Embedded Pico Systems

Developer's Guide

Timing Controller Solutions for Pervasive Displays 10.2″ Panels

TCM-P102_v1.0(Beta)

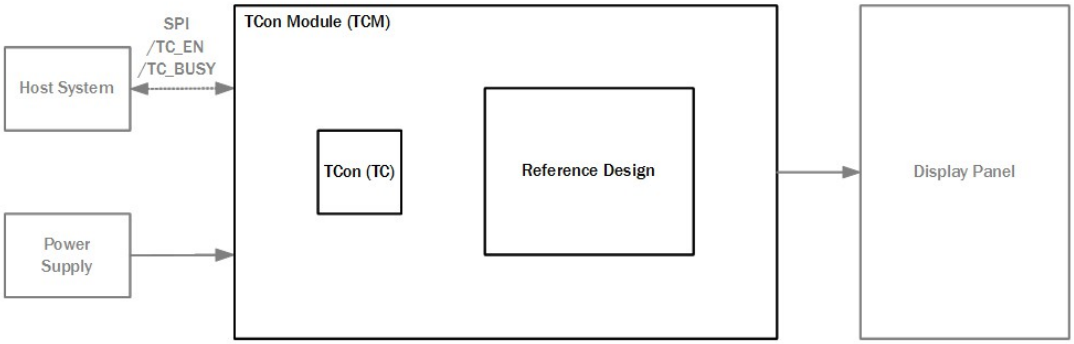
Classification: **Confidential**

Document Revision: **A**

Table of Contents

1 Introduction

E-paper Timing Controller Solutions provide timing controller (TCon) functionalities for **Pervasive Displays'10.2″** panel. 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-P102_v1.0 (Beta)	TC-P102_v1.0 (Beta)	10.2″	EZ102A011	1024×1280 px	160 dpi

1.2 Features

- Temperature compensation
- 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 50 °C operating temperature range

2 Electrical Characteristics

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

2.1 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 2.1: Absolute maximum ratings

2.2 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	+50	°C

Table 2.2: Typical operating conditions

2.3 TCM Supply Current Characteristics

Measurement Setup

ZXCT1110 current monitor with Rs=0.5R/1% resistor; Agilent MSO7054 oscilloscope, setup: 50mV/div (5mA/div), 200ms/div, acquire mode: Normal

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

NOTE Values vary with supply voltage and the displayed pattern.

Symbol	Description	Operation	Min	Typ	Max	Unit
IDD	Average current consumption	Display update	38	38	100	mA
		Data reception on SPI	TBD	TBD	TBD	mA
		Disabled (/TN_EN inactive)	0.02	0.1	2.0	µA
IDD peak	Peak current	Display update	-	-	250	mA
E	Average energy consumption in room temperature	Display update	TBD	TBD	TBD	mJ

Table 2.3: 4.41″ supply current characteristics

3 TCon Hands-on

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

3.1 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.

3.2 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

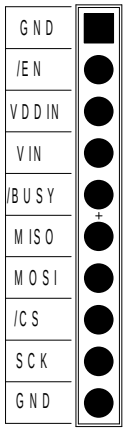


Table 3.1: TCM host connector

3.3 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.

3.4 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.

3.5 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:

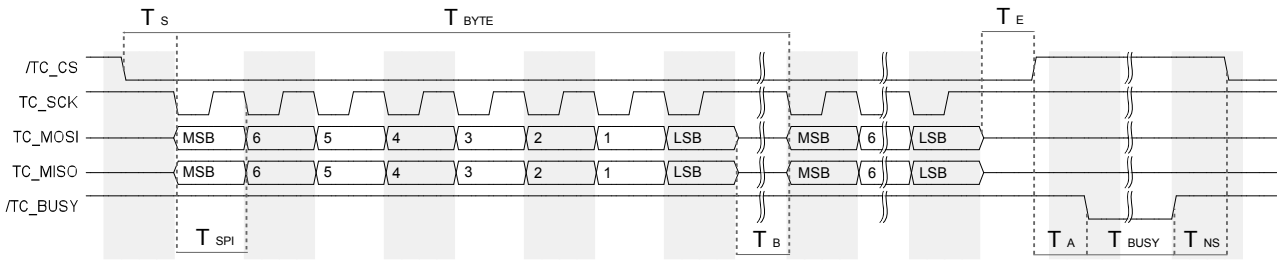


Figure 3.1: SPI timing diagram

Time	T_S	T_{BYTE}[1]	T_{SPI}[1]	T_B[1]	T_E	T_A	T_{BUSY}	T_{NS}
Min.	6.2 µs	2.67 µs	166 ns	0	7.0 µs		30 µs	2.0 µs
Typ.	7.0 µs		333 ns	1.34 µs		25 µs		
Max.			1 ms					

Table 3.2: 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.

Initialization Sequence

TCon requires T_{INIT} initialization delay to be applied after it is switched on by activating the /TC_EN line, before TCon is ready to accept the commands.

Commands.

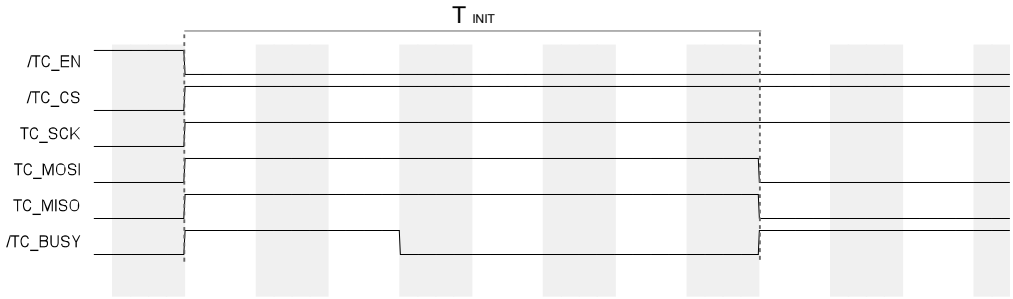


Figure 3.2: Initialization sequence

T_{INIT}: minimum 6.5 ms

3.6 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:

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.

- *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

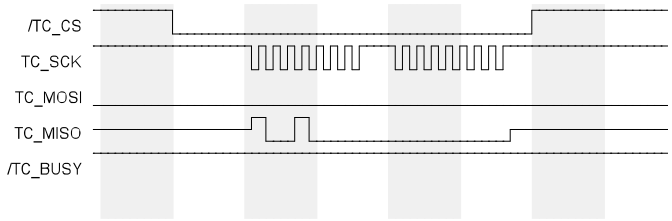


Figure 3.3: Example readout - 0x9000 response

3.6.1 Upload Image Data

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

3.6.1.1 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.

Data pointer will then start from the beginning.

Data

Image file in EPD format, see 4 EPD File Format). Maximum packet size is 250 bytes (as maximum command size is 255 bytes.)

Possible return values

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

3.6.1.2 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

3.6.1.3 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

3.6.1.4 DisplayUpdateExtTemp

Command

INS	P1	P2	Lc	Data
0x23	0x01	0x00	0x01	Temperature

Description

The command starts the display refresh sequence, displaying the current content of the image memory, bypassing the internal temperature measurement.

- 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)

Data

In Data field pass one byte of temperature value in degrees Celsius. Sub-zero temperature shall be represented in two's complement.

Accepted data range: from -128 to 127.

Possible return values

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

3.6.2 Device Info

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

3.6.2.1 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-P102_v1.0" terminated by 0x00 byte] + 0x9000
- 6700
- 6C00
- 6A00

3.6.2.2 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

3.6.3 System Info

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

3.6.3.1 GetSystemInfo

Command

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

Description

The command returns information on system firmware.

Possible return values

- [String: "MpicoSys TC-P102_fA_BIN" terminated by 0x00 byte] + 0x9000
- 6700
- 6C00
- 6A00

3.6.3.2 GetSystemVersionCode

Command

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

Description

The command returns information on system version.

Possible return values

- 0x D0 AC 00 01 00 00 00 00 3D 01 00 00 00 00 00 00 + 0x9000
- 6700
- 6C00
- 6A00

3.6.4 Sensor Data

3.6.4.1 ReadSensorData

Command

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

Description

The command returns the temperature value measured by the TCM temperature sensor.

Possible return values

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

4 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]
10.2″	1024×1280	1	16	163,840	163,856

4.1 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	0x3D	Panel code 10.2″
X res	2 bytes	0x0400	1024 px
Y res	2 bytes	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
RFU	9 bytes	0x00	Reserved for future use

Based on the information from the table above, here is the complete header value:

- TC-P102: 0x 3D 04 00 05 00 01 00 00 00 00 00 00 00 00 00 00

4.2 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 0b1 corresponds to black color while value 0b0 represents white color.

4.2.1 Pixel Data Format Type 0

This format is used in TC-P102. 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 4.1: 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 4.2: Output data – single byte

3) Go back to Step 1), getting the following eight bytes; 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)
      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;
}
```

5 Revision History

Document Revision	Release Date	Document Status	Supersedes
A	2013-12-24	Approved	–

Table 5.1: Revision history

Document Revision	Change Log
A	Initial version

Table 5.2: Change log

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