AFBR-S20T1xxx: QtubeSpectrometer Series

Mini Process Spectrometer

Data Sheet

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Chapter 1: Overview

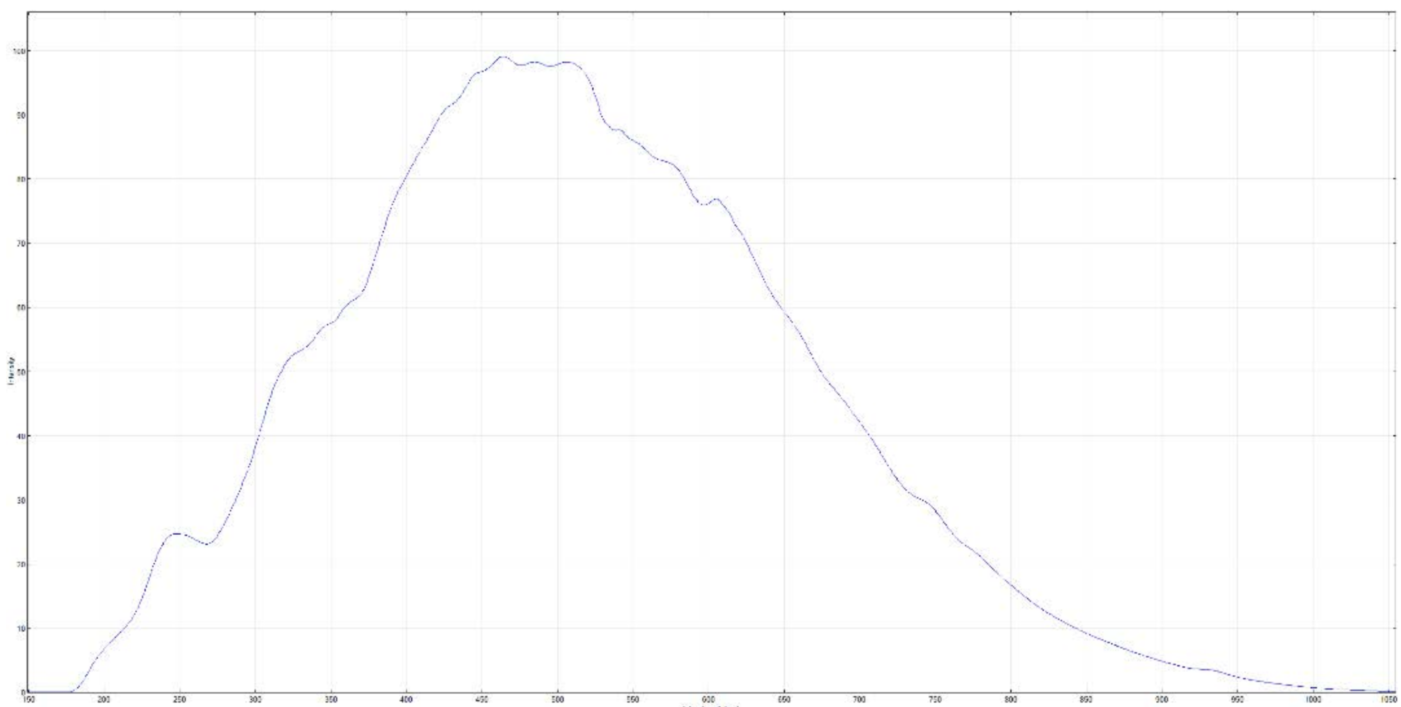
Spectroscopy is a powerful tool used to analyze the properties of materials and substances based on their interaction with light. In process analytics, mini spectrometers are used to monitor and control chemical reactions, assess the quality of materials, and optimize production processes. This chapter provides an overview of the different QtubeSpectrometer models, their specifications, features, and possible applications.

1.1 Ordering Information

Broadcom® spectrometers detect light from the very low ultraviolet wavelengths starting at 185 nm to signals that appear in ranges up to 1700 nm in the near infrared region. The AFBR-S20T1xxx cylindrical spectrometer module product line is available in the following wavelengths configurations.

Part Number	Description	Wavelength Range	Typical Spectral Resolution (FWHM)	Blaze Wavelength
AFBR-S20T1WU	QtubeSpectrometer Wide UV	190 nm to 1000 nm	2 nm	270 nm

Figure 1: AFBR-S20T1WU Sensitivity Overview



1.2 Features

This miniature spectrometer is designed for flexible integration where space is limited. The QtubeSpectrometer offers high optical performance, is proven in industrial surroundings, and features the following:

- Miniature design
- High spectral resolution
- High sensitivity and dynamic range
- Exceptional thermal stability
- 2500-pixel linear CCD sensor
- Optical input via an SMA fiber connector or a free focused beam
- Two I/O channels for external triggering, shutter control, and general-purpose I/O (GPIO)
- UART communication interface
- Calibration data stored in internal memory
- Easy-to-use ASCII-based communication protocol

1.3 Applications

Broadcom spectrometers are the ideal tool for many optical measurement applications, such as the following:

- Light analysis
- Chemical research
- Raman spectroscopy
- Color measurement
- Quality control
- Counterfeit detection
- Environmental analysis
- Forensic analysis
- System integration
- Process control and monitoring

Chapter 2: Specifications

This chapter describes the full technical details of the QtubeSpectrometer product line including optical, electrical, and mechanical specifications.

2.1 Absolute Maximum Ratings

Parameter	Symbol	Conditions	Min.	Max.	Unit	Notes
Supply Voltage	V_{DD}	—	–0.5	+5.5	V	
Input Voltage	V_I	UART_RXD pin	–0.3	+3.6	V	
		All other pins on the connector; V_{DD} = 0V	–0.3	+3.6	V	
		All other pins on the connector; V_{DD} = +5V	–0.3	+5.5	V	
Storage Temperature	T_{STG}	—	–25	70	°C	
Operating Temperature	T_{OP}	Non-condensing	–15	60	°C	

2.2 Optical Specifications

V_{DD} = +5V, T_{amb} = 25°C, unless otherwise specified.

Parameter	Symbol	Configuration	Min.	Typ.	Max.	Unit	Notes
Wavelength Range	R_{λ}	AFBR-S20T1WU	190	—	1000	nm	
Resolution (FWHM)	RES		—	2	5.5	nm	a, b
Wavelength Accuracy	—		—	1/3 × RES	—	nm	
Thermal Wavelength Drift	—		—	0.1	—	nm/°C	
Parameter	**Symbol**	**Conditions**	**Min.**	**Typ.**	**Max.**	**Unit**	**Notes**
Pixel Count	—	—	—	2500	—	pixel	
Focal Length	—	—	—	50	—	mm	
Width of Entrance Slit	—	—	—	20	—	µm	c
Numerical Aperture	NA	—	—	0.1	—	—	
Dynamic Range	DR	Single acquisition	—	850:1	—	—	d
Bad Pixel	—	—	—	0	1	pixel	e
Signal-to-Noise Ratio	SNR	Value for each single pixel	—	200:1	—	—	f
Stray Light	SL	—	—	—	0.2	%	g
Exposure Time	T_{EXP}	—	0.0001	—	2000	s	
Trigger-to-Exposure Jitter	$Jitter_{Tr\ igger}$	For continuous synchronous trigger	0	—	T_{EXP}	µs	h
		For synchronous trigger (low-jitter hardware trigger)	0	—	100	µs	

a. Valid only with a slit width of 20 µm.

b. For detailed resolution data over the entire wavelength range, see Figure 2.

c. The standard slit width is 20 µm. Other slit widths are available for OEM customers.

d. DR (dynamic range) is defined as follows:
DR = saturation value / average readout noise

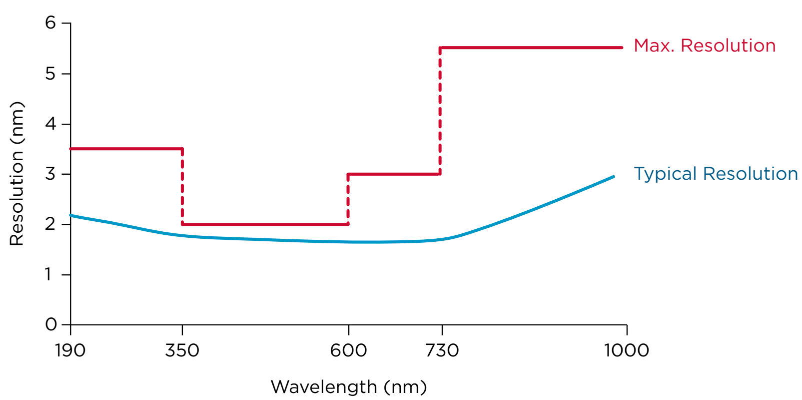
e. A hot or cold pixel is defined as a bad pixel. Two or more adjacent pixels are not allowed. The value refers to the complete pixel number of the used sensor.

f. SNR (signal-to-noise ratio) per pixel averaged over 100 single spectra is defined as follows:
SNR = saturation value / RMS noise

g. Measured with long-pass filter RG645, λ_{CutOn} = 645 nm.

h. T_{EXP} means the current adjusted time for exposing this spectrum.

Figure 2: Overview of the Resolution Distribution over the Wavelength Range of AFBR-S20T1WU



2.3 Electrical Specifications

V_{DD} = +5V, T_{amb} = 25°C, unless otherwise specified.

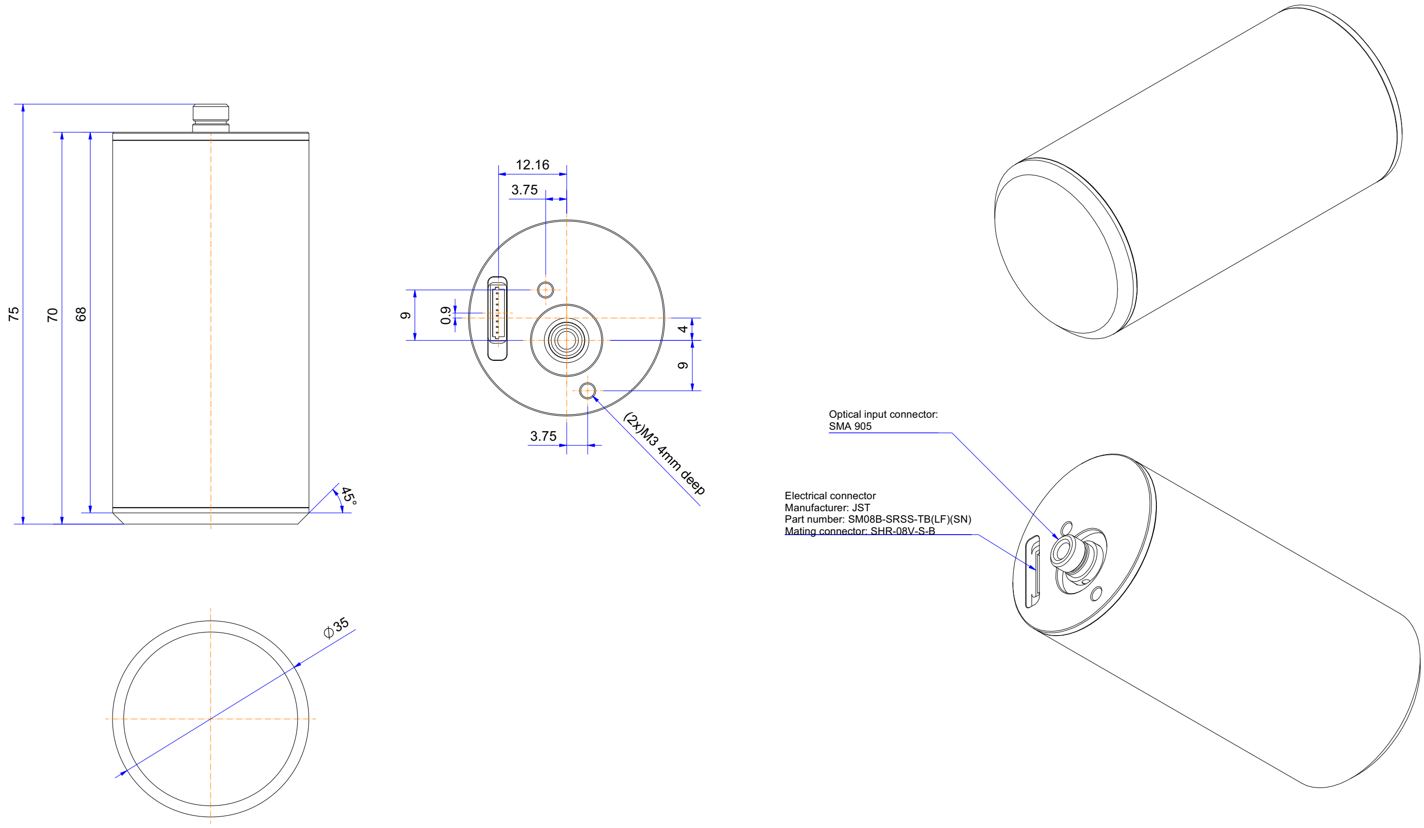
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	Notes
Supply Voltage	V_{DD}	—	+4.5	+5.0	+5.5	V	
Input Voltage	V_I	UART_RXD pin	0	—	3.3	V	
		All other pins on the connector; V_{DD} = 0V	0	—	3.3	V	
		All other pins on the connector; V_{DD} = +5V	0	—	5.0	V	
HIGH-Level Input Voltage	V_{IH}	—	2.1	—	—	V	
LOW-Level Input Voltage	V_{IL}	—	—	—	0.7	V	
HIGH-Level Output Voltage	V_{OH}	—	2.6	3.3	—	V	
LOW-Level Output Voltage	V_{OL}	—	—	0	0.5	V	
Supply Current	I_I	—	—	150	—	mA	a
Output Current	I_O	—	6	—	—	mA	
A/D Resolution	—	—	—	16	—	bit	
A/D Sample Rate	—	—	—	1	—	MSa/s	
A/D Readout Time	—	Readout time of all pixels from the sensor	—	2.547	—	ms	
Pulsed Output Cycle Period	T_{PWMCP}	On each trigger-I/O	—	320	—	ms	
Pulsed Output Duty Cycle	T_{PWMDC}	On each trigger-I/O	49	50	51	%	
UART Baud Rate	BR_{UART}	See Section 3.2.1 UART, for more details	300	57600	3000000	baud	

a. Device initialized and taking spectra; no additional connection or external load on the auxiliary connector.

2.4 Mechanical Specifications

Parameter	Symbol	Conditions	Typical	Unit
Weight	M	—	80	g
Dimensions	—	(D × L)	35.0 × 70.0	mm
Optical Input Connector	—	—	SMA 905	—

2.5 Technical Drawing



NOTE: All dimensions are in mm. 3D CAD files are available for download.

2.6 Device Connector

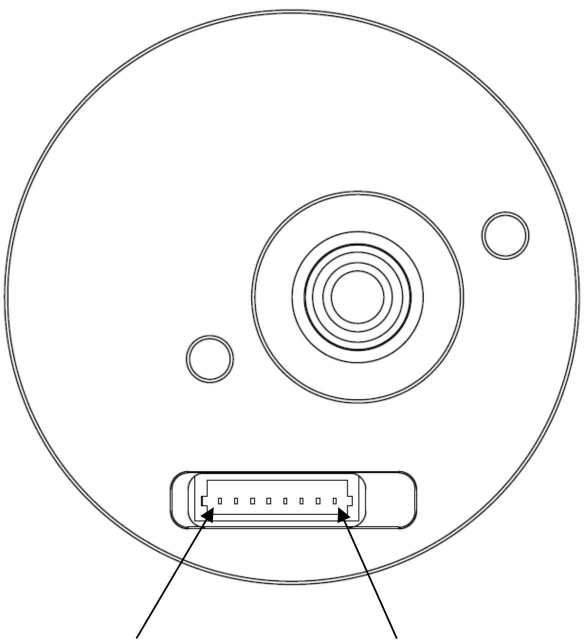
The front-side connector of the spectrometer provides different input and output signals such as trigger-I/Os and a standard UART serial communication interface.

The connector used in the QtubeSpectrometer is an SM08B-SRSS-TB manufactured by JST.

Broadcom recommends using the following mating connector: SHR-08V-S-B.

There are many other suppliers that have mating connectors available.

Figure 3: 8-Pin Connector Interface



The following table describes all the interface pins. Contact Broadcom for additional information on the interface.

Table 1: Interface Pin Descriptions

Pin Number	Signal Name	Type	Description	Notes
1	V_{DD}	PWR	Power input	
2	GND	PWR	Ground	
3	UART_TXD	O	Transmitter output for UART	
4	UART_RXD	I	Receiver input for UART	a
5	TRIG_IO_0	IO	Low-latency trigger input/output	b
6	TRIG_IO_1	IO	Low-latency trigger input/output	b
7	BOOTLOADER_EN	I	Enable on-chip bootloader	b
8	POWER_EN	I	Enable internal power rail	b

a. Internally pulled up.

b. Internally pulled down.

Chapter 3: Operation

The QtubeSpectrometer is equipped with a UART communications interface. This chapter describes this communication, other interactions such as trigger modes between, for example, light sources, and standard operation.

3.1 Trigger

Learn more about the different trigger modes of the QtubeSpectrometers.

3.1.1 Trigger Modes

The QtubeSpectrometer provides three different trigger modes:

- Continuous asynchronous trigger (trigger on end of exposure): This is the default mode. The spectrometer is continuously taking spectra. If a trigger event occurs, the currently exposed spectrum is read out.
- Continuous synchronous trigger (trigger on start of exposure): The spectrometer is continuously taking spectra, and when a trigger event occurs, the next spectrum after the one currently being taken is read out. Choose this mode to ensure that no light is collected for the spectrum before the trigger event occurs. This mode requires more time to take a spectrum. It causes a random trigger delay between zero and the exposure time.
- Synchronous trigger (low-jitter hardware trigger): To allow low jitter between a trigger event and the actual start of the exposure, this trigger mode is implemented into the device. To make sure that the sensor is still read out continuously, the exposure time is adjusted to 100 µs while the device is in the idle state. After a trigger event occurs, the exposure time is configured to the adjusted value, and after the current running 100-µs period ends, the sensor is exposed with the adjusted exposure time. After the sensor data has been read out and the state of the sensor is idle again, the exposure time returns to 100 µs until a trigger event occurs again. In this trigger mode, the nonlinearity of the sensor cannot be completely compensated, but for some measurements this is not a problem at all.

All trigger modes are usable via an internal (software) or external trigger event.

The readout time of the sensor data is about 2.55 ms. Depending on the adjusted exposure time, the readout behavior in continuous trigger mode is slightly different for an exposure time smaller or larger than the readout time.

If the exposure time is larger than the readout time, the QtubeSpectrometer reads the sensor data of the requested spectrum, while the next exposure takes place. Because of the continuous exposure, there is always a following exposure period regardless of a trigger event.

If the exposure time is smaller than the readout time, the QtubeSpectrometer reads the sensor data after the exposure period ends, without starting the next exposure. This leads to a slight nonlinear sensitivity for the next exposure, and therefore a dummy exposure is added before the next stable spectrum can be taken. This will introduce a small delay for the readout cycle.

Figure 4 shows both continuous trigger modes in the idle state with an exposure time greater than 2.55 ms and after a trigger event has occurred. Each spectrum, which must be read out, must be triggered by a discrete trigger event. This means that in a series of spectra or if averaging is active, each single spectrum must be triggered for readout.

Figure 5 shows the same with an exposure time less than 2.55 ms.

For the synchronous trigger, the sensor is always read out after the exposure period ends. A new exposure period starts after the readout is finished.

Figure 6 shows the behavior of the synchronous trigger.

Figure 4: Trigger Mode Diagram with T_{EXP} > 2.55 ms

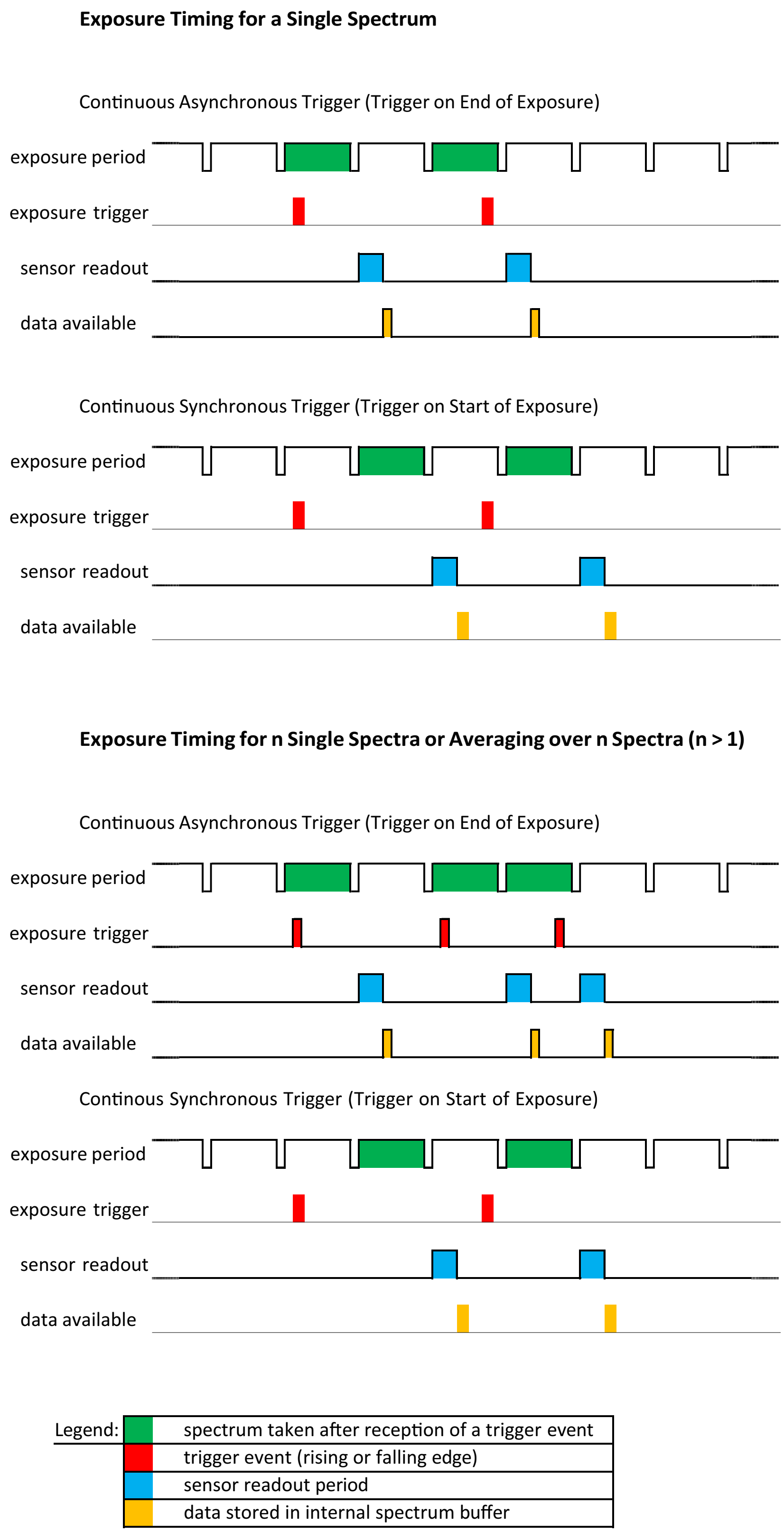


Figure 5: Trigger Mode Diagram with T_{EXP} < 2.55 ms

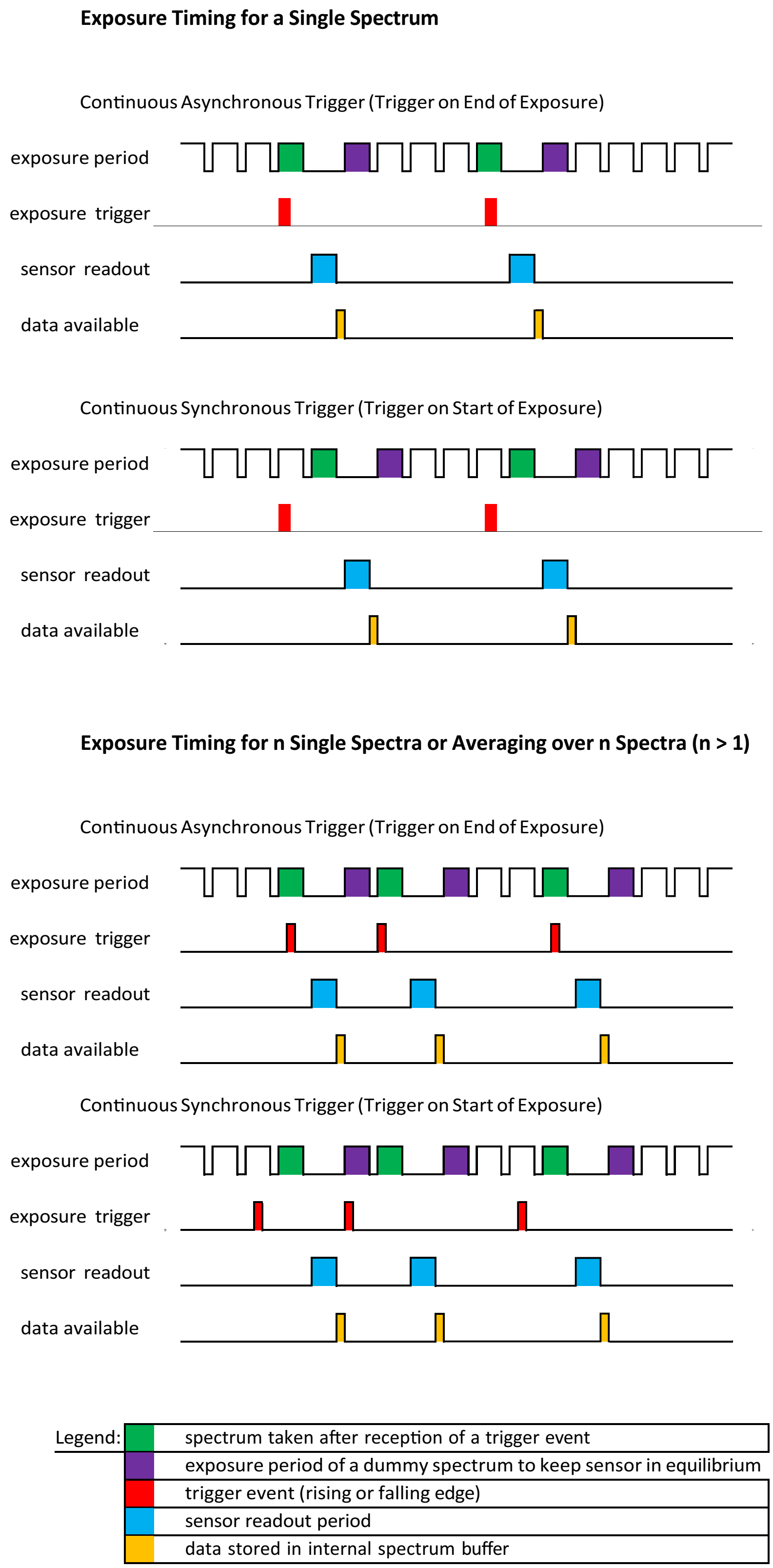
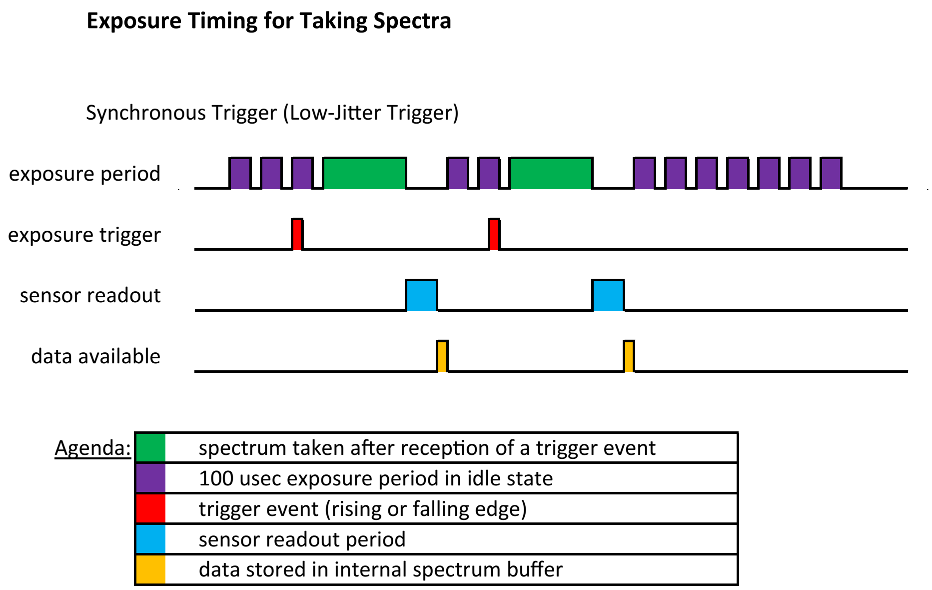


Figure 6: Synchronous Trigger (Low-Jitter Hardware Trigger)



3.1.2 Trigger Pins

The connector provides up to two trigger input and output pins (pin numbers 5 and 6). Regardless of the configured direction, the spectrometer can read the logical state of the pin.

Adjusted as an input, the pins detect logical voltage levels and can be used as an external trigger source. If a pin is configured as an output, several different output modes are supported, for example to control a shutter or a constant or flashing light source. The following table gives an overview of the output modes.

Table 2: Trigger Pin Configurations

Output Configuration	Description
Low	Output is always low.
High	Output is always high.
Low during exposure	Output is high and goes low during the exposure period.
High during exposure	Output is low and goes high during the exposure period.
Pulsed	Output is always pulsed with 50% duty cycle and the adjusted pulse period.
Pulsed low during exposure	Output is high and pulsed with 50% duty cycle and the adjusted pulse period during the exposure period.
Pulsed high during exposure	Output is low and pulsed with 50% duty cycle and the adjusted pulse period during the exposure period.

For an external trigger event, each pin can be configured to receive the trigger event. The trigger is recognized on either the rising edge or the falling edge.

To use a channel as an external trigger source, perform the following steps (pin 1 is used in this explanation):

1. Configure trigger pin 1 as the input.
2. Set the trigger pin number to pin 1.
3. Select either the rising edge or the falling edge.
4. Set the trigger mode to external.

3.2 Communication Interfaces

The QtubeSpectrometer has a UART communication interface for controlling the device.

3.2.1 UART

The universal asynchronous receiver/transmitter (UART) interface is located on pins 3 and 4. The signal level for these pins is LVTTL. Using an RS-232 level shifter, it is also possible to have a regular RS-232 interface for serial communication. The communication parameters are 8N1, which means 8 data bits, no parity, and 1 stop bit. The following baud rates are available: 300, 600, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 38400, 57600, 115200, 128000, 230400, 256000, 460800, 921600, and 3 Mbaud. The standard baud rate is configured to 57600 baud and can be changed after device initialization. For the command description of the UART interface, refer to the ShortLink protocol manual.

3.3 Other Signals on the Connector

The connector provides two additional inputs that can help you conveniently control the spectrometer in your application:

- POWER_EN – If the spectrometer is supplied, it is possible to shut down the internal power supply rail via the POWER_EN input. This switches the spectrometer completely off. This input can also represent an external device reset.
- BOOTLADER_EN – The BOOTLADER_EN input lets the spectrometer enter the on-chip bootloader to perform a firmware update. This pin is used only if the command to start the bootloader is not recognized by the spectrometer. For normal operation, this pin can be left unconnected.

3.4 Calibration

An individual calibration is performed in the final test of the production process. This data is stored in the internal memory of the QtubeSpectrometer. This so-called user calibration can be overwritten by a customer-specific calibration. A second set of calibration data represents the factory calibration and is used only if the user calibration will be reset to the factory settings. The data of the user calibration can be used by the customer software to correct the raw spectra.

Chapter 4: Software

This chapter provides an overview of where to find the latest version of the WAVES spectrometer application software and the software development kit, which includes several Windows libraries.

4.1 WAVES Spectroscopy Software

The Broadcom free-to-use and feature-rich WAVES spectroscopy software enables you to use our spectrometers for acquiring spectra, manipulating or analyzing spectra, adjusting the trigger pins, and much more. It also provides functions to do customer calibrations for wavelength, spectral sensitivity, nonlinearity, and more. For a more detailed description, refer to the WAVES user manual on the Broadcom website.

4.2 Software Development Kit

The software development kit (SDK) for the spectrometer can be used to control it and take spectra from additional custom software. The SDK includes a Windows dynamic link library (DLL) for the .NET framework, documentation, and sample code. The SDK can be downloaded from the Broadcom website and is free to use.

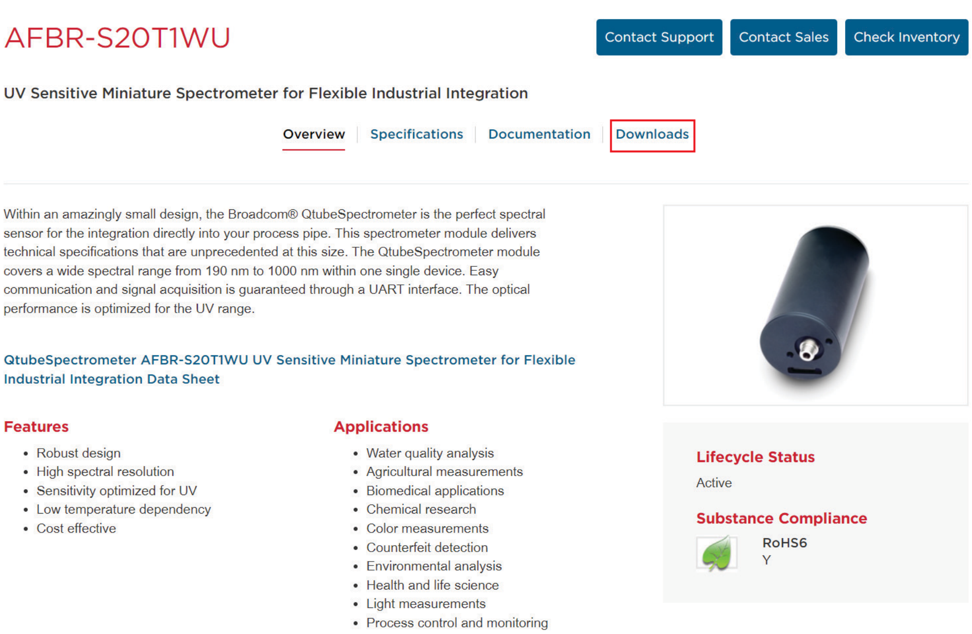
Alternatively, it is possible to directly communicate with the spectrometer from custom software including embedded systems. The open ASCII-based and intuitive-to-use communication protocol ShortLink enables you to control the spectrometer in a very flexible way. See the communication protocol manuals in the SDK for additional details.

You can download the latest version of WAVES and the SDK from each product page on the Broadcom website.

4.3 Software Updates

Software updates are available on the Broadcom website. Find the latest version on each product page.

https://www.broadcom.com/products/optical-sensors/spectrometers



Chapter 5: Technical Support

This chapter provides some information on troubleshooting and getting direct help from the support team, if you face any problems or need help to successfully evaluate the Broadcom QtubeSpectrometer.

5.1 Package Contents

The package contains the spectrometer only. Powerful electronics are integrated into the spectrometer housing. Links to the documentation, software development kit (SDK), and software are written on a small note inside the spectrometer package.

5.2 Customization

If your application needs a special configuration, for example a different wavelength range, contact Broadcom to discuss your OEM module by sending an email to support.spectrometer@broadcom.com.

5.3 Getting Help

For any questions, comments, or requests concerning the spectrometer, the WAVES software, or the SDK, contact the Technical Support Team by sending an email to support.spectrometer@broadcom.com.

5.4 Troubleshooting

This section helps identify problems connecting to the spectrometer and how to proceed.

5.4.1 Software Cannot Find the Device

Normally you use a USB-to-UART converter or a level shifter for RS-232 signals to connect the QtubeSpectrometer to your PC. In both cases, the interface will show up as a serial port called COM*xx*. Those interfaces are not shown automatically in the device open window. To show those devices, activate the **Manual port selection** option. If this does not resolve the issue, restart the PC and try again.

Check the website for software updates.

If the software still cannot find the device, check the Device Manager from the Windows Control Panel. The COM port should display as COM*xx* in the Ports category. If the device is marked with an exclamation or question mark, remove the device, uninstall the driver software from the Windows Control Panel, restart the PC, and install the driver software again.

If the port is not listed in the Device Manager, try a different USB port.

If you use your own developed software, try to connect to the spectrometer with the Broadcom WAVES software.

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