

LINUX ON AN FPGA

Chris Major

CSCI460 – Operating Systems

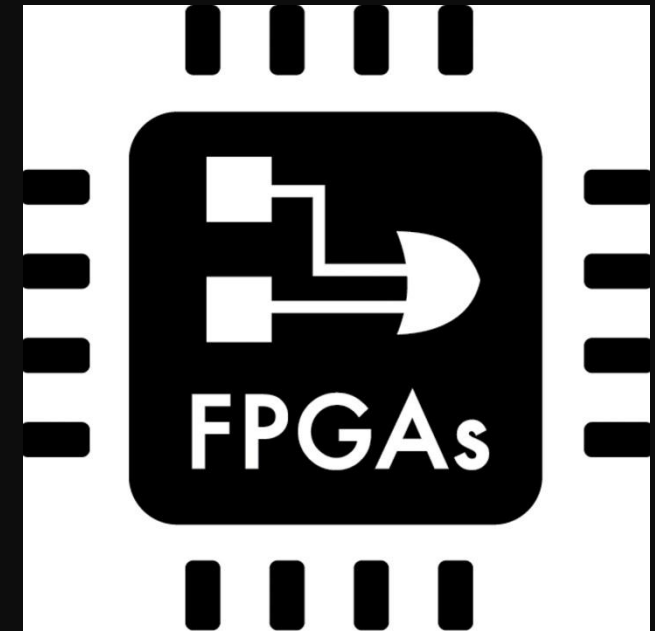
Fall 2019

IMPLEMENT AN OS ONTO AN FPGA

Develop a custom hardware design to support Yocto Linux

WHAT IS AN FPGA?

- Field Programmable Gate Array
- Create custom digital logic design
- Can create Softcore Processors



THE DEVELOPMENT BOARD

- Artix-7 “Arty” Board
- 5 V power source
- Ethernet support
- GPIO for additional functionality
- QSPI Flash and DDR3L Memory

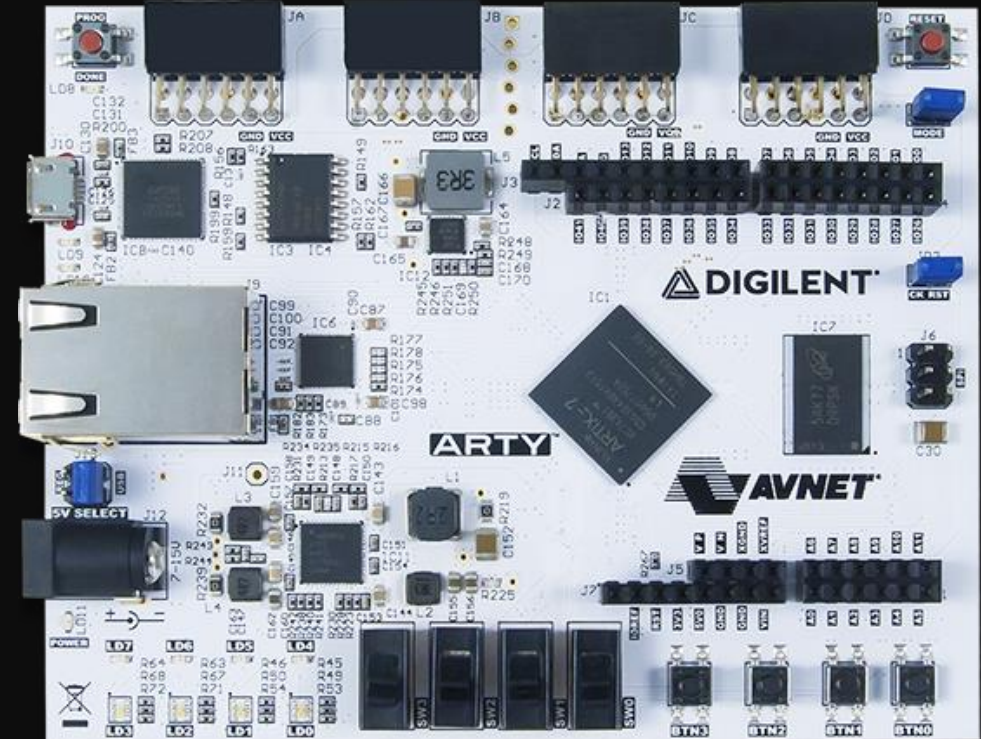


Image from <https://store.digilentinc.com/artix-7-artix-7-fpga-development-board-for-makers-and-hobbyists/>

THE DEVELOPMENT BOARD

- Uses a Xilinx Artix-7 XC7A35T FPGA chip

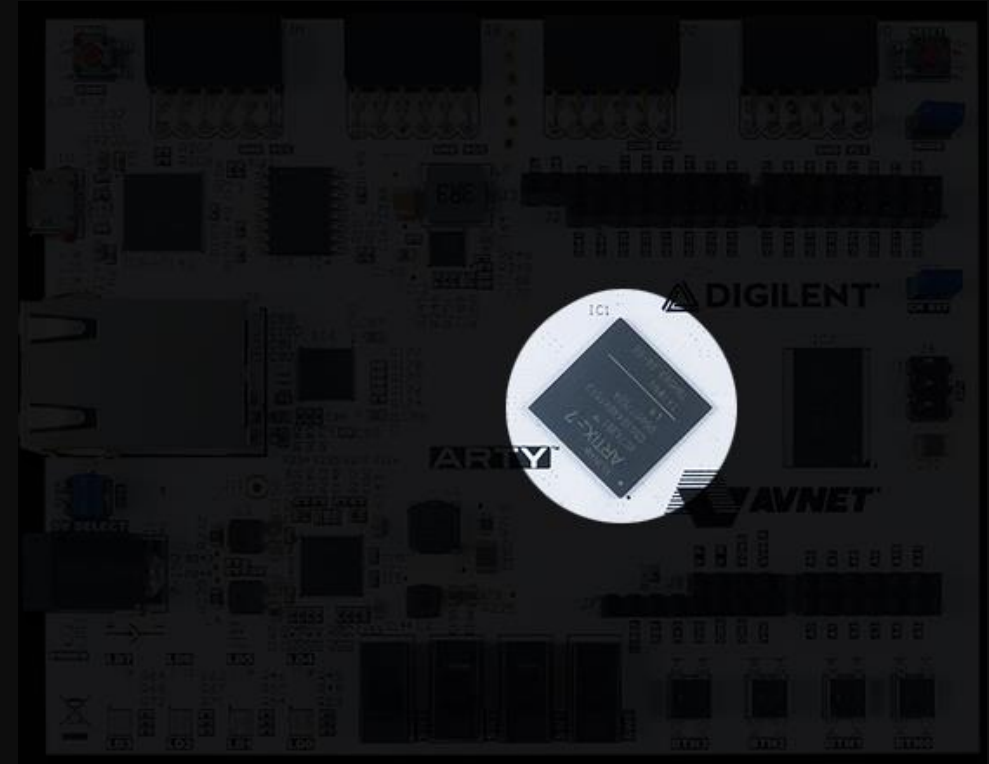
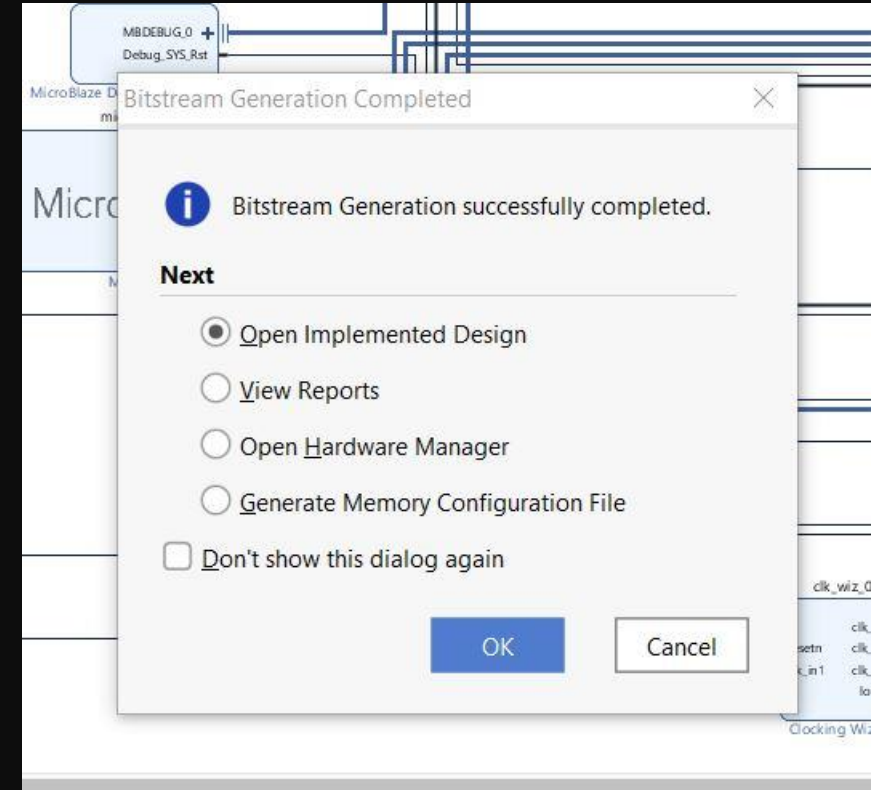


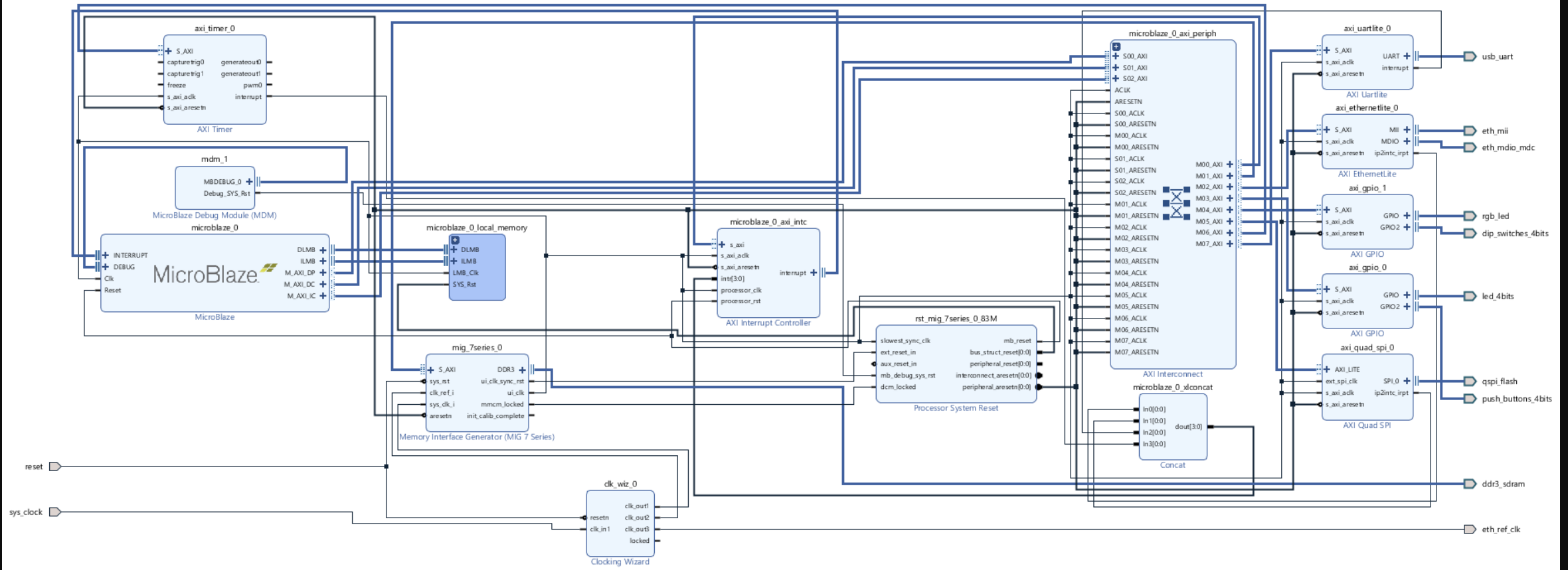
Image from <https://store.digilentinc.com/artix-a7-artix-7-fpga-development-board-for-makers-and-hobbyists/>

WORKFLOW

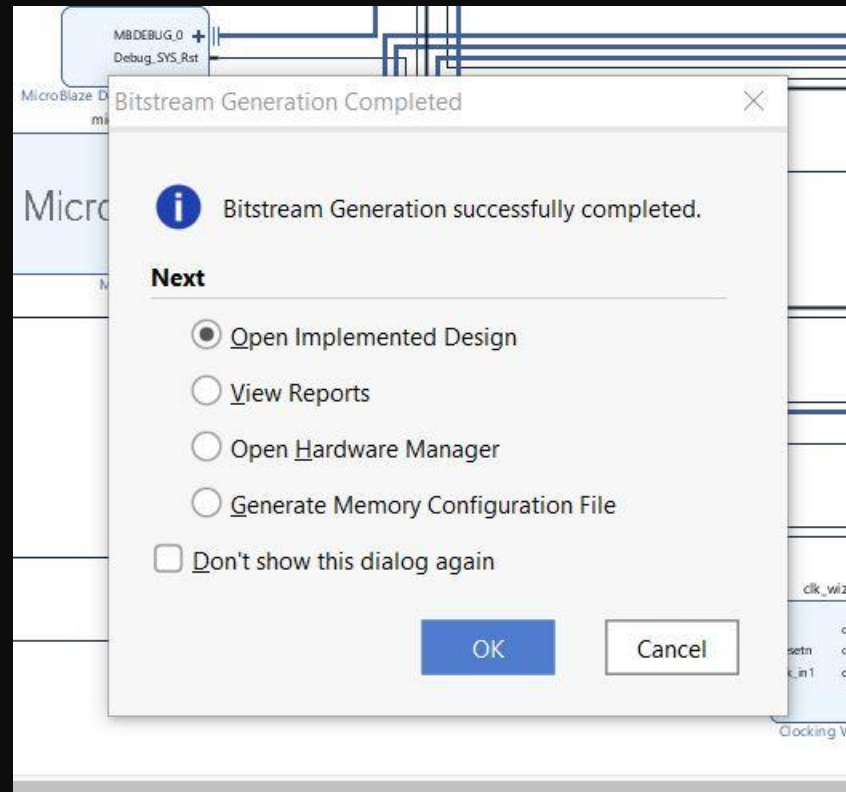
- Generate design
- Bitstream Generation
- Test Software
- Create Petalinux Project
- Configure Petalinux
- Build Petalinux Image
- Boot
- Demo



GENERATE DESIGN



BITSTREAM GENERATION



TEST SOFTWARE

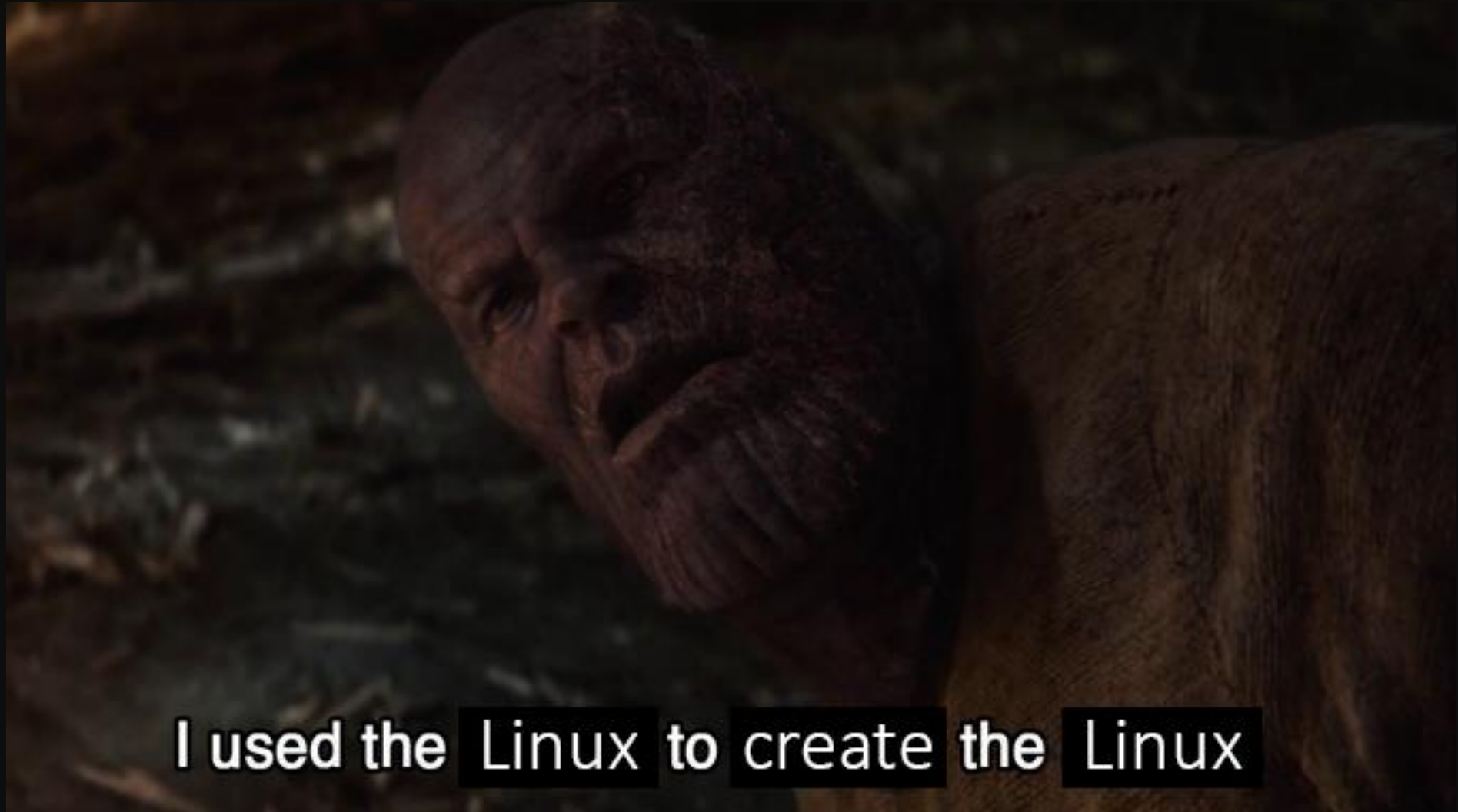
The screenshot displays a software development environment with the following components:

- COM8 - Tera Term VT**: A terminal window showing the output "Hello World".
- MicroBlaze #0 (Running)**: A status indicator for the target processor.
- Code Editor**: Displays C code for a "helloworld.c" file. The code includes headers for `<stdio.h>`, `"platform.h"`, and `"xil_printf.h"`. The `main` function calls `init_platform()` and prints "Hello World\".
- Build Console**: Shows the output of a build process, including the message "Build Finished (too)".
- File Explorer**: Lists files such as `platform.h`, `Iscrip.ld`, and `csci460_test_app.prj`.

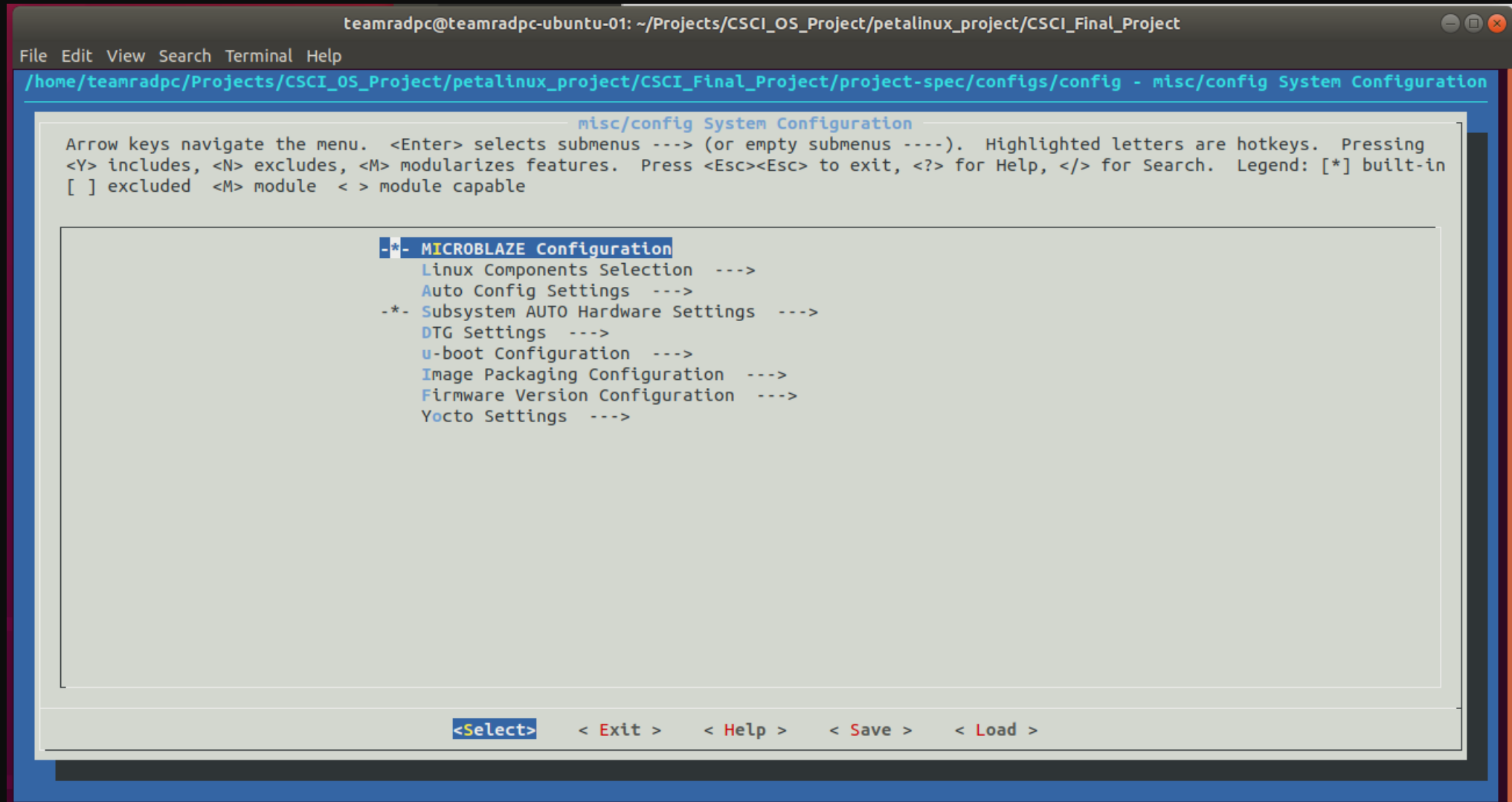
```
27 /* Except as contained in this file, Xilinx does not warrant,
28 * in advertising or otherwise, that the Software will meet
29 * your requirements or that the Software is free from defects.
30 *
31 * *****
32 */
33 /*
34 * helloworld.c: simple
35 *
36 * This application configures the PS7 UART (Zynq) is
37 * bootrom/bsp configuration
38 *
39 *
40 *
41 * | UART TYPE   BAUD RATE
42 *
43 * uarts550     9600
44 * uartlite     Config
45 * ps7_uart     115200
46 */
47
48 #include <stdio.h>
49 #include "platform.h"
50 #include "xil_printf.h"
51
52
53 int main()
54 {
55     init_platform();
56
57     print("Hello World\n");
58
59     while(1) {
60         // Do nothing
61     }
62 }
63
64
```

Build Console [csci460_test_app_system]
22:33:28 **** Build of configuration make all
Skipping SD card image generation
22:33:29 Build Finished (too)

CREATE PETALINUX PROJECT



CONFIGURE PETALINUX



The screenshot shows a terminal window titled "teamradpc@teamradpc-ubuntu-01: ~/Projects/CSCI_OS_Project/petalinux_project/CSCI_Final_Project". The terminal displays the "misc/config System Configuration" menu. The menu is titled "misc/config System Configuration" and contains instructions: "Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty submenus ----). Highlighted letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] built-in [] excluded <M> module < > module capable". The menu items are: "MICROBLAZE Configuration", "Linux Components Selection --->", "Auto Config Settings --->", "Subsystem AUTO Hardware Settings --->", "DTG Settings --->", "u-boot Configuration --->", "Image Packaging Configuration --->", "Firmware Version Configuration --->", and "Yocto Settings --->". At the bottom of the menu, there are navigation options: "<Select>", "< Exit >", "< Help >", "< Save >", and "< Load >".

```
teamradpc@teamradpc-ubuntu-01: ~/Projects/CSCI_OS_Project/petalinux_project/CSCI_Final_Project
File Edit View Search Terminal Help
/home/teamradpc/Projects/CSCI_OS_Project/petalinux_project/CSCI_Final_Project/project-spec/configs/config - misc/config System Configuration

misc/config System Configuration
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty submenus ----). Highlighted letters are hotkeys. Pressing
<Y> includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] built-in
[ ] excluded <M> module < > module capable

[*]- MICROBLAZE Configuration
  Linux Components Selection --->
  Auto Config Settings --->
  *- Subsystem AUTO Hardware Settings --->
    DTG Settings --->
    u-boot Configuration --->
    Image Packaging Configuration --->
    Firmware Version Configuration --->
    Yocto Settings --->

<Select>  < Exit >  < Help >  < Save >  < Load >
```

BUILD PETALINUX IMAGE

```
teamradpc@teamradpc-ubuntu-01: ~/Projects/CSCI_OS_Project/petalinux_project/CSCI_Final_Project
File Edit View Search Terminal Help
^[[B^[[A[INFO] generating user layers
[INFO] generating workspace directory
[INFO] generating machine configuration
[INFO] generating bbappends for project . This may take time !
[INFO] generating u-boot configuration files
[INFO] generating kernel configuration files
[INFO] generating kconfig for Rootfs
[INFO] silentconfig rootfs
[INFO] generating petalinux-user-image.bb
teamradpc@teamradpc-ubuntu-01:~/Projects/CSCI_OS_Project/petalinux_project/CSCI_Final_Project$ petalinux-build
[INFO] building project
[INFO] sourcing bitbake
[INFO] generating user layers
[INFO] generating workspace directory
INFO: bitbake petalinux-user-image
Loading cache: 100% |#####| Time: 0:00:00
Loaded 3978 entries from dependency cache.
Parsing recipes: 100% |#####| Time: 0:00:04
Parsing of 2893 .bb files complete (2885 cached, 8 parsed). 3980 targets, 558 skipped, 0 masked, 0 errors.
NOTE: Resolving any missing task queue dependencies
Initialising tasks: 100% |#####| Time: 0:00:03
Checking sstate mirror object availability: 100% |#####| Time: 0:00:05
Sstate summary: Wanted 814 Found 649 Missed 330 Current 0 (79% match, 0% complete)
NOTE: Executing SetScene Tasks
NOTE: Executing RunQueue Tasks
NOTE: Tasks Summary: Attempted 3016 tasks of which 2197 didn't need to be rerun and all succeeded.
INFO: Copying Images from deploy to images
INFO: Creating /home/teamradpc/Projects/CSCI_OS_Project/petalinux_project/CSCI_Final_Project/images/linux directory
NOTE: Failed to copy built images to tftp dir: /tftpboot
[INFO] successfully built project
teamradpc@teamradpc-ubuntu-01:~/Projects/CSCI_OS_Project/petalinux_project/CSCI_Final_Project$
```

BOOT

```
teamradpc@teamradpc-ubuntu-01: ~/Projects/CSCI_OS_Project/petalinux_project/CSCI_Ar...  
Firefox Web Browser  
File Edit View Search Terminal Help  
petalinux-build effect.  
-v, --verbose output debug messages  
-h|--help Display help messages  
Please specify a boot mode for the detailed options:  
  
Show jtag boot options:  
$ petalinux-boot --jtag --help  
  
Show qemu boot options:  
$ petalinux-boot --qemu --help  
  
teamradpc@teamradpc-ubuntu-01:~/Projects/CSCI_OS_Project/petalinux_project$ ls  
CSCI_Arty_OS  
teamradpc@teamradpc-ubuntu-01:~/Projects/CSCI_OS_Project/petalinux_project$ cd C  
SCI_Arty_OS  
teamradpc@teamradpc-ubuntu-01:~/Projects/CSCI_OS_Project/petalinux_project/CSCI_  
Arty_OS$ petalinux-boot --jtag --fpga  
INFO: sourcing build tools  
INFO: Use bitstream: "/home/teamradpc/Projects/CSCI_OS_Project/petalinux_project  
/CSCI_Arty_OS/images/linux/system.bit.  
INFO: Please use --fpga --bitstream <BITSTREAM> to specify a bitstream if you wa  
nt to use other bitstream.  
INFO: Launching XSDB for file download and boot.  
INFO: This may take a few minutes, depending on the size of your image.  
rlwrap: warning: your $TERM is 'xterm-256color' but rlwrap couldn't find it in t  
he terminfo database. Expect some problems.: Inappropriate ioctl for device  
INFO: Configuring the FPGA...  
  
INFO: Downloading bitstream: /home/teamradpc/Projects/CSCI_OS_Project/petalinux_  
project/CSCI_Arty_OS/images/linux/system.bit to the target.  
  
teamradpc@teamradpc-ubuntu-01:~/Projects/CSCI_OS_Project/petalinux_project/CSCI_  
Arty_OS$ petalinux-boot --jtag --kernel  
INFO: sourcing build tools  
INFO: Launching XSDB for file download and boot.  
INFO: This may take a few minutes, depending on the size of your image.  
rlwrap: warning: your $TERM is 'xterm-256color' but rlwrap couldn't find it in t  
he terminfo database. Expect some problems.: Inappropriate ioctl for device  
INFO: Downloading ELF file: /home/teamradpc/Projects/CSCI_OS_Project/petalinux_p  
roject/CSCI_Arty_OS/images/linux/image.elf to the target.  
  
teamradpc@teamradpc-ubuntu-01:~/Projects/CSCI_OS_Project/petalinux_project/CSCI_  
Arty_OS$
```

```
/dev/ttyUSB1 - PuTTY  
UDP-Lite hash table entries: 128 (order: 0, 6144 bytes)  
NET: Registered protocol family 1  
RPC: Registered named UNIX socket transport module.  
RPC: Registered udp transport module.  
RPC: Registered tcp transport module.  
RPC: Registered tcp NFSv4.1 backchannel transport module.  
PCI: CLS 0 bytes, default 32  
random: fast init done  
Skipping unavailable RESET gpio -2 (reset)  
workingset: timestamp_bits=30 max_order=16 bucket_order=0  
romfs: ROMFS MTD (C) 2007 Red Hat, Inc.  
io scheduler noop registered  
io scheduler deadline registered  
io scheduler cfq registered (default)  
io scheduler mq-deadline registered  
io scheduler kyber registered  
Serial: 8250/16550 driver, 4 ports, IRQ sharing disabled  
40600000,serial: ttyUL0 at MMIO 0x40600000 (irq = 6, base_baud = 0) is a uartlite  
console [ttyUL0] enabled  
bootconsole [uartlite_a0] disabled  
bootconsole [uartlite_a0] disabled  
brd: module loaded  
m25p80 spi0.0: found n25q128a13, expected n25q512a  
m25p80 spi0.0: n25q128a13 (16384 Kbytes)  
4 fixed-partitions partitions found on MTD device spi0.0  
Creating 4 MTD partitions on "spi0.0":  
0x00000000000000-0x00000004000000 : "fpga"  
0x00000004000000-0x00000004000000 : "boot"  
0x00000004000000-0x00000004500000 : "bootenv"  
0x00000004500000-0x0000000a500000 : "kernel"  
libphy: Fixed MDIO Bus: probed  
xilinx_emaclite 40e00000.ethernet: Device Tree Probing  
libphy: Xilinx Emaclite MDIO: probed  
xilinx_emaclite 40e00000.ethernet: MAC address is now 00:0a:35:00:01:22  
xilinx_emaclite 40e00000.ethernet: Xilinx Emaclite at 0x40E00000 mapped to 0xF0140000, irq=1  
NET: Registered protocol family 17  
Key type encrypted registered  
Warning: unable to open an initial console.  
Freeing unused kernel memory: 13108K  
This architecture does not have kernel memory protection.  
Run /init as init process  
random: dd: uninitialized urandom read (512 bytes read)  
xilinx_emaclite 40e00000.ethernet eth0: Link is Down  
random: dropbearkey: uninitialized urandom read (32 bytes read)  
random: dropbearkey: uninitialized urandom read (32 bytes read)  
random: crng init done  
  
PetaLinux 2019.2 CSCI_Arty_OS /dev/ttyUL0  
  
CSCI_Arty_OS login: root  
Password:  
root@CSCI_Arty_OS:~# ls  
root@CSCI_Arty_OS:~#
```

DEMO

Stand by for SSH ...

SOURCES

- https://www.xilinx.com/support/documentation/sw_manuals/xilinx2019_2/ug1144-petalinux-tools-reference-guide.pdf
- https://www.xilinx.com/support/documentation/sw_manuals/xilinx2019_2/ug1157-petalinux-tools-command-line-guide.pdf
- <https://www.yoctoproject.org/>
- https://reference.digilentinc.com/media/reference/programmable-logic/arty/arty_rm.pdf
- https://reference.digilentinc.com/media/reference/programmable-logic/basys-3/basys3_rm.pdf?_ga=2.8933622.29982397.1565915174-26851832.1557255277&_gac=1.211996064.1565915174.EAlaIQobChMIg4fPyJCG5AIVGh6tBh38AgkFEAAAYASAAEgITxPD_BwE
- <https://www.youtube.com/watch?v=8olZxv3fJxs>
- <https://www.youtube.com/watch?v=TR2g6pAKRT0>

GIT REPO

The screenshot shows a GitHub repository page. At the top, the repository name is 'chrismajor2124 / CSCI460_Final_Project_Yocto_on_Microblaze'. Below the name are buttons for 'Unwatch', 'Star', and 'Fork'. A navigation bar includes links for 'Code', 'Issues', 'Pull requests', 'Actions', 'Projects', 'Wiki', 'Security', 'Insights', and 'Settings'. The repository description is 'Implementation and demonstration of the Yocto Linux distribution onto the softcore processor of an Artix-7 FPGA.' Below this, statistics show '12 commits', '1 branch', '0 packages', '0 releases', and '1 contributor'. A bar chart shows the commit history. Below the statistics are buttons for 'Branch: master', 'New pull request', 'Create new file', 'Upload files', 'Find file', and 'Clone or download'. The file list shows several directories and files, including 'arty_linux.cache', 'arty_linux.hw', 'arty_linux.ip_user_files', 'arty_linux.runs', 'arty_linux.srcs', 'docs', 'images', and 'petalinux_project/CSCI Artv OS'.

chrismajor2124 / CSCI460_Final_Project_Yocto_on_Microblaze

Unwatch 1 Star 0 Fork 0

Code Issues 0 Pull requests 0 Actions Projects 0 Wiki Security Insights Settings

Implementation and demonstration of the Yocto Linux distribution onto the softcore processor of an Artix-7 FPGA. Edit

Manage topics

12 commits 1 branch 0 packages 0 releases 1 contributor

Branch: master New pull request Create new file Upload files Find file Clone or download

TeamRadPC README updated Latest commit 08b0900 yesterday

arty_linux.cache	Working Petalinux image, tested on Arty board through PuTTY	yesterday
arty_linux.hw	Working Petalinux image, tested on Arty board through PuTTY	yesterday
arty_linux.ip_user_files	Working Arty hardware design	13 days ago
arty_linux.runs	Working Petalinux image, tested on Arty board through PuTTY	yesterday
arty_linux.srcs	Working Petalinux image, tested on Arty board through PuTTY	yesterday
docs	Added SDK project to test network ports	13 days ago
images	Working Petalinux image, tested on Arty board through PuTTY	yesterday
petalinux_project/CSCI Artv OS	Working Petalinux image, tested on Arty board through PuTTY	yesterday

https://github.com/chrismajor2124/CSCI460_Final_Project_Yocto_on_Microblaze