

WillFA7

Williams MPU based on FPGA

Hardware version v1.3

Software Version x.20

user manual

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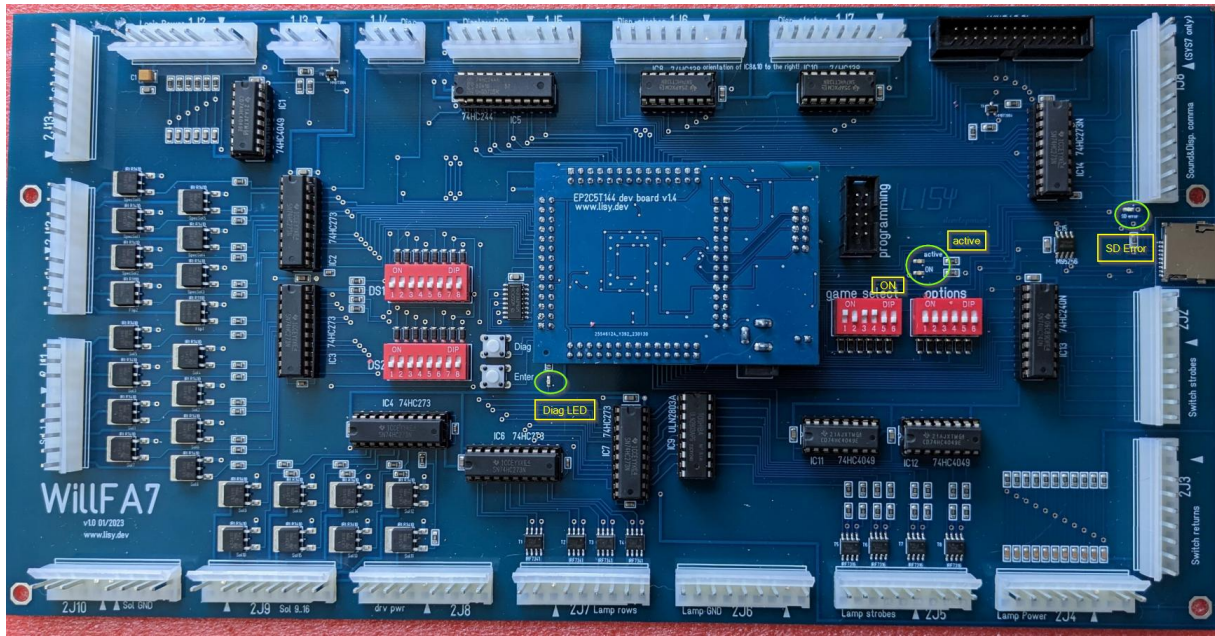
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Important remark

By using WillFA7 it is possible to damage your pinball machine. As this is a private project with NO commercial interest the author accepts no liability for any damage that may arise by using WillFA7!



1. Introduction

WillFA7 uses a (low cost) FPGA which emulates the hardware of a Williams MPU type SYS3 up to SYS7; the driverboard is integrated on the PCB.

Note: The games 'Defender' and 'Star Light' are not supported on the 'standard' Cyclone II board. To run them you need my Cyclone IV board. With the Cyclone IV board **all SYS3..SYS7 games** are supported.

What do you need?

- Possibility to read/write micro SD cards
- A PC with an USB port in order to be able to program the FPGA

2. Quickstart

1. Download latest versions of the SD card Image and the FPGA program from lisy.dev
2. Write the image to a SD card
3. Program the FPGA
4. Configure switch 'game select' according to your pinball (Appendix A)
5. Replace your original Williams MPU and Driverboard with WillFA7
6. On first boot with your game set option DIP1 to ON (init nvram)
 - a. Switch the game ON
 - b. Game will show Williams prom number, wait until 'Diag LED' goes off
 - c. Switch the game OFF
7. Switch the Game ON
8. Enjoy

3. Installation

WillFA7 boards have the same connectors and same mounting holes as the original Williams MPUs, so replacing of the board can be done in seconds. The board needs to be placed at the former location of the Williams driverboard.

4. Dip Switch Settings

4.1. DIP Switch S1: game select

Here you can select what game WillFA7 should run. This depends on the roms placed on the SD card. See Appendix A for a full list and Chapter 'SD card' for an explanation of the structure of the SD card content.

4.2. DIP Switch S2: options

Default setting is all 'OFF'

4.2.1. S2-Dip1 -> init nvram

With Dip1 to 'ON' WillFA7 during boot will initialize the nvram ram for the selected game to zero. This is useful if you want to reset ALL ram content **and for the very first boot with your game.**

4.2.2. S2-Dip2 & DIP3 pulse time

With DIP2 & DIP3 the pulse time for the special solenoids can be adjusted. By default (both OFF) the pulse time is 60ms which should fit the original gameplay. Possible settings are:

OFF – OFF	60ms
OFF – ON	50ms
ON – OFF	40ms
ON – ON	35ms

4.2.3. S2-Dip4 -> special solenoid debounce

The trigger inputs of the special solenoids are debounced inside the FPGA. With DIP4 to 'OFF' the filter is 57µs, with DIP4 to 'ON' it is 250µs. Default is 'OFF'.

4.2.4. S2-Dip5 -> switch matrix debounce

With DIP5 to 'ON' the returns of the switch matrix are debounced inside the FPGA. With DIP5 to 'OFF' they are passed through unfiltered, which is the behaviour of software x.17 and earlier. Default is 'OFF'.

4.2.5. S2-Dip6 no protection on spec. sol 6 (SOL 22)

Needed for game 'CONTACT' as spec. sol 6 needs to be permanently activated (moving target relay) pin 9 on 2P12

5. Boot sequence

5.1. Phase 1: boot message

Immediately after switching on the pinball the 'ON' Led will go on and you will see the following output on the display of your pinball machine

Player 1: version of the FPGA program running

Player 2: value of selected game on S1 (game select)

Player 3: lisy.dev unique identifier for FPGA based MPUs

Player 4: current boot phase

Credit Display: value of the option switches S2 (game options)

5.2. Phase 2: SD card read

WillFA7 tries to read the SD card content. If this fails the red LED 'SD card error' will go ON and '56' will be shown on display 4.

5.3. Phase 3: program execution

The code indicated by the Dip switch 'game select' is read from the SD card and executed. If the code runs (regular display strobes are present) the 'active' LED will go ON.

6. Game settings

In general game settings can be done in the same way as with the original MPU. WillFA7 uses a serial EEPROM to store the game settings individually per game. There are small differences due to the different board layout which are described below.

6.1. System3

WillFA7 has only one diagnostic LED, but does provide Data, Enter, Diagnostic and Function switches with the same functionality as with the original board. Refer to the picture below for the locations on the WillFA7 board. For settings have a look at the manual of your Williams pinball game.

Setting on SYS3 with WillFA7:

Do a 'fresh' boot (Turning OFF the machine and then turning it back ON)

Press the 'Diag' button on WillFA7, the LED nearby will blink twice

Determine which function is to be changed by looking at table 1 in your game Manual.

Set the Bottom switch to the function you want to change

(e.g. function 19 'Maximum Tilts' by setting Dip 4,7 & 8 to ON)

Set the Top switch to the value you want to store

(e.g. to 1 by setting DIP 8 to ON (default is 3))

To store the value press 'Enter', the LED nearby will blink to indicate the change has been made.

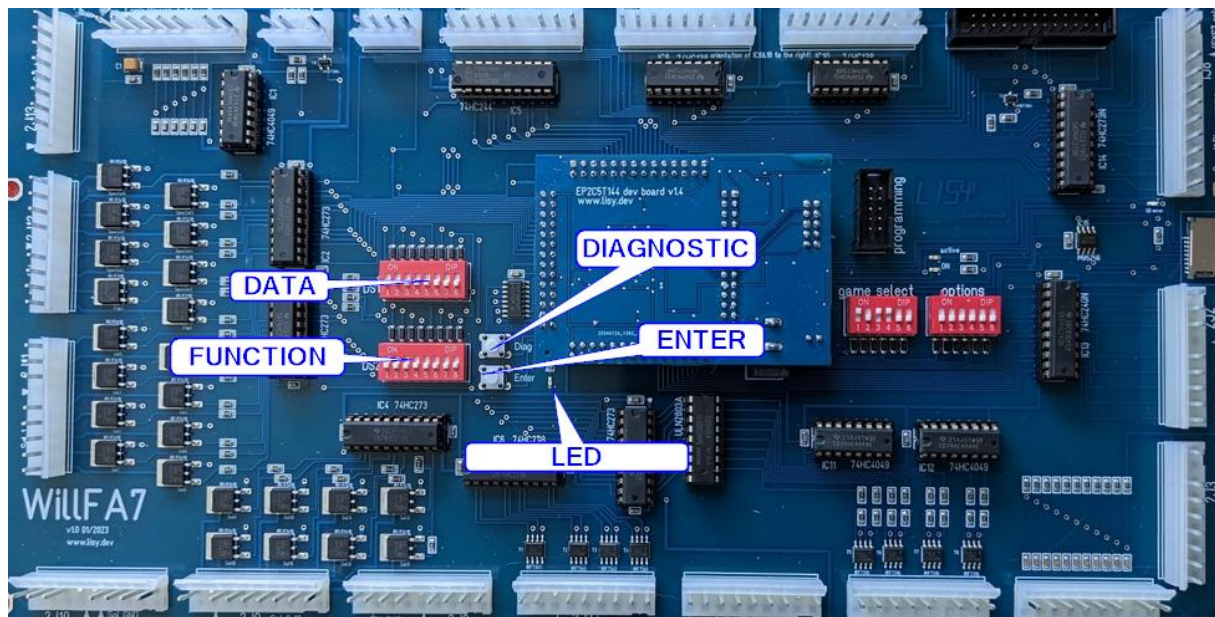
You can check the values by pressing 'Advance' in the coin door

The status display will show '1804' to indicate that you are in 'test 4' and can read

the value for 'Readout No.' 18 (High Score to date) in display for player 1

By pressing Advance again you step through the different Readouts.

After Readout 23 it starts again with Readout 1 (Replay 1). Have a look at your game Manual for a complete list!



6.2. System4

Settings for SYS4 games are made in the same way as with the original MPU, using the Data, Enter, Diagnostic and Function switches on the board. Refer to the picture in chapter 'system3' for their location.

6.3. System6

From SYS6 on, the settings are made through the coin door, with the Advance button and the Auto/Manual switch, exactly as described in the manual of your pinball game. WillFA7 passes both signals to the emulated MPU in the same way as the original board, so the procedure is unchanged.

6.4. System7

SYS7 games are set up through the coin door in the same way as SYS6, see above, following the manual of your pinball game.

7. Put the WillFA7 Image to the SD card

On my website you will find the latest version of WillFA7 as a (zipped) image file. After unpacking the image can be put on a SD card. I do recommend using Win32DiskImager for doing that.

This article uses content from the eLinux wiki page [RPi Easy SD Card Setup](#), which is shared under the [Creative Commons Attribution-ShareAlike 3.0 Unported license](#)

Win32DiskImager

- Insert the SD card into your SD card reader. You can use the SD card slot if you have one, or an SD adapter in a USB port. Note the drive letter assigned to the SD card. You can see the drive letter in the left hand column of Windows Explorer, for example **E:**
- Download the Win32DiskImager utility from the [Sourceforge Project page](#) as an installer file, and run it to install the software.
- Run the Win32DiskImager utility from your desktop or menu.
- Select the LISY image file you extracted earlier.
- In the device box, select the drive letter of the SD card. Be careful to select the correct drive: if you choose the wrong drive you could destroy the data on your computer's hard disk! If you are using an SD card slot in your computer, and can't see the drive in the Win32DiskImager window, try using an external SD adapter.
- Click 'Write' and wait for the write to complete.
- Exit the imager and eject the SD card.

8. Programming the FPGA

To program the FPGA you need the Quartus Programmer.

8.1. Programmer software

It can be downloaded from the Intel Website for free. You just need to create a user account.

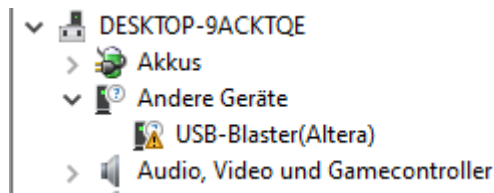
<https://fpgasoftware.intel.com/13.0sp1/?edition=web>

Go to Additional Software and Download **Quartus II Programmer and SignalTap II**

Note: Intel has discontinued support for Cyclone II by end of 2021 and will eventually remove version 13.0sp1 from the download section (the used FPGA for WillFA7 is quite old, and therefore cheap.) I have tested latest version (v21.4) which worked also, but I recommend to use 13.0sp1 if available.

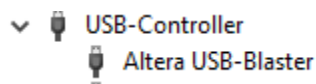
8.2. Install the driver for your USB Blaster

When connecting your USB Blaster the first time it will not be recognized correctly by Windows.



You also need to install the driver for your USB Blaster. The driver comes together with the installation of the programmer and is located in the 'driver' subdirectory.

- Right click on the entry in the device manager and choose 'update driver' (Treiber aktualisieren)
- Choose 'search for driver on this PC' (auf dem Computer nach Treibersoftware suchen)
- For a default installation select 'C:\altera\13.0sp1\qprogrammer\drivers'
- Confirm installation
- Now the Altera USB Blaster should be visible under 'USB controllers'

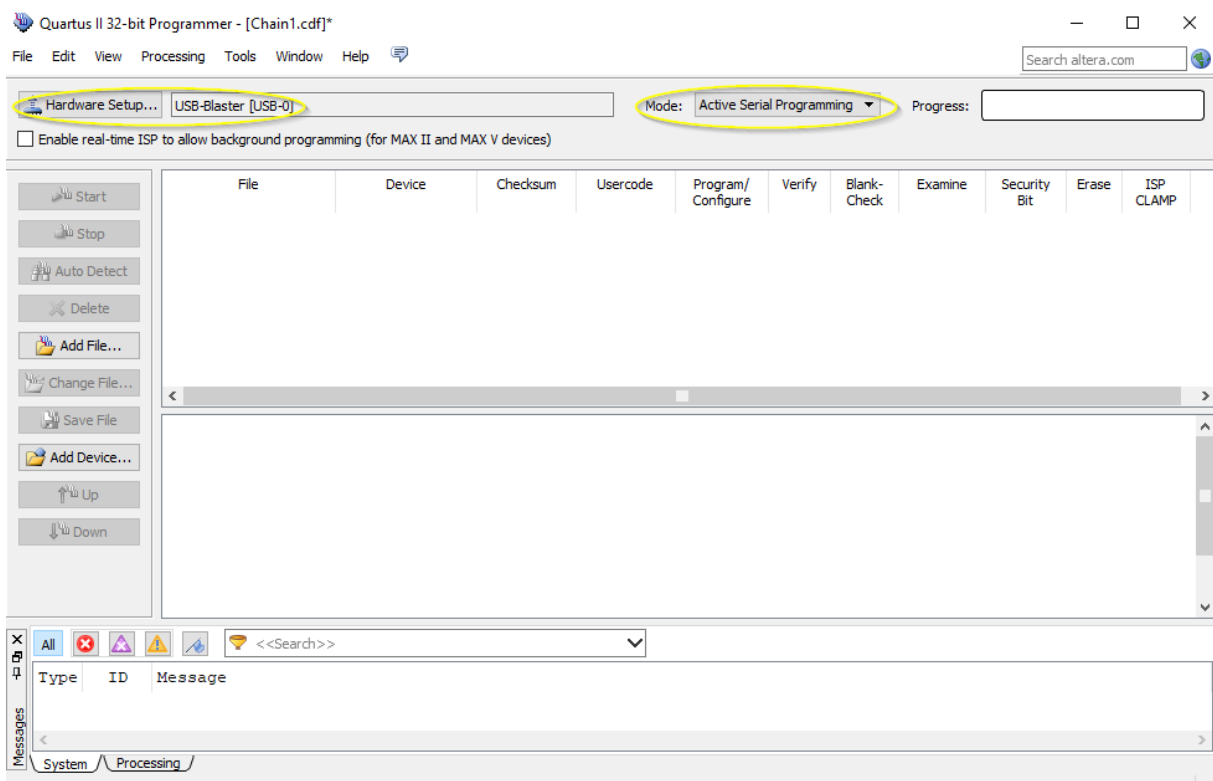


8.3. Program your FPGA

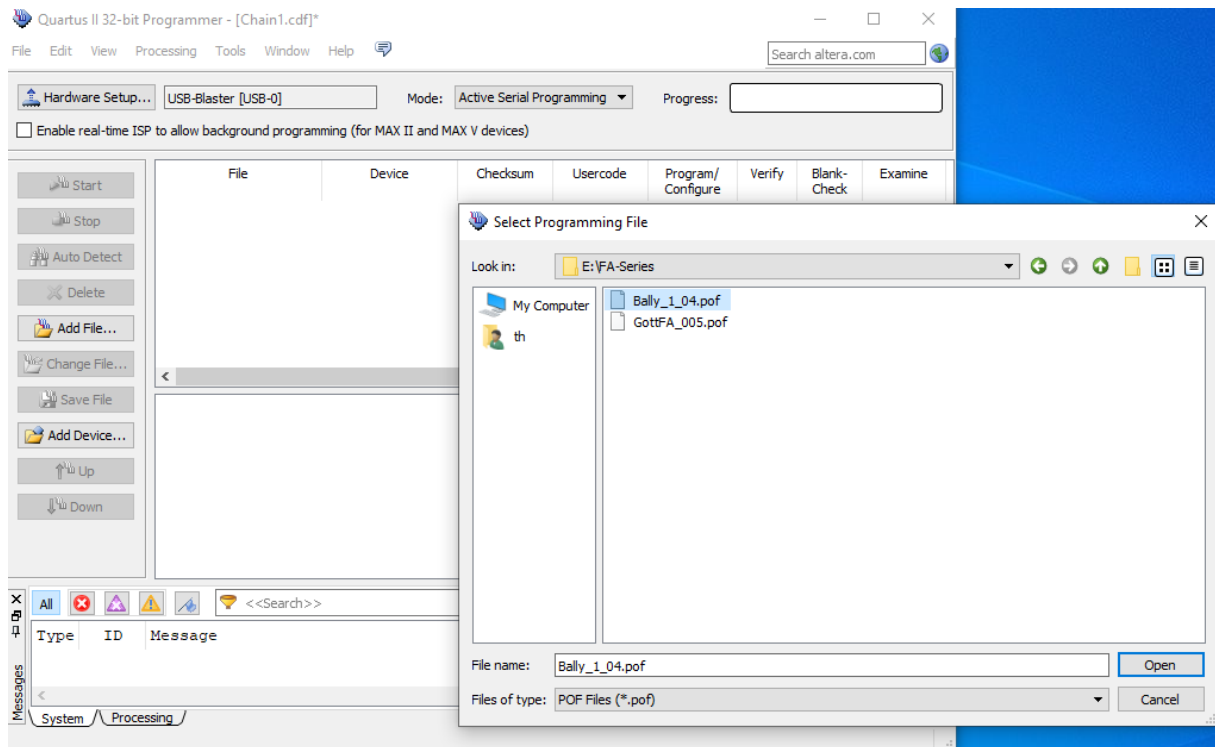
- 1) Connect the USB Blaster to the PC



- 2) Start the programmer, make sure in the Hardware setup 'USB-Blaster' is visible and set the Mode to 'Activeserial Programming'



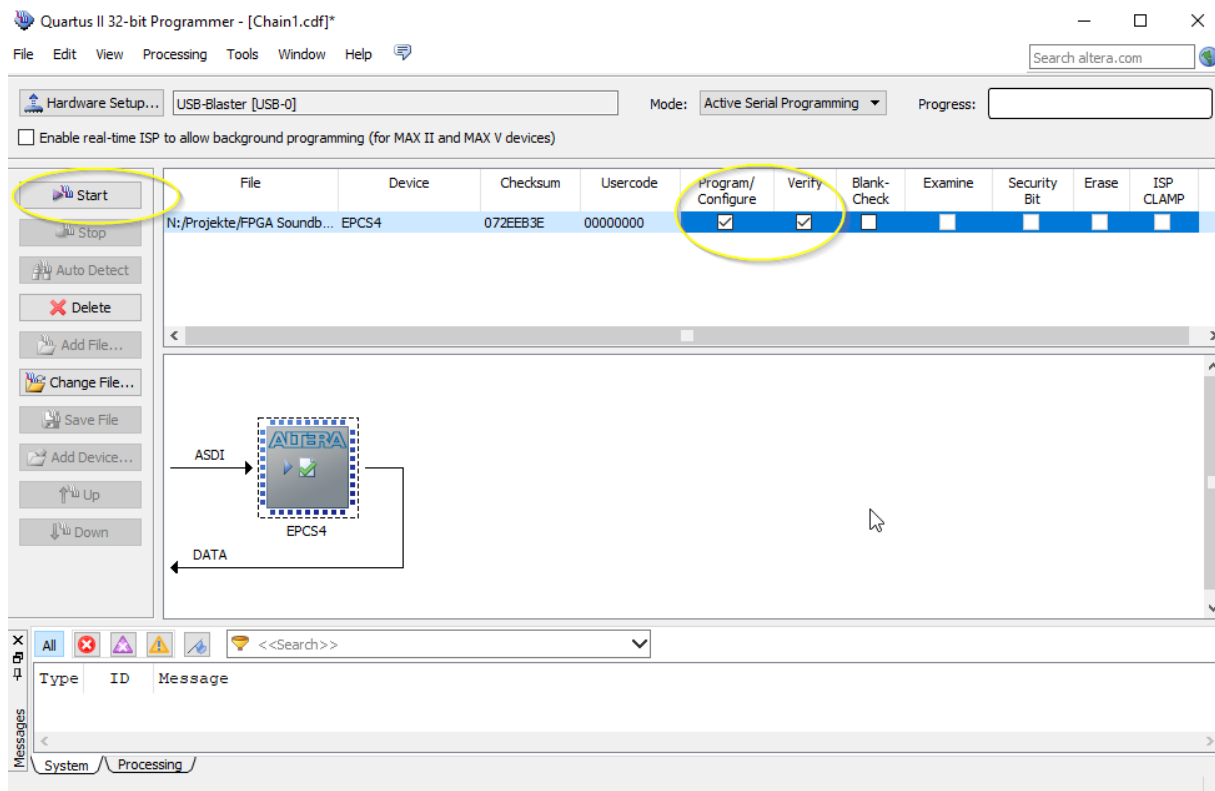
- 3) Select 'Add File' and choose the right 'pof' file for your game



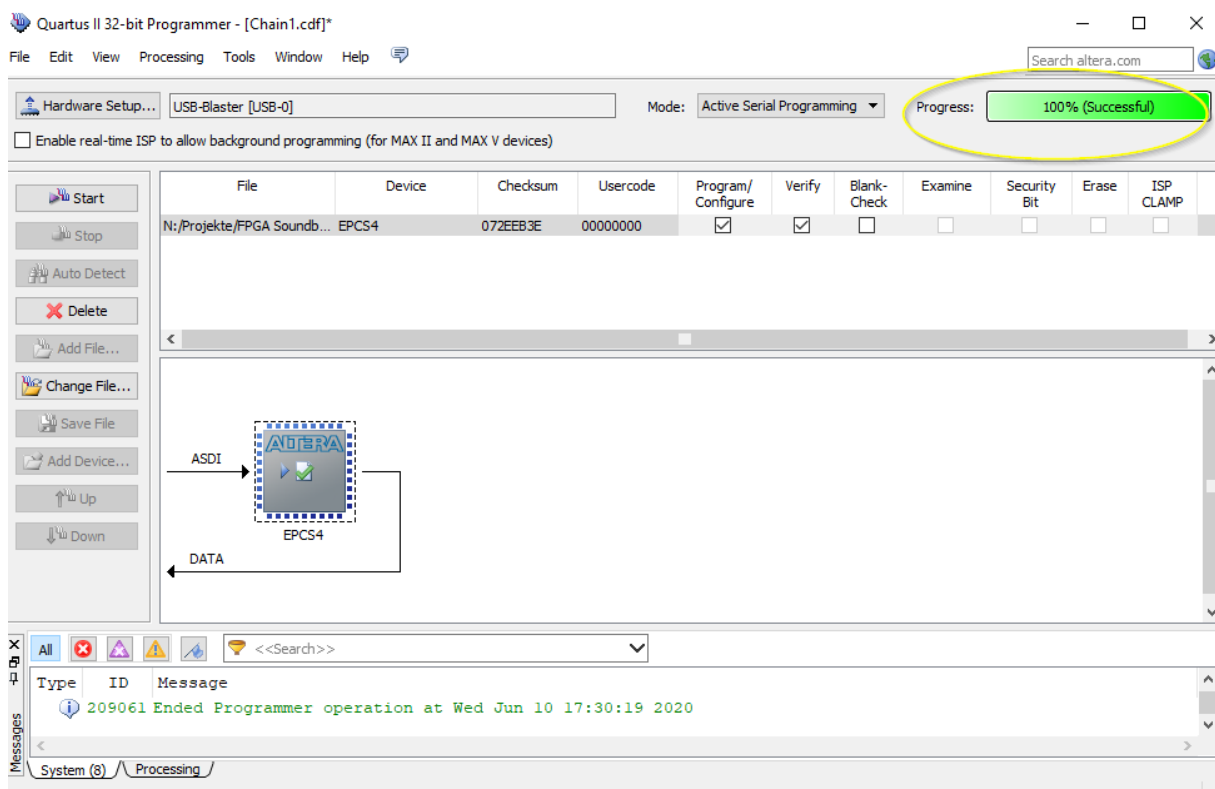
- 4) Power the FPGA with 5 Volt (middle pin '+', outer pin '-') and connect the USB Blaster to the 'AS programming' connector on the WillFA7 PCB



- 5) Select 'Program/Configure' and 'Verify'



6) Push start, wait for progress 100%



That's it!

9. Structure of SD card

Due to limitations of the SD card read routine in the FPGA (it does read fix sector numbers instead of looking for filenames) it is necessary to use my SD-card image (128 Mbyte). You can write the image to a SD-card of your choice.

With game select all '0' WillFA7 will try to read the first rom image at sector number 660. With my 128MB WillFA7 image this is the location of the first file you write to an empty SD card.

9.1. WillFA7 image

My WillFA7 SD card image has almost all available roms 'on board'. See appendix A for a gamelist

9.2. Use your own roms

The SD card image holds one slot per game number, so a rom set can be exchanged without changing the FPGA program.

Every slot is 24 sectors of 512 bytes, that is 12 KByte, and the first slot starts at sector 660. The slot of a game therefore starts at sector $660 + \text{game number} \times 24$, with the game number being the value set on switch S1 (see Appendix A).

Write your rom set to that position with a sector editor. It is read as one block and has to be complete: boards with Cyclone IV or Cyclone 10 read 12 KByte, which the MPU sees from \$5000 on, boards with Cyclone II read 10 KByte, which the MPU sees from \$5800 on.

Appendix A 'game select'

No	S1	S2	S3	S4	S5	S6	type	Name
0	off	off	off	off	off	off	SYS3	Hot Tip
1	on	off	off	off	off	off	SYS3	Lucky Seven
2	off	on	off	off	off	off	SYS3	World Cup
3	on	on	off	off	off	off	SYS3	Contact
4	off	off	on	off	off	off	SYS3	Disco Fever
5	on	off	on	off	off	off	SYS4	Pokerino
6	off	on	on	off	off	off	SYS4	Phoenix
7	on	on	on	off	off	off	SYS4	Flash
8	off	off	off	on	off	off	SYS4	Stellar Wars
9	on	off	off	on	off	off	SYS6	Tri Zone
10	off	on	off	on	off	off	SYS6	Time Warp
11	on	on	off	on	off	off	SYS6	Gorgar
12	off	off	on	on	off	off	SYS6	Laser Ball
13	on	off	on	on	off	off	SYS6	Firepower
14	off	on	on	on	off	off	SYS6	Blackout
15	on	on	on	on	off	off	SYS6	Scorpion
16	off	off	off	off	on	off	SYS6A	Algar
17	on	off	off	off	on	off	SYS6A	Alien Poker
18	off	on	off	off	on	off	SYS7	Black Knight
19	on	on	off	off	on	off	SYS7	Jungle Lord
20	off	off	on	off	on	off	SYS7	Pharaoh
21	on	off	on	off	on	off	SYS7	Solar Fire
22	off	on	on	off	on	off	SYS7	Barracora
23	on	on	on	off	on	off	SYS7	Cosmic Gunfight
24	off	off	off	on	on	off	SYS7	Varkon
25	on	off	off	on	on	off	SYS7	Warlok
26	off	on	off	on	on	off	SYS7	Time Fantasy
27	on	on	off	on	on	off	SYS7	Joust
28	off	off	on	on	on	off	SYS7	Firepower II
29	on	off	on	on	on	off	SYS7	Laser Cue
30	off	on	on	on	on	off	SYS7	Defender *
31	on	on	on	on	on	off	SYS7	Star Light *

(*) Cyclone IV board & SD image needed