Jelly

Ryuz(https://github.com/ryuz/)

Jun 21, 2022

Contents:

CHAPTER 1

Overview

1.1 ãĄŕãĄŸãĆĄãĄń

Jelly ãĄĺãĄŕãĂĄFPGAäÿŁãĄńãĄęãČłãĆćãČńãĆ£ãĆd'ãČăãĆşãČşãČŤãČěãČijãČĘãĆčãČşãĆřãĆŠèąŇãĄęçĆžãĄőãČŮãČl'ãČČãČĹãČ

ãĆĆãĄĺãĆĆãĄĺãĄŕFPGAåŘŚãĄŚãĄő MIPS-I ãČl'ãĆd'ãĆŕãĄłåŚ¡äżd'ãĆżãČČãČĹãĄőãĆşãĆćãĆŠæIJL'ãĄŮãĄ§ãĆ¡ãČŢãČĹãĆşãĆćãČ
time OS ãĆŠåŃŢãĄŃãĄŹãĄŞãĄĺãĄŃãĆL'ãĆźãĆ£ãČijãČĹãĄŮãĄ§ãČŮãČ■ãĆÿãĆğãĆŕãČĹãĄğãĄŹãĄŃãĂĄæŸĺäżŁãĄğãĄŕXILINX
åŘřéä■ãĄŮãĄęãĄ■ãĄ§ãĄ§ãĆĄãĂĄãĆĹãĆŁæ§Ťèż§ãĄńRTLãČ■ãĆÿãČČãĆŕèşĞçŤč(Verilog)ãĄĺãĂĄCPUèşĞçŤč(C/C++/PythonãĄł

FPGAãĄĺèĺĂãĄĎãĄd'ãĄd'ãĄŃãĄłãĆŁ Xilinx åřĆçŤĺãĄńãĄłãĄčãĄęãĄĎãĆŃçĆźãĄŕãĄŤåőźèţęãĄŘãĄäãĄŢãĄĎãĂĆRTLèĞłä¡ŞãĄŕ

1.2 æğŃæĹŘ

1.2.1 ãČĹãČČãČŮãČĞãĆčãČňãĆŕãČĹãČł

1.2.2 rtl ãČĞãĆčãČňãĆŕãČĹãČł

1.2.3 project ãČĞãĆčãČňãĆŕãČĹãČł

ãĄİãĄőäżŰæIJłæŢť åĆŹãĄőãČŮãČ■ãĆÿãĆğãĆŕãČĹåŘĎçĺő

1.3 Real-time OS ãĄńãĄďãĄĎãĄę

æŃŹä¡IJãĄő HOS-V4a ãĄńãĄęãĂĄäÿŁèÍŸãĄő MPISäžŠæŘŻãĆşãĆćãĂĄMicroBlazeãĂĄCortex-R5 ãĄłãĄľãĄńåŕ¿å£IJäÿ■ãĄğãĄŹãĂĆ

1.4 Real-time Neural Network ãĄńãĄďãĄĎãĄę

å¿őåĹęåŘŕèČ¡åŻđèůŕèÍŸè£řãĄńå§žãĄěãĄŘLUT çŻťæŐěå■ęç£ŠãĄńãĆĹãĆŃæůśåśďå■ęç£ŠãČćãČĞãČń(LUT-Network)çŤÍãĄőå■ęç£ŠçŠřåćČãĄÍãĄŮãĄęéŰŃçŹžäÿ■ãĄőBinaryBrainãĆĆJellyãĄőçŤżåČŘåĞęçŘĘãĆşãČşãČÍãČijãČ■ãČşãČĹãĆŠçŤ AXI4-Stream ãĄłãĄőãĄğæśŐçŤÍçŽĎãĄğãĄŹ)ãĂĆ

ãČąãČćãČłãĆŠäżŃãĄŢãĄŽãĄńãČłãĆćãČńãĆ£ãĆďãČăãĄńæŐÍèńŰçţŘæđIJãĄŇåĞžåŁŻåŘŕèČ¡ãĄğãĄĆãĆŁãĂĄæIJňãČŮãČľãČČãČ

1.5 JellyãĆŠä¡£ãĄčãĄ§ãĆůãĆźãČĘãČăãĄőãČĞãČćåŃŢçŤż

- Real-Time Deep Neural Network
- Real-Time GPU
- IMX219 1000fps
- IMX219+OLED

CHAPTER 2

DMA

2.1 jelly_buffer_manager

DMAãĄłãĄl'ãĄńèĞłåŃŢãĄğåL'šãĆŁå¡ŞãĄęãĆŃãČŘãČČãČŢãĆąãĆŠçőąçŘĘãĄŹãĆŃãĆşãĆć

2.2 jelly_buffer_allocator

jelly_buffer_manager ãĄŃãĆL'ãĆ¡ãČŢãČĹãĆęãĆğãĆćãĄŇãČŘãČČãČŢãĆąåL'šãĆŁå¡ŞãĄęãĆŠåŘŮãĄŚãĆŃåăť'åŘĹãĄőãĆd'ãČşãĆ£ã

2.3 jelly_dma_stream_write

2.3.1 æęĆèęĄ

NæňąåĚČæğŃéĂăãĄő Stream ãĄŃãĆL' AXI4 ãČąãĆćãČłãČŘãĆźãĄÿãĄĺãĄŮãĄęæŻÿãĄ■è¿ijãĄ£ãĆŠèąŇãĄĘãĂĆ
æŻÿãĄ■è¿ijãĄ£åĚĹãĄőãČŘãČČãČŢãĆąåĹűå¿ąãĄĺãĂĄãČĞãČijãĆ£ãĄőæŻÿãĄ■è¿ijãĄ£åĄť'ãĄĺãĆŠçŃňçńŃæĂğéńŸãĄŘæL'śãĄĐãĄ

åĘĚéČĺãĄńFIFOãČŘãČČãČŢãĆąãĆŠæIJL'ãĄŮãĄęãĄŁãĆŁãĂĄãČŘãČČãČŢãĆąãĄńæžŰåĆŹãĄğãĄ■ãĄ§ãĆţãĆd'ãĆžåĹĘãĄőãĄ£äÿ

CPUãĄŃãĆL'ãĄőãČňãĆÿãĆźãĆ£çŁűæĚŃåď'L'åŇŰãĆĎåL'šãĆŁè¿ijãĄ£ãĄŕãĂĄåĘĚéČĺFIFOãĄőæőŃéĞŘãĄńçĎąéŰćä£ĆãĄńAXI4ã

NæňąåĚČæğŃéĂăãĆŠåŘĎæňąåĚČãĄő first ãĄĺ last ãĄğèąĺãĄŹãĂĆçL'źãĄń last ãĆŠåĹl'çŤĺãĄŮãĄę
äÿ■èűşãČĞãČijãĆ£ãĆŠãČŠãČĞãĆčãČşãĆřãĄŮãĄ§ãĆŁãĂĄä¡ŹåĹĘãČĞãČijãĆ£ãĆŠãĆńãČČãČĹãĄŮãĄ§ãĆŁãĄğãĄ■ãĆŃãĂĆãĄ¿ãĄ
DMA éĬđåŃŢä¡IJæŹĆãĄń Streama ãĄő ready ãĆŠãĆćãĆţãČijãČĹãĄŮãĄęãĂĄãČĞãČijãĆ£ãĆŠãĆźãĆ■ãČČãČŮãĄŹãĆŃæl'§èČ¡ãĄŃ

2.3.2 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČL'ãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČL'ãĆćãČL'ãČňãĆźãĄĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂd'ãĄŕ parameter æŇĞåőŽãĄgåd'L'æŻt'åŘŕèČ¡ãĂĆ

2.3.3 åŃŢä¡IJèłňæŸŐ

CTL_CONTROL ãĄő bit0 ãĄŇ1ãĄőæŹĆãĄńNæňąåĚČæğŃéĂããĄőãČĞãČijãĆ£ãĄőèł■åĞžãĄŮãĆŠèąŇãĄĎãĂĄåŘĎæňąåĚČãĄőåĚ

CTL_CONTROL ãĄő bit2 ãĄń1ãĆŠçńŃãĄęãĄłãĄĎéŹŘãĆŁãĄŕãĂĄçźŕãĆŁè£ŤãĄŮåŘŇãĄŸåŃŢä¡IJãĆŠèąŇãĄęãĂĆCTL_CONTRO
ãĄő bit2 ãĄń1ãĆŠçńŃãĄęãĄ§åăť'åŘĹãĄŕæňąåŻđèżćéĂĄåőŇäžęãĄğãĂĄbit0ãĄŕèĞłåŃŢãĆŕãČłãĆćãĄŢãĆŃãĄęåĄIJæ■ćãĄŹãĆŃãĂ

CTL_CONTROL ãĄő bit1 ãĆŠçńŃãĄęãĆŃãĄĺ 1ãĄőæŹĆãĄŕçźŕãĆŁè£ŤãĄŮãĄőãĆ£ãĆd'ãČ§ãČşãĆŕãĄğãČŚãČľãČąãČijãĆ£ãĄőãĄ£ã
CTL_CONTROL ãĄő bit1 ãĄŕèĞłåŃŢãĆŕãČłãĆćãĄŢãĆŃãĆŃãĂĆ åĚĚéČĺçŽĎãĄńãĆůãČčãČL'ãČijãČňãĆÿãĆźãĆ£ãĆŠæIJL'ãĄŮãĄęã

åL'šãĆŁè¿ijãĄ£ãĄŕãĂĄ1åŻđãĄőèżćéĂĄãĄŇçţĆãĆŘãĆŃæŕŐãĄńçŹžçŤ§ãĄŹãĆŃãĂĆãČŚãČľãČąãČijãĆ£ãĄőæŻt'æŰŕäžĹçť'ĎãĆŠã

2.3.4 parameter èĺ■åőŽ

ãČĞãČŢãĆľãČňãČĹåĂd'ãĄŃãĆL'åd'L'æŻt'ãĄŹãĆŃå£ĚèęĄãĄőãĄĆãĆŃåŘŕèČ¡æĂğãĄőãĄĆãĆŃãĆĆãĄőãĄäãĄŚèĺŸèijL'ãĄŹãĆŃã

2.3.5 ãČİãČijãČĹäżŢæğŸ

æIJňãČćãĆÿãČěãČijãČňãĄőãČĺãČijãČĹãĄőåŘĎä£ąåŘůãĄŕäżěäÿŃãĄőéĂŽãĆŁãĂĆ

endian ãĄŕ åŃŢçŽĎãĄńåd'L'æŻt'ãĄŹãĆŃãĄŞãĄĺãĄŕæČşåőŽãĄŮãĄęãĄĎãĄłãĄĎãĄőãĄğæşĺæĎŘãĂĆãČŘãĆźåźĚåd'L'æŘŻãĄŃä¡IJ

2.4 jelly_dma_stream_read

2.4.1 æęĆèęĄ

(ãĄ¿ãĄäãČĞãČŘãČČãĆŕäÿ■ãĂĄwriteãĆĆãĆżãČČãČĹãĄğéŰŃçŹžäÿ■)

AXI4 ãČąãČćãČłãČŘãĆźãĄŃãĆL'NæňąåĚČèł■ãĄ£åĞžãĄŮãĄę Stream ãĆŠåĞžåŁŻãĄŹãĆŃãĂĆ
èł■åĞžãĄŮåĚĹãĄőãČŘãČČãČŢãĆąåĹűå¿ąãĄĺãĂĄèł■åĞžãĄŮãČĞãČijãĆ£ãĄőåĹl'çŤĺåĄt'ãĄĺãĆŠçŃňçńŃæĂğéńŸãĄŘæL'śãĄĎãĄd

åĚĚéČĺãĄńFIFOãČŘãČČãČŢãĆąãĆŠæIJL'ãĄŮãĄęãĄŁãĆŁãĂĄãČŘãČČãČŢãĆąæžćãĆŃãĄŮãĄłãĄĎåĹĚéĞŘãĄőãĄ£ãĆŠèł■ãĄ£åĞ

CPUãĄŃãĆL'ãĄőãČňãĆÿãĆźãĆ£çŁűæĚŃåd'L'åŃŰãĆĎåL'šãĆŁè¿ijãĄ£ãĄŕãĂĄåĚĚéČĺFIFOãĄőæőŃéĞŘãĄńçĎąéŰćä£ĆãĄńAXI4ã
(ãČĞãČijãĆ£ãĄőåőŃäžęãĆŠç§ěãĆŁãĄ§ãĄĎåăť'åŘĹãĄŕãĂĄãČĞãČijãĆ£ãĆŠåĹl'çŤĺãĄŹãĆŃåĄt'ãĄőãĆşãĆćãĄŃãĆL'åőŃäžęåL'šãĆ

2.4.2 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČL'ãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČL'ãĆćãČL'ãČňãĆźãĄĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂd'ãĄŕ parameter æŇĞåőŽãĄgåd'L'æŻt'åŘŕèČ¡ãĂĆ

2.4.3 åŃŢä¡IJèłňæŸŐ

CTL_CONTROL ãĄő bit0 ãĄŃ1ãĄőæŹĆãĄńNæňąåĚČæğŃéĂäãĄőãČĞãČijãĆ£ãĄőèł■åĞžãĄŮãĆŠèąŃãĄĎãĂąåŘĎæňąåĚČãĄőåĚ

CTL_CONTROL ãĄő bit2 ãĄń1ãĆŠçńŃãĄęãĄłãĄĎéŹŘãĆŁãĄŕãĂĄçźŕãĆŁè£ŤãĄŮåŘŃãĄŸåŃŢä¡IJãĆŠèąŃãĄęãĂĆCTL_CONTRO
ãĄő bit2 ãĄń1ãĆŠçńŃãĄęãĄ§åăť åŘĹãĄŕæňąåŻđèżćéĂĄåőŇäžĘãĄğãĂĄbit0ãĄŕèĞłåŃŢãĆŕãČłãĆćãĄŢãĆŃãĄęåĄIJæ■ćãĄŹãĆŃãĂć

CTL_CONTROL ãĄő bit1 ãĆŠçńŃãĄęãĆŃãĄĺ 1ãĄőæŹĆãĄŕçźŕãĆŁè£ŤãĄŮãĄőãĆ£ãĆď ãČ§ãČşãĆřãĄğãČŚãČľ ãČąãČijãĆ£ãĄőãĄ£ã
CTL_CONTROL ãĄő bit1 ãĄŕèĞłåŃŢãĆŕãČłãĆćãĄŢãĆŃãĆŃãĂĆ åĘĚéČĺçŽĎãĄńãĆůãČčãČĽ ãČijãČňãĆÿãĆźãĆ£ãĆŚæIJĽ ãĄŮãĄę

åĽ šãĆŁè¿ijãĄ£ãĄŕãĂĄ1åŻđãĄőèżćéĂĄãĄŃçţĆãĆŘãĆŃæŕŐãĄńçŹžçŤ§ãĄŹãĆŃãĂĆãČŚãČľ ãČąãČijãĆ£ãĄőæŻť æŰřäžĹçť ĎãĆŚã

2.4.4 parameter èĺ■åőŽ

ãČĞãČŢãĆľ ãČńãČĹåĂď ãĄŃãĆĽ åď Ľ æŻť ãĄŹãĆŃå£ĚèęĄãĄőãĄĆãĆŃåŘŕèČ¡æĂğãĄőãĄĆãĆŃãĆĆãĄőãĄăãĄŚèĺŸèijĽ ãĄŹãĆŃã

2.4.5 ãČİãČijãČĹäżŢæğŸ

æIJňãČćãĆÿãČěãČijãČńãĄőãČİãČijãČĹãĄőåŘĎä£ąåŘůãĄŕäžěäÿŃãĄőéĂŽãĆŁãĂĆ

endian ãĄŕ åŃŢçŽĎãĄńåď Ľ æŻť ãĄŹãĆŃãĄŞãĄĺãĄŕæČşåőŽãĄŮãĄęãĄĎãĄłãĄĎãĄőãĄğæşĺæĎŘãĂĆãČŘãĆźåźĚåď Ľ æŘŻãĄŃä¡IJ

2.5 jelly_dma_fifo

åď ŰéČĺãČąãĆćãČłãĆŠåĹľçŤĺãĄŮãĄ§åď ğãĆţãĆď ãĆžãĄőFIFOãĆŠæğŃæĹŘãĄŹãĆŃ

2.5.1 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČĽ ãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČĽ ãĆćãČĽ ãČňãĆźãĂĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂď ãĄŕ parameter æŃĞåőŽãĄğåď Ľ æŻť åŘŕèČ¡ãĂĆ

å§žæIJňçŽĎãĄńãČąãĆćãČłãĆŠåĽ šãĆŁå¡ŞãĄęãĄęãĄŮãĄ¿ãĄĹãĄřãĂĄãĆźãČĹãČłãČijãČäãČĞãČijãĆ£ãĄńåŕ¿ãĄŮãĄęåůĺåď ğãĄłFIF
ãĄ§ãĄäãĄŮãĂĄãČąãĆćãČłãČŘãĆźåźĚãĄŃãĆźãČĹãČłãČijãČäãČŘãĆźåźĚãĆĹãĆŁåď ğãĄ■ãĄĎåăť åŘĹãĂĄãČŘãĆźåźĚåĹĘãĄőãČ

ãČąãĆćãČłèł■ãĄ£æŻÿãĄ■ãĄőäÿąçńŕãĄğãĆşãĆćåĚĚãĄńãĆĆåřŘãĄŢãĄłFIFOãĆŠæŃĄãĄčãĄęãĄłãĆŁãĂĄãČĞãČijãĆ£ãĄőæŘČãĄ

ãČňãĆÿãĆźãĆ£ãĄńãĄŕãĆ£ãĆď ãČäãĆćãĆęãČĹãČňãĆÿãĆźãĆ£ãĆŚçŤĺæĎŘãĄŮãĄęãĄłãĆŁãĂĄãČĞãČijãĆ£ãĆĎçľ žãĄ■ãĄŃ
awlen/wrlen ãĄőãĆţãĆď ãĆžæŘČãĆŘãĄłãĄŘãĄęãĆĆãĆ£ãĆď ãČäãĆćãĆęãČĹãĄŹãĆŃãĄŕèżćéĂĄãĆŠèąŃãĄęãĂĆãĆ£ãĆď ãČäãĆćã

2.6 jelly_dma_video_write

AXI4 Stream Video æŻÿãĄ■è¿ijãĄ£çŤĺãĄőDMA jelly_dma_stream_write ãĄő N=3
ãĄőãČľ ãČČãČŚãČijãĄĺãĄŮãĄęåő§èčĚãĄŢãĆŃãĄęãĄĎãĆŃ

2.6.1 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČL'ãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČL'ãĆćãČL'ãČňãĆźãĂĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂď'ãĄŕ parameter æŃĞåőŽãĄğåď'L'æŻť'åŘŕèČ¡ãĂĆ

2.7 jelly_dma_video_read

AXI4 Stream Video è■ãĄ£åĞžãĄŮçŤĺãĄőDMA

CHAPTER 3

Video éŰćéĂč

/rtl/video äżěäÿŃãĄńãĄĆãĆŃãČćãĆÿãČěãČijãČń

3.1 jelly_video_parameter_update

3.1.1 æęĆèęĄ

frame start ãĆŠæď IJåĞžãĄŮãĄęãČŚãČľãČąãČijãĆ£æŻť æŰřä£ąåŘůãĆŠåĞžãĄŹ

3.1.2 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČL'ãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČL'ãĆćãČL'ãČňãĆźãĂĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂď ãĄŕ parameter æŇĞåőŽãĄğåď L'æŻť åŘŕèČ¡ãĂĆ

3.1.3 åŃŢä¡IJèłňæŸŐ

åŘĎçŤżåČŘåĞęçŘĘãĆşãĆćãĄğåĞęçŘĘéĂŤäÿ■ãĄńãČŚãČľãČąãČijãĆ£ãĄŇåď L'åŇŰãĄŹãĆŃãĄĺäÿ■æŢť åŘĹãĆŠèţůãĄŞãĄŹãĆśãČ
æIJňãĆşãĆćãĄŕãĂĄãĄŢãĆL'ãĄńçŤżåČŘåĞęçŘĘãĆşãĆćéŰŞãĄğäÿ■æŢť åŘĹãĆŠèţůãĄŞãĄŢãĄłãĄĎãĄ§ãĆĄãĄńãĂĄå¿ŇçűŽãĆşãĆć

3.2 jelly_video_format_regularizer

3.2.1 æęĆèęĄ

AXI4-Stream Video ãĆŠæŇĞåőŽãČŢãĆľãČijãČđãČČãČĹãĄńæ■čèęŔåŇŰãĄŹãĆŃ

3.2.2 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČĽãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČĽãĆćãČĽãČňãĆźãĂĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂď'ãĄŕ parameter æŇĞåőŽãĄğåď'Ľ'æŻť'åŔŕèČ¡ãĂĆ

3.2.3 åŃŢä¡IJèłňæŸŐ

äÿżãĄńçŤżåČŔåĚěåŁŻãČĞãČŘãĆď'ãĆźãĄőçłĄçĎűãĄőåĹĞæŰ■ãĆĎãČĞãČijãĆ£æňăãĄŚãĂĄãČŢãĆľãČijãČđãČČãČĹäÿ■äÿĂèĞť'ã

3.3 jelly_vin_axi4s

ãČŞãČĞãĆłåĚěåŁŻãĆŠ AXI4 Stream video ãĄńåď'Ľ'æŔŻ

3.4 jelly_vout_axi4s

AXI4 Stream video ãĆŠãČŞãČĞãĆłåĞžåŁŻãĄńåď'Ľ'æŔŻ

3.5 jelly_vsync_generator

ãČŞãČĞãĆłåĞžåŁŻçŤĺãĄőåŘŇæIJ§ä£ąåŔůçŤ§æĹŘ

3.6 jelly_dvi_tx

DVIåĞžåŁŻãĆşãĆć

3.7 jelly_mipi_csi2_rx

MIPI-CSI2 ãĄőåŔŮä£ąãĆşãĆć

3.8 jelly_hdmi_rx

HDMI åŘŮä£ąãĆşãĆć

3.9 jelly_vdma_axi4s_to_axi4

Video write DMA(AXI4-Stream to AXI4)

3.9.1 æęĆèęĄ

AXI4-Stream Video ãĆŠ AXI4 ãČąãČćãČłãČŘãĆźãĄńæŻÿãĄ■è¿ijãĄ£èżćéĂĄãĆŠèąÑãĄĘ

3.9.2 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČL'ãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČL'ãĆćãČL'ãČňãĆźãĂĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂd'ãĄŕ parameter æŃĞåőŽãĄğåd'L'æŻť'åŘŕèČ¡ãĂĆ

3.9.3 åŃŢä¡IJèłňæŸŐ

CTL_CONTROL ãĄő bit0 ãĄÑ1ãĄőæŹĆãĄńçŤżåČŘãČĞãČijãĆ£ãĄŇæİěãĆÑãĄÍèżćéĂĄãĆŠèąÑãĄĘãĂĆCTL_CONTROL
ãĄő bit2 ãĄÑ1ãĄőåăť'åŘĹãĄŕãĂĄPARAM_SIZE åĹĘèżćéĂĄãĄŹãĆÑãĄÍåĄIJæ■ćãĄŹãĆŃ(bit0ãĄŕèĞłåŃŢãĆŕãČłãĆć)ãĂĆ
ãĄİãĄĘãĄğãĄłãĄĐåăť'åŘĹãĄŕçŤżåČŘãĄŇæİěãĆÑãĄ§ãĄşãĄńçźřãĆŁè£ŤãĄŮèżćéĂĄãĆŠèąÑãĄĘãĂĆ
CTL_CONTROL ãĄő bit1 ãĄÑ1ãĄőæŹĆãĄŕèżćéĂĄéŰŃåğÑãĆĎçźřãĆŁè£ŤãĄŮãĄőãĆ£ãĆd'ãČ§ãČşãĆřãĄğãČŠãČl'ãČąãČijãĆ£ãĄ

PARAM_SIZE ãĄŕ PARAM_WIDTHÃŮPARAM_HEIGHT ãĄőåĂ■æŢřãĄğãĄĆãĆÑå£ĚèęĄãĄÑãĄĆãĆÑãĄÑãĂĄèÍ■åőŽæňąçňňãĄ

3.10 jelly_vdma_axi4_to_axi4s

Video read DMA(AXI4 to AXI4-Stream)

3.10.1 æęĆèęĄ

AXI4 ãČąãČćãČłãČŘãĆźãĄÑãĆL'èł■ãĄ£åĞžãĄŮãĄę AXI4-Stream Video ãĆŠåĞžåŁŻ

3.10.2 ãČňãĆÿãĆźãĆ£äżŢæğŸ

ãĆćãČL'ãČňãĆźãĄŕWISHBONEãĄőãČŕãČijãČL'ãĆćãČL'ãČňãĆźãĂĆ ãČňãĆÿãĆźãĆ£åźĚãĆĎåĹİæIJ§åĂd'ãĄŕ parameter æŃĞåőŽãĄğåd'L'æŻť'åŘŕèČ¡ãĂĆ

3.10.3 åŃŢä¡IJèłňæŸŐ

CTL_CONTROL ãĄő bit0 ãĄŇ1ãĄőæŹĆãĄńçŤżåČŔãČĞãČijãĆ£ãĄőèł■åĞžãĄŮãĆŠèąŇãĄĘãĂĆCTL_CONTROL
ãĄő bit2 ãĄŇ1ãĄőåăť åŘĹãĄŕãĂĄPARAM_SIZEåĹĘèżćéĂĄãĄŹãĆŃãĄĺåĄIJæ■ćãĄŹãĆŃ(bit0ãĄŕèĞłåŃŢãĆŕãČłãĆć)ãĂĆ
ãĄİãĄĘãĄğãĄłãĄĎåăť åŘĹãĄŕçŤżåČŔãĄŇæİěãĆŃãĄ§ãĄşãĄńçźřãĆŁè£ŤãĄŮèżćéĂĄãĆŠèąŇãĄĘãĂĆ
CTL_CONTROL ãĄő bit1 ãĄŇ1ãĄőæŹĆãĄŕèżćéĂĄéŰŃåğŇãĆĎçźřãĆŁè£ŤãĄŮãĄőãĆ£ãĆď ãČ§ãČşãĆřãĄğãČŚãČľ ãČąãČijãĆ£ãĄŃ

PARAM_SIZE ãĄŕ PARAM_WIDTHÃŮPARAM_HEIGHT ãĄőãĆţãĆď ãĆžãĄğãĄĆãĆŃå£ĚèęĄãĄŇãĄĆãĆŃãĂĆ

CHAPTER 4

çŤżåČŕåĞęçŘĘéŰćéĂč

4.1 img ãČŘãĆźäżŢæğŸ

çŤżåČŕåĞęçŘĘãĄńãĄŁãĄĎãĄęãĂĄAXI4 Stream ãČŘãĆźãĄőä£ąåŕůãĆŠãĄŢãĆL'ãĄńçřąæŸŞãĄńæL'śãĄĘçĆžãĄńãĂĄJellyãĄğãĄ
imgãČŘãĆźãĄĺãĄĎãĄĘçŃňèĞłäżŢæğŸãĄńåď'L'æŕŽãĄŮãĄęåĞęçŘĘãĄŮãĄęãĄĎãĆŃãĂĆ

imgãČŘãĆźãĄőäÿżãĄłä£ąåŕůãĄŕäżěäÿŃãĄőéĂŽãĆŁãĄğãĄĆãĆŁãĂĄå£ĚèęĄãĄńå£IJãĄŸãĄęåĂŃåĹěçŤżåČŕåĞęçŘĘãĄńäżŸéŽŕã

img ãČŘãĆźãĄŕæIJL'åŁźãČŤãĆŕãĆżãČńãĄŇçĎąãĄĎåăť'åŘĹãĄń cke(ãĆŕãČ■ãČČãĆŕãĆď'ãČ■ãČijãČŰãČń)ãĆŠãČ■ãĆšãČijãČĹãĄŹã

ãĄŮãĄ§ãĄŃãĄčãĄęãĂĄcke ãĄőæIJL'åŁźãĄłæIJ§éŰŞãĄőãĄ£ãĆŠåĞęçŘĘãĄŹãĆŃãĄřãĂĄãČĞãČijãĆ£ãĄŕãĄŹãĄźãĄęéĂčçűŽãĄğ

ãĄ¿ãĄ§ãĂĄçŤżåČŕåĞęçŘĘãĄńãĄŁãĄĎãĄęãĄŮãĄřãĄŮéĞ■èęĄãĄńãĄłãĆŃãČIJãČijãČĂãČijåĞęçŘĘãĄńãĄŁãĄĎãĄęãĂĄçŤżåČŕ

äÿĂæŰźãĄğæIJL'åŁźãČŤãĆŕãĆżãČńãĆŠçď'žãĄŹ de ä£ąåŕůãĆĆåĆŹãĄĹãĄęãĄĎãĆŃãĂĆå§žæIJňçŽĎãĄńãĄŕçĎąåŁźãČŤãĆŕãĆżãČ
cke ãĄŇäÿŃãĄŠãĆL'ãĆŃãĆŃãĄŃãĂĄ3x3ãĄłãĄĺ'ãĄőãČŰãČ■ãČČãĆŕåĞęçŘĘãĆŠèąŃãĄĘåăť'åŘĹãĄŕæIJĂçţĆãČĺ'ãĆď'ãČşãĄőæŐČ
ãĄ¿ãĄ§ãĂĄçŤżåČŕåĞęçŘĘãĄőåĞžåŁŻéĄŐçÍŃãĄńãĄŁãĄĎãĄęãĄŕãĂĄäÿ■èęĄãČŤãĆŕãĆżãČńãĄődeãĆŠäÿŃãĄŠãĆŃãĄŞãĄĺãĄğ

ãĄŞãĆŃãĆL'ãĄńãĆĹãĆŁåď'ŽãĄŘãĄőåĹűå¿ąä£ąåŕůãĆŠæIJL'ãĄŮãĄęãĄĎãĆŃãĄŃãĂĄãĄŞãĆŃãĆL'ãĆŠãĄŹãĄźãĄęå£ĚéăĹãĄĺãĄ
ãĄőçńŃãĄ§ãĄłãĄĎãČĞãČijãĆ£ãĄŕäżŰãĄőãĄŹãĄźãĄęãĄőä£ąåŕůãĄŕçĎąåŁźãĄĺãĄŹãĆŃãĄŞãĄĺãĄğãĂĄãČłãĆżãČČãČĹä£ąåŕůã
valid ãĄńãĄŃãĄŃãĆŕãĆŃä£ąåŕůãĄăãĄŚãĄńãĄŹãĆŃãĄŞãĄĺãĆĆåŕŕèČ¡ãĄĺãĄŮãĄęãĄĎãĆŃãĂĆ

4.2 jelly_axi4s_to_img

AXI4 Stream ãĆŠ img ãČŘãĆźãĄńåď'L'æŕŽãĄŮãĂĄçŤżåČŕåĞęçŘĘå¿ŃãĄńåĘ■ãĄş AXI4 Stream ãĄńæĹżãĄŹãĆşãĆćãĂĆ

4.3 jelly_img_blk_buffer

çŤżåČŔãĆŠ NÃŮM ãĄőãČŰãČ■ãČČãĆŕãĄńåď'L'æŔŻãĄŮãĄęçŤżåČŔåĞęçŘĘãĆŠãĆćãĆůãĆźãČĹãĄŹãĆŃãĆşãĆćãĂĆ
ãČľãĆď'ãČşãČŘãČČãČŢãĆąãĄÍãČŤãĆŕãĆżãČńãČŘãČČãČŢãĆąãĆŠåĆŹãĄĹãĂĄãČŰãČ■ãČČãĆŕåĞęçŘĘãĄńå£ĚèęĄãĄłå■Ÿä¡■ãĄğ
M-1 ãČľãĆď'ãČşåĹĘãĄőéĄĚåżűãĄÑçŹžçŤ§ãĄŹãĆŃãĂĆ

ãĄİãĄőéŽŻãĂĄãČIJãČijãČĂãČijåĞęçŘĘãĄÍãĄŮãĄę NONE, CONSTANT, REPLICATE, REFLECT, REFLECT_101 ãĄłãĄľãĄőåĞęçŘĘãĄŇéĄÿæŁđåŔŕèČ¡ãĄğãĄĆãĆŁãĂĄOpenCV ãĄőãĄİãĆŃãĄÍãĄżãĄijäÿĂèĞťãĄŹãĆŃãĂĆ

4.4 jelly_img_demosaic_acpi

ACPIæşŢãĄńãĆĹãĆŃãČĞãČćãĆűãĆď'ãĆŕ

4.5 jelly_img_color_matrix

ãĆńãČľãČijãČđãČĹãČłãČČãĆŕãĆźåĞęçŘĘ

4.6 jelly_img_gaussian_3x3

3x3 éŹŘåőŽãĄőãĆňãĆęãĆůãĆćãČşãČŢãĆčãČńãĆ£

4.7 jelly_img_sobel_core

Sobel ãČŢãĆčãČńãĆ£ãĆşãĆć åŻžåőŽåĂď'ãĄğãĄőæijŤçőŮãĄłãĄőãĄğãČŻãĆźãČĹãĄŃãĆL'èÍ■åőŽãĄŹãĆŃãČňãĆÿãĆźãĆ£ãĄŕãĄłãA

4.8 jelly_img_binarizer

ïijŠåĂď'åŇŰãĆşãĆć

4.9 jelly_img_selector

çŤżåČŔãĆżãČňãĆŕãĆ£ãĂĆ äÿżãĄńãČĞãČŘãČČãĆŕæŹĆãĄńäÿ■éŰŞãČĞãČijãĆ£ãĆŠåĹĞãĆŁæŻ£ãĄĹãĄęåĞžåŁŻãĄŹãĆŃãĄłãĄľãĄ

4.10 jelly_img_previous_frame

1ãĄď'åĽ'■ãĄőãČŢãČňãČijãČăăĆŠåď'ŰéČÍãČąãČćãČłãĄńä£İå■ŸãĄŮãĄęåĹľçŤÍãĄŹãĆŃãĄ§ãĆĄãĄőDMAãČćãĆÿãČěãČijãČń

4.11 jelly_img_dnn_maxpol

DNNçŤÍãĄő MaxPooling åšď'ãĂĆ

çÿőåřŘãĆŠèąŇãĄĎ de ãĄőçńŃãĄ§ãĄłãĄĎãČĞãČijãĆ£ãĆŠåĞžåŁŻãĄŹãĆŃãĄ§ãĆĄãĂĄãĄŞãĄőå¿ŇãĄńãĄŢãĆĽãĄńçŤżåČŘåĞęçĎ
AXI4 Stream ãĄńæĹżãĄŹå£ĚèęĄãĄŇãĄĆãĆŃãĂĆ

CHAPTER 5

Library éŰćéĂč

5.1 æęĆèęĄ

/rtl/library äżěäÿŃãĄńãĂĄãĆĹãĄŕä¡£ãĄĘãČľãĆďãČŰãČľãČłçŽĎãĄłãČćãĆÿãČěãČijãČńç¿ďãĆŠéŻĘãĆĄãĄęãĄĎãĆŃãĂĆ
ãĄłãĆŃãĄźãĄŕäÿŃèÍŸãĄőåĘ■æŢťçŘĘãĄŮãĆĹãĄĘãĄÍãĄŮãĄęãĄĎãĆŃãĄŇãĂĄçŕ¿çŁűãĄ¿ãĄăåŕďãĄĎãĆĆãĄőãĆĆæůůåIJÍãĄŮ

5.2 åŘĎçÍőãČľãĆďãČŰãČľãČł

5.2.1 jelly_ram_XXX çşż

åĘĚèŤţãČąãČćãČłéŰćéĂčãĄőãČľãĆďãČŰãČľãČłç¿ď

5.2.2 jelly_fifo_XXX çşż

FIFOãĆŠæğŃæĹŘãĄŹãĆŃãČľãĆďãČŰãČľãČłç¿ď

5.2.3 jelly_data_XXX çşż

ãĄďãĄłãĄŇãĆŁãĆŠæŇĄãĄ§ãĄłãĄĎå■ŸçŹžãĄőãČĞãČijãĆ£ãĄńåŕ¿ãĄŮãĄęåĞęçŘĘãĆŠèąŇãĄĘãČľãĆďãČŰãČľãČłç¿ď
å§žæIJňçŽĎãĄń AXIãČŘãĆźæŰźåijŔãĄő valid/ready æŰźåijŔãĄğãČŔãČşãČĽãĆůãĆğãČijãĆŕãĄŹãĆŃ

5.2.4 jelly_stream_XXX çşż

last ãČŢãČľãĆřãĄłãĄľãĄğåŇžåĹĞãĆĽãĆŇãĆŃäÿĂéĂčãĄőãĆźãČĹãČłãČijãČäãČĞãČijãĆ£ãĄńåŕ¿ãĄŮãĄęåĞęçŘĘãĆŠèąŇãĄĘãČľ

ä¿£åőIJäÿŁãĆźãČĹãČłãČijãČäåĚĹéã■ãĆŠèąĺãĄŹ first ãĆŠäżŸãĄŚãĆĽãĆŇãĆŃãĆĆãĄőãĆĆãĄĆãĆŃãĂĆ
å§žæIJňçŽĎãĄń AXIãČŘãĆźæŰźåijŘãĄő valid/ready æŰźåijŘãĄğãČŘãČşãČĽãĆůãĆğãČijãĆŕãĄŹãĆŃ

5.2.5 jelly_address_XXX çşż

åŘĎçÍőãĆćãČĽãČňãČČãĆůãČşãĆřãĄőçĆžãĄőãĆď ãČşãČĞãČČãĆŕãĆźçŤ§æĹŘãČ■ãĆÿãČČãĆŕ

5.2.6 jelly_capacity_XXX çşż

åŘĎçÍőåőźéĞŘçőąçŘĘãĆńãĆęãČşãĆ£

5.2.7 jelly_func_XXX çşż

çţĎãĄ£åŘĹãĆŘãĄŻåŻđèůŕãĄńãĆĹãĆŃåŘĎçÍőãČŢãĆąãČşãĆŕãĆůãČğãČşæŘŘä¿Ż

5.2.8 ãĄİãĄőäżŰ

ãĄİãĄőäżŰãĄĎãĆ■ãĄĎãĆ■

CHAPTER 6

CPU (MIPS-I compatible)

6.1 æęĆèęĄ

Jelly ãĄÍãĄŕãĂĄFPGAåŘŚãĄŚãĄő MIPS-I ãČľãĆďãĆŕãĄłåŚ¡äżďãĆżãČČãČĹãĄőãĆşãĆćãĆŠæIJĽãĄŮãĄ§ãĆ¡ãČŢãČĹãĆşãĆć
ãČŮãČ■ãĆżãČČãĆůãČşãĆřãĆůãĆźãČĘãČäãĄğãĄŹãĂĆ

6.2 CPUãĆşãĆćãĄőæęĆèęĄ

Jelly ãĄőåĆŹãĄĹãĆŃ CPU ãĆşãĆćãĄŕåŚ¡äżďãĆżãČČãČĹãĄÍãĄŮãĄęãĄŕãĂĄ MIPS-I
ãČľãĆďãĆŕãĄłåŚ¡äżďãĆżãČČãČĹãĆŠ åĆŹãĄĹãĄęãĄŁãĆŁãĂĄgcc ãĄłãĄľãĄńãĆĹãĆŃéŰŃçŹžãĄŇåŘŕèČ¡ãĄğãĄŹãĂĆ
ãĄ§ãĄäãĄŮãĂĄlwl, lwr, swl, swr åŚ¡äżďãĄŕåĆŹãĄĹãĄęãĄĎãĄłãĄĎãĄőãĄğæşÍæĎŘãĄŇå£ĚèęĄãĄğãĄŹãĂĆ
åĽšè¿ijãĄ£ãĄłãĄľãĄőåŚ¡äżďãĆżãČČãČĹäžěåď ŰãĄőælľ§èČ¡ãĄŕå§žæIJňçŽĎãĄńçŃňèĞłäżŢæğŸãĄłãĄőãĄğãĄĆãĄŘãĄ¿ãĄğ
ãĆşãČşãČŚãĆďãČľãĄŇæţĄçŤÍãĄğãĄ■ãĆŃãĄÍãĄĎãĄĘäžěåď ŰãĄŕMIPSãĆůãĆźãČĘãČäãĄÍäžŠæŘŻæĂğãĄŕãĄĆãĆŁãĄ¿ãĄŻãĆŞã

6.3 jelly_cpu_top ãČćãĆÿãČěãČijãČń

6.3.1 ãČŚãČľãČąãČijãĆ£

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6.3.2 ãČĺãČijãČĹä£ąåŘů

[redacted]

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(continued from previous page)

[redacted]

6.4 CPUãČĞãČŘãČČãĆřãČİãČijãČĹ

ãČĞãČŘãČČãĆřãČİãČijãČĹãĄŃãĆL'äÿŃèÍŸãĄőãĆćãČL'ãČňãĆźãĄńãĆćãĆŕãĆżãĆźãĄğãĄ■ãĄ¿ãĄŹãĂĆ

6.4.1 ãČňãĆÿãĆźãĆ£äżŢæğŸ

[redacted]

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[redacted]

6.5 UARTçţŇçŤśãČĞãČŘãČČãĆřåĹúå¿ą

Jelly ãĄğãĄŕãĂĄäÿŁèÍŸãĄőCPUãČĞãČŘãČČãĆřãČÌãČijãČĹãĆŠ UART çţŇçŤśãĄğåĹúå¿ąãĄŹãĆŃãČćãĆÿãČěãČijãČńãĆŠçŤÍæĎŘãĄŮãĄęãĄĎãĄ¿ãĄŹãĂĆ UARTãČŮãČ■ãČĹãĆşãČńãĄŕäżěäÿŇãĄőãĄÍãĄŁãĆŁãĂĆ

[redacted]

6.6 WISHBONEãČŘãĆź

JellyãĄğãĄŕ OpenCores(http://www.opencores.org/) ãĄőåőŽãĆĄãĆŃWISBONEãČŘãĆźãĆŠ
åĹľçŤĺãĄŮãĄęãĄĎãĄ¿ãĄŹãĂĆ WISHBONEãČŘãĆźèęŘæăijãĄŕåď'ŽåšŘãĄńãĆŘãĄ§ãĄčãĄęãĄĎãĄ¿ãĄŹãĄŇãĂĄJellyãĄğãĄŕãĆů
å£ĚèęĄãĄłæIJĂåřŘéŹŘãĄőä£ąåŘůãĄőãĄ£åĹľçŤĺãĄŮãĄęãĄĎãĄ¿ãĄŹãĂĆ äžěäÿŃãĄńåĹľçŤĺãĄŮãĄęãĄĎãĆŃä£ąåŘůãĄőãĄ£çřąå

[redacted]

ãĄğ4GbyteãĄőãĆ

6.7 Jelly bus

WISHBONEãČŘãĆźãĄŕãĆţãĆď'ãĆŕãČńåĘĚãĄğãČĹãČľãČşãĆűãĆŕãĆůãČğãČşãĄŇåőŇçţŘãĄŹãĆŃãĄ§ãĆĄåď'ŽãĄŘãĄőåăť'åŘĹ
ä¿£åĹľãĄğãĄŹãĄŇãĂĄFPGAãĄőåĘĚèŤţSRAMãĄőæğŸãĄńREADçţŘæđIJãĄőåŘŰå¿ŮãĄŇæňąãĆţãĆď'ãĆŕãČńãĄĺãĄłãĆŁãĂĄ
ãČąãČćãČłãĄńCPUãĆşãĆćãĆŠçŽť'çţŘãĄŹãĆŃåăť'åŘĹãĄńçŽÿæĂğãĄŇæĆłãĄĎãĄğãĄŹãĂĆ
ãĄİãĄŞãĄğäÿŃèÍŸãĄőãĆĹãĄĘãĄłçŃňèĞłãČŘãĆźãĆŠ jbus ãĄĺãĄŮãĄęåőŽç¿ľãĄŮãĄęãĄĎãĄ¿ãĄŹãĂĆ

[redacted]

↪ãĄőãĆţãĆď'ãĆŕãČńãĄğåĂď'ãĆŠåď'L'åŇŰãĄŢãĄŻãĄęãĄŕãĄłãĆL'ãĄłãĄĎ (continues on next page)

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6.8 åŚ¡äżď'ãĆżãČČãČĹç■Ľ

ãĄŞãĄąãĆĽ'ãĄńç¡őãĄĎãĄęãĄŁãĄ■ãĄ¿ãĄŹãĂĆ

files/jelly_cpu.ods

CHAPTER 7

MIPS-I äžŠæŔŻãĆ¡ãČŢãČĹãĆşãĆćçŠřåćČ

7.1 ãĄŕãĄŸãĆĄãĄń

MicroBlazeãĄŇçĎąåĎ§ãĄğåĹľçŤĺãĄğãĄ■ãĂĄZynqãĄńARMãĆşãĆćãĄŇæŘ■èijĽãĄŢãĆŇãĂĄäżŁãĄĺãĄłãĄčãĄęãĄŕéĄŐåŐżãĄőé
Jelly ãĆůãĆźãČĘãČäãĆŠä¡IJãĆŁåğŃãĆĄãĄ§ãĄ■ãĄčãĄŃãĄŚãĄŕãĂŇCPUãĆŠæŻÿãĄĎãĄęãĄ£ãĄ§ãĄĎãĂ■ãĄŇçŹžçńŕãĄäãĄčãĄ§
rtl/cpu ãČŢãĆľãČńãČĂãĄőäÿŃãĄńå¡ŞæŹĆRTLãĆŠèęŽãĄĹãĄ§ãĄřãĄŃãĆŁãĄőěČãĄńæŻÿãĄĎãĄ§CPUãĄőRTLãĆşãČijãČĽãĄŇ
HTML ãĄğæŻÿãĄĎãĄ§èłňæŸŐæŰĞãĆŠäżŁéćĺãĄń Markdown ãĄńæŻÿãĄ■çŻť ãĄŮãĄęãĄ£ãĄ§ãĄĎãĄĺæĂİãĄĎãĄ¿ãĄŹãĂĆ

7.2 Jelly-CPUãĄőçĽźå¿ť

- MIPS-IãČľãĆďãĆŕãĄłåŚ¡äżďãĆżãČČãČĹãĄğãĂĄgcc ãĄğCèÍĂèłđéŰŃçŹžãĄŇèąŇãĄĹãĆŃ
- ãĆ■ãČčãČČãĆůãČěæľ§èČ¡
- åŕEçţŘåŘĹãČąãČćãČł(TCM)æľ§èČ¡
- Verilog 2001 ãĄğèÍŸè£ř
- DDR-SDRAMåŕ¿å£IJ
- ÎijITRON4.0äżŢæğŸ HOS-V4a åŕ¿å£IJäÿ■
- ICEæŃąåijţçŤÍãĄőãČĞãČŘãČČãĆřãČÌãČijãČĹãĆŠåĆŹãĄĹãĄęãĄĐãĆŃ
- ãĆ■ãČěãČąãČşãČĹãĄŇæŮěæIJňèłđ(ä¡IJèĂĚãĄŇèŃśèłđãĆŘãĄŃãĆŞãĄłãĄĐ)

7.3 ãĆůãĆźãČĘãČăãĄőèłňæŸŐ

7.4 CPUãĆşãĆćãĄőãČŰãČ■ãČČãĆŕåŻş

åĚÿåđŃçŽĎãĄłæŢŹçğŚæŻÿãĄľãĄŁãĆŁïijŢæőţãČŚãĆďãČŮãČľãĆďãČşãĄőãĆćãČijãĆ■ãČĘãĆŕãČĄãČčãĄğãĂĄãĆşãĆćéČĺãĄŕãČŘ

ãĄ¿ãĄ§ãĂĄåĘĚèŤţãĄğãČĞãČŘãČČãĆŕãČęãČŃãČČãČĹãĆĆçŤĺæĎŘãĄŮãĄęãĄŁãĆŁãĂĄåď'ŰéČĺãĄŃãĆĽCPUãĆşãĆćãĆŠçŻť'æŐ

ãČŢãĆľãČŕãČijãČĞãĆčãČşãĆŕãĆĆåĚěãĄčãĄęãĄŁãĆŁãĂĄæőĘãĄľãĄőåő§èąŃãČęãČŃãČČãČĹãĆŠEXãĆźãČĘãČijãĆÿãĄńåŻžãĆĄ
IãĄğãĄŕãČ■ãČijãČĽåŚ¡äżďãĄőæňąåŚ¡äżďãĄğãĄŕãČ■ãČijãČĽãĄŮãĄ§ãČňãĆÿãĆźãĆ£ãĄŕåĹľçŤĺçęĄæ■ćãĄğãĄŹãĄőãĄğãĂĄçĽźã

ãĄİãĄőäżŰãĂĄFPGAçŽĎãĄłåůěåď'ńçĆźãĄĺãĄŮãĄęãĄŕãĂĄãČŢãĆľãČŕãČijãČĞãĆčãČşãĆŕãĄőãČđãČńãČĄãČŮãČňãĆŕãĆţãĄŃFP
mflo)ãĄğäźŮçőŮãĄŹãĆŃãĆĹãĄĘãĄńãĄŮãĄęãĂĄèęŃãĄŃãĄŚäÿŁãĂĄäźŮçőŮãĄŕ1ãĆţãĆď'ãĆŕãČńãĄğåő§çŔ¿ãĄğãĄ■ãĄ¿ãĄŮãĄ

ãČĞãČŘãČČãĆŕãČęãČŃãČČãČĹãĄőãĆĹãĄĘãĄłãČIJãČĹãČńãČ■ãČČãĆŕãĆŚæŃ§ãĆŞãĄğ Spartan-3
ãĄőãĆźãČŤãČijãČĽãĆŕãČňãČijãČĽ-4ãĄğ50MHzãĄğåŃŢãĄĐãĄęãĄĐãĄ¿ãĄŹãĄőãĄğãĄ¿ãĄĆãĄ¿ãĄĆãĄĺãĄĐãĄčãĄ§ãĄĺãĄŞãĆ■

7.4.1 CPUãČĹãČČãČŮãĄőèłňæŸŐåŻş

CPUãĆşãĆćãĄőåď'ŰãĄńãĂĄåŕEçţŘåŘĹãČąãČćãČł(TCM)ãĄĺãĆ■ãČčãČČãĆůãČěãĆŠæŘ■èijĽãĄŮãĄęãĄĐãĄ¿ãĄŹãĂĆTCMãĄĺãĆ
FPGAãĄőåĘĚèŤţãČĞãČěãĆćãČńãČÌãČijãČĹRAMãĆŠèąŃãĄŃãĄŮãĄęãĂĄïijŠãĄď'ãĄőãČÌãČijãČĹãĆŠåŚ¡äżď/ãČĞãČijãĆ£ãĄńåĽ
åŕEçţŘåŘĹãČąãČćãČł(TCM)ãĆĆFPGAãĄőåĘĚèŤţãČĞãČěãĆćãČńãČÌãČijãČĹRAMãĄőãĄŁãĄŃãĄŠãĄğãĂĄåŚ¡äżď/ãČĞãČijãĆ£ãĆ

åŘĎçÍőãČŘãĆźãĄńãĄŕOPENCORES.ORG ãĄő WISHBONEãČŘãĆź ãĄÍäžŠæŘŻæĂğãĄÑãĄĆãĆŃãĆĹãĄĘãĄńä¡IJãĄčãĄ§ãĄď ãĆĆ

7.4.2 Spartan3e statrer kit ãĄğãĄőãĆůãĆźãČĘãČäãĄőèłňæŸŐåŻş

äżŁåŻđãĄőãČIJãČijãČĽãĄńãĄŕRS-232CãĄŇïijŠãČÍãČijãČĹãĄĆãĆŃãĄőãĆŠãĄĎãĄĎãĄŞãĄÍãĄńãĂĄãČĞãČŘãČČãĆřãČÍãČijãČĹ

ãĄ¿ãĄ§ãĂĄéÍđåÿÿãĄńãĆůãČşãČŮãČńãĄłãĆĆãĄőãĄğãĄŹãĄŇDDR-SDRAMãĄőåĹűå¿ąRTLãĆĆæŻÿãĄĎãĄęãĄ£ãĄ¿ãĄŮãĄ§ãĂĆ
SDRAMãĄŕ100MHzéğĘåŃŢãĄłãĄőãĄğãĆŕãČ■ãČČãĆŕäźŮãĄŻãĄŇãĄĹçŤÍãĄőãČŰãČłãČČãĆÿãĄŇåĚěãĄčãĄęãĄĎãĄ¿ãĄŹãĂĆ

ãČŽãČłãČŢãĆğãČľãČńãČŘãĆźãĄńãĄŕåŘĎçÍőåŚÍè¿žåŻđèůŕãĆŠãĄď ãĄłãĄĎãĄğãĄĎãĄ¿ãĄŹãĂĆIRC(åĽšãĆŁè¿ijãĄ£ãĆşãČşãČĹãČ

7.5 éŰŃçŹžçŠřåćČãĄńãĄď ãĄĎãĄę

7.5.1 ãČŕãČijãČĽãĆęãĆğãĆćçŠřåćČ

éŰŃçŹžãČIJãČijãČĽãĄńãĄŕ Xilinx ãĄő Spartan-3e Starter KitãĆŠä¡£ãĄčãĄęãĄĎãĄ¿ãĄŮãĄ§ãĂĆ
äżŁãĄäãĄĺåĚěæĽŃãĄŕéŻčãĄŮãĄĎãĄĺæĂİãĄĎãĄ¿ãĄŹãĄőãĄğãĂĄãĄĆãĄŕãĄ¿ãĄğåŕĆèĂČãĄğãĄŹãĂĆ

7.5.2 ãĆ¡ãČŢãČĹãĆęãĆğãĆćçŠřåćČ

Xilinx ãĄő ISE WebPack ãĆŠä¡£ãĄčãĄęãĄĎãĄ¿ãĄŹãĂĆ

CèĺĂèłđãĆşãČşãČŚãĆď ãČľãĄŕå¡ŞæŹĆ gcc ãĄőãĆŕãČ■ãĆźãĆşãČşãČŚãĆď ãČľãĆŠ cyg-
win äÿŁãĄğæğŃçŕĽãĄŮãĄęä¡£ãĄčãĄęãĄĎãĄ¿ãĄŮãĄ§ãĂĆäżŁãĄäãĄĺ Windows
æť¿ãĄőäžžãĄğãĆĆ WSL ãĆĎ VirtualBox ãĄŇãĄĆãĆŁãĄ¿ãĄŹãĄőãĄğ Linux
äÿŁãĄğãĆŕãČ■ãĆźãĆşãČşãČŚãĆď ãČľãĄŇä¡£ãĄĹãĆŃãĄĺæĂİãĄĎãĄ¿ãĄŹãĂĆ

swl,swr,lwl,lwr ç■Ľ ãĄŇä¡£ãĄĹãĄłãĄĎãĄőãĄğãĄİãĄŞãĄäãĄŚãĄŁæřŮãĆŠãĄď ãĄŚãĄŕãĄäãĄŢãĄĎãĂĆ

CHAPTER 8

Indices and tables

- genindex
- modindex
- search