



[Embedded Pico Systems]

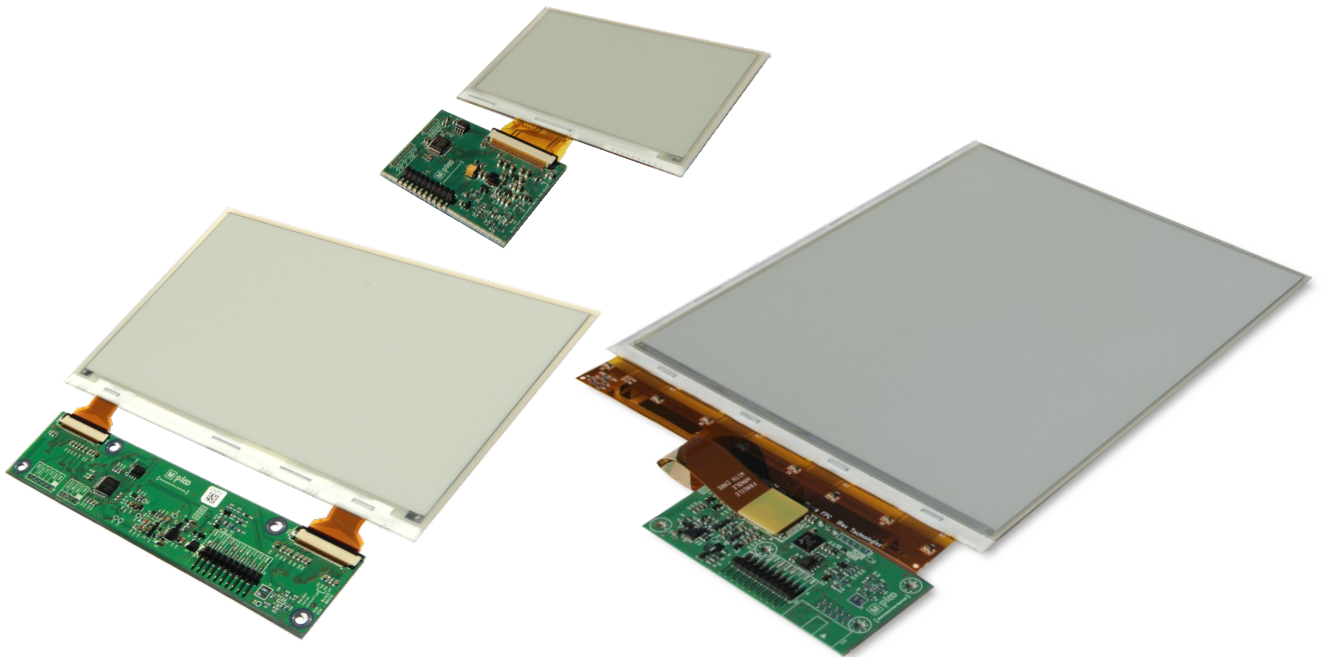
Developer's Guide

**Timing Controller Solutions for Pervasive
Displays 4.41", 7.4" and 10.2" Panels**

TCM-P441-230_v1.0, TC-P441-230_v1.0

TCM-P74-230_v1.0, TC-P74-230_v1.0

TCM-P102-220_v1.1



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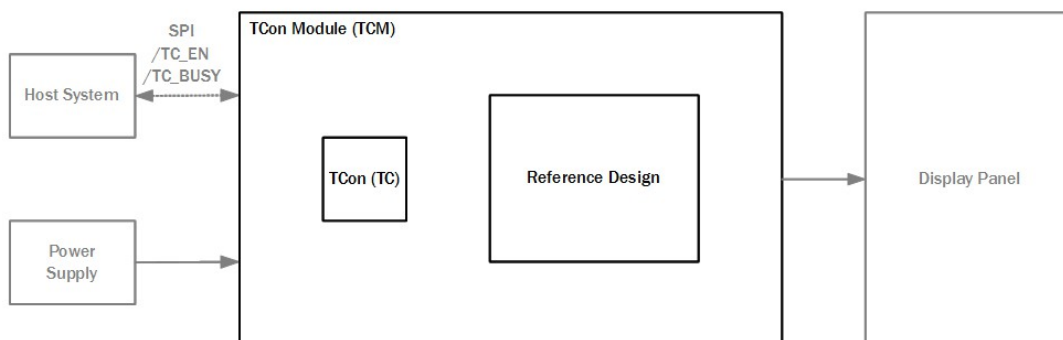
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1 Introduction

E-paper Timing Controller Solutions provide timing controller (TCon) functionalities for **Pervasive Displays'** large size panels (**4.41"**, **7.4"**, and **10.2"**⁴). Solution for each of the panels provides identical functionality, command set and physical interface. Offered as a chip only (**Timing Controller – TC**) or as fully-assembled PCB module (**Timing Controller Module – TCM**), the solution allows a quick and easy integration with your host system, minimizing the cost and time-to-market.



TCon (as well as TCM) can be connected to a host microsystem via fast and reliable Serial Peripheral Interface (SPI). TCon is controlling both the source and gate drivers, composing waveforms required to generate high quality images on the display.

1.1 Supported Display Panels

| TCon Module Part # | TCon Part # | Display Type | Display Part # | Display Resolution | Display Density |
|--------------------|------------------|------------------|--------------------------|--------------------|-----------------|
| TCM-P441-230_v1.0 | TC-P441-230_v1.0 | 4.41" (v230 FPL) | RET044BS011 ² | 400×300 px | 113 dpi |
| TCM-P74-230_v1.0 | TC-P74-230_v1.0 | 7.4" (v230 FPL) | MEW074BT011 ² | 480×800 px | 126 dpi |
| TCM-P102-220_v1.1 | - | 10.2" (v220 FPL) | MEZ102AT011 | 1024×1280 px | 160 dpi |

1.2 Features

- SPI interface to host
- SPI (slave device) with additional /TC_EN and /TC_BUSY lines
- 1-bit color (black and white)
- Temperature compensation
- Internal image buffer retains content during system power down

1.3 Characteristics

- From 2.7 to 3.3 V supply voltage
- From 0 to 40³/50⁴ °C operating temperature range

- 1) TCon for 10.2" display is not yet available
- 2) This display panel MPN may not become available for mass production
- 3) v230 FPL displays characteristics
- 4) V220 FPL displays characteristics

2 Outline

2.1 TCon

The information below applies to TC-P441-230_v1.0 and TC-P74-230_v1.0 products.

LQFP48: plastic low profile quad flat package; 48 leads; body 7×7 × 1.4 mm

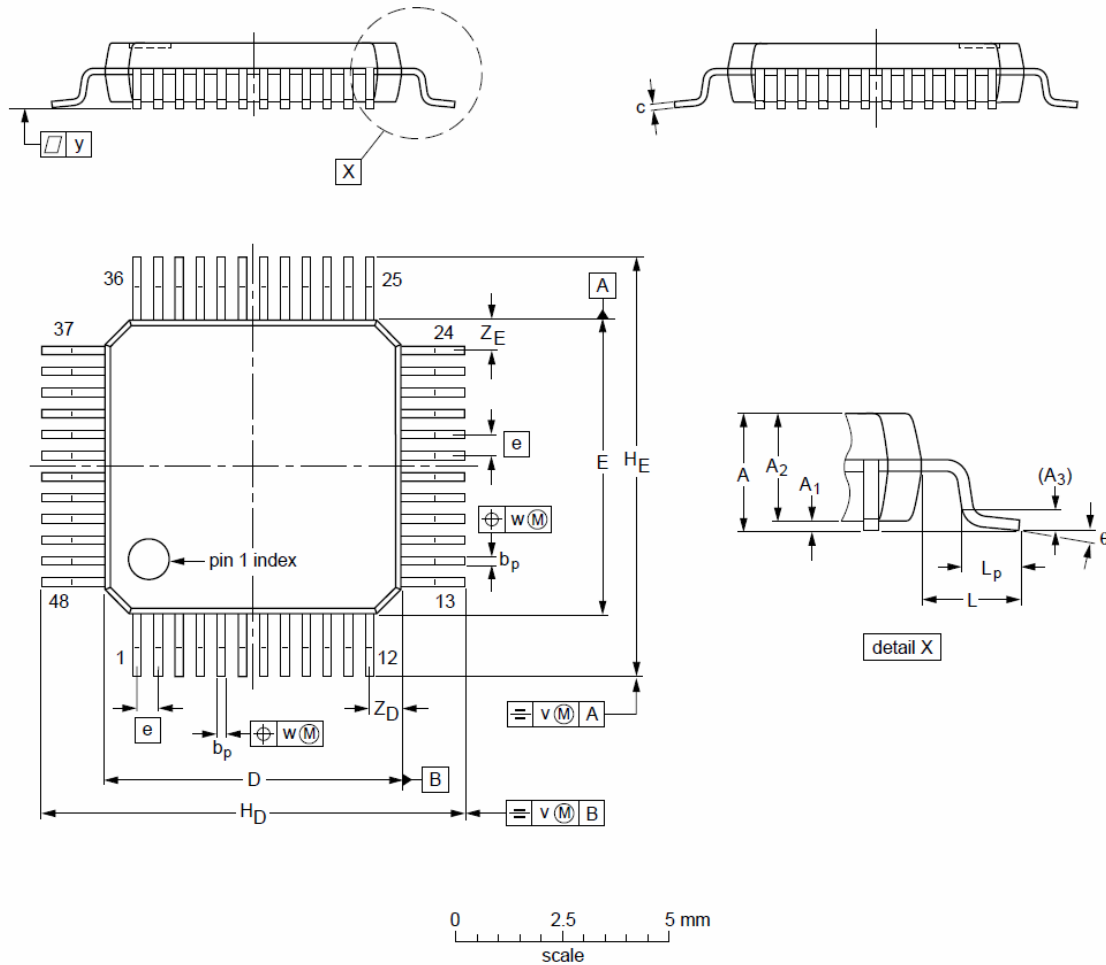


Figure 2.1: TCon dimensions

| Unit | A | A ₁ | A ₂ | A ₃ | b _p | c | D ⁽¹⁾ | E ⁽¹⁾ | e | H _D | H _E | L | L _p | v | w | y | Z _D ⁽¹⁾ | Z _E ⁽¹⁾ | θ |
|------|-----|----------------|----------------|----------------|----------------|------|------------------|------------------|-----|----------------|----------------|---|----------------|-----|------|-----|-------------------------------|-------------------------------|----|
| | max | | | | | | | | | | | | | | | | | | |
| mm | 1.6 | .20 | 1.45 | 0.25 | 0.27 | 0.18 | 7.1 | 7.1 | 0.5 | 9.15 | 9.15 | 1 | 0.75 | 0.2 | 0.12 | 0.1 | 0.95 | 0.95 | 7° |
| | | .05 | 1.35 | | 0.17 | 0.12 | 6.9 | 6.9 | | 8.85 | 8.85 | | 0.45 | | | | 0.55 | 0.55 | 0° |

Table 2.1: Dimensions (mm are the original dimensions)¹

¹ © NXP B.V. 2012. All rights reserved.

NOTE TCM features solder pads for overvoltage protection 3.6 V Zener diode (D11). The diode is by default not mounted to limit the TCM current consumption. If required, the diode can be mounted in the designated spot at the Customer's own account. The diode placement is marked **orange** on the figures 2.2, 2.3 and 2.4. MpicoSys recommends using BZX384 3V6 diode. This will increase the average current consumption by 1 mA during all operations.

3 Electrical Characteristics

Unless specified otherwise, the values in this chapter are applicable to the whole product family, and both to TC and TCM.

3.1 Absolute Maximum Ratings

| Symbol | Description | Min | Typ | Max | Unit |
|-----------------|------------------------|------|-----|-----|------|
| VDDIN | Digital supply voltage | 0 | - | 3.6 | V |
| VIN | Analog supply voltage | -0.3 | - | 6.0 | V |
| T _{st} | Storage temperature | -20 | - | +60 | °C |

Table 3.1: Absolute maximum ratings

3.2 Operating Conditions

| Symbol | Description | Min | Typ | Max | Unit |
|-----------------|------------------------------------|-----|-----|------------------------------------|------|
| VDDIN | Standard digital operating voltage | 2.7 | 3.0 | 3.3 | V |
| VIN | Standard analog operating voltage | 2.0 | 3.0 | 5.5 | V |
| T _{op} | Operating temperature | 0 | +23 | +40 ⁵ /+50 ⁶ | °C |

Table 3.2: Typical operating conditions

3.3 TCM Supply Current Characteristics

Measurement Setup

Current consumption measured with Agilent 34411A Multimeter;

VDDIN shorted with VIN; range from 2.7 V to 3.3 V.

NOTE Values vary with ambient temperature, supply voltage and the displayed pattern.

5) TCM-P441-230 and TCM-P74-230

6) TCM-P102-220

4.41" v230

| Symbol | Description | Operation | Min | Max | Unit |
|--------|--|----------------------------|------|------|------|
| IDD | Average current consumption | Display update | 21.7 | 31.0 | mA |
| | | Data reception on SPI | 21.9 | 23.0 | mA |
| | | Disabled (/TN_EN inactive) | 0.02 | 1.0 | µA |
| E | Average energy consumption in room temperature | Display update | 145 | 216 | mJ |

Table 3.3: 4.41" v230 supply current characteristics

7.4" v230

| Symbol | Description | Operation | Min | Max | Unit |
|--------|--|----------------------------|------|------|------|
| IDD | Average current consumption | Display update | 38.3 | 108 | mA |
| | | Data reception on SPI | 23.1 | 24.0 | mA |
| | | Disabled (/TN_EN inactive) | 0.02 | 1.0 | µA |
| E | Average energy consumption in room temperature | Display update | 233 | 649 | mJ |

Table 3.4: 7.4" v230 supply current characteristics

10.2" v220

| Symbol | Description | Operation | Min | Max | Unit |
|--------|--|----------------------------|------|-------|------|
| IDD | Average current consumption | Display update | 35.2 | 142 | mA |
| | | Data reception on SPI | 16.1 | 16.4 | mA |
| | | Disabled (/TN_EN inactive) | 0.02 | 1.0 | µA |
| E | Average energy consumption in room temperature | Display update | 286 | 1,030 | mJ |

Table 3.5: 10.2" v220 supply current characteristics

Measurement Results Conditions


The below table describes conditions at which the results from tables above were achieved. *ESL* images are presented below the table. *Checkerboard* image is a 1 pixel by 1 pixel black and white checkerboard fulfilling the whole display area.

| Measurement | | Value | Power Supply (VDD = VIN) [V] | Image Used for Measurement | Ambient Temp. [°C] |
|--|-----------------------|-------|------------------------------|---|--------------------|
| Average current consumption | Display update | Min | 3.3 | Transition <i>ESL</i> to <i>ESL</i> | 22 |
| | | Max | 2.7 | Transition <i>Checkerboard</i> to <i>Checkerboard</i> | 22 |
| | Data reception on SPI | Min | 2.7 | <i>ESL</i> | 22 |
| | | Max | 3.3 | <i>Checkerboard</i> | 22 |
| Average energy consumption in room temperature | Display update | Min | 2.7 | <i>ESL</i> | 22 |
| | | Max | 3.3 | <i>Checkerboard</i> | 22 |

Table 3.6: Measurement results conditions

CHIMEI LED DeskLamp

- Flicker free LED lighting for pleasant reading.
- Natural color rendition for a more realistic image reproduction.
- Long-life, energy-saving, and economical LED lighting.
- V-CLUT Anti-glare Filter for undisturbed reading
- Green lighting free of lead, mercury and UV rays with zero pollution.



123456789012

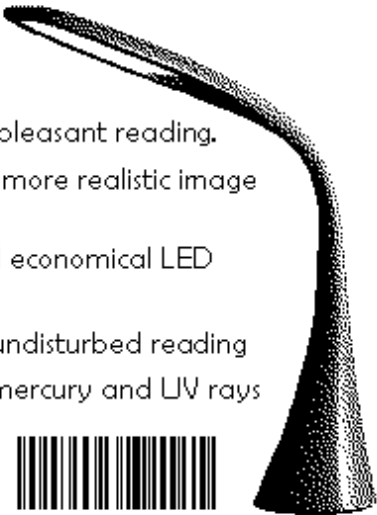


Figure 3.1: 4.41" ESL image

KIWI CONTAINER 2 KG

ORIGIN

NEW ZEALAND



4 € **90**

2.45€/KG

PROCESSING: NONE
CATEGORY: 1
PACKAGING: CONTAINER

Figure 3.2: 7.4" ESL image

KIWI CONTAINER 2 KG
ORIGIN
NEW ZEALAND



4[€] 90
2.45€/KG

PROCESSING: NONE
CATEGORY: 1
PACKAGING: CONTAINER

Figure 3.3: 10.2" ESL image

3.4 DC Characteristics

| Symbol | Description | Min | Max | Unit |
|--------|---------------------------|---------|---------|------|
| VIH | Input high level voltage | 0.7×VDD | – | V |
| VIL | Input low level voltage | – | 0.3×VDD | V |
| VOH | Output high level voltage | VDD-0.4 | – | V |
| VOL | Output low level voltage | – | 0.4 | V |

Table 3.7: Typical operating conditions

4 Display Refresh Time

| T _{amb} [°C] | 0÷5 | 5÷10 | 10÷15 | 15÷20 | 20÷25 | 25÷30 | 30÷35 | 35÷40 | 40÷45 | 45÷50 |
|-------------------------|-----|------|-------|-------|-------|-------|-------|-------|-------|-------|
| 4.41" v230 | 4.6 | 3.7 | 2.5 | 1.5 | 1.4 | 1.3 | 1.1 | 1.1 | - | - |
| 7.4" v230 | 5.3 | 4.2 | 2.8 | 1.4 | 1.5 | 1.7 | 1.7 | 1.6 | - | - |
| 10.2" v220 | 5.3 | 3.8 | 2.9 | 2.7 | 2.6 | 2.6 | 2.3 | 2.0 | 2.1 | 2.1 |

Table 4.1: Display refresh time versus ambient temperature

5 TCon Hands-on

Unless specified otherwise, all information contained in this chapter is applicable to the whole product family.

5.1 TCon Integration

TCon together with the reference schematic can be integrated with user's own host system. This enables the user to develop their own application utilizing e-paper technology.

Reference design is included in the Design Guide, distributed separately. Please contact sales@mpicosys.com for more information.⁷

5.2 TCM Interconnection

Use the below described host connector to connect TCM to your host system. It is a 10-pin single-row 2.54 mm-pitch male header.

NOTE Forward slash "/" in front of the pin name indicates the signal is active low

| Pin # | Pin Name | Remarks |
|-------|----------|----------------------------------|
| 1 | GND | Supply ground |
| 2 | /TC_EN | TC enable |
| 3 | VDDIN | Power supply for digital part |
| 4 | VIN | Power supply for analog part |
| 5 | /TC_BUSY | Host interface busy output |
| 6 | TC_MISO | Host interface data output |
| 7 | TC_MOSI | Host interface data input |
| 8 | /TC_CS | Host interface chip select input |
| 9 | TC_SCK | Host interface clock input |
| 10 | GND | Supply ground |

Table 5.1: TCM host connector

7) TCon for 10.2" display is not yet available

5.3 TCM Power On

Connect your power supply to the VDDIN and VIN pins.

VDDIN supply for digital part has to be supplied from a stable power supply, e.g. stabilized by a DC/DC converter or a low-dropout regulator (LDO).

VIN can either be supplied directly from the battery (e.g. coin-cell) for improved efficiency, or can be shorted to VDDIN.

When connected to power supply, TCM is by default turned off to conserve energy. To switch it on, activate the /TC_EN signal.

5.4 Image Slot

TCon features one slot for storing image data. The image is stored in flash memory, thus it is retained when the system is not powered.

5.5 Interface

Connection To Host

User's host system can communicate with TCon via Serial Peripheral Interface (SPI) with additional /TC_EN and /TC_BUSY line. TCon works as a SPI slave device. TCon power has to be supplied by the host system. The SPI supports 8-bit frames of data flowing from the master to the slave and from the slave to the master.

Signals

Inputs:

- /TC_EN – active low
- /TC_CS – active low
- TC_SCK
- TC_MOSI

Outputs:

- TC_MISO
- /TC_BUSY – active low

SPI Settings

- Bit rate – up to 3 MHz
- Polarity – CPOL = 1; clock transition high-to-low on the leading edge and low-to-high on the trailing edge
- Phase – CPHA = 1; setup on the leading edge and sample on the trailing edge
- Bit order – MSB first
- Chip select polarity – active low

Reference SPI timing diagram below:

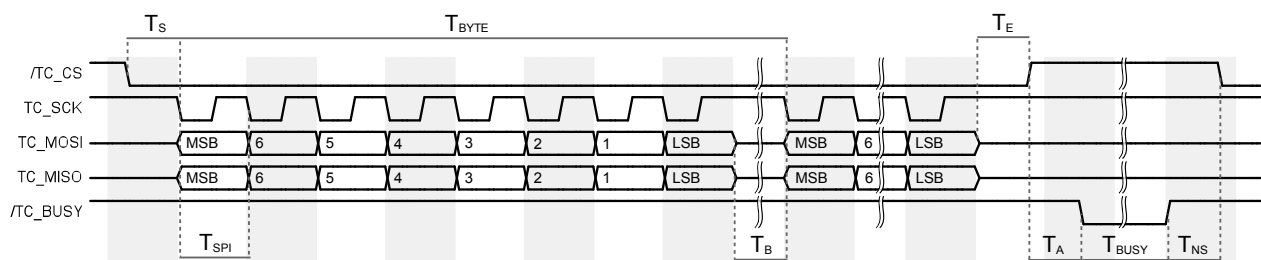


Figure 5.1: SPI timing diagram

| Time | T _S | T _{BYTE} ¹ | T _{SPI} ¹ | T _B ¹ | T _E | T _A | T _{BUSY} | T _{NS} |
|------|----------------|--------------------------------|-------------------------------|-----------------------------|----------------|----------------|-------------------|-----------------|
| Min. | 6.0 μs | | 82 ns | 0 | 7.0 μs | | 30 μs | 2.0 μs |
| Typ. | | 2.67 μs | 333 ns | 1.34 μs | | 25 μs | | |
| Max. | | | 8 us | | | | | |

Table 5.2: TC-P441-230 SPI timing description

| Time | T _S | T _{BYTE} | T _{SPI} | T _B | T _E | T _A | T _{BUSY} | T _{NS} |
|------|----------------|-------------------|------------------|----------------|----------------|----------------|-------------------|-----------------|
| Min. | 6.0 μs | | 82 ns | 0 | 11.0 μs | 5 μs | 21 μs | 2.0 μs |
| Typ. | | 2.67 μs | 333 ns | | | | | |
| Max. | | | 8 us | | | | | |

Table 5.3: TC-P74-230 SPI timing description

| Time | T _S | T _{BYTE} | T _{SPI} | T _B | T _E | T _A | T _{BUSY} | T _{NS} |
|------|----------------|-------------------|------------------|----------------|----------------|----------------|-------------------|-----------------|
| Min. | 4.0 μs | | 166 ns | 0 | 1.0 μs | 6.4 μs | 12.4 μs | 1.5 μs |
| Typ. | | 2.67 μs | 333 ns | | | 10 μs | | |
| Max. | | | 1 ms | | | | | |

Table 5.4: TC-P102-220 SPI timing description

Communication Flow

TCon is able to communicate to the host system if /TC_BUSY signal is inactive. To start communication, the /TC_CS line has to be activated by the host. Then the command data can be passed. There is no timeout during the communication, so the command data can be passed with any delays. Only when /TC_CS line is deactivated, is the command interpreted by the TCon.

After passing the command, it is being interpreted and executed by the TCon. The time of execution is indicated by /TC_BUSY signal active. During this time, the TCon does not accept any new commands.

1 Minimum T_{BYTE} value and typical T_{SPI} value reflect the maximum supported bit rate of 3 MHz. In this case T_B can equal 0 (typical value). However, the SPI clock can be set to higher frequency – up to 6 MHz – but in that case T_B value needs to be increased accordingly, so that T_{BYTE} minimum value is ensured.

Startup and Initialization Sequence

TC-P441-230 and TC-P74-230:

The below timing diagram (Figure 5.2) represents the TCon startup and initialization sequence after power-up. The TCon is ready for communication after $T_{STARTUP} + T_{INIT}$ which is indicated by $/TC_BUSY$ rising edge.

T_{INIT} time is constant, whereas $T_{STARTUP}$ is related to flash memory access and increases with every use cycle. At the first use cycle the time has the minimum value as in the Table 5.5 below. After 256 use cycles the flash memory page storing initialization values is erased and the time increases; subsequently the time decreases back to the minimum value. The maximum value represents worst-case performance after 100,000 flash memory erase cycles.

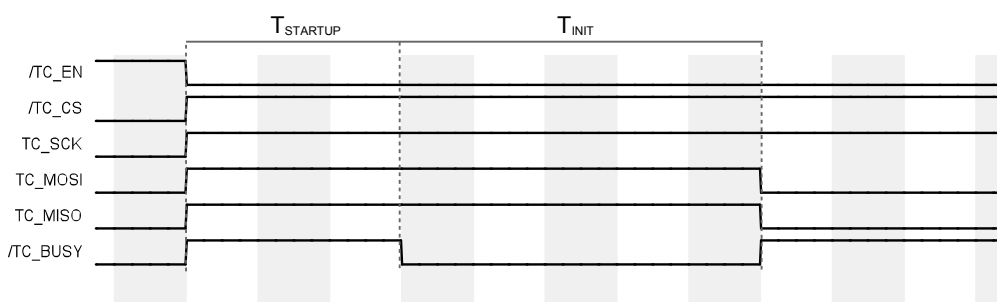


Figure 5.2: TC-P441-230 and TC-P74-230 initialization sequence

| Time | Min | Max | Unit |
|---------------|-----|-----|------|
| $T_{STARTUP}$ | 3.0 | 3.0 | ms |
| T_{INIT} | 1 | 200 | ms |

Table 5.5: TC-P441-230 and TC-P74-230 startup and initialization times

TC-P102-220:

The below timing diagram (Figure 5.3) represents the TCon startup and initialization sequence after power-up. The TCon is ready for communication after $T_{STARTUP+INIT}$ which is indicated by $/TC_BUSY$ rising edge.

$T_{STARTUP+INIT}$ is related to flash memory access and increases with every use cycle. At the first use cycle the time has the minimum value as in the Table 5.6 below. After 256 use cycles the flash memory page storing initialization values is erased and the time increases; subsequently the time decreases back to the minimum value. The maximum value represents worst-case performance after 100,000 flash memory erase cycles.

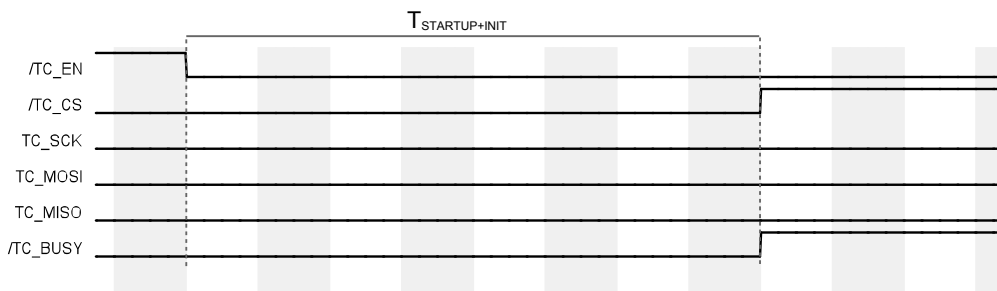


Figure 5.3: TC-P102-220 initialization sequence

| Time | Min | Max | Unit |
|---------------------------|-----|-----|------|
| T _{STARTUP+INIT} | 2.2 | 200 | ms |

Table 5.6: TC-P102-220 startup and initialization time

5.6 Command Description

Command Format

Each command is built up from 3 to 255 bytes. The command is divided into six fields.

The first three fields are used in each command:

- *INS* – command group specific
- *P1* – parameter
- *P2* – parameter

whereas the next three fields are only used by some particular commands:

- *Lc* – number of bytes in *Data* field
- *Data* – bytes forming command data; number of bytes determined by *Lc*
- *Le* – number of bytes of expected response

Returned Values

Upon each command, TCon returns a 2-byte command status code. The command status code is not included in the *Le* (expected response length).

Possible status codes are as follows:

- 0x9000 – EP_SW_NORMAL_PROCESSING – command successfully executed
- 0x6700 – EP_SW_WRONG_LENGTH – incorrect length (invalid *Lc* value or command too short or too long)
- 0x6C00 – EP_SW_INVALID_LE – invalid *Le* field
- 0x6A00 – EP_SW_WRONG_PARAMETERS_P1P2 – invalid *P1* or *P2* field
- 0x6D00 – EP_SW_INSTRUCTION_NOT_SUPPORTED – command not supported

If a command returns specific data, the status code is attached to the end of the data.

Data Readout

During each SPI clock cycle, a full-duplex data transmission takes place: the host sends a bit on the MOSI line, and the TCon sends a bit on the MISO line at the same time.

Thus, the command status should be read after the command is executed. To read the command status, the host should send the expected number of 0x00 bytes to TCon. The amount of bytes to be sent is dependent on the type of a command:

- If a command does not use the *Le* field, it will return only the two-byte status code; thus only two bytes should be sent by the host
- When *Le* field is used and set to 0x00, the response length is not determined; then the response should be read until 0x00 is encountered, indicating the response termination, and two additional bytes should be sent to acquire the command status
- When *Le* field is set to a value other than 0x00, the response length is determined by the value at *Le* field. The host should send the number of bytes indicated by the *Le* field, and two additional bytes to acquire the command status

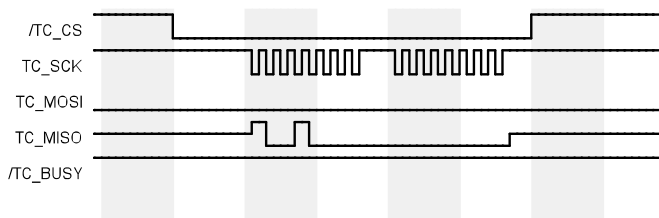


Figure 5.4: Example readout - 0x9000 response

5.6.1 Upload Image Data

This group of commands, starting with 0x20, handles the process of data upload to the TCon memory.

5.6.1.1 UploadImageData

Command

| INS | P1 | P2 | Lc | Data |
|------|------|------|-----------------------------|-----------------|
| 0x20 | 0x01 | 0x00 | Data packet size (max 0xFA) | [Lc Data bytes] |

Description

The command uploads image data (in EPD file format) to TCon image memory. The data needs to be divided into packets and transferred with multiple UploadImageData commands. In order to send the full image data, the user has to make sure to send it packet by packet.

While writing to the TCon internal memory, the TCon data pointer will be internally increased by the size of the current packet, until reaching maximum of slot memory:

- 16,384 bytes in case of TC-P441
- 49,152 bytes in case of TC-P74

Data pointer will then start from the beginning.

Data

Image file in EPD format, see 6 EPD File Format). Maximum packet size is 251 bytes (as maximum command size is 255 bytes.)

Possible return values

- 0x9000
- 0x6700
- 0x6C00
- 0x6A00

5.6.1.2 ResetDataPointer

Command

| INS | P1 | P2 |
|------|------|------|
| 0x20 | 0x0D | 0x00 |

Description

The command resets data pointer for Upload Image Data command.

NOTE Data pointer is automatically reset when TCon is enabled by /TC_EN activation

Possible return values

- 0x9000
- 0x6700
- 0x6C00
- 0x6A00

5.6.1.3 DisplayUpdate

Command

| INS | P1 | P2 |
|------|------|------|
| 0x24 | 0x01 | 0x00 |

Description

The command starts the display refresh sequence, displaying the current content of the image memory.

- If data was uploaded with UploadImageData command, the new data is going to be displayed
- If no data was sent, currently visible image will be refreshed (cleared and displayed again)

Possible return values

- 0x9000
- 0x6700
- 0x6C00
- 0x6A00

5.6.2 Device Info

This group of commands, starting with INS = 0x30 byte, manages the acquirement of hardware information from TCon.

5.6.2.1 GetDeviceInfo

Command

| INS | P1 | P2 | Le |
|------|------|------|------|
| 0x30 | 0x01 | 0x01 | 0x00 |

Description

The command returns information on system hardware. String data is specific for the particular device type and is constant for the same type of devices if no hardware differences occur.

Possible return values

- [String: "MpicoSys TC-P441-230_v1.0" terminated by 0x00 byte] + 0x9000
- [String: "MpicoSys TC-P74-230_v1.0" terminated by 0x00 byte] + 0x9000
- [String: "MpicoSys TC-P102-220_v1.1" terminated by 0x00 byte] + 0x9000
- 6700
- 6C00
- 6A00

5.6.2.2 GetDeviceId

Command

| INS | P1 | P2 | Le |
|------|------|------|------|
| 0x30 | 0x02 | 0x01 | 0x14 |

Description

The command returns unique device ID number.

Possible return values

- [20 bytes of data] + 0x9000
- 6700
- 6C00
- 6A00

5.6.3 System Info

This group of commands, starting with INS = 0x31 byte, deals with acquirement of firmware information from TCon.

5.6.3.1 GetSystemInfo

Command

| INS | P1 | P2 | Le |
|------|------|------|------|
| 0x31 | 0x01 | 0x01 | 0x00 |

Description

The command returns information on system firmware.

Possible return values

- [String: "MpicoSys TC-P441-230_fD_BIN" terminated by 0x00 byte] + 0x9000
- [String: "MpicoSys TC-P74-230_fC_BIN" terminated by 0x00 byte] + 0x9000
- [String: "MpicoSys TC-P102-220_fG_BIN" terminated by 0x00 byte] + 0x9000
- 6700
- 6C00
- 6A00

5.6.3.2 GetSystemVersionCode

Command

| INS | P1 | P2 | Le |
|------|------|------|------|
| 0x31 | 0x02 | 0x01 | 0x10 |

Description

The command returns information on system version.

Possible return values

- 0x D0 A5 00 03 00 00 00 00 33 01 03 00 00 00 00 00 + 0x9000 in case of TC-P441-230
- 0x D0 AA 00 01 00 00 00 00 3A 01 03 00 00 00 00 00 + 0x9000 in case of TC-P74-230
- 0x D0 AC 01 06 00 00 00 00 3D 01 00 00 00 00 00 00 + 0x9000 in case of TC-P102-220
- 6700
- 6C00
- 6A00

5.6.4 Sensor Data

5.6.4.1 ReadSensorData

Command

| INS | P1 | P2 | Le |
|------|------|------|------|
| 0xE5 | 0x01 | 0x00 | 0x02 |

Description

The command returns the temperature value measured by the TCon temperature sensor. The sensor is built in the TCM board and is included in the TCon reference design. The measurement is based on a NCP18WB473E03RB Thermistor and 8-bit ADC. The read value (x) is mapped to temperature value according to the following chart:

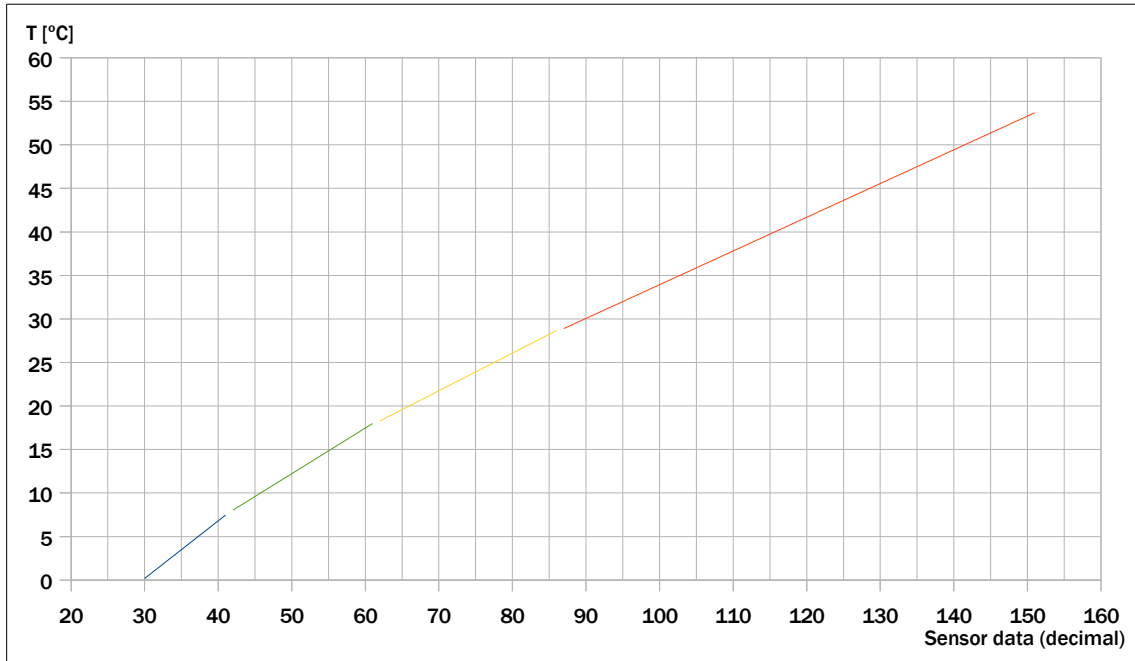


Figure 5.5: Temperature versus ADC 8-bit value chart

For more accurate approximation, the ADC values have been divided into four ranges. The temperature can be calculated based on the following linear approximation formula:

$$T = ax + b$$

where:

T – temperature [°C]

x – sensor data

| x | 30÷41 | 42÷61 | 62÷86 | 87÷160 |
|-----|--------|--------|-------|--------|
| a | 0.66 | 0.52 | 0.43 | 0.39 |
| b | -19.69 | -13.95 | -8.55 | -4.75 |

Table 5.7: Linear approximation of the sensor data readout

Possible return values

- [2 bytes of sensor data] + 0x9000
- 6700
- 6C00
- 6A00

6 EPD File Format

EPD is a specific raster graphics image file format, accepted by TCon. EPD file format was developed to maximize the decoding efficiency on the target platform. The EPD file comprises of two parts:

- Header
- Image data

Table below describes the various panels resolution and corresponding image data array sizes, as well as EPD files sizes.

| Panel size | Image resolution [px] | Image color depth [bit] | Header size [bytes] | Image data array size [bytes] | EPD file size [bytes] |
|------------|-----------------------|-------------------------|---------------------|-------------------------------|-----------------------|
| 4.41" | 400×300 | 1 | 16 | 15,000 | 15,016 |
| 7.4" | 480×800 | | | 48,000 | 48,016 |
| 10.2" | 1024×1280 | | | 163,840 | 163,856 |

6.1 Header

EPD file begins with a header. The header size is 16 bytes. The consecutive bytes are described in the table below:

| Field name | Size | Possible values | Description |
|-------------------|---------|-----------------|---|
| panel type | 1 byte | 0x33 | Panel code 4.41" |
| | | 0x3A | 7.4" |
| | | 0x3D | 10.2" |
| X res | 2 bytes | 0x0190 | 400 px |
| | | 0x01E0 | 480 px |
| | | 0x0400 | 1024 px |
| Y res | 2 bytes | 0x012C | 300 px |
| | | 0x0320 | 800 px |
| | | 0x0500 | 1280 px |
| color depth | 1 byte | 0x01 | Image color depth – 1-bit (black and white) |
| pixel data format | 1 byte | 0x00 | Image pixel data format type 0 |
| | | 0x02 | Image pixel data format type 2 |
| | | 0x04 | Image pixel data format type 4 |
| RFU | 9 bytes | 0x00 | Reserved for future use |

Based on the information from the table above, here are complete header values depending on the panel size:

- TC-P441-230: 0x 33 01 90 01 2C 01 00 00 00 00 00 00 00 00 00 00
- TC-P74-230: 0x 3A 01 E0 03 20 01 04 00 00 00 00 00 00 00 00 00
- TC-P102-220 0x 3D 04 00 05 00 01 00 00 00 00 00 00 00 00 00 00

6.2 Image Data

Each byte of the image data encodes information on eight pixels (a single pixel is described by one bit of a single byte).

1-bit gray scale provides 2 colors. Bit value 0 corresponds to black color while value 1 represents white color.

6.2.1 Pixel Data Format Type 0

This format is used in TC-P441-230 and TC-P102-220. Each byte of image data shall convey information on 8 consecutive pixels of the RAW image.

Conversion Algorithm

The algorithm for conversion from standard RAW 4-bit data to EPD format is described below.

- Start with a byte array of image data which is already downsampled to 1-bit monochrome; each byte conveys information on 1 pixel

1) Get a single row of 8 bytes (8 pixels):

| | | | | | | | | |
|------------------------|---|---|---|---|---|---|---|---|
| Input byte No.: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Pixel value: | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |

Table 6.1: Input data – 8 bytes

2) Merge the input byte values (numbering from 0 to 7) into one output byte, conveying information on 8 pixels

| | | | | | | | | |
|---------------------------|-------------------|---|---|---|---|---|---|---|
| Input byte No.: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Pixel value: | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| Output byte value: | 0x76 0b01110110 | | | | | | | |

Table 6.2: Output data – single byte

3) Go back to Step 1), getting the following row; repeat until all the bytes are processed

Sample Code

Below is sample Java code for image conversion:

```
static byte[] convertTo1bit_PixelFormatType0(byte[] picData, int w, int h)
{
    byte[] newRow = new byte[picData.length * 1 / 8];
    // join nibbles (so 1 byte is 8 pixels)
    int j = 0;
    for (int i = 0; i < picData.length; i += 8)
    {
        newRow[j] = (byte) ( ((picData[i + 0] << 7) & 0x80) |
                             ((picData[i + 1] << 6) & 0x40) |
                             ((picData[i + 2] << 5) & 0x20) |
                             ((picData[i + 3] << 4) & 0x10) |
                             ((picData[i + 4] << 3) & 0x08) |
                             ((picData[i + 5] << 2) & 0x04) |
                             ((picData[i + 6] << 1) & 0x02) |
                             ((picData[i + 7]) & 0x01));

        j++;
    }
    return newRow;
}
```

6.2.2 Pixel Data Format Type 2

This format is used in TC-P441-230.

Conversion Algorithm

The algorithm for conversion from standard RAW 4-bit data to EPD format is described below.

- Start with a byte array of image data which is already downsampled to 1-bit monochrome; each byte conveys information on 1 pixel

4) Get a single row of 8 bytes (8 pixels):

| | | | | | | | | |
|------------------------|---|---|---|---|---|---|---|---|
| Input byte No.: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Pixel value: | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |

Table 6.3: Input data – 8 bytes

5) Assign the input byte values (numbering from 0 to 7) to the output byte, conveying information on 8 pixels, as follows:

- Input byte 0: assign to output byte bit 0
- Input byte 1: assign to output byte bit 2
- Input byte 2: assign to output byte bit 4
- Input byte 3: assign to output byte bit 6
- Input byte 4: assign to output byte bit 1
- Input byte 5: assign to output byte bit 3
- Input byte 6: assign to output byte bit 5
- Input byte 7: assign to output byte bit 7

| | | | | | | | | |
|-----------------------------|-------------------|---|---|---|---|---|---|---|
| Output byte bit No.: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Input byte No.: | 0 | 4 | 1 | 5 | 2 | 6 | 3 | 7 |
| Pixel value: | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| Output byte value: | 0x3E 0b00111110 | | | | | | | |

Table 6.4: Output data – single byte

6) Go back to Step 1), getting the following row; repeat until all the bytes are processed

Sample Code

Below is sample Java code for image conversion:

```
static byte[] convertTo1bit_PixelFormatType2(byte[] picData, int w, int h)
{
    byte[] newRow = new byte[picData.length * 1 / 8];
    // join nibbles (so 1 byte is 8 pixels) and interlace at the same time
    int j = 0;
    for (int i = 0; i < picData.length; i += 8)
    {
        newRow[j] = (byte) ( ((picData[i + 0] << 7) & 0x80) |
                             ((picData[i + 4] << 6) & 0x40) |
                             ((picData[i + 1] << 5) & 0x20) |
                             ((picData[i + 5] << 4) & 0x10) |
                             ((picData[i + 2] << 3) & 0x08) |
                             ((picData[i + 6] << 2) & 0x04) |
                             ((picData[i + 3] << 1) & 0x02) |
                             ((picData[i + 7]) & 0x01));

        j++;
    }
    return newRow;
}
```

6.2.3 Pixel Data Format Type 4

This format is used in TC-P74-230.

Conversion Algorithm

The algorithm for conversion from standard RAW 4-bit data to EPD format is described below.

- Start with a byte array of image data which is already downsampled to 1-bit monochrome; each byte conveys information on 1 pixel

1) Get a single row of 480 bytes (480 pixels) – the *Bytes value* represent the value of 8 consecutive bytes if merged into one byte:

| | | | | | | | | | |
|------------------------|------|------|-------|-------|-----|-----|-----|-----|---------|
| Input Byte No.: | 0÷7 | 8÷15 | 16÷23 | 24÷31 | ... | ... | ... | ... | 472÷479 |
| Bytes value: | 0x76 | 0x4C | 0xA3 | 0x1F | ... | ... | ... | ... | ... |

Table 6.5: Input data – 60 bytes (480 pixels)

2) Get first 16 bytes from that row:

| | | | | | | | | | | | | | | | | |
|------------------------|-------------------|---|---|---|---|---|---|---|-------------------|---|----|----|----|----|----|----|
| Input Byte No.: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Pixel value: | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| Bytes value: | 0x76 0b01110110 | | | | | | | | 0x4C 0b01001100 | | | | | | | |

Table 6.6: Input data – first 16 bytes

3) Create a 2-byte Intermediate array:

| | | | | | | | | | | | | | | | | |
|-------------------------|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|
| Int. byte No.: | 0 | | | | | | | | 1 | | | | | | | |
| Position: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Input byte No.: | | | | | | | | | | | | | | | | |
| Pixel value: | | | | | | | | | | | | | | | | |
| Int. byte value: | | | | | | | | | | | | | | | | |

Table 6.7: Intermediate array – empty

4) Assign the Input Byte values (numbering from 0 to 15) to Intermediate array, conveying information on 16 pixels, as follows:

- Input byte 0: assign to Intermediate array position 6
- Input byte 1: assign to Intermediate array position 8
- Input byte 2: assign to Intermediate array position 4
- Input byte 3: assign to Intermediate array position 10
- Input byte 4: assign to Intermediate array position 2
- Input byte 5: assign to Intermediate array position 12
- Input byte 6: assign to Intermediate array position 0
- Input byte 7: assign to Intermediate array position 14
- Input byte 8: assign to Intermediate array position 7
- Input byte 9: assign to Intermediate array position 9
- Input byte 10: assign to Intermediate array position 5
- Input byte 11: assign to Intermediate array position 11
- Input byte 12: assign to Intermediate array position 3
- Input byte 13: assign to Intermediate array position 13
- Input byte 14: assign to Intermediate array position 1
- Input byte 15: assign to Intermediate array position 15

| | | | | | | | | | | | | | | | | |
|-------------------------|-------------------|----|---|----|---|----|---|---|-------------------|---|----|----|----|----|----|----|
| Int. byte No.: | 0 | | | | | | | | 1 | | | | | | | |
| Position: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Input Byte No.: | 6 | 14 | 4 | 12 | 2 | 10 | 0 | 8 | 1 | 9 | 3 | 11 | 5 | 13 | 7 | 15 |
| Pixel value: | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| Int. byte value: | 0x98 0b10011000 | | | | | | | | 0xEC 0b11101100 | | | | | | | |

Table 6.8: Intermediate array – first 16 bytes processed

- 5) Create an output array of 60 bytes
- 6) Assign Intermediate byte 0 (the one with even pixels) to position 29 of the Output Array;
 Assign Intermediate byte 1 (the one with odd pixels) to position 59 of the Output Array

| | | | | | | | | | | | | | | | | |
|---------------------------|------|---|-----|-----|-----|-----|----|----|------|----|-----|-----|-----|-----|----|----|
| Output Byte No.: | 0 | 1 | ... | ... | ... | ... | 28 | 29 | 30 | 31 | ... | ... | ... | ... | 58 | 59 |
| Int. byte No.: | 0 | | | | | | | | 1 | | | | | | | |
| Output Byte value: | 0x98 | | | | | | | | 0xEC | | | | | | | |

Table 6.9: Output data filled in with first two bytes

- 7) Go back to Step 2), getting the following 16 bytes from the row (bytes 16÷31)

| | | | | | | | | | | | | | | | | |
|------------------------|-------------------|----|----|----|----|----|----|----|-------------------|----|----|----|----|----|----|----|
| Input Byte No.: | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Bytes value: | 0xA3 0b10100011 | | | | | | | | 0x1F 0b00011111 | | | | | | | |

Table 6.10: Input data – following 16 bytes

- Assign the bytes as in Step 4)

| | | | | | | | | | | | | | | | | |
|-------------------------|-------------------|--|--|--|--|--|--|--|-------------------|--|--|--|--|--|--|--|
| Int. byte No.: | 2 | | | | | | | | 3 | | | | | | | |
| Int. byte value: | 0xDA 0b11011010 | | | | | | | | 0x17 0b00010111 | | | | | | | |

Table 6.11: Intermediate data – following 16 bytes processed

- Assign Intermediate byte 2 to position 28 of the Output Array
 Assign Intermediate byte 3 to position 58 of the Output Array

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------|------|---|-----|-----|-----|-----|----|----|------|----|-----|-----|-----|-----|----|----|------|--|--|--|--|--|--|--|
| Output Byte No.: | 0 | 1 | ... | ... | ... | ... | 28 | 29 | 30 | 31 | ... | ... | ... | ... | 58 | 59 | | | | | | | | |
| Int. byte No.: | 2 | | | | | | | | 0 | | | | | | | | | | | | | | | |
| Output Byte value: | 0xDA | | | | | | | | 0x98 | | | | | | | | | | | | | | | |
| Output Byte value: | | | | | | | | | 0x17 | | | | | | | | 0xEC | | | | | | | |

Table 6.12: Output data filled in with following two bytes

- 8) Repeat until the full 480-byte row is processed
- 9) Get the following 480-byte row and repeat the process until the whole image is processed

Sample Code

Below is sample Java code for image conversion:

```
static byte[] convertTo1bit_PixelFormatType4(byte[] picData, int w, int h)
{
    byte[] newPicData = new byte[picData.length / 8];
    int row = 30, s = 1;
    for (i = 0; i < picData.length; i += 16)
    {
        newPicData[row-s] = (byte) (
            ((picData[i + 6 ] << 7) & 0x80) |
            ((picData[i + 14] << 6) & 0x40) |
            ((picData[i + 4 ] << 5) & 0x20) |

```



```

                                                                    ((picData[i + 12] << 4) & 0x10) |
                                                                    ((picData[i + 2 ] << 3) & 0x08) |
                                                                    ((picData[i + 10] << 2) & 0x04) |
                                                                    ((picData[i + 0 ] << 1) & 0x02) |
                                                                    ((picData[i + 8 ] << 0) & 0x01));

    newPicData[row+30-s] = (byte) ( ((picData[i + 1 ] << 7) & 0x80) |
                                                                    ((picData[i + 9 ] << 6) & 0x40) |
                                                                    ((picData[i + 3 ] << 5) & 0x20) |
                                                                    ((picData[i + 11] << 4) & 0x10) |
                                                                    ((picData[i + 5 ] << 3) & 0x08) |
                                                                    ((picData[i + 13] << 2) & 0x04) |
                                                                    ((picData[i + 7 ] << 1) & 0x02) |
                                                                    ((picData[i + 15] << 0) & 0x01));

    s++;
    if(s==31)
    {
        s=1;
        row+=60;
    }
}
return newPicData;
}
```

7 Revision History

| Document Revision | Release Date | Document Status | Supersedes |
|-------------------|--------------|-----------------|------------|
| F | 2014-07-29 | Approved | E |
| E | 2014-05-09 | Approved | - |
| D | 2013-08-09 | Approved | C |
| C | 2013-07-30 | Approved | B |
| B | 2013-07-10 | Approved | A |
| A | 2013-03-15 | Approved | - |

Table 7.1: Revision history

| Document Revision | Change Log |
|-------------------|--|
| F | 5.4: Updated Startup and Initialization Sequence for TC-P102-220 5.6.3.1 & 5.6.3.2: Updated TC-P102-220 possible return values |
| E | Update for TCM-P441-230, TCM-P74-230 and TCM-P102-220 and respective TCons |
| D | 2.2: Updated outlines and dimensions Table 3.5: Corrected average energy consumption values |
| C | 6.2.3 6) & 7); Table 6.9 & Table 6.12: Corrected description of Output Array order for even pixels |
| B | Update for product version 1.1 Removed information on TCM-P102 Removed information on CC version 3: Separated information on VDDIN and VIN; updated values 4: Updated values 5.2: Updated VDDIN and VIN remarks 5.3: Added information on power supply; edited Table 5.2: Updated T_E 5.6: Updated return values; updated ReadSensorData approximation equation 6.1: Corrected typo 6.2.2: Edited 6.2.3: Added new format description |
| A | Initial version |

Table 7.2: Change log

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