Application Note

Akademie věd České republiky
Ústav teorie informace a automatizace AV ČR, v.v.i.

Simple Gesture Detector Based on TE0706 with TE0720-2IF and Ultrasonic Range Finder PmodMAXSONAR

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Revision history

Rev.	Date	Author	Description
0	31.10.2018	L.Kohout	Initial version

Contents

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1 Introduction

This application note describes a simple gesture detector based on ultrasonic range finder Digilent PmodMAXSONAR™ [1] implemented on FPGA module Trenz TE0720-2IF [2] plugged into Trenz TE0706 carrier [3]. It recognizes two gestures, moving hand to the left and to the right. These gestures are translated to commands that are sent via RS232 interface (PmodRS232™ [4]). It is intended to use with access control system designed by IMA company [5] as a demonstrator in SILENSE project.

2 Description

The gesture detector consists of FPGA module Trenz TE0720-2IF [2] with Trenz TE0706 carrier [3] (see Figure 1), two ultrasonic range finders PmodMAXSONAR™ [1] from Digilent, two LED modules and PmodRS232™ [4]. The ultrasonic range finders and the LED modules are assembled together using common holder (Figure 2).

Figure 1: FPGA module TE0720 with TE0706 carrier.

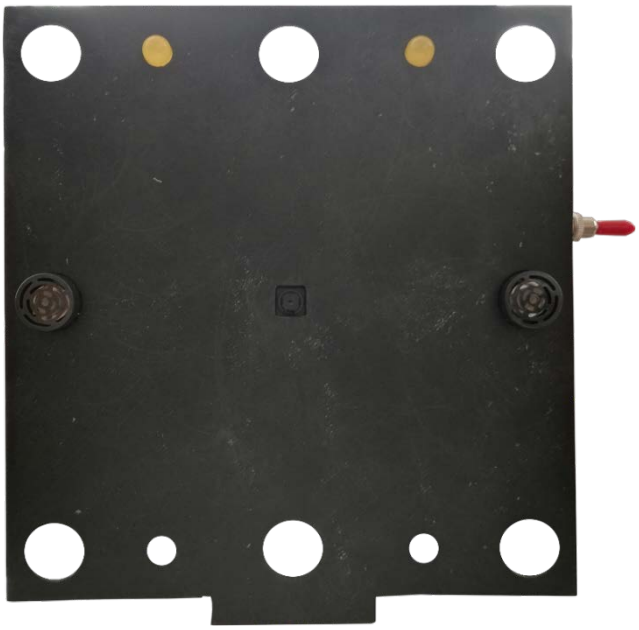

Figure 2: The ultrasonic range finders and the LED modules holder.

2.1 FPGA Implementation

To implement the gesture detector was used Xilinx Vivado 2018.2 tool. The block diagram of the system is shown in Figure 3. The design is based on the reference design from Trenz: (http://www.trenz-electronic.de/fileadmin/docs/Trenz_Electronic/Modules_and_Module_Carriers/4x5/TE0720/Reference_Design/2018.2/test_board/te0720-test_board-vivado_2018.2-build_03_20180823185142.zip).

It uses standard blocks provided by Vivado tool except two of them. Block *SC0720_0* has been designed by Trenz, it provides a couple of FPGA pin to pin interconnections. Block *axi_ms_pwm_0* has been designed in UTIA. This block is the controller of the ultrasonic range finder(s) from Digilent. It reads PWM value corresponding to measured distance and it generates enable signal to selected ultrasonic range finder. The block can handle up to eight ultrasonic range finders.

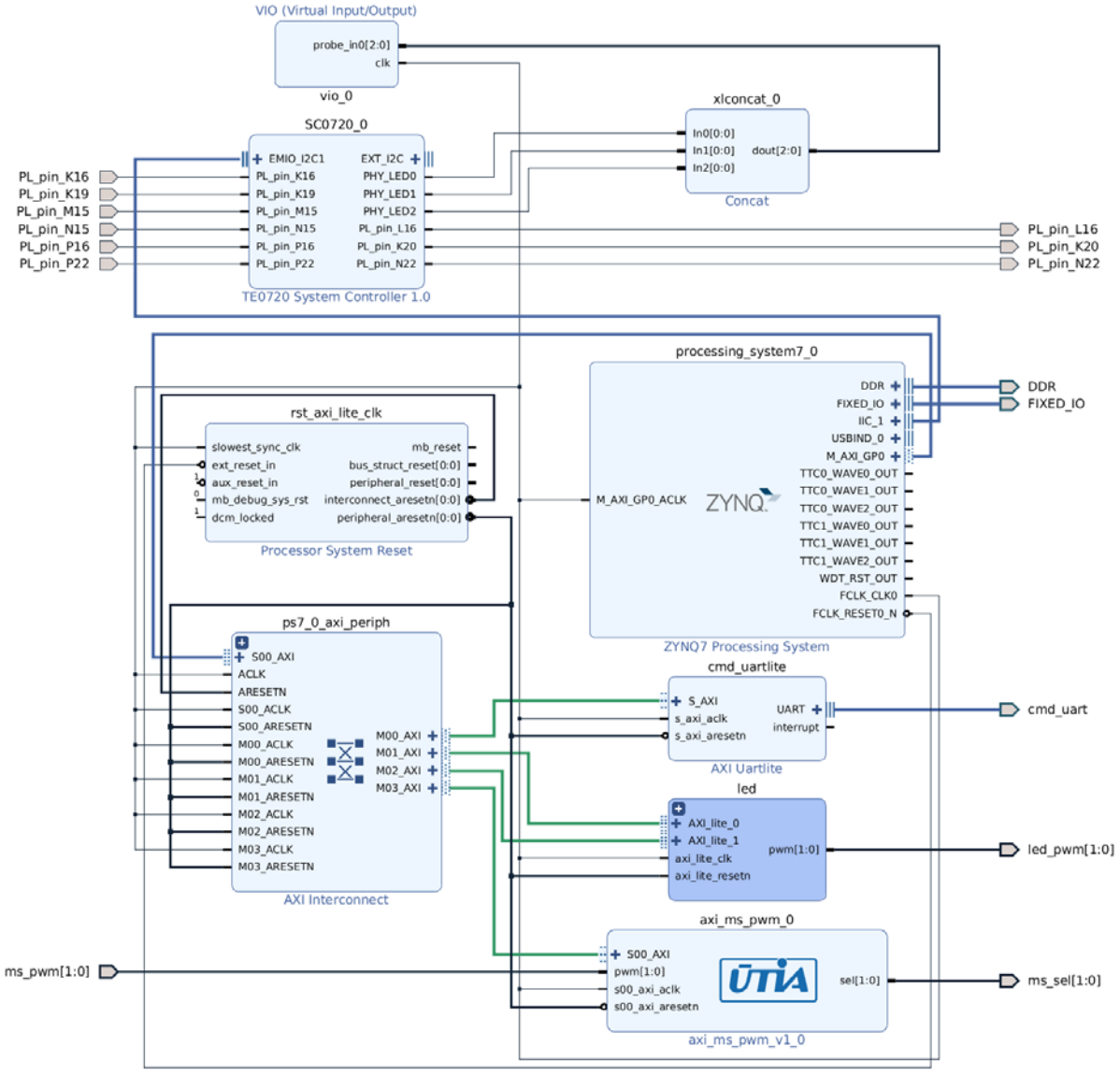

Figure 3: System block design in Xilinx Vivado 2018.2.

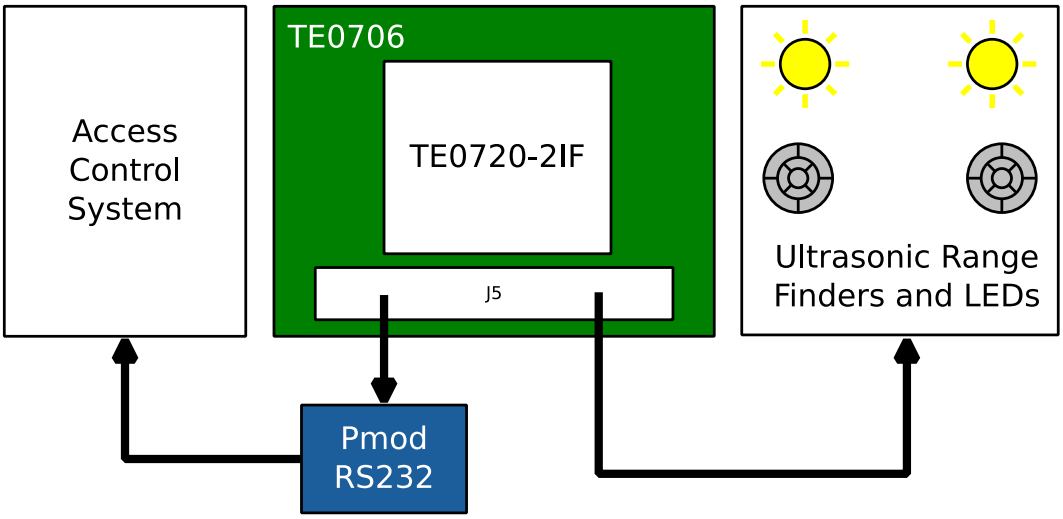

Figure 4: Brief block scheme of the system.

2.2 Hardware

Figure 4 shows block diagram of the system. PmodRS232™ and ultrasonic range finders PmodMAXSONAR™ with LED modules are connected via J5 connector on the TE0706 carrier. Table 1 describes connection between PmodRS232™ and TE0706 board, Table 2 describes connections between ultrasonic range finders with LEDs and TE0706 board. FPGA I/O pins are set to use 3.3 V logic levels. Electric scheme of the LED module is shown in Figure 5.

Table 1: TE0706.J5 to PmodRS232™.

PmodRS232™		TE0706	TE0720-2IF
Pin	Signal	J5 pin	FPGA pin
1	CTS	NC	
2	RTS	NC	
3	TXD	42	B19
4	RXD	44	E21
5	GND	50	
6	VCC	46	

Table 2: TE0706.J5 to PmodMAXSONARTM + LEDs

PmodMAXSONAR™ + LEDs		TE0706	TE0720-2IF
Pin	Signal	J5 pin	FPGA pin
1	Vcc	5	
2	GND	1	
3	US_0_PWM	7	W18
4	US_0_EN	9	W21
5	US_1_PWM	11	AB16
6	US_1_EN	13	AB17
7	LED_0_PWM	15	AA18
8	LED_1_PWM	17	AA19

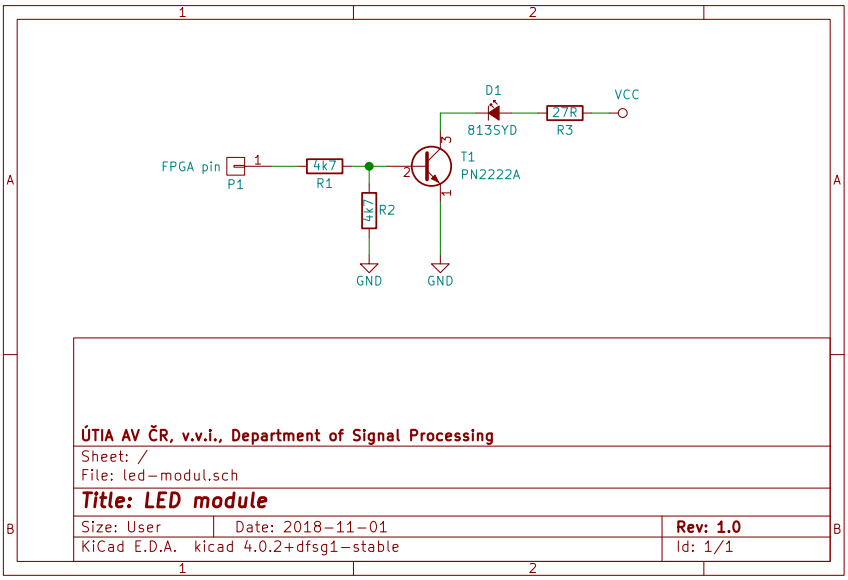

Figure 5: LED module schematic diagram.

2.3 Software

To recognize the gestures, the system uses two ultrasonic range finders. They detect whether the hand is present in some range of distance or not; the sensors return PWM values corresponding to the distances of the hand from the sensors. This information can be translated to the set of observations, they are summarized in Table 3. The system can recognize two simple gestures, moving hand to the left and moving hand to the right. To recognize the gestures the system uses Hidden Markov Model (HMM, [6]). To find the most likely sequence of hidden states within the model the Viterbi algorithm is used [7].

Table 3: Set of observations.

Observation	Description
n	None of the sensors see the hand
l	Only left sensor see the hand
r	Only right sensor see the hand
a	Both sensor see the hand

In this case one model is enough to make decision between two gestures. The model has three states N, L and R. Start probability defines the initial state of the system at the beginning.

```
                      //   N    L     R
start_probability[] = { 1.0, 0.00, 0.00 }
```

Transition probability matrix defines transitions for each state in the system with the probability which state will be the next.

```
transition_probability[STATE_NUM][STATE_NUM] = {
//     N      L      R
    { 0.4  , 0.3  , 0.3  }, // N
    { 0.1  , 0.6  , 0.3  }, // L
    { 0.1  , 0.3  , 0.6  }  // R
}
```

Emission probability matrix defines the transitions for each state according to current observation.

```
emission_probability[STATE_NUM][OBS_NUM] = {
//     n      l      r      a
    { 0.39 , 0.3  , 0.3  , 0.01 },  // N
    { 0.1  , 0.45 , 0.1  , 0.35 },  // L
    { 0.1  , 0.1  , 0.45 , 0.35 }   // R
}
```

When valid gesture is recognized, the system sends a command. On move-right gesture the system sends “12345678901;” command and once flashes with the LED on the right side. On move-left gesture the system sends “23456789012;” command and once flashes with the LED on the left side. On unrecognized gesture the system does not send any command and make a double flesh with both LEDs. The commands are sent via RS232 interface, the settings are in Table 4.

Table 4: RS232 interface settings.

Parameter	Setting
Speed	9600
Data bits	8b
Stop bits	1b
Parity	None
Control flow	None

3 Quick start

To run the demonstrator follow the steps in the list bellow

1. Connect PmodRS232™ module to the J5 connector of the TE0706 carrier (UART side of the module). See Table 1 in Section 2.2.
2. Connect PmodRS232™ RS232 side (standard Canon 9 connector) to the control access system. For testing purpose, it can be connected directly to the PC, settings of the serial terminal are 9600 baud rate, 8 data bits, 1 stop bit, no parity and no control flow.
3. Connect ultrasonic range finders PmodMAXSONAR™ and LED modules to the J5 connector of the TE0706 carrier. See Table 2 in Section 2.2.
4. Connect USB UART on the TE0706 carrier to observe the state of the demonstrator (micro USB connector). Settings of the serial terminal are 115200 baud rate, 8 data bits, 1 stop bit, no parity and no control flow.
5. Copy *BOOT.bin* file from attached package to the micro-SD card and plug the card to the TE0706 board. See the package content in Section 4.
6. Plug the 5V power supply to the TE0706 board.
7. Observe both serial terminals.

4 Package content

```
.
├── gesture-terminal-v1.pdf
└── SD
    └── BOOT.bin
```

5 References

[1] DIGILENT, „PmodMAXSONAR™ Reference Manual,“ 12 April 2016. [Online]. Available: https://reference.digilentinc.com/_media/pmod:pmod:pmodMAXSONAR_rm.pdf.

[2] Trenz Electronic, „TE0720 TRM,“ 14 11 2017. [Online]. Available: https://www.trenz-electronic.de/fileadmin/docs/Trenz_Electronic/Modules_and_Module_Carriers/4x5/TE0720/REV03/Documents/TRM-TE0720-03.pdf.

[3] Trenz Electronic, „TE0706 TRM,“ 13 06 2018. [Online]. Available: https://www.trenz-electronic.de/fileadmin/docs/Trenz_Electronic/Modules_and_Module_Carriers/4x5/4x5_Carriers/TE0706/REV02/Documents/TRM-TE0706-02.pdf.

[4] DIGILENT, „PmodRS232™ Reference Manual,“ 24 May 2016. [Online]. Available: https://reference.digilentinc.com/_media/reference/pmod/pmodrs232/pmodrs232_rm.pdf.

[5] IMA, „IMA Access Control Systems,“ [Online]. Available: https://www.ima.cz/products/access-control-systems/?lang=en.

[6] Wikipedia, „Hidden Markov model,“ [Online]. Available: https://en.wikipedia.org/wiki/Hidden_Markov_model. [01.11.2018].

[7] Wikipedia, „Viterbi Algorithm,“ [Online]. Available: https://en.wikipedia.org/wiki/Viterbi_algorithm. [01.11.2018].