General Description

TOF>range 611 is a TOF range-finder module based on the epc611 chip. It allows distance measurement in a very cost effective design from a few centimeters up to several meters.

The firmware is built to operate in a high dynamic range of up to 90dB. However, the lens is designed with aspheric lenses in order to reduce the required dynamic range as much as possible. A high dynamic range can be used even with a high measurement rate.

The TOF>range 611 comes fully calibrated, so the user can simply readout the clean distance data. The device is designed in a lightweight but very stable plastic frame which allows it to be mounted to a fast rotating turnable. Mounting posts on top and on bottom allow various mounting locations and concepts.

Features

- Up to 15 m distance measurement range on white target
- Measurement rates of more than 500 measurements per second possible
- Customer specific versions and functionality available upon request
- Very light weight
- Low power consumption
- Very robust and stable
- Ambient-light compensated up to 100 kLux
- Temperature compensated
- High speed serial interface
- Small detection spot 3 x 3 mm @ 1m

Applications

- Distance measurement from centimeters to meters
- Rotating scanners for scenery mapping (SLAM)
- Level measurement
- Object classification

Figure 1: Product photo, front view

Block Diagram

Figure 2: Block diagram
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1. Technical data

\( T_a = 25^\circ C, \ VDD = 5V, \) object reflectivity 90%, unless otherwise stated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ</th>
<th>Max.</th>
<th>Units</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>Main supply voltage</td>
<td>Ripple ( ^1 ) &lt; 50 mV(_{pp})</td>
<td>4.75</td>
<td>5.0</td>
<td>5.25</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>VDDLED</td>
<td>LED supply voltage</td>
<td>Ripple ( ^1 ) &lt; 200 mV(_{pp})</td>
<td>4.75</td>
<td>5.0</td>
<td>5.25</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>IDD</td>
<td>Main supply current</td>
<td>Acquisition</td>
<td>17</td>
<td>mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power down</td>
<td>86</td>
<td>mA</td>
<td></td>
<td></td>
<td>@ VDD 5V</td>
</tr>
<tr>
<td>IDDLED</td>
<td>LED supply current</td>
<td>Acquisition</td>
<td>130</td>
<td>mA</td>
<td>Peak</td>
<td>@ VDDLED 5V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power down</td>
<td>9</td>
<td>mA</td>
<td></td>
<td></td>
<td>@ VDDLED 5V</td>
</tr>
<tr>
<td>D</td>
<td>Operating range</td>
<td>10 MHz mod. freq.</td>
<td>0.05</td>
<td>15.0</td>
<td>m</td>
<td></td>
<td>Measured with an object of at least the size of the spot ( d_{\text{SPOT}} ) depends on integration time ( t_{\text{INT}} ) and object reflectivity.</td>
</tr>
<tr>
<td>FOVh/v</td>
<td>Horizontal field of view</td>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
<td>°</td>
<td></td>
</tr>
<tr>
<td>( d_{\text{SPOT}} )</td>
<td>Sensor spot size</td>
<td>( d = 1.0m ) distance</td>
<td>3 x 3</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( d = 2.0m ) distance</td>
<td>6 x 6</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( d = 3.5m ) distance</td>
<td>11 x 11</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( d = 5.0m ) distance</td>
<td>16 x 16</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( d = 7.0m ) distance</td>
<td>22 x 22</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( d = 10.0m ) distance</td>
<td>31 x 31</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acc(_{\text{TRIM}})</td>
<td>Accuracy calibrated and compensated, mean of 100 samples</td>
<td>0.2 ... 2.0 m ( \pm 4 ) cm</td>
<td>2.0 ... 7.5 / 15.0 m ( \pm 2 ) %</td>
<td>cm</td>
<td>%</td>
<td>Independent of the object reflectivity. Amplitude between 13k – 37 kLSB, 10 or 20MHz modulation frequency</td>
<td></td>
</tr>
<tr>
<td>( D_{\text{NOISE}} )</td>
<td>Distance noise to value</td>
<td>10 MHz</td>
<td>0.40</td>
<td>cm</td>
<td></td>
<td></td>
<td>Amplitude between 13k – 37 kLSB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 MHz</td>
<td>0.25</td>
<td>cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{\text{INT}} )</td>
<td>Integration time selectable</td>
<td></td>
<td>1</td>
<td>1’600</td>
<td>µs</td>
<td>Default 125µs</td>
<td></td>
</tr>
<tr>
<td>( t_{\text{CYCLE}} )</td>
<td>Measurement cycle time</td>
<td></td>
<td>1.9</td>
<td>ms</td>
<td></td>
<td>@ ( t_{\text{INT}} = 125)µs</td>
<td></td>
</tr>
<tr>
<td>( t_{\text{WARM_UP}} )</td>
<td>Warm-up time until output data are in tolerance</td>
<td>Refer to chapter 6.6</td>
<td></td>
<td></td>
<td>mm/LSB</td>
<td>Refer to chapter 6.6</td>
<td></td>
</tr>
<tr>
<td>Res</td>
<td>Resolution</td>
<td></td>
<td>0.1</td>
<td>mm/LSB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement output for 0.0 ... 15.0m</td>
<td></td>
<td>0</td>
<td>150'000</td>
<td>LSB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{\text{AMP}} )</td>
<td>Amplitude</td>
<td></td>
<td>18'000</td>
<td>131'000</td>
<td>LSB</td>
<td>Amplitude range for accurate results</td>
<td></td>
</tr>
<tr>
<td>( T_a )</td>
<td>Ambient temperature range (operation)</td>
<td></td>
<td>-20</td>
<td>85</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( T_{\text{STO}} )</td>
<td>Storage temperature range</td>
<td></td>
<td>-20</td>
<td>85</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Phi_L )</td>
<td>Ambient-light</td>
<td></td>
<td>100</td>
<td>kLux</td>
<td></td>
<td>indirect, on target</td>
<td></td>
</tr>
<tr>
<td>RH</td>
<td>Relative humidity</td>
<td></td>
<td>15</td>
<td>90</td>
<td>%</td>
<td>Non condensing</td>
<td></td>
</tr>
<tr>
<td>ESD</td>
<td>Electrostatic discharge rating</td>
<td></td>
<td>2</td>
<td>kV</td>
<td></td>
<td>Human body model</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td></td>
<td>12.5</td>
<td>g</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Technical data

Note:

\(^1\) Min. and Max. voltage values include noise and ripple voltages.
2. Mechanical dimensions

![Mechanical dimensions diagram](image)

Notes:
- Zero value is for measured distances at the front of the housing.
- The TOF>range 611 is a very light-sensitive device but its main body is not totally hermetic for stray-light from sides or backside. Therefore for achieving best performance in ambient-light environments, it is suggested to build it into a stray-light dense application housing which is usually anyway the case.

3. Sensor interface

3.1. Connection

Connector type: JST BM10B-SRSS-TB(LF)(SN), 10 pin

![Connector diagram](image)
3.2. Pin table

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Function</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VDD</td>
<td>Main supply voltage</td>
<td>Stable and free of noise. Decouple with min. 10µF low ESR capacitor to GND</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>Ground</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>PIN3</td>
<td>reserved</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PIN4</td>
<td>Do not connect</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>PIN5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>UART_TX</td>
<td>Data output Tx</td>
<td>UART interface, LV TTL levels (3.3V)</td>
</tr>
<tr>
<td>7</td>
<td>UART_RX</td>
<td>Data input Rx</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>PIN8</td>
<td>no function</td>
<td>Do not connect</td>
</tr>
<tr>
<td>9</td>
<td>GND</td>
<td>Ground</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>VDDLED</td>
<td>LED supply voltage</td>
<td>Stable and free of noise. Decouple with min. 10µF low ESR capacitor to GND</td>
</tr>
</tbody>
</table>

Table 2: Pin list

3.3. Communication protocol

The communication interface uses 8 bit UART standard on LV TTL levels (3.3V) It operates with following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baud rate</td>
<td>921’600</td>
<td>Bit/s</td>
<td>1 bit = 1.085µs</td>
</tr>
<tr>
<td>Start bits</td>
<td>1</td>
<td>Bit</td>
<td>low active</td>
</tr>
<tr>
<td>Data</td>
<td>8</td>
<td>Bit</td>
<td></td>
</tr>
<tr>
<td>Stop bits</td>
<td>1</td>
<td>Bit</td>
<td>high active</td>
</tr>
<tr>
<td>Parity</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: UART configuration

The UART operates in a master-slave mode with the application as the master and the TOF>range 611 as the slave. A request is initiated with a command of the master by polling. The TOF>range 611 as the slave returns the answer to the request after the internal processing time $t_{\text{PROC}}$. TOF>range 611 does not accept commands during the processing $t_{\text{PROC}}$ and the communication $t_{\text{COM,TX}}$. A next command can be issued earliest after finishing Data Out.

Figure 5: UART frame format

Figure 6: Command and answer sequence
4. System Boot-up

Apply power: VDD and VDDLED. The sequence does not matter. The device notifies the power-up with a short red LED flash and is now in the power down mode. After sending the command for power-up, the green LED turns on and the device is ready.

Error cases:
■ Red LED flashing: Firmware not correctly downloaded. Download the firmware anew with the GUI of the epc611 evaluation kit or with the bootloader (refer to chapter 5.20 and 5.27).
■ Red LED stays on: Error during boot-up. Switch off/on power again.
■ If the error remains, contact your sales responsible.

5. Commands and responses

TOF>range 611 answers to each command with either the required data, acknowledge, not acknowledge or an error. LSBByte is transmitted first, MSByte last. Use only commands listed.

5.1. Command format

The command packet has a fixed length of 14 Bytes: A start byte (value 0xF5), followed by 1 byte command ID (CMD), 8 bytes of parameters corresponding to the command and 4 closing bytes with a 32bit CRC.

5.2. Response format

The answer packet has variable length: A start byte (value 0xFA), followed by 1 byte type definition, 2 byte length definition n, n bytes data and 4 closing bytes with a 32bit CRC.

5.3. CRC calculation

The Cyclic Redundancy Check (CRC) calculation includes all bytes of the packet except the CRC itself. Examples are listed in the command list.

CRC specification:
■ Bytewise CRC32
■ Init value: 0xFFFFFFFF
■ Xor value: 0x00000000
■ Polynom: 0x04C11DB7

CRC calculation function:

```c
uint32_t CrcCalc::calcCrc32(const uint8_t *data, const uint32_t size)
{
    uint32_t crc = initValue;
    for(uint32_t i = 0; i < size; i++)
    {
        crc = calcCrc32Uint8(crc, data[i]);
    }
    return crc ^ xorValue;
}

uint32_t CrcCalc::calcCrc32Uint8(uint32_t crc, uint8_t data)
{
    int32_t i;
    //This shift is done to make it compatible to the STM32 hardware CRC
    crc = crc ^ (data << 24);
    for (i = 0; i < 8; i++)
    {
        if (crc & 0x80000000)
        {
            crc = (crc << 1) ^ polynom;
        }
        else
```

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5.4. **SET POWER** [0x40]

Puts the device in power-up or power-down mode and returns after $t_{PROC}$ acknowledge. Before any acquisition commands, power must be enabled. The green LED indicates power on.

**Parameter**
- byte 0: 0x00 disables power, 0x01 enables power
- others: 0x00

**Command e.g.** | 0xF5 | 0x40 | 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x9C 0xD7 0xD6 0x91 | (power enable)

**Response type** 0x00: Acknowledge

**Response data** 0 bytes

**Response time**
- power up $t_{PROC}$: < 200 ms
- power down $t_{PROC}$: < 30 µs

**Response e.g.** | 0xFA | 0x00 | 0x00 0x00 | (0 bytes) | 0xB2 0xAB 0xFC 0xE8 |

5.5. **SET MODULATION FREQUENCY** [0x05]

Sets the modulation frequency and returns after $t_{PROC}$ acknowledge. The modulation frequency is stored and used as long power is on or until a new value is set. Default at startup is 10MHz.

**Parameter**
- byte 0: 0x00 = 10 MHz; 0x01 = 20 MHz
- others: 0x00

**Command e.g.** | 0xF5 | 0x05 | 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xCF 0x9D 0x83 0xC7 | (20 MHz)

**Response type** 0x00: Acknowledge

**Response data** 0 bytes

**Response time** $t_{PROC}$: ~ 45 µs

**Response e.g.** | 0xFA | 0x00 | 0x00 0x00 | (0 bytes) | 0xB2 0xAB 0xFC 0xE8 |

5.6. **SET INTEGRATION TIME DIS** [0x00]

Sets the integration time for distance measurements and returns after $t_{PROC}$ acknowledge. The integration time is stored and used as long power is on or until a new time is set. Range: 1 … 1'600 µs. After power-up, default is 125 µs.

**Parameter**
- byte 1, 2: Integration time in microseconds, 16 bit unsigned integer
- others: 0x00

**Automatic Mode**
Integration time = 0: The device selects the integration time automatically. Refer to chapter 6.1.

**Command e.g.** | 0xF5 | 0x00 0x1E 0x00 0x00 0x00 0x00 0x00 0x00 | 0xD9 0x85 0x1A 0x99 | (30 µs integration time)

**Response type** 0x00: Acknowledge

**Response data** 0 bytes

**Response time** $t_{PROC}$: ~ 45 µs

**Response e.g.** | 0xFA | 0x00 | 0x00 0x00 | (0 bytes) | 0xB2 0xAB 0xFC 0xE8 |

5.7. **GET INTEGRATION TIME DIS** [0x27]

Returns after $t_{PROC}$ the selected or used integration time for distance measurements.

**Parameter**
- no, all bytes 0x00

**Command e.g.** | 0xF5 | 0x27 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x98 0x53 0xE9 0x9B |

**Response type** 0x09: Data

**Response data** 2 bytes: Integration time in microseconds, 16 bit unsigned integer

**Response time** ~ 40 µs

**Response e.g.** | 0xFA | 0x09 | 0x02 0x00 | 0x5E 0x01 | 0x83 0xF9 0x91 0xF0 | (350 µs)

5.8. **GET DISTANCE** [0x20]

Starts a new distance acquisition and returns after $t_{PROC}$ the result or status.

**Parameter**
- no, all bytes 0x00

**Command e.g.** | 0xF5 | 0x20 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x98 0x53 0xE9 0x9B |

**Response type** 0x03: Data
Response data  
4 bytes: Distance, 0.1mm/LSB or status, 32 bit unsigned integer. Zero according the note of Figure 3.
Readout order: Starts at row 0, pixel 0 … pixel 7 and ends with row 7, pixel 7.
Ranges: 10 MHz modulation frequency, 0 … 15m: 0 … 150'000d
20 MHz modulation frequency, 0 … 7.5m: 0 … 75'000d
Status:
16'001'000d: Low TOF amplitude
16'002'000d: ADC overflow
16'003'000d: Saturation
16'004'000d: Reserved
16'005'000d: ADC underflow
16'006'000d: High TOF amplitude
Response time  Refer to chapter 6.2, Timing.
Response e.g.  | 0xFA | 0x03 | 0x04 0x00 | 0xE8 0x04 0x00 0x00 | 0x14 0x97 0x4E 0xE1 | (e.g distance 125.6 mm)

Figure 9: Timing of the distance measurements

5.9. GET_DISTANCE_AMPLITUDE  [0x22]
Starts a new distance and TOF amplitude acquisition and returns after tPROC the result or status. The amplitude is a quality indicator for the distance result.
Parameter  no, all bytes 0x00
Command e.g.  | 0xF5 | 0x22 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xE3 0x1A 0x29 0x7B |
Response type  0x06: Data
Response data  4 bytes distance followed 4 bytes amplitude
Distance  byte 0..3: Distance, 0.1mm/LSB or status, 32 bit unsigned integer. Zero according the note of Figure 3.
Ranges: 10 MHz modulation frequency, 0 … 15m: 0 … 150'000d
20 MHz modulation frequency, 0 … 7.5m: 0 … 75'000d
Amplitude  byte 0..3: TOF amplitude or status, 32 bit unsigned integer.
Status: Values < 13’000 LSB, distance noise is significant; > 100’000 LSB, the distance can contain considerable error.
16’001’000d: Low TOF amplitude
16’002’000d: ADC overflow
16’003’000d: Saturation
16’004’000d: Reserved
16’005’000d: ADC underflow
16’006’000d: High TOF amplitude
Response time  Refer to chapter 6.2, Timing. Refer to Figure 9 for the timing diagram.
Response e.g.  | 0xFA | 0x05 | 0x08 0x00 | 0xD3 0x04 0x00 0x00 0x89 0x81 0x00 0x00 | 0x88 0x36 0x4A 0x63 | (distance 123.5mm and amplitude 33’161 LSB)
5.10. **GET_DCS [0x25]**

Starts a new acquisition and returns after \( t_{\text{proc}} \) DCS values only.

**Parameter**
- no, all bytes 0x00

**Command e.g.**
\[ \text{| 0xF5 | 0x25 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xBF 0x76 0xA8 0xAC |} \]

**Response type**
- 0x07: Data

**Response data**
- 4 bytes DCS0 followed by 4 bytes DCS1, 4 bytes DCS2 and 4 bytes DCS3
  - byte 0..3: DCSx, 32 bit 2's complement signed integer. Range: -131'072 … +131'071 LSB
    - 0x 00 00 1F FF: Saturation
    - 0x 00 00 1F FE: ADC overflow
    - 0x FF FE 00 00: ADC underflow

**Response time**
- Refer to chapter 6.2, Timing. Refer to Figure 9 for the timing diagram.

**Response e.g.**
\[ \text{| 0xFA | 0x07 | 0x10 0x00 | 0xDC 0x65 0x00 0x00 0x57 0x54 0x00 0x00 0x0D 0x9E 0xFF 0xFF 0x57 0xAE 0x5F |} \]

5.11. **GET_DCS_DISTANCE_AMPLITUDE [0x23]**

Starts a new acquisition and returns after \( t_{\text{proc}} \) DCS, distance and amplitude values as a set.

**Parameter**
- no, all bytes 0x00

**Command e.g.**
\[ \text{| 0xF5 | 0x23 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x85 0xB0 0x29 0x89 |} \]

**Response type**
- 0x08: Data

**Response data**
- 4 bytes DCS0 followed by 4 bytes DCS1, 4 bytes DCS2, 4 bytes DCS3, 4 bytes distance and 4 bytes amplitude
  - DCSx byte 0..3: DCSx, 32 bit 2's complement signed integer. Range: -131'072 … +131'071 LSB
    - 0x 00 00 1F FF: Saturation
    - 0x 00 00 1F FE: ADC overflow
    - 0x FF FE 00 00: ADC underflow
  - Distance byte 0..3: Distance, 0.1mm/LSB or status, 32 bit unsigned integer. Zero according the note of Figure 3.
    - Ranges: 10 MHz modulation frequency, 0 … 15m: 0 … 150'000d
    - 20 MHz modulation frequency, 0 … 7.5m: 0 … 75'000d
  - Amplitude byte 0..3: TOF amplitude or status, 32 bit unsigned integer.
    - Status: Values < 13'000 LSB, distance noise is significant; > 100'000 LSB, the distance can contain considerable error.
      - 16'001'000d: Low TOF amplitude
      - 16'002'000d: ADC overflow
      - 16'003'000d: Saturation
      - 16'004'000d: Reserved
      - 16'005'000d: ADC underflow
      - 16'006'000d: High TOF amplitude

**Response time**
- Refer to chapter 6.2, Timing. Refer to Figure 9 for the timing diagram.

**Response e.g.**
\[ \text{| 0xFA | 0x08 | 0x18 0x00 | 0x6F 0x65 0x00 0x00 0x83 0x54 0x00 0x00 0x2D 0x9F 0xFF 0xFF 0x28 0xAE 0xFF 0xFF |} \]

5.12. **GET_TEMPERATURE [0x4A]**

Returns after \( t_{\text{proc}} \) the chip temperature during last distance acquisition. Temperature information is useful for error compensation of the measured distance.

**Parameter**
- no, all bytes 0x00

**Command e.g.**
\[ \text{| 0xF5 | 0x4A | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x18 0x41 0xF5 0xA4 |} \]

**Response type**
- 0xFC: Data

**Response data**
- 2 bytes: Temperature, 0.01 ºC / LSB, 16 bit 2's complement signed integer.

**Response time**
- \( t_{\text{proc}} \): ~ 40 µs

**Response e.g.**
\[ \text{| 0xFA | 0xFC | 0x02 0x00 | 0x47 0x13 | 0x4F 0x0E 0x12 0x1F |} \]

5.13. **DRNU_COMPENSATION [0x41]**

Enables or disables the Distance Response Non-Uniformity (DRNU) compensation and returns after \( t_{\text{proc}} \) acknowledge.

**Parameter**
- byte 0: 0x00 = Compensation enabled; 0x01 = Compensation disabled
- others: 0x00

**Command e.g.**
\[ \text{| 0xF5 | 0x41 | 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xFA 0x7D 0xD6 0x63 |} \] (disable compensation)
5.14. **GET_FIRMWARE_VERSION [0x49]**

Returns after \( t_{\text{PROC}} \) the firmware version of the TOF>range 611: Version.Subversion (V.s)

Parameter no, all bytes 0x00

Command e.g. | 0xF5 | 0x49 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x05 0xA2 0x35 0xB6 |

Response type 0xFE: Data

Response data 4 bytes

- byte 0, 1: Subversion \( s \), 16 bit unsigned integer
- byte 2, 3: Version \( V \), 16 bit unsigned integer

Response time \( t_{\text{PROC}} \): \(~ 40 \, \mu s\)

Response e.g. | 0xFA | 0xFE | 0x04 0x00 | 0x0E 0x00 0x01 0x00 | 0xA2 0x35 0xB6 0x16 0x33 | (Version 1.14)

5.15. **GET_CHIP_INFORMATION [0x48]**

Returns after \( t_{\text{PROC}} \) the ep611 Chip ID and Wafer ID.

Parameter no, all bytes 0x00

Command e.g. | 0xF5 | 0x48 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x63 0x08 0x35 0x44 |

Response type 0xFD: Data

Response data 4 bytes

- byte 0, 1: Chip ID, 16 bit unsigned integer
- byte 2, 3: Wafer ID, 16 bit unsigned integer

Response time \( t_{\text{PROC}} \): \(~ 40 \, \mu s\)

Response e.g. | 0xFA | 0xFD | 0x04 0x00 | 0x01 0x04 0x10 0x00 | 0x4F 0x56 0xF8 0x21 | (Chip ID 1040, Wafer ID 16)

5.16. **GET_PROD_DATE [0x50]**

Returns after \( t_{\text{PROC}} \) the production date of the TOF>range 611.

Parameter no, all bytes 0x00

Command e.g. | 0xF5 | 0x50 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x8B 0x10 0x32 0xD2 |

Response type 0xF9

Response data 2 bytes

- byte 0: Last two digits of the year as unsigned integer e.g. 18
- byte 1: Number of the week as integer e.g. 22

Response time \(~ 40 \, \mu s\)

Response e.g. | 0xFA | 0xF9 | 0x02 0x00 | 0x12 0x16 | 0x00 0x76 0x04 0xA7 | (year 18, week 22)

5.17. **DATA_NACK**

System response only: Command not accepted or unknown.

Response type 0x01: Not acknowledged

Response data 0 bytes

Response e.g. | 0xFA | 0x01 | 0x00 0x00 | (0 bytes) | 0x35 0x07 0x24 0xE9 |

5.18. **DATA_ERROR**

System response only: Error occurred during the execution of the command. Response instead of the required data

Response type 0xFF: Error

Response data 2 bytes:

- bit 0..14: Error number. Try it again. If the error remains, contact your sales responsible.
- bit 15: 0

Response e.g. | 0xFA | 0xFF | 0x02 0x00 | 0x03 0x00 | 0x94 0xFB 0x35 0x81 | (error No. 3)
5.19. **IDENTIFY [0x47]**

Returns after \( t_{\text{PROC}} \) the device identification ID and the mode (normal operation or bootloader e.g. a firmware update was not successful). Is TOF>range 611 in bootloader mode, run a firmware update with the epcc611 evaluation kit GUI or with the bootloader (see next). The GUI detects missing firmware and runs update automatically. This command may be used for communication check.

**Parameter**
- no, all bytes 0x00

**Command e.g.**
- | 0xF5 | 0x47 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x0A 0x67 0xF6 0x1D |

**Response type**
- 0x02: Data

**Response data**
- 4 bytes:
  - byte 0: Hardware version
  - byte 1: Device type, TOF>range 611 = 0x00
  - byte 2: Chip type, epcc611 = 0x06
  - byte 3: 0x00 = normal operation, 0x80 = bootloader

**Response time**
- \( \sim 40 \mu s \)

**Response e.g.**
- | 0xFA | 0x02 | 0x04 0x00 0x00 0x00 0x00 0x00 | 0x0A 0x67 0xF6 0x1D | (HW version 0, TOF>range 611, epcc611, normal operation)
- | 0xFA | 0x02 | 0x04 0x00 0x00 0x00 0x00 0x06 0x80 | 0xE2 0x61 0x57 0x41 | (HW version 0, TOF>range 611, epcc611, bootloader)

5.20. **JUMP TO BOOTLOADER [0x44]**

Stops all normal operation activities and changes to bootloader. Now, the bootloader is answering to this and all following commands. Refer also to chapter 5.27.

**Parameter**
- no, all bytes 0x00

**Command e.g.**
- | 0xF5 | 0x44 | 0x00 0x00 0x00 0x00 0x00 0x00 | 0x17 0x84 0x36 0x0F |

**Response type**
- 0x00: Acknowledge

**Response data**
- 0 bytes

**Response time**
- \( t_{\text{PROC}} = < 5 \text{ms} \)

**Response e.g.**
- | 0xFA | 0x00 | 0x00 0x00 | (0 bytes) | 0xB2 0xAB 0xFC 0xE8 |

5.21. **UPDATE_FIRMWARE [0x45]**

Bootloader command only: Copies the firmware into the flash memory of the sensor. It returns acknowledge after \( t_{\text{PROC}} \).

**Procedure:**
1st, write control byte "start" with password and file size; 2nd, write control byte "write" with index and data; 3rd, write control byte "complete".

**Parameter**
- 8 bytes: Contents differs and depends on operation step: Refer to Table 4.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Byte 7</th>
<th>Byte 6</th>
<th>Byte 5</th>
<th>Byte 4</th>
<th>Byte 3</th>
<th>Byte 2</th>
<th>Byte 1</th>
<th>Byte 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Start</td>
<td>Size of the update file</td>
<td>Password = 0x654321</td>
<td>0x00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>Write data</td>
<td>Firmware data (4 bytes)</td>
<td>FirmwareData[index] (3 bytes)</td>
<td>0x01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td>Complete</td>
<td>All 7 bytes = 0x00</td>
<td>0x02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Command e.g.**
- | 0xF5 | 0x45 | 0x00 0x21 0x43 0x65 0x10 0x00 0x00 0x00 | 0x29 0x7B 0xFA 0x1C | (start for 16 byte file size)
- | 0xF5 | 0x45 | 0x01 0x00 0x00 0x00 0x10 0x4A 0x56 0x50 | 0x10 0x20 0x8A 0xE6 | (write data to index 0)
- | 0xF5 | 0x45 | 0x02 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xE5 0x97 0x75 0x4A | (complete)

**Response type**
- 0x00: Acknowledge

**Response data**
- 0 bytes

**Response time**
- \( t_{\text{PROC}} = < 400 \text{ms} \)

**Response e.g.**
- | 0xFA | 0x00 | 0x00 0x00 | (0 bytes) | 0xB2 0xAB 0xFC 0xE8 |
5.22. **WRITE_CALIBRATION_DATA [0x4B]**

Writes the calibration data into the flash memory and returns after \( t_{\text{PROC}} \) acknowledge. This data are used during DRNU compensation. **Warning:** Deletes previous stored calibration.

**Procedure:**
1. write control byte "start" with password and file size;
2. write control byte "write" with index and data;
3. write control byte "complete".

**Parameter**
- 8 bytes: Contents differs and depends on operation step: Refer to Table 5.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Byte 7</th>
<th>Byte 6</th>
<th>Byte 5</th>
<th>Byte 4</th>
<th>Byte 3</th>
<th>Byte 2</th>
<th>Byte 1</th>
<th>Byte 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Start</td>
<td>Size of the update file</td>
<td>Password = 0x654321</td>
<td>0x00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>Write data</td>
<td>Calibration data (4 bytes)</td>
<td>CalibrationData[index] (3 bytes)</td>
<td>0x01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td>Complete</td>
<td>All 7 bytes = 0x00</td>
<td>0x02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Calibration data download format

**Command e.g.**
- |0xF5| 0x45 | 0x00 0x21 0x43 0x65 0x10 0x00 0x00 0x00 | 0x29 0x7B 0xFA 0x1C | (start for 16 byte file size)
- |0xF5| 0x45 | 0x01 0x00 0x00 0x00 0x10 0x4A 0x56 0x50 | 0x10 0x20 0x8A 0xE6 | (write data to index 0)
- |0xF5| 0x45 | 0x02 0x00 0x00 0x00 0x00 0x00 0x00 | 0xE5 0x97 0x75 0x4A | (complete)

**Response type** 0x00: Acknowledge
**Response data** 0 bytes
**Response time** \( t_{\text{PROC}} \): < 400ms
**Response e.g.** |0xFA| 0x00 | 0x00 0x00 |

5.23. **SET_DLL_STEP [0x06]**

Sets the number of DLL steps for artificial phase/distance shifting and returns after \( t_{\text{PROC}} \) acknowledge. 1 step is around 2.15ns / 315mm.

**Parameter**
- byte 0: Number of DLL steps
- others: 0x00

**Command e.g.**
- |0xF5| 0x06 | 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xD2 0x7E 0x43 0xD5 | (Number of steps = 1)

**Response type** 0x00: Acknowledge
**Response data** 0 bytes
**Response time** \( t_{\text{PROC}} \): ~ 40 \( \mu \)s
**Response e.g.** |0xFA| 0x00 | 0x00 0x00 |

5.24. **WRITE_REGISTER [0x4C]**

Writes the value into a register of the sensor and returns after \( t_{\text{PROC}} \) 16bit SPI response from epc611 chip.

**Parameter**
- 3 bytes:
  - byte 0: Register address inside the page (0x00 ... 0x20)
  - byte 1: Page address
  - byte 2: Register value
  - others: 0x00

**Command e.g.**
- |0xF5| 0x4C | 0x01 0x00 0x56 0x00 0x00 0x00 0x00 0x00 0x00 | 0x7D 0xAD 0xE1 0xE6 | (Write into page 0, register 1 = 0x56)

**Response type** 0xFB: Data
**Response data** 2 bytes: 16bit SPI response from epc611 chip
**Response time** \( t_{\text{PROC}} \): ~ 40 \( \mu \)s
**Response e.g.** |0xFA| 0xFB | 0x02 0x00 | (2 bytes) | CRC (4 bytes) |

5.25. **READ_REGISTER [0x4D]**

Reads the value of the sensor register and returns after \( t_{\text{PROC}} \) 16bit SPI response from epc611 chip.

**Parameter**
- 2 bytes:
  - byte 0: Register address inside the page (0x00 ... 0x20)
  - byte 1: Page address
  - others: 0x00

**Command e.g.**
- |0xF5| 0x4D | 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x8E 0xF1 0xD5 0x28 | (read page, 0, register 1)

**Response type** 0xFB: Data
**Response data** 2 bytes: 16bit SPI response from epc611 chip
**Response time** \( t_{\text{PROC}} \): ~ 40 \( \mu \)s
**Response e.g.** |0xFA| 0xFB | 0x02 0x00 | (2 bytes) | CRC (4 bytes) |
5.26. **READ_NOP [0x4E]**

Returns after t\(_{PROC}\) the value of the last SPI command to the epc611.

**Parameter**
- no, all bytes 0x00

**Command e.g.**
- | 0xF5 | 0x4E | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0x59 0xCE 0xB4 0x61 |

**Response type** 0xFB : last 16 bit SPI command to the epc611

**Response data** 2 byte

**Response time** t\(_{PROC}\) : ~ 40 µs

**Response e.g.**
- | 0xFA | 0xFB | 0x02 0x00 | (2 bytes) | CRC (4 bytes) |
5.27. Firmware update

A firmware update of the TOF>range 611 in the field is possible. In such a case, ESPROS provides a valid update file on their website in the ESPROS epc611 Evaluation Kit Software package. The upgrade will neither touch nor overwrite the calibration with the bootloader. The bootloader is bounded on 12 kByte Flash Memory for the update file. Calibration data has additionally own 2 kByte.

A certain sequence of commands needs to be executed for uploading the file to the device:

Update file, used in the table below (no valid file, example only)
0x10 0x4A 0x56 0x50 0xFF 0x67 0xA0 0xC0
0x23 0x45 0xAA 0x00 0x34 0x78 0x99 0xBB

<table>
<thead>
<tr>
<th>Host action</th>
<th>Device reaction</th>
<th>Device answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Send command &quot;JUMP_TO_BOOTLOADER&quot;:</td>
<td>Jump to bootloader</td>
<td>ACK *</td>
</tr>
<tr>
<td>0xF5</td>
<td>0x44</td>
<td>0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00</td>
</tr>
<tr>
<td>Send command &quot;UPDATE_FIRMWARE&quot; with control byte &quot;0&quot;, the password and the size of the update file:</td>
<td>Verify password and store file size</td>
<td>ACK *</td>
</tr>
<tr>
<td>0xF5</td>
<td>0x45</td>
<td>0x00 0x65 0x43 0x21 0x10 0x00 0x00 0x00</td>
</tr>
<tr>
<td>Send the command &quot;UPDATE_FIRMWARE&quot; with control byte &quot;1&quot;, the index and 4 bytes of the update file. Repeat this step as often as needed, update file size / 4, e.g. with given update file above:</td>
<td>Store data</td>
<td>ACK *</td>
</tr>
<tr>
<td>0xF5</td>
<td>0x45</td>
<td>0x01 0x00 0x00 0x00 0x10 0x4A 0x56 0x50</td>
</tr>
<tr>
<td>0xF5</td>
<td>0x45</td>
<td>0x01 0x04 0x00 0x00 0x0F 0x67 0xA0 0x00</td>
</tr>
<tr>
<td>0xF5</td>
<td>0x45</td>
<td>0x01 0x08 0x00 0x00 0x23 0x45 0x56 0x50</td>
</tr>
<tr>
<td>0xF5</td>
<td>0x45</td>
<td>0x01 0x0C 0x00 0x00 0x34 0x78 0x99 0x2B</td>
</tr>
<tr>
<td>Send command &quot;UPDATE_FIRMWARE&quot; with control byte &quot;2&quot;:</td>
<td>Verify data and return to normal operation</td>
<td>ACK *</td>
</tr>
<tr>
<td>0xF5</td>
<td>0x45</td>
<td>0x02 0x00 0x00 0x00 0x00 0x00 0x00 0x00</td>
</tr>
<tr>
<td>Wait to exceed boot time. The device is now ready to operate. Communication may be tested with the command &quot;IDENTIFY&quot;</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 6: Update procedure

Notes:
- * ACK: ACKNOWLEDGE: Response e.g.: | 0xFA | 0x00 | 0x00 0x00 0x00 0x00 0x00 0x00 0x00 | 0xB2 0xAB 0xFC 0xE8 |
- If an error occurs (e.g. corrupted data, invalid command), the device answers with "NOT ACKNOWLEDGE".
- Is the update procedure interrupted, no valid application is in the flash. The device stays in bootloader mode.
- In such cases, the update procedure must be restarted. It can be repeated at any time.

6. Application information

6.1. Automatic Mode

It will be enabled by setting the integration time = 0. If chosen, the TOF>range 611 selects automatically an adequate integration time for getting most reliable results. It uses the following simple algorithm which will be done after every distance acquisition:

\[
\text{result} = 35'000 - \text{TOF_Amplitude}
\]

\[
\text{if (result > 2'000)}\{
\quad \text{newIntegrationTime} = (\text{integrationTime} * 12) / 10
\}
\]

\[
\text{else if(result < -2'000)}\{
\quad \text{newIntegrationTime} = (\text{integrationTime} * 8) / 10
\}
\]

GET_INTEGRATION_TIME_DIS [0x27] reads back the integration time selected by TOF>range 611. In automatic mode, it will read back the integration time of the next distance acquisition.

6.2. Timing

The timings for distance, amplitude and DCS acquisition are

\[
\text{t}_{\text{IR}} < 650 \, \mu s \quad \Rightarrow \text{t}_{\text{IR}} = 4 \times \text{t}_{\text{IR}} + 860 \, \mu s \quad (\text{acquisition + grayscale time}) + 150 \, \mu s \quad (\text{calculation time}) + 210 \, \mu s \quad (\text{t}_{\text{COM}}) + 180 \, \mu s \quad (\text{t}_{\text{COM,tx}})
\]

\[
\text{t}_{\text{IR}} > 650 \, \mu s \quad \Rightarrow \text{t}_{\text{IR}} = \text{t}_{\text{IR}} \times 10 \quad (\text{to not exceed their maximum power limit of illumination})
\]

<table>
<thead>
<tr>
<th>Command</th>
<th>\text{t}_{\text{IR}}</th>
<th>\text{t}_{\text{IR}}</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>GET_DISTANCE</td>
<td>1.51</td>
<td>1.90</td>
<td>ms</td>
</tr>
<tr>
<td>GET_DISTANCE_AMPLITUDE</td>
<td>1.51</td>
<td>1.96</td>
<td>ms</td>
</tr>
</tbody>
</table>

Table 7: Examples for \text{t}_{\text{IR}} @ \text{t}_{\text{IR}} = 125\mu s
6.3. Operating range (unambiguity distance)
The TOF>range 611 uses the continuous wave TOF phase-shift measurement technique with a modulation frequency of 10 / 20 MHz. This leads to an unambiguity distance of 15 / 7.5 m. Highly reflective objects at a distance greater than 15 / 7.5 m will appear closer due to wrap-around of the modulation period.
Example @ 20MHz: With a highly reflective object at a distance of 8.5m, the output of the TOF>range 611 displays 1m (8.5m – 7.5m). This is obviously wrong.

6.4. Object reflectivity
The reflectivity of the object can have an impact on the distance accuracy. Such a distance error can be corrected by an additional compensation based on measuring the amplitude.

6.5. Measurement example
The following figure shows a typical example result of a distance measurement from a TOF>range 611 pointing to a white object.

6.6. Warm-up distance drift

Figure 10: Typical measurement error versus distance

Figure 11: Typical warm-up phase of TOF>range 611
7. Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Part Name</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>P100 483</td>
<td>TOF-range 611</td>
<td></td>
</tr>
<tr>
<td>P100 498</td>
<td>USB-UART Adapter</td>
<td>Refer to epc611 Evaluation Kit</td>
</tr>
<tr>
<td>P100 516</td>
<td>Cable 10 Pin F JST 1.0 mm (L=76 mm)</td>
<td>Refer to epc611 Evaluation Kit.</td>
</tr>
<tr>
<td>P100 487</td>
<td>epc611 Evaluation Kit</td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Ordering Information

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