0xCB) registers. The Integration Time [millisecond] calculated using the following

Equation 1:

$tint = (ATIME + 1) \times (ASTEP + 1) \times 2.78\ \mu s$

Integration Time is one parameter that affects the sensor digital counts or raw value. ADC Full-scale value for a particular setting is calculated as –

Equation 2:

$$\text{ADC Full Scale Value} = (ATIME + 1) \times (ASTEP + 1)$$

Sensed raw values exceed the ADC full-scale value results in saturation.

Break time: This item specifies the break between the finished measurement and the start of the next measurement.

Gain: The gain amplifies the six integrated ADCs signal to increase sensitivity. The AGAIN consists of 11 possible gain selections between 0.5x and 512x.

Number: Select 0 for continuous measurements or define the number of steps to be measured.

Interrupt: When enabled, it means the interrupt pin will be used otherwise, the time of integration will be calculated internally.

Enable Graph activates the diagram and digital output of the results.

Enabling Logging to file activates the logging of the measured data to *SpectralLoggingData.csv* in the *.exe* directory. The log file contains the setup and sensor results per line for each measurement.

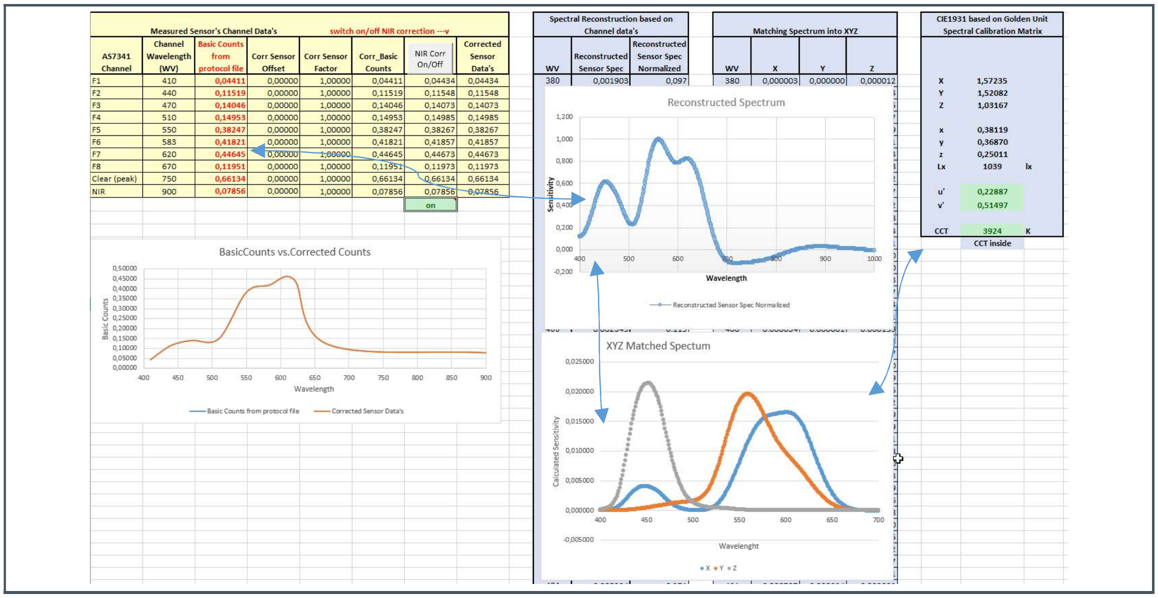
Figure 10:
SpectralLoggingData.csv Includes Setup and Results for Pre-Selected Channels

Serial: 0x5	ITIME_MS	FULLSCALI	GAIN: 512	BREAK_M:	NUM: 0	INT_PIN: False	
timestamı	error code	F1	F2	F3	F4	F5	F6
93,18548	0	5121	7998	11098	16975	65535	65535
93,23668	0	5126	8009	11114	17006	65535	65535
93,28787	0	5142	8034	11147	17050	65535	65535
93,33907	0	5145	8036	11152	17052	65535	65535
93,39027	0	5145	8033	11147	17051	65535	65535
93,44147	0	5137	8025	11137	17026	65535	65535

The spectral interpretation, verification of spectral footprints, calibration/correction of spectral data, and color matching for AS73xx signals, are described in special application notes (e.g. AN000633 Spectral

Sensor Calibration Methods), the user manual for the standard EVK, and Excel spreadsheets (see Figure 11).

Figure 11:
Part of Excel Spreadsheet - From Sensor's RAW Counts to XYZ Based Results



4.2 FIFO Tab

The AS73xx includes an integrated ambient light flicker detection in the FIFO tab. The sensor transforms light into a sequence of time and digits. FFT and software algorithm idents an existing flicker and its frequency.

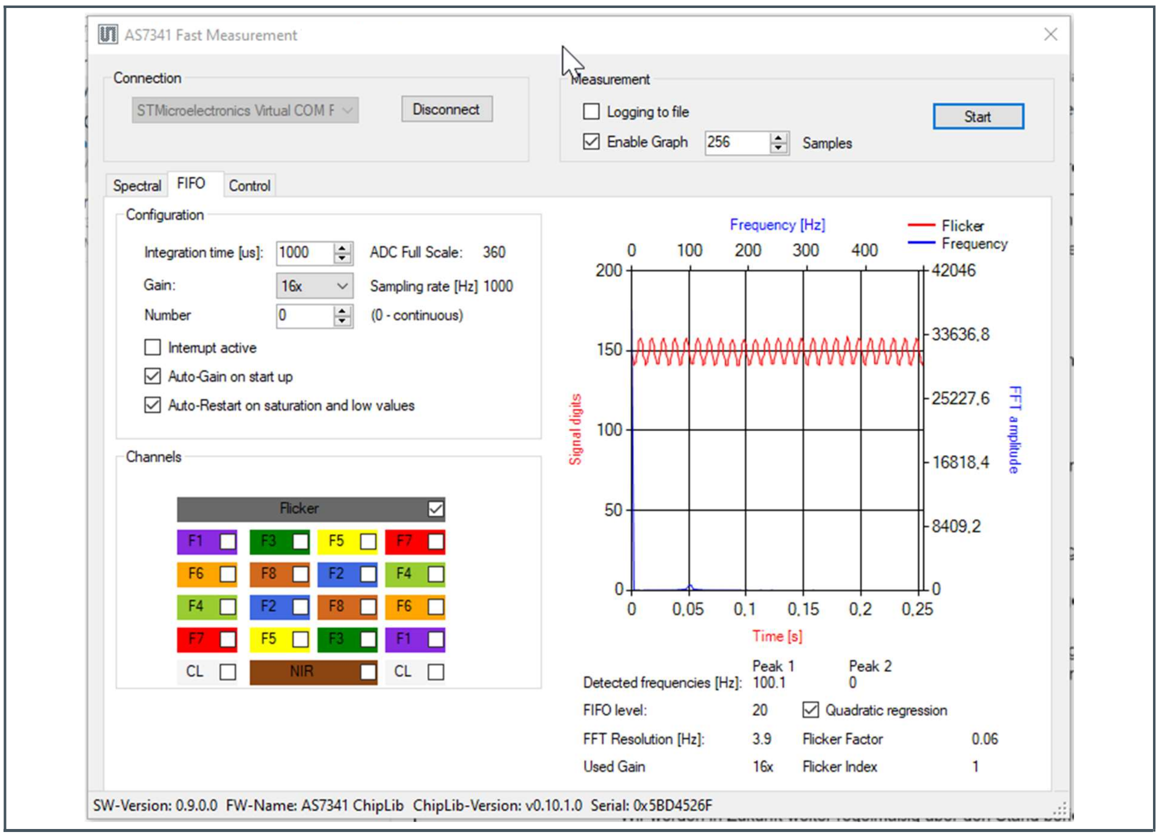
Sensor-specific parameters and other setups, as well as environmental conditions and disruptions, affect the dynamic and accuracy of flicker detection.

Generally, the kits work with alternative duty cycles between 20 Hz and 18 kHz under ideal conditions and application-specific optimized setups.

Figure 12:
Process of Flicker Detection in AS73xx EVK Fast Demo

The following chapters describe all the parameters, their effects, the GUI, and examples.

Figure 13:
Flicker Tab for 100Hz Detection



Enable Logging to file activates the logging of:

- The FIFO flickering sample data to *FlickerLoggingData.csv*.
- The FFT results to *FftLoggingData.csv*.

Checking the **Enable Graph** displays the flickering data values graphically.

Samples (=buffer) determines the number of measurements for FFT analyzes. The maximum value is 10k. Start with 256ms but increase if the results from FFT verification are not stable. Samples are used to calculate FFTtime in combination with FD Integration Time to FFT buffer time.

Pressing the **Start** button starts the continuous flicker measurement until the *Stop* button is pressed.

The **Interrupt active** button enables and disables the Interrupt pin on the AS73xx sensor board.

Similar to the spectral data, the Flicker tab can use alternative channels to detect flicker by selecting **SMUX Configuration**. Flicker enables the standard channel. Adding other channels with the SMUX configuration means activating and adding up the counts of all selected channels. The higher the number of counts, the higher the sensitivity, and the better the accuracy.

FD Integration Time and **Gain**: Select the configuration for flicker detection by choosing the FD_TIME, FD_GAIN, and number of samples in points. The sampling rate is determined by an inverse of the integration time.

The *FD Integration Time [ms] = (Fd_time +1) * 2.78*[3] *ADC Full Scale = Fd_time +1*

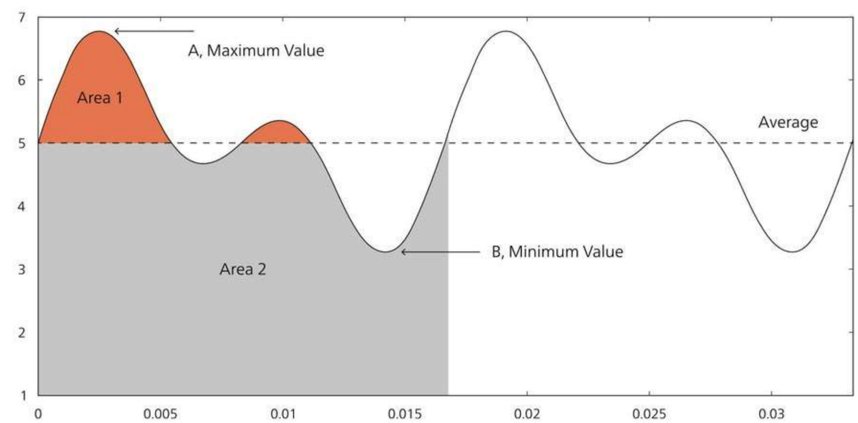
The measured samples exceeding the ADC full-scale value, results in a saturation of FIFO sample data. On the other side, integration time affects mainly the limitations for the flicker frequencies as the sample rate. Therefore, use Gain manually to adapt the digital counts, prevent saturation, or adapt the digits to the optimum. Select a suitable gain from the selection list (0.5x, 1x, 2x, 4x, 8x, 16x, 32x, 64x, 128x, 256x, or 512x). Another method is to use the implemented **Auto-gain**[4] function, where the GUI always tries to work with an optimized gain setup (**Used Gain**) to get optimized digital counter values as sensor results.

The sensor measures detected light with the selected integration time and gain. The result is a sequence of digital counts depending on discrete points in time. This time and the digital continuum are examined for periodic sequences using FFT analysis. An algorithm implemented in the GUI tries to calculate the FFT results as flicker frequency and other flicker typical units by means of detected max-min sequences, their integrals, and by **Quadratic regression**.

The used algorithms in the GUI are only examples and demos. They should be verified and adapted to the application in the customer’s software. The corresponding flickering frequencies calculated from the measured flicker samples are displayed as detected frequencies in the Flicker tab (Flicker with the most frequent and second most frequent detected frequencies - **Peak1 and Peak 2**). The FIFO flickering data is represented in red on the graph, and the corresponding, calculated fast Fourier transformation (FFT) is in blue.

[3] Better to calculate with the result of ‚2000/720‘
[4] “Auto-Gain on start up” selects optimized gain only one-time before measurements start. ‘Auto-Restart on saturation and low values’ considers always optimized gain. While saturation may occur in the first case, the Auto-Restart process interrupts running measurements for a short time for Auto-Gain.

Figure 14:
Flicker Tab for 100Hz Detection (source IEEE 1789 standard)



Flicker factor characterizes the modulation depth of the temporal change in illuminance at a location. It is the results of the minimum and maximum illuminance within a period (= peak-to-peak contrast).

$$FF = (A - B) / (A + B)$$

Flicker index is defined as the area above the line of average light, divided by the total area of the light output curve for a single cycle.

$$FI = Area\ 1 / (Area\ 1 + Area\ 2)$$

FFT resolution results from the considered time window for the FFT (see samples) and correspondents FFTtime = Samples * *FD Integration Time*. The higher the FFTtime, the better the stability and accuracy for flicker.

5 Appendix

In this chapter, practical case studies are described, independent of the currently valid program version, including how the sensor setup and other conditions influence the measurement results.

5.1 Basics for Flicker Detection

A flicker detection is determined by two parameters. The sampling rate must be fast enough, and the number of digits must be sufficient to identify the different periods.

The sampling rate must be at least twice or higher, as high as the detectable frequency (Nyquist-Shannon Sampling Theorem). The smallest impulse in a period determines the detectable frequency. For example, in a PWM-based LED light, different sampling rates are needed if, in a constant PWM, different duty cycles are used. Figure 15 shows different sample rates in the case of alternative duty cycles of a given PWM LED light.

Sample rate (= integration time) affects the digits. The higher the integration time, the higher the counts (linear). However, as known, an increase in the integration time reduces the detectable frequency of the flicker. This opposite effect can only be compensated by the parameter gain. With the gain, the digits can be increased or decreased (linear). Depending on the application, select gain in such a way that the FFT algorithm can detect the flicker periods without errors, by using the digits ‘as high as necessary’.

Figure 15:
Different Sample Rates T and f for a 400 Hz PWM in Case of Alternative Duty Cycles

PWM Hz	pulse ms	duty	factor duty %	T ms	f scan Hz	min FDTIME
400	2,50	**90%**	10	**0,25**	**4000**	**1440**
400	2,50	**80%**	5	**0,50**	**2000**	**720**
400	2,50	**75%**	4	**0,63**	**1600**	**576**
400	2,50	**50%**	2	**1,25**	**800**	**288**
400	2,50	**25%**	4	**0,63**	**1600**	**576**
400	2,50	**20%**	5	**0,50**	**2000**	**720**
400	2,50	**10%**	10	**0,25**	**4000**	**1440**

Figure 16 shows an example of a detected 100Hz flicker - where the parameter settings Gain and FD_Time, like integration time, result in digits between 160 and 280, within which the 0-1 period and flicker can be identified very clearly.

Figure 17 shows the results of a positively detected flicker function and its frequency of 100 Hz, with a sampling rate of 1000Hz. The blue line in the diagram represents the frequencies with amplitudes as

FFT result(s). In this case, the results include a unique result in one frequency with maximum amplitude. Such a clear result refers to an optimized setup under normal application-specific conditions, far away from any limitations.

Figure 16:
Example of Flicker with Recognized Digital Function (Gain = 10; FD_Time = 360)

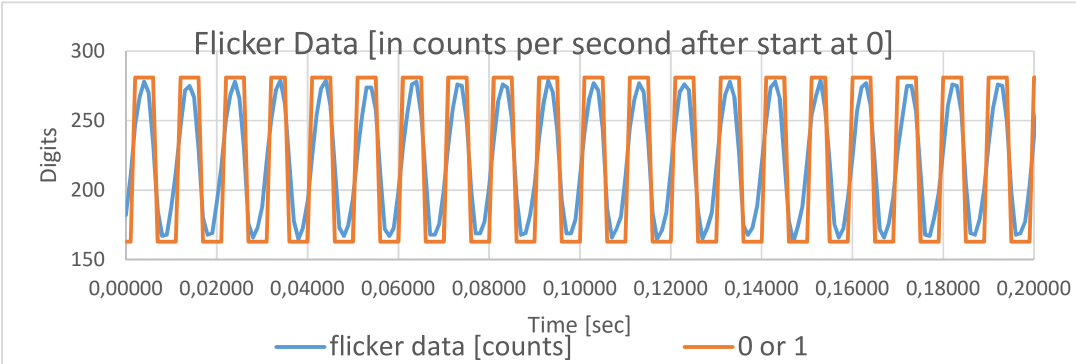
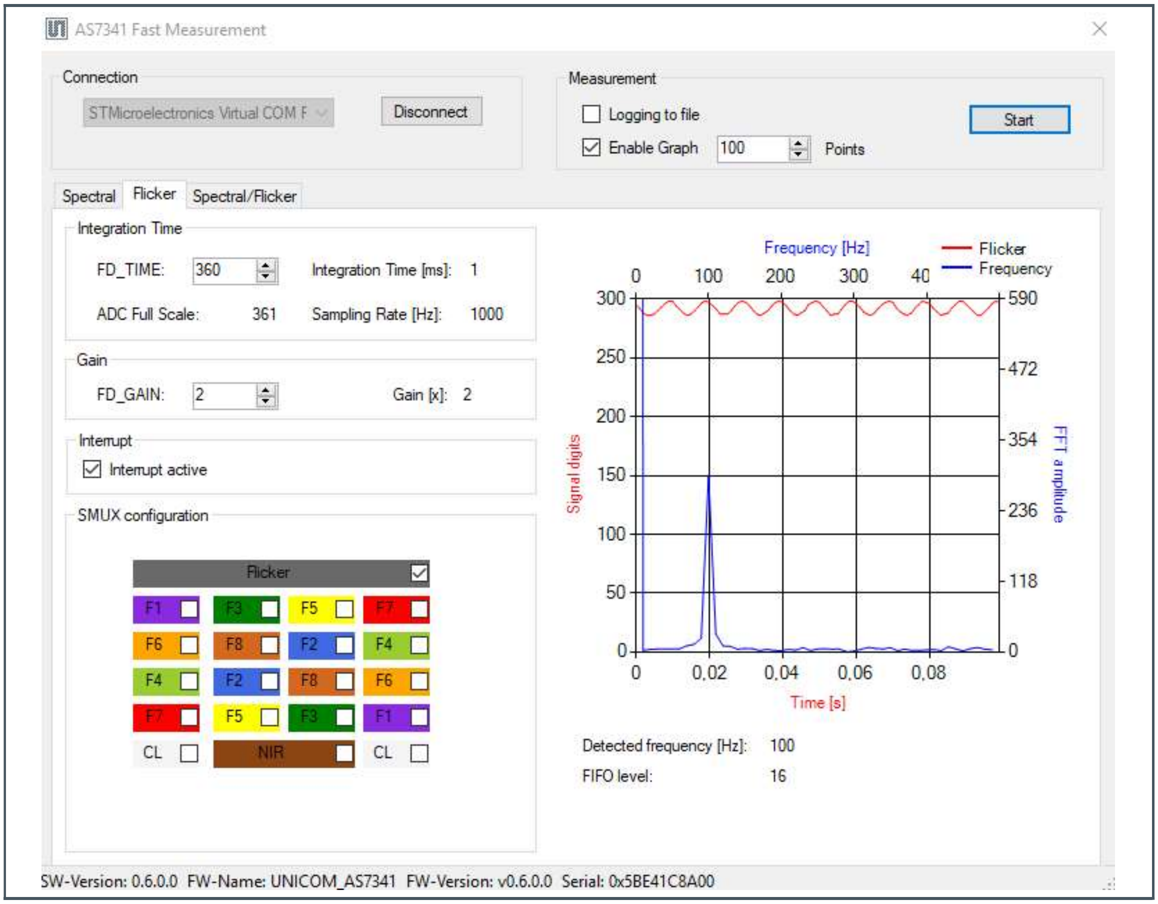
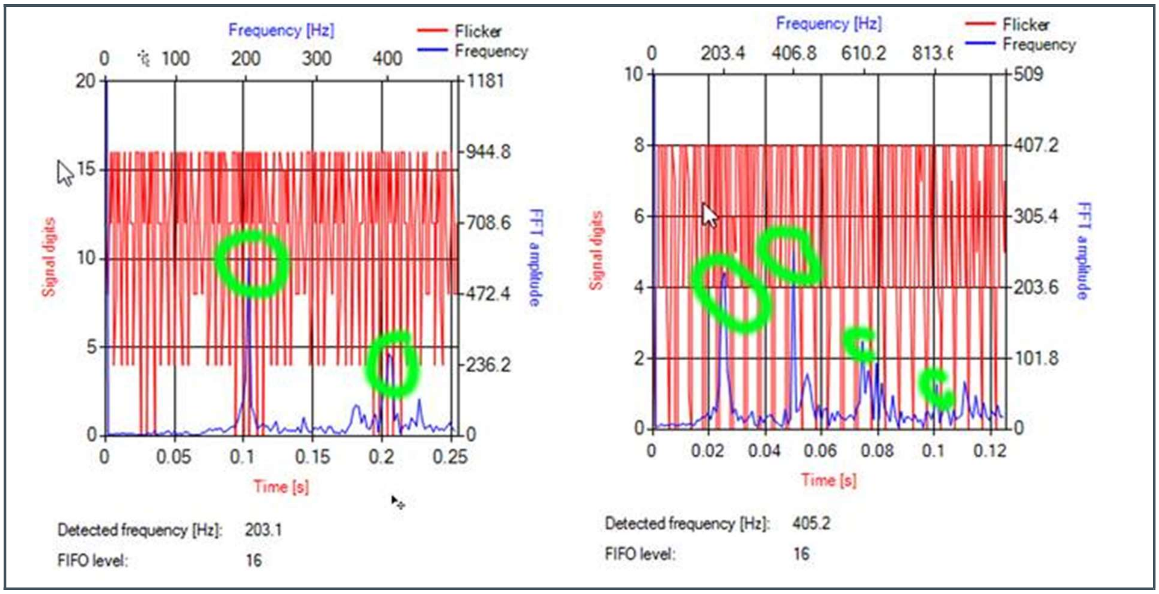


Figure 17:
Results of Flicker Detection – Diagram with Flicker, Frequency and Digital Output



Other results can be not so obvious. Figure 18 shows two FFT Results of disturbed flicker detections with the correct and wrong result.

Figure 18:
FFT Results of Two Disturbed Flicker Detections with Correct and Wrong Result



The measurements are with one identical hardware, under the same conditions but using different sampling rates of 1 kHz and 2 kHz. The high rates are to achieve a high dynamic range. If the flicker frequency is unknown, then a high sampling rate is recommended, to be able to sample high and low frequencies. However, a high sampling rate may lead to low digits. It causes the 1-0-1 transitions to become less clean (noisy or deleted), and the FFT may result in mirrored flicker frequencies.

In Figure 18, on the left-hand side, is the result of the FFT (blue line) for a sampling rate of 1000 Hz sampling rate with up to 16 digits for a high signal. The detected frequency is 203 Hz and correct. The red line is flicker which shows clear unclean transitions, but with <2 lux the sensor is already in the limit range. Nevertheless, the result is still correct - see a strong peak for 203 Hz '600' amplitude with various smaller highs and lows below ‘250'.

In Figure 18, on the right-hand side, is the result with double the sampling rate = 2033 Hz for the same measurement. The counts are halved due to the shorter sampling rate. This leads to stronger noise and unclean transitions. The reflections of the flicker frequency, because of the FFT, increase. There are two peaks, at 203 Hz and 406 Hz, with maximum amplitude (406 Hz is Max) on the blue line. Further reflections generally follow at n * 203 Hz (n=2, 3, 4 ...). The evaluation = Flicker frequency is the frequency with a maximum amplitude, which leads to a wrong result here.

In such cases, there is not enough information in the FFT results to make a correct decision based on such a situation, i.e. to build it into the software as a rule. This would be possible if:

1. The frequency searched for is approximately known in the application (as in the measuring range).
2. There is always enough light available that a high sampling rate does not lead to insufficient digits and insufficient 1-0-1 transitions, which become frequency mirroring in the FFT.

Unfortunately, (1) and (2) are not always possible. For such cases, the gain must increase (if possible), or sample time must decrease before new measurements start with a new FFT run. This could have the effect of preventing 'not clean transitions' and noise, which make the result more unique. Alternatively, the parameter optimization could lead to termination because, under the given conditions, a measurement flicker is not possible. However, this changing of setup requires at least one additional measurement and thus costs time. On the other side, a reduction of sample time will limit the dynamic to recognize the flicker frequency. It is always better to know the ranges for measurements and to consider them during parameter setup.

5.2 Limitations of Flicker Detection

- When the amplitude of the FIFO samples is more than the FD_TIME, digital saturation is signaled. To overcome this condition, FD_GAIN should be lowered or any other optical adaptation is recommended to reduce the optical signal (aperture, filter, etc.).
- The maximum detectable frequency is half the sampling frequency rate (see chapter 5.1).
- Faster scanning can give results with higher accuracy. On the other hand, due to lower counts, faster scanning leads to a lower signal-to-noise ratio or less accurate signal separation. The result can be no flicker detection or wrong flicker detection. Try to stabilize an unstable flicker result by increasing the FFTtime or reducing the integration time = sampling time to twice the flicker frequency.
- The range of practical and detectable flickering frequency is from 10 Hz to 8150 Hz. The range of detectable frequency always depends on the given light situation and/or application, optical coupling light into the sensor, and the selected integration time and gain.
- The most practicable integration time[5] (FD_TIME) is 21 to 2047 i.e. FDint time 0.078 ms (12,8 kHz) to 5.688 ms (175.8 Hz).

5.3 Example for Detection Flicker and Duty Cycle from Log File

The example below shows the complete procedure of a flicker measurement. First, parameters must be selected to determine a flicker signal, optimized for an application as a function of gain and integration time (see also chapter 0). The following figures show alternative setups and results in the enabled graph. The next two figures (Figure 19 and Figure 20) show parameter setups where the FFT algorithm could not detect useful and clear flicker frequencies. The software produces a rushing digital and graphic result.

[5] Integration times, outside this range, can result in FIFO overflow.

Figure 19:
Rushing Results Based on Too Low Gain

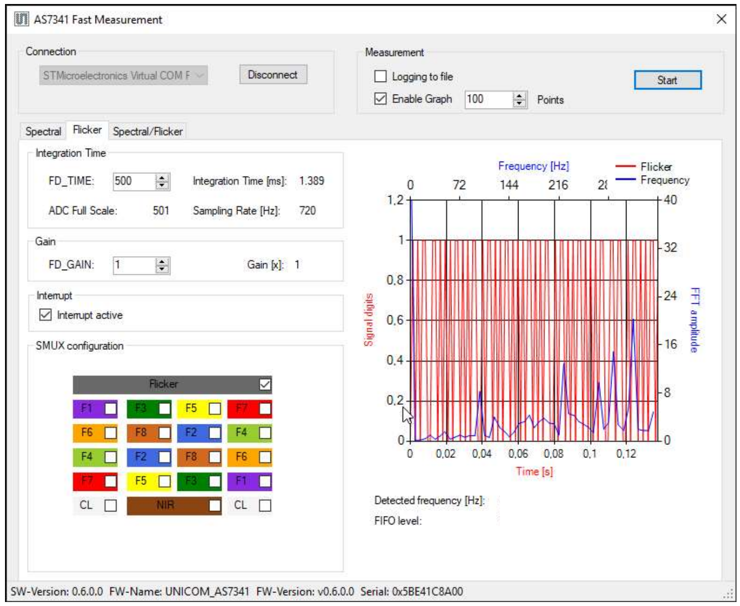


Figure 20:
Rushing Results Based on Too Low Integration Time

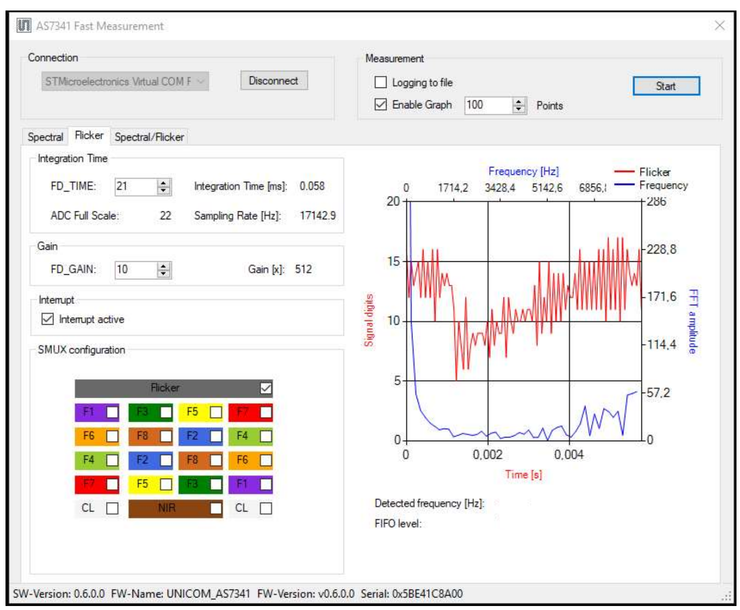
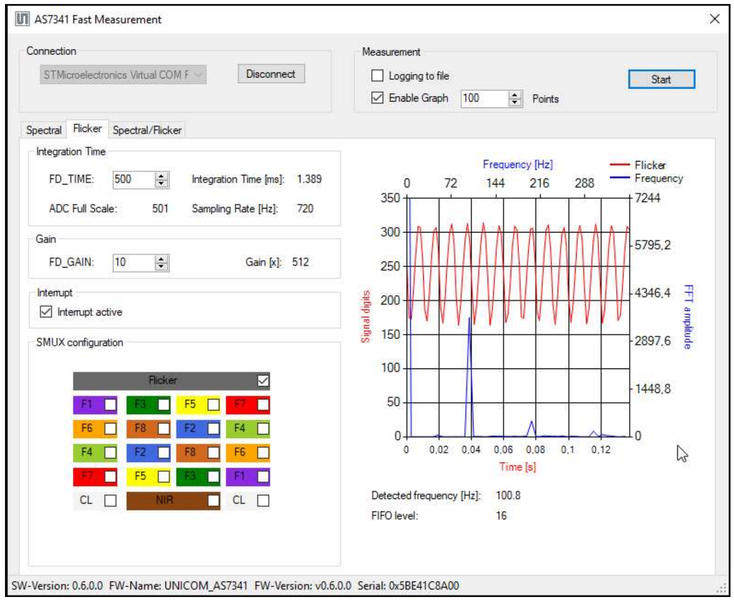


Figure 21:
Correct Setup for Gain and TINT with Still Image and Results without Noise



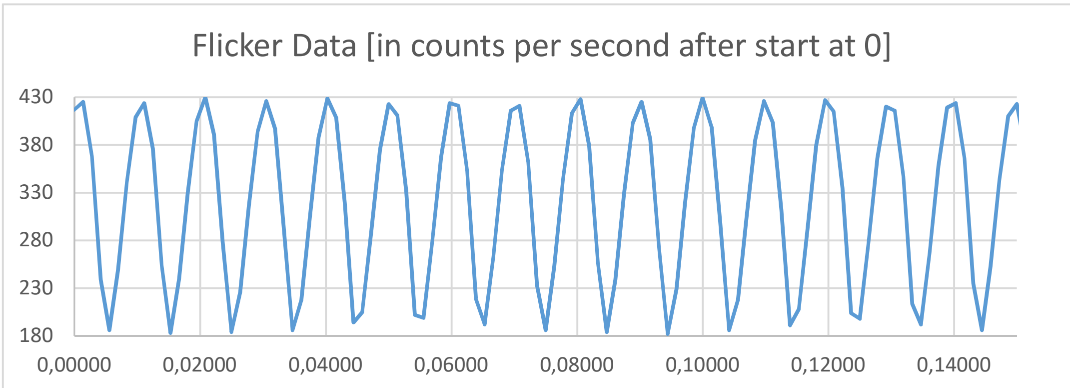
If a log file is enabled in the GUI, then the flicker results can be used in your software to detect flicker frequency and duty cycle of the measured light. Figure 22 shows a part of a log file. Use the column's timestamp in seconds and flicker data in counts to identify the light parameters.

Figure 22:
Part of Log file with Timestamp and Flicker Data

error code	FIFO level	timestamp [s]	flicker data [counts]
0	16	0,00000	417
0	16	0,00139	425
0	16	0,00278	368
0	16	0,00417	239
0	16	0,00556	186
0	16	0,00694	249
0	16	0,00833	341
0	16	0,00972	409
0	16	0,01111	424
0	16	0,01250	376
0	16	0,01389	254
0	16	0,01528	183
0	16	0,01667	240
0	16	0,01806	330
0	16	0,01944	405
0	16	0,02083	430
0	16	0,02222	391
0	16	0,02361	279
0	16	0,02500	184
0	16	0,02639	226

Figure 23 shows the graphical results as a diagram in the range 0 sec up to 0.1 sec after the sensor starts.

Figure 23:
Diagram of measured Flicker Data from Figure 22



In the next steps, the flicker frequency and duty cycle by a simple algorithm are computed. Often FFT based algorithms are common, which are provided in mathematical libraries. For example, the following steps are in an MS Excel spreadsheet.

- Use the Max/Min function to detect the counts for the high/low signal – see "cell C2' in Figure 24.
- The counts for each timestamp are transferred to high (=max) if greater than the Mean (average between high and low) or low (=min) if smaller than the Mean – see 'column E' in Figure 24.
- Use a digital filter to eliminate unwanted spikes – see the red broken line ellipse in Figure 25. In the example, n steps from 'cell D5' are used as the minimum-high sequence to eliminate high levels spikes.
- Marking the filtered 1-0 transitions to detect period and frequency – see 'columns E up to I' in Figure 24.
- Counting of highs and lows per detected period can be used to calculate the duty cycles per period – see 'columns L up to N' in Figure 24.
- Using Maximum or Averaging results, similar duty cycles are shown in 'cell K6:N6' in Figure 24.

Figure 24:
MS Excel Spread Sheet to Calculate Flicker and Duty Cycle

	C	D	E	F	G	H	I	J	K	L
1	min	182	0					Duty Cycle		
2	max	431	1		Number 1	1129	57%	1,31		Frequency
3	mean	306,5			Number 0	864	43%	1,00		101,1
4	digiF	3								
5	timestamp [s]	flicker data [counts]	0 or 1	Signal Raw	Digit Filter 1	Digit Filter 2	0-1	TimeDiff	TimePeriod	Frequency
6	0,00000	417	431	1	1	1	0	FALSE	0	FALSE
7	0,00139	425	431	1	2	1	0	FALSE	0	FALSE
8	0,00278	368	431	1	3	1	0	FALSE	0	FALSE
9	0,00417	239	182	0	0	0	0	FALSE	0	FALSE
10	0,00556	186	182	0	0	0	0	FALSE	0	FALSE
11	0,00694	249	182	0	0	0	0	FALSE	0	FALSE
12	0,00833	341	431	1	1	1	1	0,008333333	0,008333333	120,0
13	0,00972	409	431	1	2	1	0	FALSE	0	FALSE
14	0,01111	424	431	1	3	1	0	FALSE	0	FALSE
15	0,01250	376	431	1	4	1	0	FALSE	0	FALSE
16	0,01389	254	182	0	0	0	0	FALSE	0	FALSE
17	0,01528	183	182	0	0	0	0	FALSE	0	FALSE
18	0,01667	240	182	0	0	0	0	FALSE	0	FALSE
19	0,01806	330	431	1	1	1	1	0,018055556	0,009722222	102,9
20	0,01944	405	431	1	2	1	0	FALSE	0	FALSE
21	0,02083	430	431	1	3	1	0	FALSE	0	FALSE
22	0,02222	391	431	1	4	1	0	FALSE	0	FALSE
23	0,02361	279	182	0	0	0	0	FALSE	0	FALSE
24	0,02500	184	182	0	0	0	0	FALSE	0	FALSE
25	0,02639	226	182	0	0	0	0	FALSE	0	FALSE
26	0,02778	316	431	1	1	1	1	0,027777778	0,009722222	102,9
27	0,02917	394	431	1	2	1	0	FALSE	0	FALSE
28	0,03056	426	431	1	3	1	0	FALSE	0	FALSE
29	0,03194	397	431	1	4	1	0	FALSE	0	FALSE
30	0,03333	294	182	0	0	0	0	FALSE	0	FALSE
31	0,03472	186	182	0	0	0	0	FALSE	0	FALSE
32	0,03611	217	182	0	0	0	0	FALSE	0	FALSE
33	0,03750	305	182	0	0	0	0	FALSE	0	FALSE
34	0,03889	388	431	1	1	1	1	0,038888889	0,011111111	90,0
35	0,04028	429	431	1	2	1	0	FALSE	0	FALSE
36	0,04167	409	431	1	3	1	0	FALSE	0	FALSE
37	0,04306	319	431	1	4	1	0	FALSE	0	FALSE
38	0,04444	194	182	0	0	0	0	FALSE	0	FALSE
39	0,04583	205	182	0	0	0	0	FALSE	0	FALSE
40	0,04722	290	182	0	0	0	0	FALSE	0	FALSE
41	0,04861	375	431	1	1	1	1	0,048611111	0,009722222	102,9

Figure 25:
Measured Flicker Counts with SET High and Low

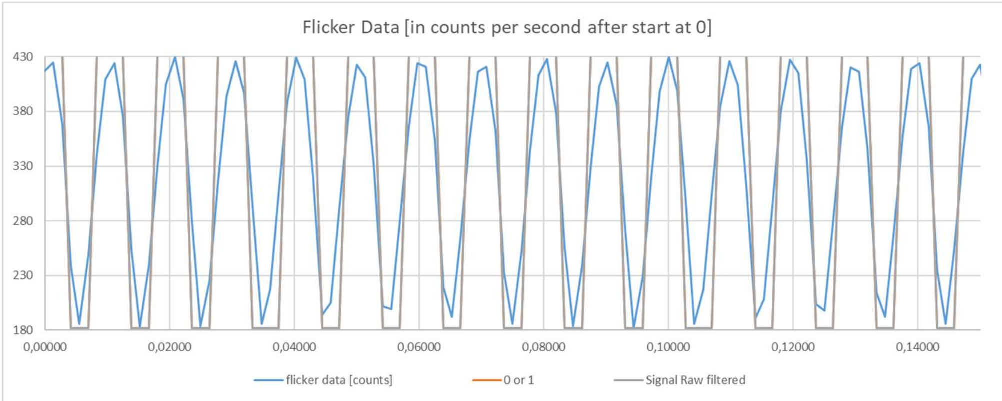


Figure 26:
Measured Flicker Counts with Marked Periods

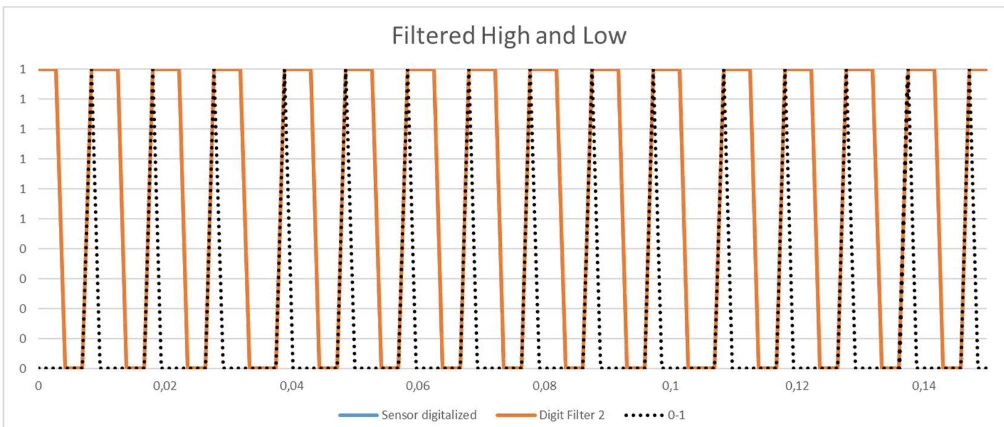


Figure 27:
Results for the Flicker Example 102 Hz with a Duty Cycle of 1:1.3

			Duty Cycle		
Number 1	**1129**	57%	**1,31**		**Frequency**
Number 0	**864**	43%	**1,00**		**101,1**

The algorithm shown to calculate flicker frequency and the duty cycle is not optimized and does not consider limited conditions and parameters as described. It is only an example, to give an impression of how to use the sensor and its data for such an application. It should be clear that every application needs its optimized parameters, which an application-specific algorithm must first find out and test internally.

The next figures show Excel sheets and results as log files, based on identical parameters for gain and integration time but different sizes for using digital filters. The results are different (positive with detected frequency and negative without calculable frequency). Filter, integration time, and the number of digitized steps, are very closely related. They influence the results considerably. In the example, the frequency could be calculated successfully after the digital filter was reduced.

Figure 28:
No Calculated Flicker because Digital Filter Is Defined Too Large for the Integration Time

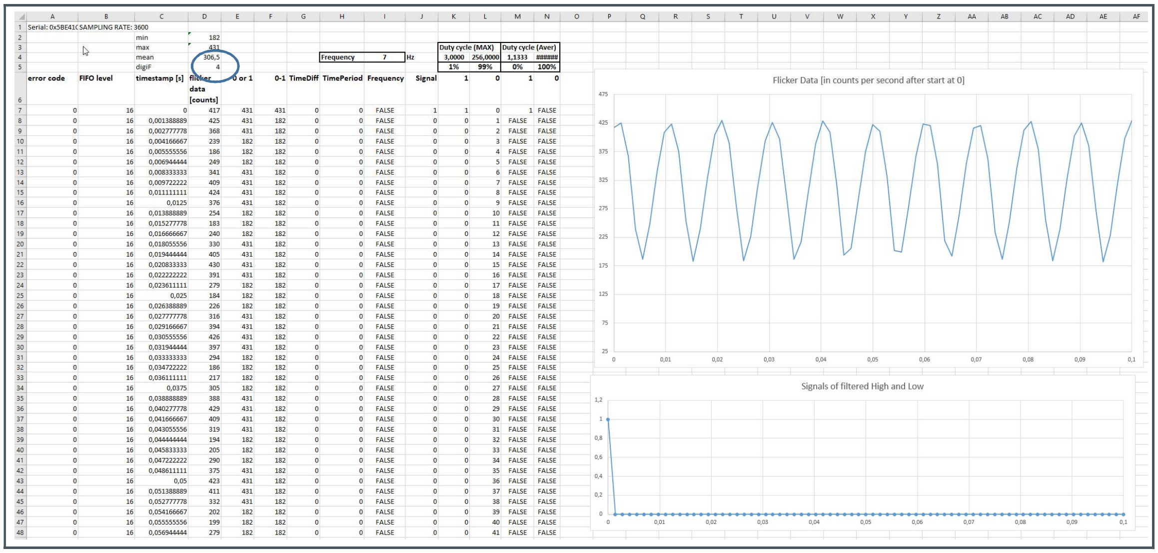
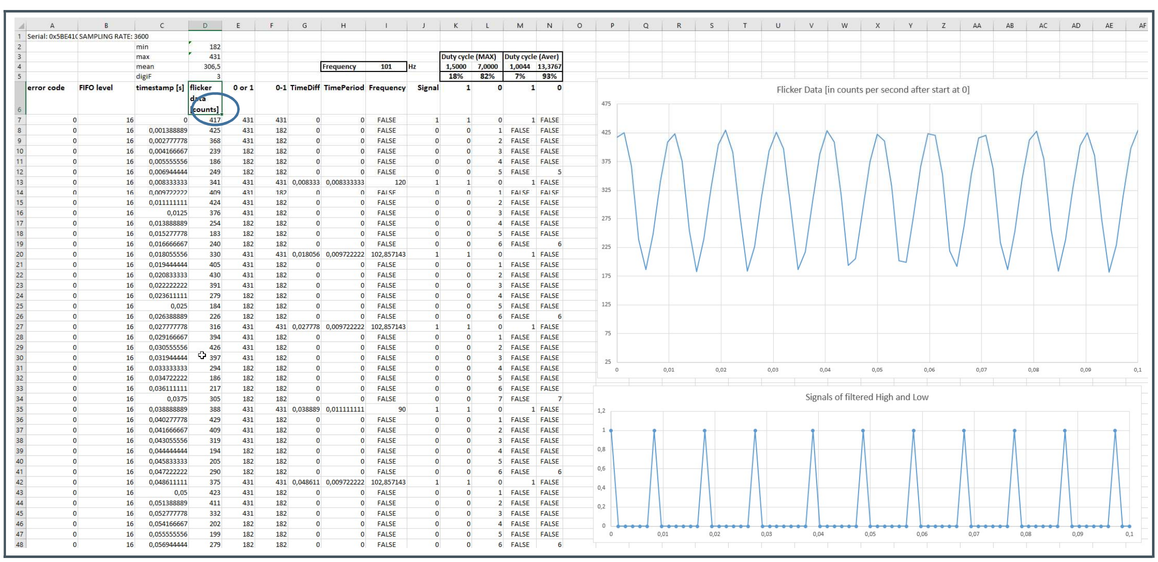


Figure 29:
Flicker after Reducing Digital Filter



5.4 Protocol Files

5.4.1 FlickerLoggingData

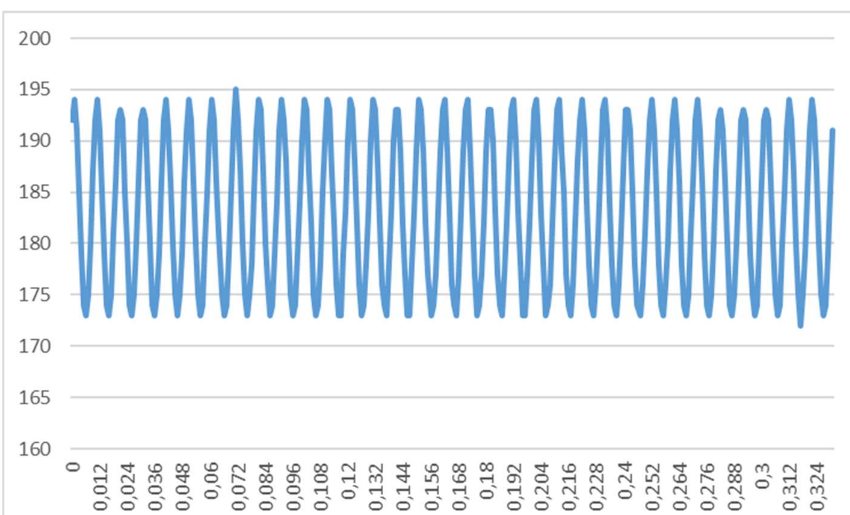
This file includes the sensor setup and sensor results as a function of time and counts. These data are the basis for the FFT algorithm to calculate the Flicker and its values.

The timestamp is continuous, starting at 0 seconds on line 4. The times and frequencies can be continuously calculated as the difference of the documented time to the measurement and origin at a time of 0 seconds. The measured digits depend on the used gain and must be considered in case automatic gain is used. Integration time or others are documented in the file header.

The data from this protocol file can be used for other FFTs or algorithms to calculate flicker from a time-based digital sequence.

Figure 30:
Sensor Log File Opened in MS Excel (only partially displayed) with Digital Chart

	A	B	C	D	E	F
1	Serial: 0x5BD4526F	FD_TIME_US: 1000	FD_GAIN: AUTO	INT_PIN: False	Channels: 0x80000	
2						
3	error code	FIFO level	timestamp in sec	flicker data in digits	Used gain	
4	0	16	0	192	32x	
5	0	16	0,001	194	32x	
6	0	16	0,002	191	32x	
7	0	16	0,003	185	32x	
8	0	16	0,004	179	32x	
9	0	16	0,005	174	32x	
10	0	16	0,006	173	32x	
11	0	16	0,007	175	32x	
12	0	16	0,008	180	32x	
13	0	16	0,009	187	32x	
14	0	16	0,01	192	32x	



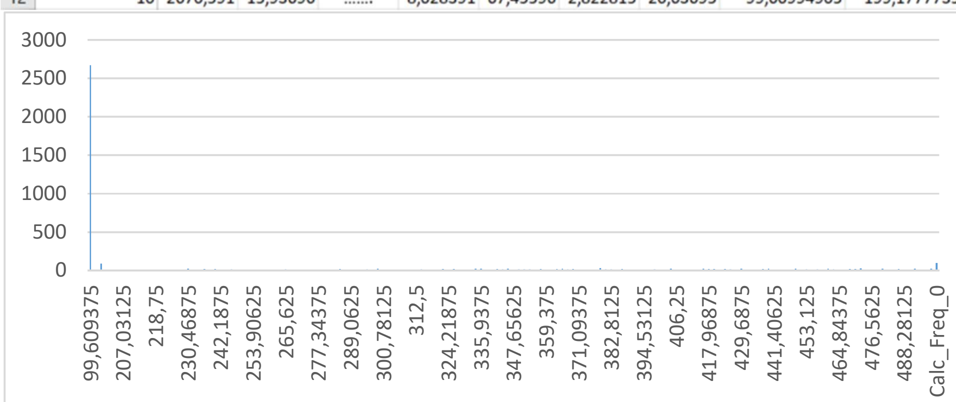
5.4.2 FftLoggingData

This file includes the FFT results as time and its frequency. Figure 31 shows the FFT Log File opened in MS Excel with its first example lines.

Line 1 in the protocol includes all potential flicker frequencies, and the following lines contain their frequencies of occurrence. In the example, the frequency 99.609 (in column BA) has the most frequent occurrence (in red) and is recognized as “Calc_Freq_0” (=Peak 0; in column IY, in blue). “Calc_Freq_1” is the second most frequent frequency (=Peak 1; in column IZ, in green).

Figure 31:
FFT Log File Opened in MS Excel (only partially displayed) with Digital Chart

	A	BA	BB	BC	CZ	DA	DB	IX	IY	IZ
1	FD_TIME_MS	99,60938	101,5625	....	197,2656	199,2188	201,1719	498,0469	Calc_Freq_0	Calc_Freq_1
2	0	2672,553	6,926958	....	16,63322	85,9768	2,159928	22,29177	99,60939242	199,1264672
3	1	2663,563	17,95128	....	5,025672	72,86057	16,02878	10,52883	99,61040884	199,3049416
4	2	2663,377	8,802027	....	1,430658	78,35918	8,356564	12,05889	99,60968396	199,2647823
5	3	2666,252	9,323791	....	16,02023	77,23647	11,51015	8,30673	99,60758939	199,1840541
6	4	2670,037	2,579653	....	8,426073	71,33215	2,955004	4,71279	99,60859457	199,1780529
7	5	2667,227	12,31822	....	19,51711	63,14478	11,7227	17,07925	99,60988875	199,1386685
8	6	2663,672	13,59884	....	12,04237	68,50809	7,39091	8,529115	99,6091791	199,1801182
9	7	2669,6	3,598865	....	3,438963	73,63569	7,860223	6,139925	99,60903167	199,2505038
10	8	2659,531	8,479196	....	9,61122	73,79416	3,414073	11,40681	99,60920548	199,1737755
11	9	2666,671	8,844087	....	5,940269	72,22633	7,359099	14,43184	99,60905606	199,2293146
12	10	2670,591	15,93696	....	8,028391	67,45596	2,822815	20,63695	99,60994905	199,1777735



6 Revision Information

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Appendix	13 - 22
Hardware description and housing	3 - 8

- 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.

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