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Embedding Ideas

TIM-UP – 19k-S3-Spartan 6 V2.1.0

Software User Manual

Version 7

Contact

Bluetechnix

Waidhausenstraße 3/19

A-1140 Vienna

AUSTRIA

office@bluetechnix.com

http://www.bluetechnix.com

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Information

For further information on technology, delivery terms and conditions and prices please contact Bluetechnix (http://www.bluetechnix.com).

Warning

Due to technical requirements components may contain dangerous substances.

1 General Information

This guide applies to the TIM^{uP} - 19k-S3-Spartan6 module from Bluetechnix GmbH. Follow this guide chapter by chapter to set up and understand your product. If a section of this document only applies to certain camera parts, this is indicated at the beginning of the respective section.

1.1 Symbols Used

This guide makes use of a few symbols and conventions:

Warning

Indicates a situation which, if not avoided, could result in minor or moderate injury and/or property damage or damage to the device.

Caution

Indicates a situation which, if not avoided, may result in minor damage to the device, in malfunction of the device or in data loss.

Note

Notes provide information on special issues related to the device or provide information that will make operation of the device easier.

Procedures

A procedure always starts with a headline

1. The number indicates the step number of a certain procedure you are expected to follow. Steps are numbered sequentially.

This sign ➤ indicates an expected result of your action.

References

This symbol indicates a cross reference to a different chapter of this manual or to an external document.

2 Overview

The TIM^{uP}-19k-S3-Spartan6 module is a Time-of-Flight Imaging Module with a resolution of 160 x 120 Pixels. It is designed to provide depth imaging data for any controller equipped with an USB Host interface, a Camera Sensor Interface (CSI) or an Image Sensor Module (ISM) interface. For easy access via USB, an powerful SDK is provided.

This document describes the necessary steps and settings to work with the TIM^{uP} - 19k-S3-Spartan6 module and describes the firmware dependent interfaces.

This document applies to firmware version v2.1.0

For a hardware compatibility list please refer to our support site.

Software and documentation

https://support.bluetechnix.at/wiki/TIM-UP-19k-S3-Spartan6

3 Hardware Connector

The following table shows the pin-out of the 100-pin TIM connector:

Pin #	Type	Signal name	Description
1	I	ISM.nDE	ISM Output enable: 0: ISM bus enabled, 1: ISM bus high Z
2	NC		
3	NC		
4	NC		
5	NC		
6	PWR	GND	Power ground
7	O	ISM.D7	ISM Data Bit 7 (MSB)
8	O	ISM.D6	ISM Data Bit 6
9	O	ISM.D5	ISM Data Bit 5
10	O	ISM.D4	ISM Data Bit 4
11	PWR	GND	Power ground
12	NC		
13	O	ISM.D3	ISM Data Bit 3
14	O	ISM.D2	ISM Data Bit 2
15	O	ISM.D1	ISM Data Bit 1
16	O	ISM.D0	ISM Data Bit 0 (LSB)
17	O	TRIGGER.OUT	Trigger output signal: rising edge after LED modulation
18	I	TRIGGER.IN	Trigger input signal: trigger on rising edge
19	O	ISM.HSYNC	ISM Line Sync (HSYNC)
20	O	ISM.VSYNC	ISM Frame Sync (VSYNC)
21	O	ISM.PCLK	ISM Pixel clock
22	PWR	GND	Power ground
23	NC		
24	I/O	ISM.SDA	ISM Configuration bus data signal
25	I	ISM.SCL	ISM Configuration bus clock signal
26	I	nRESET	Reset signal: hardware reset on low
27	NC		
28	I	ISM.SADDR	ISM Slave address (currently not supported)
29	PWR	GND	Power ground
30	NC		
31	NC		
32	PWR	GND	Power ground
33	NC		
34	NC		
35	PWR	GND	Power ground
36	NC		
37	NC		
38	PWR	GND	Power ground
39	NC		
40	NC		
41	PWR	GND	Power ground
42	NC		
43	NC		
44	NC		
45	NC		
46	I	UART.RX	UART Receive

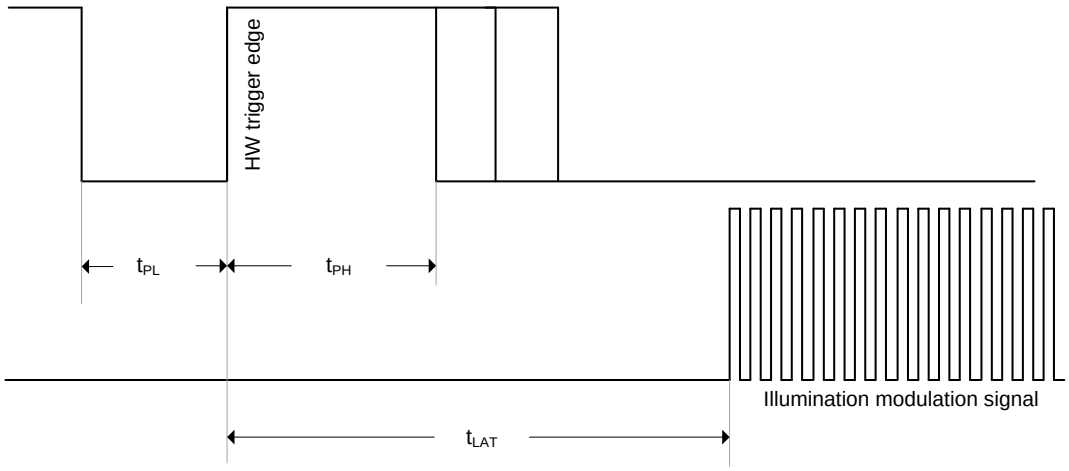
Pin #	Type	Signal name	Description
47	O	UART.TX	UART Transmit
48	NC		
49	NC		
50	NC		
51	O	LED.SMOD	LIM Single ended mod signal
52	I/O	LED.IO	LIM one-wire communication bus (currently not supported)
53	PWR	GND	Power ground
54	O	LED.MOD_N	LIM Differential pair mod signal – negative
55	O	LED.MOD_P	LIM Differential pair mod signal – positive
56	PWR	GND	Power ground
57	O	GPIO.3	GPIO 3: status signal (toggle on every frame capture)
58	I	GPIO.2	Factory Default Reset: 4sec on low while reboot to delete register map from flash and boot default configuration
59	I	GPIO.1	GPIO 1: not used – internal pull up
60	NC		
61	NC		
62	NC		
63	PWR	GND	Power ground
64	NC		
65	NC		
66	NC		
67	NC		
68	PWR	GND	Power ground
69	NC		
70	NC		
71	PWR	GND	Power ground
72	NC		
73	NC		
74	I	PEN	Module power enable
75	NC		
76	O	SPI.SCLK	Not used – high Z
77	I/O	SPI.SIO0	Not used – high Z
78	I/O	SPI.SIO1	Not used – high Z
79	O	SPI.nCS	Not used – high Z
80	NC		
81	NC		
82	NC		
83	PWR	GND	Power ground
84	NC		
85	NC		
86	NC		
87	NC		
88	PWR	GND	Power ground
89	I/O	USB.D_N	USB D- Signal: high Z on reset
90	I/O	USB.D_P	USB D+ Signal: high Z on reset
91	NC		
92	NC		
93	O	I2CM.SCL	I2C Master Clock signal: connect I2C bus from LIM
94	O	I2CM.SDA	I2C Master Data signal: connect I2C bus from LIM
95	PWR	GND	Power ground

Pin #	Type	Signal name	Description
96	PWR	GND	Power ground
97	PWR	VIN	5V Power supply
98	PWR	VIN	5V Power supply
99	PWR	VIN	5V Power supply
100	PWR	VIN	5V Power supply
101	PWR	GND	Power ground
102	PWR	GND	Power ground
103	PWR	GND	Power ground
104	PWR	GND	Power ground
105	PWR	GND	Power ground
106	PWR	GND	Power ground
107	PWR	GND	Power ground
108	PWR	GND	Power ground
109	PWR	GND	Power ground
110	PWR	GND	Power ground

Table 1 Pin-out of the TIM^{uP} – 19k-S3-Spartan6 connector

3.1 Timing of Trigger Input Pin

When the module is set to hardware trigger mode, a rising edge on the trigger input pin causes the camera to force an immediate frame capture. The typical timing constraints are shown in Table 2 Hardware trigger timing



Timing value	Description	Min	Typical	Max	Unit
t_{PL}	Pulse Low Time before Trigger	50			ns
t_{PH}	Pulse High Time	50			ns
t_{LAT}	Trigger Edge to Frame Capture Latency	TBD	60	TBD	µs

Table 2 Hardware trigger timing

3.2 Timing of Trigger Output Pin

The trigger output pin can be used for a synchronization of several TIM^{uP}-19kS3-Spartan6 modules by connecting the trigger output pin of one module to the trigger input pin of the following module. The trigger output pin defaults to low and goes high for a short time right after the modulation phases.

4 Interfacing

The TIM^{uP} - 19k-S3-Spartan6 firmware provides a USB data and control interface, an ISM parallel sensor interface and I^{2}C control interface. All interfaces are exposed on the 100pin board to board connector.

The interfaces are split into a control and data interface. The control interface is used to set and read the configuration of the TIM^{uP} - 19k-S3-Spartan6 module using a set of registers.

Note

For a complete register description refer to:
5 Register Description

4.1 General Data Format

The data output format on both, the USB and the ISM interface, is divided into four containers where each container has its own header. The data containers hold the pixel information whereas the header consists of 128 32bit double words of data stored in high byte first order. By default, the first data container and its header are disabled. The three remaining data containers are configured as follows:

- Data container 0: disabled
- Data container 1: phase values [0..0xffff equal to a phase of 0..2π]
- Data container 2: amplitudes [0..0xffff]
- Data container 3: plausibility flags

Header	Data Container 0	Header	Data Container 1	Header	Data Container 2	Header	Data Container 3

Figure 4-1 Data Containers

Note

For a complete description of the header data refer to:

4.2 5.3 Change Modulation Frequency

The TIMuP-19k-S3-Spartan6 module has two PLLs where two modulation frequencies can be configured simultaneously. The switch between the two modulation frequencies can be performed without reconfiguration of the PLLs and so without a delay. This modulation frequencies are set to 10MHz and 20MHz in registers ModulationFrequency0 and ModulationFrequency1 by default.
When it comes to configure the Frame capture sequence, one of the two modulation frequencies can be selected using the SeqXPLLSelect register or by setting the appropriate frequency in SeqXModFreq register. Both methods lead to the same result.
The modulation frequency used in any sequency can never be different to the configured frequencies in ModulationFrequency0 or ModulationFrequency1 register. The ModulationFrequency0 and ModulationFrequency1 register have to be set to the appropriate value before setting the sequences modulation frequency. Changing the registers ModulationFrequency0/1 registers will lead to a PLL setup phase of 200ms where a frame trigger is not possible.

When changing the modulation frequency to one of the values predefined in the offset registers, the offset will also automatically be set in the appropriate SeqXOffset register. This value can be overridden by setting the SeqXOffset Register again to the desired value.

4.3 Software trigger mode

In software trigger mode, the TIMuP-19k-S3-Spartan6 module is waiting in idle mode without capturing any frames until the register “SoftwareTrigger – 0x22” is set. Then one frame is triggered immediately and delivered in the ISM interface or provided on the USB. The typical delay until the frame is delivered is calculated as follows:

$$4 * IntegrationTime + fixme$$

4.4 Multiple Sequences

At the moment, the TIMuP-19k-S3-Spartan6 module provides two sequences which can be configured independently. The number of triggered sequences can be configured in register “SequenceLength – 0x0B“. When set to 2 every frame trigger will result in two frames. In freerun mode 40 frames per second will lead to 80 frames delivered on the ISM interface or provided on the USB. The two sequence frames are taken without a delay in between.
Use cases of multiple sequences are for example:

- Multiple modulation frequencies to extend the ambiguity range
- Multiple integration times to extend the dynamic range

Header Description

Note

To calculate the distance you must multiply the phase value with $\frac{c/2f}{0xffff}$

$$dist = (\text{phase value}) * \frac{c/2f}{65535}$$

dist… distance [m]
c…speed of light [m/s^2]
f…modulation frequency [Hz]

If the resulting value is greater than the ambiguity range subtract the ambiguity range. If the value is less than 0, add the ambiguity range.

This only applies to ISM data interface! In USB mode the SDK does all the calculation to get correct distances in mm.

4.5 USB Interface

For interfacing the TIM^{uP}-19k-S3-Spartan6 module over USB, a powerful SDK is provided. The SDK runs under Linux and Windows. Refer to our support website for downloading the SDK, sample code, for additional information and documentation.

Software and documentation

https://support.bluetechnix.at/wiki/TIM-UP-19k-S3-Spartan6

4.6 ISM / I²C Interface

4.6.1 I²C Configuration Interface

The TIM^{uP}-19k-S3-Spartan6 module can be configured using an I²C connection. The I²C control interface of the TIM^{uP}-19k-S3-Spartan6 module is listening on the following I²C slave address:

- **I²C Address:** 0x5D
- **SCL Frequency:** up to 400kHz

The TIM^{uP} - 19k-S3-Spartan6 module has a set of 32bit registers and is addressed by a 16bit address pointer. Following two figures show the timing diagrams of the I2C read and write.

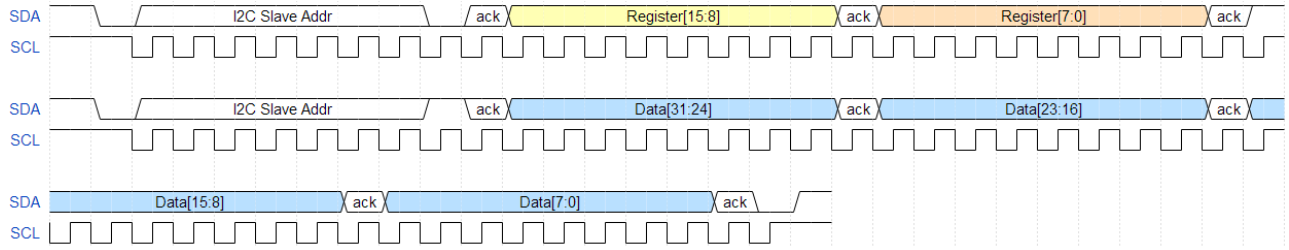


Figure 4-2 I²C register read timing diagram

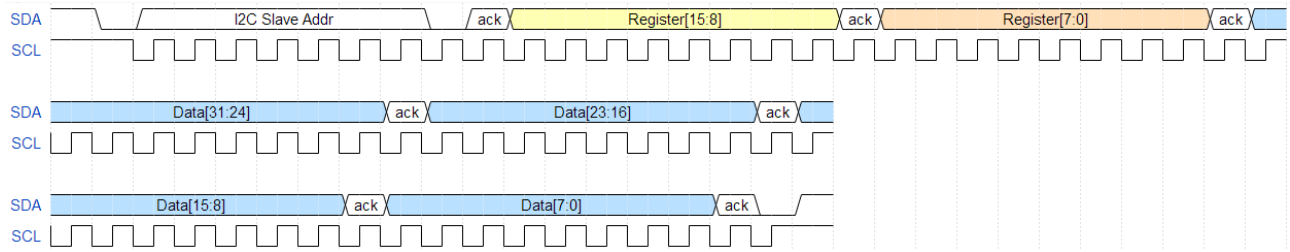


Figure 4-3 I²C register write timing diagram

Note

For a complete register description refer to:

5 Register Description

4.6.2 ISM Data Interface

When configured to stream data over ISM in free run mode, the TIM^{uP} - 19k-S3-Spartan6 module starts transferring frames automatically and can only be interrupted by switching to manual trigger mode.

Each frame starts with a rising edge on the VSYNC signal followed by a rising edge of the HSYNC signal. With the first HSYNC signal, the first data block is transmitted as shown in Figure 4-4 Timing diagram of the ISM data interface. Every data block contains 512bytes and starts with a HSYNC.

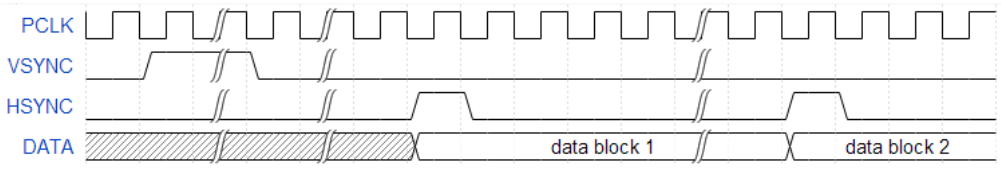


Figure 4-4 Timing diagram of the ISM data interface

Data comes low byte first and has to be captured on every rising edge starting with the rising edge of the HSYNC signal.

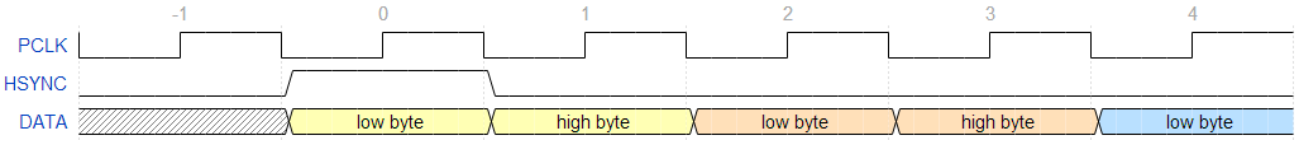


Figure 4-5 Byte order of the ISM data interface

The data stream during one frame is continuous, there is no horizontal blanking before the next HSYNC. The vertical blanking period varies depending on frame rate. Once ISM.nDE is low, the pixel clock never stops. ISM.PCLK stays constant at 48MHz.

5 Register Description

The TIM^{uP}-19k-S3-Spartan6 module has a continuous register set of 256 32bit registers which can be configured via the SDK in USB mode or I²C in ISM mode.

5.1 General Registers

Addr (hex)	Register Name	Default Value (hex)	R/W	Description
00	Status[3)]	0	R	Bit[0]: Calc FIFO overflow Bit[1]: frame dropped Bit[2]: Watchdog caused reset Bit[3:7]: reserved Bit[8]: 1.. FPN verified Bit[9]: 1.. FPPN verified Bit[10]: 0.. default register map loaded 1.. stored register map loaded Bit[11]: 1.. mainboard temperature sensor found Bit[12]: 1.. LED board temperature sensor found
01	SerialNumber[1)]	-	R	Bit[0:19]: Serial Number Bit[20:31]: Device Type
02	ReleaseDate	-	R	Release date, hex value interpreted as date For example 0x01012014 means 01.01.2014
03	FrameSize	1C800	R	Frame size in bytes
04	NumRows	78	R	Number of vertical pixels delivered
05	NumColumns	A0	R	Number of horizontal pixels delivered
0B	SequenceLength	1	R/W	Number of sequences to be calculated
10	TempMainboard	-	R	Temperature of Mainboard in fixedpoint 9.4 [°C]
11	TempIllumination	-	R	Temperature of Illumination in fixedpoint 9.4 [°C]
16	ChipsizeColumns	A0	R	Horizontal count of pixels (sensor)
17	ChipsizeRows	78	R	Vertical count of pixels (sensor)
18	TimestampIncrement	1312D	R/W	desired timestamp granularity timer value default: 78125 / 78125000 = 1ms
19	TriggerMode	0	R/W	Bit[0:1]: 0.. free run mode 1.. hardware trigger mode 2.. software trigger mode
1B	TempIlluminationGain1	0	R/W	Coefficient c3 for cubic temperature compensation of the illumination module temperature x/10000
1C	TempIlluminationGain2	0	R/W	Coefficient c2 for cubic temperature compensation of the illumination module temperature x/10000
1D	TempIlluminationGain3	0	R/W	Coefficient c1 for cubic temperature compensation of the illumination module temperature x/1000
1E	TempMainboardGain1	0	R/W	Coefficient c3 for cubic temperature compensation of the mainboard temperature x/10000
1F	TempMainboardGain2	0	R/W	Coefficient c2 for cubic temperature compensation of the mainboard temperature x/10000
20	TempMainboardGain3	0	R/W	Coefficient c1 for cubic temperature compensation of the mainboard temperature x/1000

Addr (hex)	Register Name	Default Value (hex)	R/W	Description
21	TempLimit	46	R/W	Temperature limit for over temperature protection of the illumination module (only available if TIM gets LED board temperature!)
22	SoftwareTrigger	0	R/W	Set 1 to trigger a frame capture when in software trigger mode (Register 0x19)
30	ModLedEnable[2)]	1B	R/W	Bit[0]: reserved - high Bit[1]: enable differential LED mod signal Bit[2]: enable single ended LED mod signal Bit[3]: reserved - high Bit[4]: reserved - high
31	StatusLedEnable[2)]	0	R/W	Bit[0]: 0.. Status LED disabled 1.. Status LED enabled
36	AdvancedFunctions[3)]	0	R/W	Bit[0:3]: 0.. Watchdog disabled 1.. Watchdog enabled Bit[24:27]: 1.. reset to factory default register set, reboot required Bit[28:31]: 1.. reset module
37	DataInterfaceType	0	R/W	Bit[0]: 0.. USB data interface 1.. ISM data interface
38	FirmwareInfo	-	R	Bit[0:5]: Firmware nonfunctional version Bit[6:10]: Firmware minor version Bit[11:15]: Firmware major version
76	ModulationFrequency0	1312D00	R/W	First possible modulation frequency [Hz]
77	ModulationFrequency1	989680	R/W	Second possible modulation frequency [Hz]
78	5MHz_Offset	0	R/W	Offset for 5MHz modulation frequency [mm]
79	7.5MHz_Offset	0	R/W	Offset for 7.5MHz modulation frequency [mm]
7A	10MHz_Offset	0	R/W	Offset for 10MHz modulation frequency [mm]
7B	15MHz_Offset	0	R/W	Offset for 15MHz modulation frequency [mm]
7C	20MHz_Offset	0	R/W	Offset for 20MHz modulation frequency [mm]
7D	25MHz_Offset	0	R/W	Offset for 25MHz modulation frequency [mm]
7E	30MHz_Offset	0	R/W	Offset for 30MHz modulation frequency [mm]
7F	FramesPerSecond	5	R/W	FPS considering the configured sequence length and the corresponding integration times

Table 3 General registers description of the TIM^{uP}–19k-S3-Spartan6

[1)] The Serial Number field contains the device type code and the serial number. For a list of all device type codes refer to:

https://support.bluetechnix.at/wiki/PMDSDK_/_PMDMDK_User_Manual#No._Serial.2FCustomer

[2)] For detailed information on hardware pins refer to:

3 Hardware Connector

[3)] Register available since Firmware v2.1.0

5.2 Sequence Registers

Addr (hex)	Register Name	Default Value (hex)	R/W	Description
80	Seq0PLLSelect	0	R/W	PLL config of the correct modulation frequency Modulation frequency 0 and 1 are configured in register 76 and 77
81	Seq0IntegrationTime	1F4	R/W	Integration time of sequence 0 in µs
82	Seq0ModFreq	1312D00	R/W	Modulation frequency to use for this sequence Only modulation frequencies set in register 76 and 77 are valid for this register
86	Seq0DistOffset[5)]	0	R/W	Override global offset
87	Seq0AmpMin	12C	R/W	Sets the minimal amplitude for valid pixels. Pixels with an amplitude below this value will be tagged by the amplitude low flag
8A	Seq1PLLSelect	1	R/W	PLL config of the correct modulation frequency Modulation frequency 0 and 1 are configured in register 76 and 77
8B	Seq1IntegrationTime	1F4	R/W	Integration time of sequence 1 in µs
8C	Seq1ModFreq	989680	R/W	Modulation frequency to use for this sequence Only modulation frequencies set in register 76 and 77 are valid for this register
90	Seq1DistOffset[5)]	0	R/W	Override global offset
91	Seq1AmpMin	12C	R/W	Sets the minimal amplitude for valid pixels. Pixels with an amplitude below this value will be tagged by the amplitude low flag

Table 4 Sequence registers description of the TIM^{uP} – 19k-S3-Spartan6

[5)] Distance offset is taken from global offset Registers 78 to 7E when SeqXPLLSelect or SeqXModFreq is set to one of the seven predefined Frequency values. This can be temporarily overridden to another offset.

5.3 Change Modulation Frequency

The TIMuP-19k-S3-Spartan6 module has two PLLs where two modulation frequencies can be configured simultaneously. The switch between the two modulation frequencies can be performed without reconfiguration of the PLLs and so without a delay. This modulation frequencies are set to 10MHz and 20MHz in registers ModulationFrequency0 and ModulationFrequency1 by default.

When it comes to configure the Frame capture sequence, one of the two modulation frequencies can be selected using the SeqXPLLSelect register or by setting the appropriate frequency in SeqXModFreq register. Both methods lead to the same result.

The modulation frequency used in any sequency can never be different to the configured frequencies in ModulationFrequency0 or ModulationFrequency1 register. The ModulationFrequency0 and ModulationFrequency1 register have to be set to the appropriate value before setting the sequences modulation frequency. Changing the registers ModulationFrequency0/1 registers will lead to a PLL setup phase of 200ms where a frame trigger is not possible.

When changing the modulation frequency to one of the values predefined in the offset registers, the offset will also automatically be set in the appropriate SeqXOffset register. This value can be overridden by setting the SeqXOffset Register again to the desired value.

5.4 Software trigger mode

In software trigger mode, the TIMuP-19k-S3-Spartan6 module is waiting in idle mode without capturing any frames until the register “SoftwareTrigger – 0x22” is set. Then one frame is triggered immediately and delivered in the ISM interface or provided on the USB. The typical delay until the frame is delivered is calculated as follows:

$$4 * IntegrationTime + fixme$$

5.5 Multiple Sequences

At the moment, the TIMuP-19k-S3-Spartan6 module provides two sequences which can be configured independently. The number of triggered sequences can be configured in register “SequenceLength – 0x0B“. When set to 2 every frame trigger will result in two frames. In freerun mode 40 frames per second will lead to 80 frames delivered on the ISM interface or provided on the USB. The two sequence frames are taken without a delay in between.

Use cases of multiple sequences are for example:

- Multiple modulation frequencies to extend the ambiguity range
- Multiple integration times to extend the dynamic range

6 Header Description

The TIM^{uP}-19k-S3-Spartan6 module delivers several useful registers in every frame header. The values in the header fields represent the register values during runtime when a new frame is delivered.

Addr (hex)	Header Field	Description
00	Status	See register description
01	SerialNumber	See register description
02	ReleaseDate	See register description
03	FrameSize	See register description
04	NumRows	See register description
05	NumColumns	See register description
0B	SequenceLength	See register description
10	TempMainboard	See register description
11	TempIllumination	See register description
16	ChipsizeColumns	See register description
17	ChipsizeRows	See register description
18	TimestampIncrement	See register description
19	TriggerMode	See register description
60	SeqPLLSelect	See register description
61	Seq0IntegrationTime	See register description
62	Seq0ModFreq	See register description
66	Seq0DistOffset[5)]	See register description
67	Seq0AmpMin	See register description
6A	FrameCounter	Continuous numbered frame count
6B	TimeStamp	Timestamp of frame with granularity set in Register 18

7 Support

7.1 General Support

General support for products can be found at Bluetechnix' support site

Support Link

https://support.bluetechnix.at/wiki/TIM-UP-19k-S3-Spartan6

7.2 Software Packages

Software packages and software downloads are for registered customers only

Support Link

https://support.bluetechnix.at/wiki/TIM-UP-19k-S3-Spartan6

7.2.1 Related Products

- LIM-U-LED-850

8 Product History

8.1 Version Information

8.1.1 TIM^{uP} – 19k-S3-Spartan6-USB

Version	Release date	Changes
0x28042014	April 2014	First preliminary version

Table 5: Overview TIM^{uP} – 19k-S3-Spartan6-USB firmware changes

8.1.2 TIM^{uP} – 19k-S3-Spartan6

Version	Release date	Changes
2.0.0 (0x19082014)	2014 08 19	See release notes of v2.0.0
2.1.0	TBD	

Table 6: Overview TIM^{uP} – 19k-S3-Spartan6-ISM firmware changes

8.2 Anomalies

Version	Date	Description
v0.0.0	2014 04 28	No anomalies reported yet.
v2.0.0	2014 08 19	Compatibility to PMDSDK v0.3.0: To get correct distance values when setting a new modulation frequency, a disconnect and reconnect has to be performed!
v2.0.0	2014 11 10	Switching to ISM/I2C Interface when USB was connected fails. I2C connection will not be established

Table 7 – Product anomalies

8.3 Document Revision History

Version	Date	Document Revision
1	2014 04 28	First release V1.0 of the Document
2	2014 05 16	Unused Pins changed from pulldown to high-Z
3	2014 08 01	Description of phase values added
4	2014 08 07	USB and ISM interfaces merged, register description updated
5	2014 08 19	Added new Modulation Frequency description and finalized SUM for v2.0.0 update
6	2014 09 15	FirmwareInfo register description modified
7	2014 11 24	Updates related to firmware v2.1.0

Table 8: Revision history

9 List of Abbreviations

Abbreviation	Description
CSI	Camera Sensor Interface
DC	Direct Current
EBI	External Bus Interface
ESD	Electrostatic Discharge
FPN	Fixed Pattern Noise
FPPN	Fixed Phase Pattern Noise
GPIO	General Purpose Input Output
I	Input
I²C	Inter-Integrated Circuit
I/O	Input/Output
ISM	Image Sensor Module
NC	Not Connected
O	Output
OS	Operating System
PPI	Parallel Peripheral Interface
PWR	Power
ROI	Region Of Interest
SPI	Serial Peripheral Interface
SPORT	Serial Port
UART	Universal Asynchronous Receiver Transmitter
USB	Universal Serial Bus

Table 9: List of abbreviations

A List of Figures and Tables

Figures

Tables