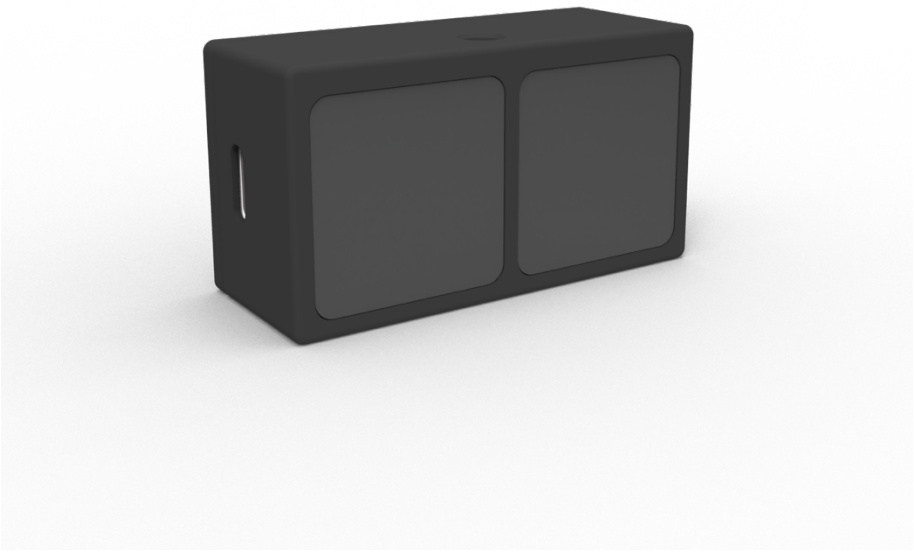
DFR1177 Development Manual



1 MMPT044-940 Working Mechanism

MMPT044-940 operates in three primary modes as described below:

Idle mode: This is the default state after power up where the system does not actively measure distance or emit laser light. Its primary function in this state is likely to await a command or condition to switch to another mode of operation.

Distance Measurement mode: In this mode, the system activates the laser to take distance measurements. After measuring, it processes the information and the result is sent via USB or UART to another system for display, storage, or immediate use.

Sleep mode: This is a protective mode activated when the input voltage levels are inappropriate, such as overvoltage or undervoltage conditions(such as input voltage is less than 3V). In this state, all active functions of the system are powered down to prevent damage. This mode conserves power and protects the system until suitable power conditions are restored.

2 MMPT044-940 System Communication Method

2.1 Device Connection

MMPT044-940 is operated by issuing commands on the following methods:

(1) UART

(2) USB Virtual COM (data sent via Bulk Transaction)

2.2 Command Format

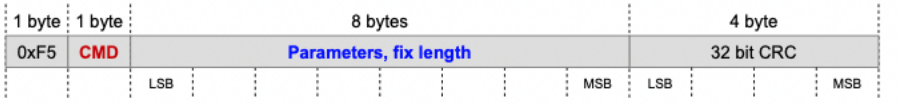
Command packets have a fixed length of 14 bytes: a start byte (value 0xF5) followed by 1 byte of command identifier (CMD), 8 bytes of command identifier parameters and 1 end byte with 32-bit CRC.

Response packets have a variable length: a start byte (value 0xFA), followed by 1 byte of type definition, 2 bytes of length definition n, n bytes of data and 1 end byte with 32-bit CRC.

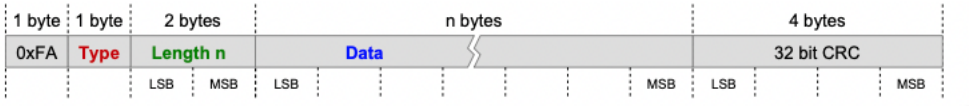
Data integrity is provided by CRC checksum added to each camera response. The calculation of CRC includes all bytes of the object except for the CRC itself. The CRC specification is as follows:

- Byte-wise CRC32
- Polynom: 0x04C11DB7
- Xor value: 0x00000000
- Init value: 0xFFFFFFFF

Command Format



Response Format



3 MMPT044-940 Command Set Overview

There are three types of commands within the Command Set:

SET Commands：Utilize these commands to configure your device. Set ranging parameters, frame rate, whether to enable filtering, etc.

GET Commands：Utilize these commands to retrieve data from the device. The data can include different types of images(such as distance images, grayscale images, amplitude images) and calibration information.

Miscellaneous Commands：Utilize these commands to get information about the device's status, version, and operating conditions(such as chip temperature)., etc.

SET Commands

Commands	CMD	Description
SET_INT_TIME_DIST	0x00	Integration time for the distance measurement setting
SET_INT_TIME_GS	0x01	Integration time for grayscale measurement setting
SET_HDR	0x0D	High dynamic range mode setting (HDR)
SET_ROI	0x02	Region of interest setting (ROI)
SET_INTERFERENCE_DETECTION	0x11	Set interference detection settings
SET_EDGE_DETECTION	0x10	Set edge detection settings
SET_FRAME_RATE	0x0C	Sets the (maximal) frame rate
SET_AMPLITUDE_LIMIT	0x09	Amplitude limits settings for the confidence information
STOP_STREAM	0x28	Stops the stream from the camera
SET_COMPENSATION	0x55	Sets the compensation flags

GET Commands

Commands	CMD	Description
GET_DIST	0x20	Performs distance acquisition
GET_DIST_GS	0x29	Performs distance and grayscale acquisition
GET_DIST_AMPLITUDE	0x22	Performs distance and TOF amplitude acquisition
GET_GS	0x24	Performs grayscale acquisition
GET_DCS	0x25	Performs DCS acquisition
GET_CALIBRATION_INFO	0x57	Returns information about the calibration on the device

Miscellaneous Commands

Commands	CMD	Description
GET_TEMPERATURE	0x4A	Returns the chip temperature
IDENTIFY	0x47	Returns the device ID and the operating mode

4.SET Commands

4.1.SET_INT_TIME_DIST [0x00]

The integration time, called exposure time in 2D cameras, is the central parameter to control the camera. Like in any 2D camera, the exposure time is essential for good image quality. If the scenery is in the dark, a longer exposure time is necessary in order to make dark areas in the picture visible. On the other hand, a high brightness

in the scenery needs a shorter exposure time in order not to saturate the pixels. Typically, the exposure time setting in modern digital cameras is set automatically, dependent on the illumination situation.

Every 3D camera depends also on a good integration time setting. The longer the integration time, the higher the sensitivity. Thus, a longer integration time allows the detection of objects farther away. However, high reflective objects in close distance lead to saturation in one or more pixels so distance measurement is no longer possible.

In the manual mode, the integration time can be set by a parameter previous to the exposure.

It is to note that a longer integration time leads to the collection of more ambient-light. The more ambient-light collected, the higher the distance noise due to the shot noise created by the ambient-light. Thus, the shorter the integration time, the lower the distance noise. As a rule of thumb, an integration time less than 1'000µs allows a very efficient ambient-light suppression. Integration times greater than 1'000µs should be used only in indoor applications.

It is also to note that the reflectivity of an object can have an impact on the distance measurement accuracy.

WFOV

IntTimeIn	FOV	No HDR	HDR	Default (us)
0x00	WFOV	Integration time used for the full pixel-field or the ROI	1. integration time WFOV	125
0x01	WFOV		2. integration time WFOV	0
0x02	WFOV		3. integration time WFOV	0
0x03	WFOV		4. integration time WFOV	0
0xFF	WFOV	Automatic mode: Integration time is set automatically between 1 and 1'000 µs	Automatic mode	

Parameter	byte 0: IntTimeIndex
	byte1,2: Integration time in microseconds, 16 bit unsigned integer, Range: 1 … 1'000 µs.
	Others：0
Response type	0x00: ACK

Response time	T_{PROC}: ~ 25µs
Example	0xF5 | 0x00 | 0x00 0x1E 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00| 0x47 0x7 0xEC 0xC0 |(integration time0 = 30µs)

Consider the following amplitude returns for adequate integration time settings:

TOF amplitude	**Consideration**
<100 LSB	Distance results contain significant distance noise. Increase the integration time and/or apply the temporal filter to reduce the distance noise.
100 ~ 1900 LSB	Good measurement data with low distance noise. However, temporal filtering is recommended.
500 ~ 1900 LSB	Ideal amplitude for best performing distance data.
>1900 LSB	Distance result can be wrong due to saturation

4.2.SET_INT_TIME_GS [0x01]

Sets the integration time for grayscale measurements. Setting gray scale integration time to zero enables the ambient light compensation. Any value different than 0 disables the ambient light compensation. There is no auto integration time mode available for gray scale.

Parameter	byte 0: IntTimeIndex.
	byte 1, 2: Integration time in microseconds, 16 bit unsigned integer, Range:1 … 1'000 µs. others:0x00s
	Others：0
Response type	0x00: ACK
Response time	T_{PROC}: ~ 25µs
Example	0xF5 | 0x01 | 0x1E 0x00 0x00 0x00 0x00 0x00 0x00 0x00| 0x59 0xB0 0xAC 0x6B |(integration time GS = 30µs)

4.3.SET_HDR [0x0D]

Sets the type of the high-dynamic range (HDR) for distance acquisition. They are preferably used in distance and TOF amplitude mode. They do not affect the grayscale modes. Two different modes are available:

1. Spatial HDR

In this mode, different integration times set with IntTimeIndex0/1/2/3 for WFOV are

used simultaneously during the acquisition of an image. After image acquisition, the MMPT044-940 then selects the pixel with the “best” amplitude value of the up to four pixels values from the two vertical adjacent pixels and stuffs (patches) the other pixel of this pixel pair with the same value. The result is an image with a very high dynamic range, best possible frame rate but with a lower vertical resolution. Virtually, the pixel becomes a vertical rectangle because always the two vertical neighbor pixels contain the same value.

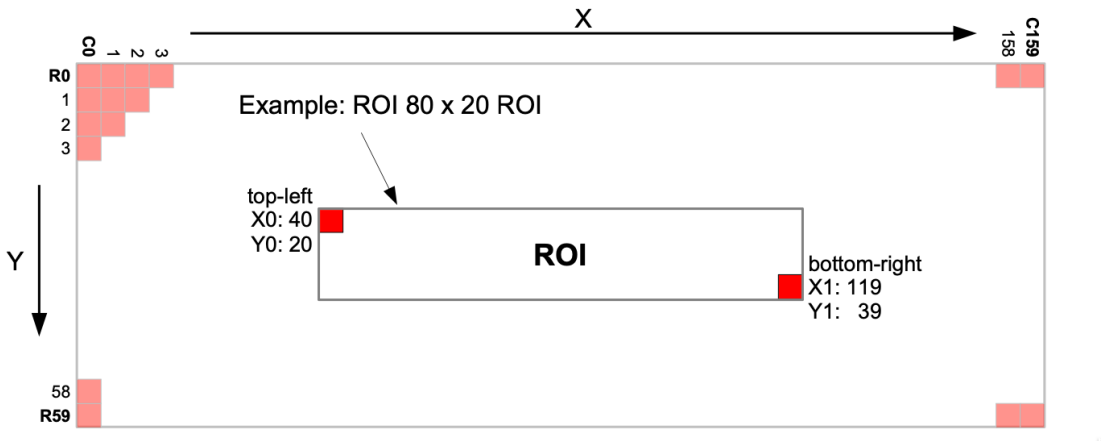
2. Temporal HDR

The camera acquires and transmits image data in a consecutive and incrementing sequence by using IntTimeIndex0, IntTimeIndex1, IntTimeIndex2, IntTimeIndex3. The host software has then to patch the up to four images to one HDR image by a selection of the best amplitude for each pixel. It is possible to use 2 or 3 integration times only. In this case, set not used integration times to zero.

Parameter	byte 0: 0 = HDR off, default 1 = spatial HDR 1st step: 2 integration times in 1 frame using row reduction - and additionally 2nd step: Time-wise by 2 consecutive frames. 2 = temporal HDR Time-wise by 2, 3 or 4 consecutive frames, only non-zero values for IntTimeIndex are acquired.
	Others：0
Response type	0x00: ACK
Response time	T_{PROC} : ~ 25µs
Example	| 0xF5 | 0x0D | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00| 0x2A 0x7C 0x6A 0xBD | (HDR off)

4.4. SET_ROI [0x02]

A full image of the MMPT044-940 has a pixel-field of 160x 60 pixels in WFOV mode. A “region of interest” acquires only a selected number of pixels which are necessary for the application. This reduces the amount of readout data and increases the frame rate. The ROI is active for the WFOV image only.



Parameter	byte 0, 1: Coordinate X0, 16 bit unsigned integer
	byte 2, 3: Coordinate Y0, 16 bit unsigned integer
	byte 4, 5: Coordinate X1, 16 bit unsigned integer
	byte 6, 7: Coordinate Y1, 16 bit unsigned integer Ranges: X0, X1 = 0 … 159, Y0, Y1 = 0 … 59, Default: Full image 160x60 pixel Boundaries: X1 – X0 > 7 pixel, Y1 – Y0 > 3 pixel, each increments by multiple of 4 pixels.
Response type	0x00: ACK
Response time	T_{PROC} : ~ 25µs
Example	0xF5 | 0x02 | 0x00 0x00 0x00 0x00 0x9F 0x00 0x3B 0x00 | 0xB9 0xFC 0xA9 0x69 | (X0 = 0, Y0 = 0, X1 = 159, Y1 = 59)

4.5.SET_INTERFERENCE_DETECTION [0x11]

Cross-interference will lead to asymmetric zero-crossing of DCS0 versus DCS2 and / or DCS1 versus DCS3. A pixel is marked as interfered if DCS0(signed) + DCS2(signed) > threshold or DCS1(signed) + DCS3(signed) > threshold.

Parameter	byte 0: 0 = disabled, 1 = enabled (default)
	byte 1: 0 = mark pixel with status code, 1 = use last valid value (default)
	byte 2/3: interference detection limit (default 500)
	Others: 0
Response type	0x00: ACK
Response time	T_{PROC} : ~ 25µs

Example	| 0xF5 | 0x11 | 0x01 0x01 0x90 0x01 0x00 0x00 0x00 0x00| 0x93 0xD8 0x1B 0x77 |（enabled, use last value, 400lsb)

4.6.SET_EDGE_DETECTION [0x10]

Set edge detection settings.

Parameter	byte 0,1: 0 = disabled, else edge detection threshold (default 300)
	Others: 0
Response type	0x00: ACK
Response time	T_{PROC} : ~ 25µs
Example	| 0xF5 | 0x10 | 0x2C 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00| 0xDA 0x6E 0xA8 0x50 |(threshold 300)

4.7. SET_FRAME_RATE [0x0C]

This command can be used to limit the maximal frame rate. The frame rate basically depends on the integration time plus the processing time. There are two different cases to consider:

1. If the integration time plus the processing time is less than the set frame time, the set frame time limits the effective frame rate.

2. If the integration time plus the processing time is greater than set frame time, the set frame rate setting is inactive. In this case, the frame rate is given by the integration rate plus the processing time.

Parameter	byte 0, 1: frame time (= 1 / frame rate) in milliseconds, 16 bit unsigned integer. Range: 10 – 200ms. Default = 1 (allows max. possible frame rate)
	Others: 0
Response type	0x00: ACK
Response time	T_{PROC} : ~ 25µs
Example	| 0xF5 | 0x0C | 0x14 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x2A 0xF7 0xB1 0x81 | (50 fps)

4.10. SET_AMPLITUDE_LIMIT [0x09]

Sets the amplitude limits for the confidence information. The limits decide if distance

is valid and confidence bits are set.

Parameter	byte 0: 0 … 3 = Index of the amplitude limit to be set, for wide field , 4 = Index for narrow field byte 2, 3: Amplitude limit in LSB, 16 bit unsigned integer.
	Others: 0
Response type	0x00: ACK
Response time	T_{PROC} : ~ 25µs
Example	| 0xF5 | 0x09 | 0x00 0x64 0x00 0x00 0x00 0x00 0x00 0x00 | 0xE7 0x34 0xAE 0x47 | (Set limit 0 = 100 LSB)

4.11.STOP_STREAM [0x28]

Stops the stream if the camera is in streaming mode.

Parameter	no, all bytes 0x00. Default: Camera is not streaming.
Response type	0x00: ACK
Response time	T_{PROC} : Max. calculation time of 1 image. Depends on settings.
Example	| 0xF5 | 0x28 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xF9 0x7F 0x68 0x81|

4.12.SET_COMPENSATION [0x55]

Without calibration and runtime compensation, the distance measurement is rather inaccurate and it drifts by changes in temperature and ambient-light. Thus, the MMPT044-940 is factory calibrated and it uses a runtime compensation for best possible accuracy. However, it is possible but not recommended to turn the runtime calibration off.

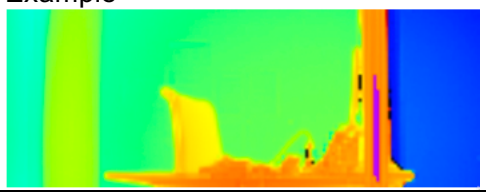
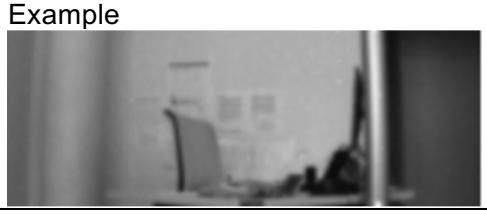
For ambient light compensation the integration time for gray scale needs to be set to 0.

Parameter	byte 0: Distance response non-uniformity compensation (DRNU), 0 = off, 1 = active (default)
	byte 1: Ambient-light compensation, 0 = off, 1 = active (default)
	byte 2: Temperature compensation, 0 = off, 1 = active (default)
	Others: 0
Response type	0x00: ACK

Response time	T_{PROC} : ~ 25µs
Example	| 0xF5 | 0x0C | 0x14 0x00 0x00 0x00 0x00 0x00 0x00 0x00 |0x2A 0xF7 0xB1 0x81 | (50 fps)

5. GET commands

The acquisition modes in the “GET” commands have the following meaning:

Distance Image	Example 
Amplitude Image	Example 
Grayscale Image	Example 
4 DCS	Example 

The GET commands do the image acquisition and the data readout.

1) 3 Acquisition mode below：

Acquisition mode	**Parameterbyte0**	**Description**
Single measurement	0x00	The camera acquires one image
Pipelined single measurement	0x01	Parallel to the data transmission of an image on command, the next image is already acquired. This reduces the processing time of the next command. This mode gets almost the same frame rate as the streaming mode.
Streaming mode	0x02	The camera acquires continuously images and streams the data. The stream can be terminated either by an other acquisition or the STOP_STREAM command

2) Data Acquisition Output Format

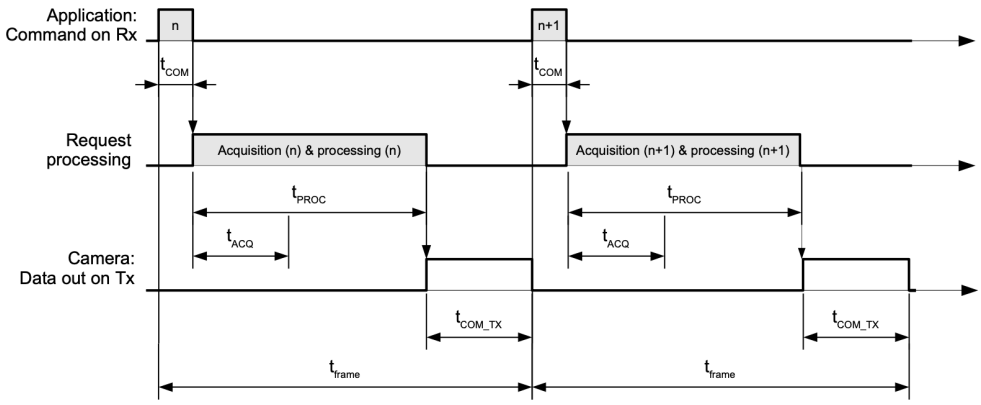
Confidence bit15、14	Distance bit13…0	Amplitude limits	Definition
WFOV			
Definition	0…7500d	-	Mod. frequency 20 MHz FOV: Full frame 160x60 pixel or ROI. Refer to Figure 2 Distance range: 0 … 7.5 m Resolution: 1 mm/LSB Data: 16 bit: 2 bit confidence and 14 bit unsigned integer distance
00	< 7500 d	TOF amplitude > AmpLimit0 Default = 50 LSB	Very low amplitude: The result shows the presence of an object, but distance information is very inaccurate.
10	< 7500 d	TOF amplitude > AmpLimit1 Default = 100 LSB	Weak amplitude: Distance result is usable but has reduced accuracy.
10	< 7500 d	TOF amplitude > AmpLimit2 Default = 200 LSB	Good amplitude: Good distance information.
11	< 7500 d	TOF amplitude > AmpLimit3 Default = 500 LSB	Excellent amplitude: Most accurate distance measurement.
	> 7500 d	TOF amplitude < AmpLimit0	Distance not available or out of range: Check distance status.
Status	16001 d	-	Low TOF amplitude
	16002 d	-	Exceeds A/D conversion limits
	16003 d	-	Pixel saturation
	16007 d	-	Modulation interference or Motion-blur
	16008 d	-	Filtered out by edge detection

3) Response header

Every response to a command request for distance, grayscale, amplitude and DCSx includes this header as a fix part of the transmission. It contains information about the parameter settings for the acquisition and to the system. The application can skip the information if not needed.

Entry	Format	byte	Comment	
Header version	8 bit unsigned integer	1	0	Protocol identification against future, changed versions.
Frame counter	16 bit unsigned integer	2	1	Increment per frame, roll over at 65'535
Timestamp	16 bit unsigned integer	2	3	Increment per millisecond, roll over at 65'535s
MMPT044-940 Version	MSBytes: 16 bit unsigned Version LSBytes: 16 bit unsigned Sub-version	4	5	

Hardware version	8 bit unsigned integer	1	9	
Chip ID	16 bit unsigned integer	2	10	
Image width (x-axis)	16 bit unsigned integer	2	12	
Image height (y-axis)	16 bit unsigned integer	2	14	
Image origin X	16 bit unsigned integer	2	16	
Image origin Y	16 bit unsigned integer	2	18	



5.1.GET_DIST (0x20)

Performs distance acquisition. It returns, in streaming mode continuously, the result or status.

Parameter	byte0: Acquisition mode. Others：0
Response type	0x03: Distance
Response data	80 byte header+max 160×60×2byte/pixel WFOV distance data
Response time	up to ~100ms depending on settings
Example	Command e.g | 0xF5 | 0x20 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00| 0x62 0xAC 0xA8 0xCC | (Acquisition mode 0) Response e.g | 0xFA | 0x03 | 0x50 0x4B | 0x28 0x0F 0x00 0x00 … (19'280 bytes total) | CRC (4 bytes) |

5.2.GET_DIST_GS (0x29)

Performs distance and grayscale acquisition. It returns, in streaming mode continuously, the result or status.

Parameter	byte0: Acquisition mode.
	Others：0
Response type	0x0A: Distance and grayscale
Response data	80 byte header+max 160x60pixelx3byte/pixel WFOV 16 bit distance data and 8 bit grayscale data
Response time	up to ~150ms depending on settings
Example	Command e.g. | 0xF5 | 0x29 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x7 0xC8 0x28 0x2A |(Acquisition mode 0) Response e.g. | 0xFA | 0x0A | 0xD0 0x70 | 0x28 0x0F 0x00 0x00…(28'880 bytes total)| CRC(4byte)

5.3. GET_DIST_AMPLITUDE [0x22]

Performs distance and TOF amplitude acquisition. It returns, in streaming mode continuously, the result or status.

Parameter	byte0: Acquisition mode.
	Others：0
Response type	0x05: Distance and amplitude
Response data	80byte header+max 160 × 60 pixel× 4bytes/pixel WFOV
Response time	up to ~150ms depending on settings
Example	| 0xF5 | 0x20 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00| 0x62 0xAC 0xA8 0xCC |(Acquisition mode 0)

5.4.GET_GS [0x24]

Performs distance and grayscale acquisition. It returns, in streaming mode continuously, the result or status.

Parameter	byte0: Acquisition mode.
	Others：0
Response type	0x06: Grayscale
Response data	80 bytes header + max. 160x60pixel x3 bytes/pixel WFOV data with 16 bit distance data and 8 bit grayscale data
Response time	up to ~150ms depending on settings
Example	| 0xF5 | 0x24 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x68 | 0x74 0x4B 0x28 0x68 |(Acquisition mode 0)| | 0xFA | 0x06 | 0xD0 0x25 | 0x28 0x0F 0x00 0x00…(9'680byte totally)| CRC(4byte)|

5.5.GET_DCS [0x25]

Performs DCS acquisition. It returns, in streaming mode continuously, the result or status.

Parameter	byte0: Acquisition mode. Others：0
Response type	0x07: DCS data
Response data	1 command “GET_DCS” transmits the data in one or two packets with the following data, 80 bytes header + 1 byte packet number + 4 bytes total size + max. 50'000 bytes (160x60 pixel x 2 bytes/pixel with 16 bit DCS data
Response time	up to ~200ms depending on settings
Example	| 0xF5 | 0x25 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x6A 0xFC 0x68 0xC3 | (Acquisition mode 0) | 0xFA | 0x07 | 0x50 0xC3 | 0x00 | 0x00 0x2C 0x01 0x00 | 0x28 0x0F 0x00 ... (50'000 bytes total) | CRC (4 bytes) | | 0xFA | 0x07 | 0xB0 0x68 | 0x01 | 0x00 0x2C 0x01 0x00 | 0x28 0x0F 0x00 ... (26'800 bytes total) | CRC (4 bytes) |

6 Miscellaneous commands

6.1. GET_TEMPERATURE [0x4A]

Returns the chip temperature during last distance acquisition.

Parameter	no, all bytes 0x00
Response type	0xFC: Data
Response data	2 bytes: Temperature, 0.01 ºC / LSB, 16 bit 2's complement signed integer.
Response time	~25us
Example	| 0xF5 | 0x4A | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x1F 0xF8 0x6E 0x87 | | 0xFA | 0xFC | 0x02 0x00 | 0x47 0x13 | 0x54 0x1E 0x4C 0x14 | (Temperature = 49.35°C)

6.2. IDENTIFY [0x47]

Returns the device identification ID.

Parameter	no, all bytes 0x00
Response type	0x02: Data
Response data	4byte： byte 0: Hardware version byte 3: 0x00 = normal operation, 0x80 = bootloader

Response time	~25us
Example	| 0xF5 | 0x47 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x8C 0x7B 0x6E 0xC5 | | 0xFA | 0x02 | 0x04 0x00 | 0x00 0x00 0x04 0x00 | 0xE5 0x48 0x22 0x5D | (HW version 0, normal operation)

7. Version Information

Version	Date	Notes
V0.1	10/25/2023	Initial Version Released
V1.0	10/30/2023	Formal Version Released