

AN 706: Mapping HPS IP Peripheral Signals to the FPGA Interface

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AN-706



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The Altera Cyclone® V and Arria® V SoC device families integrate an Arm* Cortex*-A9-based hard processor system (HPS) consisting of processor, peripherals, and memory interface with the FPGA fabric using a high-bandwidth interconnect backbone. The Cyclone V HPS interface provides up to 67 I/O pins to share with multiple peripherals through sets of configurable multiplexers. The Arria V HPS interface provides up to 71 I/O pins.

This application note describes the steps required to route an HPS peripheral through the FPGA interface using Platform Designer (Standard) and Intel® Quartus® Prime Standard Edition software. A simple design example is included to demonstrate exporting HPS EMAC0 and I2C0 peripheral signals to the FPGA interface using a Cyclone V SoC Development Kit.

Cyclone V and Arria V HPS Peripherals That Support Routing to the FPGA

The following types of Cyclone V and Arria V HPS peripherals are capable of routing to the FPGA fabric:

- Ethernet Media Access Controller (EMAC)
- Quad Serial Peripheral Interface (QSPI)
- Secure Digital/Multimedia Card (SD/MMC)
- Serial Peripheral Interface (SPI)
- Universal Asynchronous Receiver/Transmitter (UART)
- Inter-Integrated Circuit (I²C)
- Controller Area Network (CAN)⁽¹⁾

In many cases, routing the HPS IP signals to the FPGA external interface allows more signals to be exposed.

Table 1: Peripherals that Support Signal Routing from the HPS Domain to FPGA Domain

The following table lists the interface type that is available depending on whether the IP interface is pinned out in the HPS domain or the FPGA domain.

⁽¹⁾ The CAN interface is only available in the Cyclone V SoC device family.

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Peripherals	Interface Description	
	HPS Domain	FPGA Domain
EMAC	RGMII Interface	GMII Interface
QSPI	Standard QSPI interface with four slave select signals	Standard QSPI interface with four slave select signals achieved by connecting exported signals to bidirectional buffers
SD/MMC	Standard SD/MMC interface with up to 8-bit data bus	Standard SD/MMC interface, including: <ul style="list-style-type: none"> • Up to 8-bit data bus • Card detect interface • Card interrupt • Voltage switching • Power enable • Reset ⁽²⁾
SPI Master	MOSI/MISO SPI interface configurable to single or dual slaves	MOSI/MISO SPI interface with output enables that support up to four slaves; interface achieved by connecting exported signals to bidirectional buffers
SPI Slave	MOSI/MISO SPI interface configurable to single or dual slaves	MOSI/MISO SPI interface with output enables that support up to four slaves; interface achieved by connecting exported signals to bidirectional buffers
UART	Standard UART interface with flow control signals	Standard UART interface with flow control signals, including DTR and DSR; status and two user-defined output signals are also available
I ² C	Standard I ² C interface	Standard I ² C interface achieved by connecting exported signals to a bidirectional buffer
CAN ⁽³⁾	Standard CAN interface	Standard CAN interface

⁽²⁾ The SD/MMC controller does not directly support reset, voltage switching, card interrupts, power enable or write protect functions. However, you can connect these signals to general-purpose I/Os (GPIOs).

⁽³⁾ The CAN interface is only available in the Cyclone V SoC device family.

Refer to the following chapters of the *Cyclone V Hard Processor System Technical Reference Manual* for descriptions of each peripheral signal interface:

Related Information

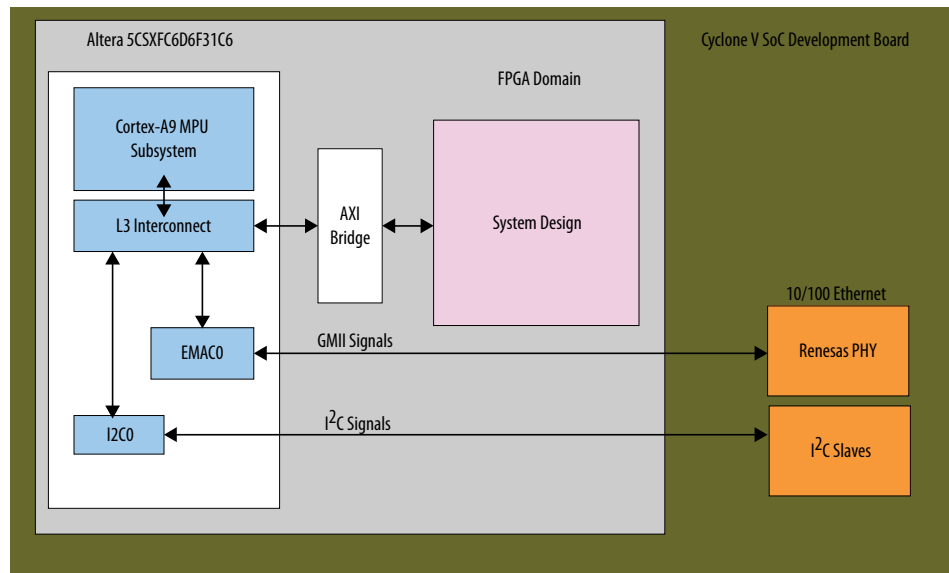
- [General-Purpose I/O Interface](#)
- [SD/MMC Controller](#)
- [Ethernet Media Access Controller](#)
- [Quad SPI Flash Controller](#)
- [SPI Controller](#)
- [UART Controller](#)
- [I²C Controller](#)
- [CAN Controller](#)

Design Example: Cyclone V HPS IP Interface to FPGA

This design example, based on the Golden System Reference Design (GSRD), uses the Cyclone V SoC development kit resources to demonstrate routing the Cyclone V HPS EMAC0 and I2C0 peripheral signals to the FPGA interface.

The Cyclone V HPS component provides up to two EMAC peripherals, which support 10/100/1000 Mbps operation. The Cyclone V SoC Development board is populated with a Micrel KSZ9021RN RGMII PHY that interfaces to the HPS domain and a Renesas uPD60620A MII Dual Port PHY that interfaces to the FPGA domain. The HPS and FPGA also share a common I²C bus to various on-board I²C slaves.

Figure 1: High-level Routing Layout of Cyclone V SoC Board Design Example



The following sections provide the necessary information to route the HPS peripherals to the FPGA interface, such as:

1. [Prerequisites](#) on page 4

2. [Getting Started](#) on page 5
3. [Generating the Initial HDL in Platform Designer \(Standard\)](#) on page 5
4. [Top Level Routing](#) on page 9
5. [Timing Constraint Configuration](#) on page 11
6. [Adding Pin Assignments in Intel Quartus Prime Standard Edition](#) on page 11
7. [Hardware Programming File Compilation and Generation](#) on page 13
8. [SD Card Image Updates](#) on page 14
9. [Board Setup and Booting Linux from the SD Card](#) on page 15

Prerequisites

This design example is based on the Cyclone V GSRD and tested with Intel Quartus Prime Standard Edition version 14.0. Refer to the links listed below and review the recommended material before starting with this design example.

Related Information

- [Cyclone V SoC Development Kit](#)
Refer to this link for *Cyclone V SoC Development Kit* documentation and installation files.
- [Golden System Reference Design User's Manual](#)
Refer to this document and step through the *Getting Started Guides*, *Prerequisites*, and the *GHRD Overview*. In addition, review the *Development Flow Overview*.

Hardware Requirements

The hardware required for this design example is:

- Cyclone V SoC Development Kit
- RJ45 Ethernet cable
- SD/MMC card preloaded with default GSRD image

Software Requirements

The software required for this design example is:

- Intel Quartus Prime Standard Edition 14.0 and above
- SoC EDS 14.0 and above
- Factory default hardware template `cv_soc_devkit_ghrd` in SoC EDS 14.0

Design example files are provided in the [AN 706 design example link](#) and are listed in the table below.

Table 2: Required Software Files

File Name	Description
<code>ghrd_top.v</code>	Top level RTL file
<code>soc_system_timing.sdc</code>	Timing constraint file
<code>an706_de_pin_assignment.tcl</code>	Pin assignment script file

File Name	Description
preloader-mkpmimage.bin	Generated preloader binary targeted to this project
u-boot.img	Modified u-boot image for EMAC0
socfpga.dtb	Modified device tree for EMAC0 and I2C0

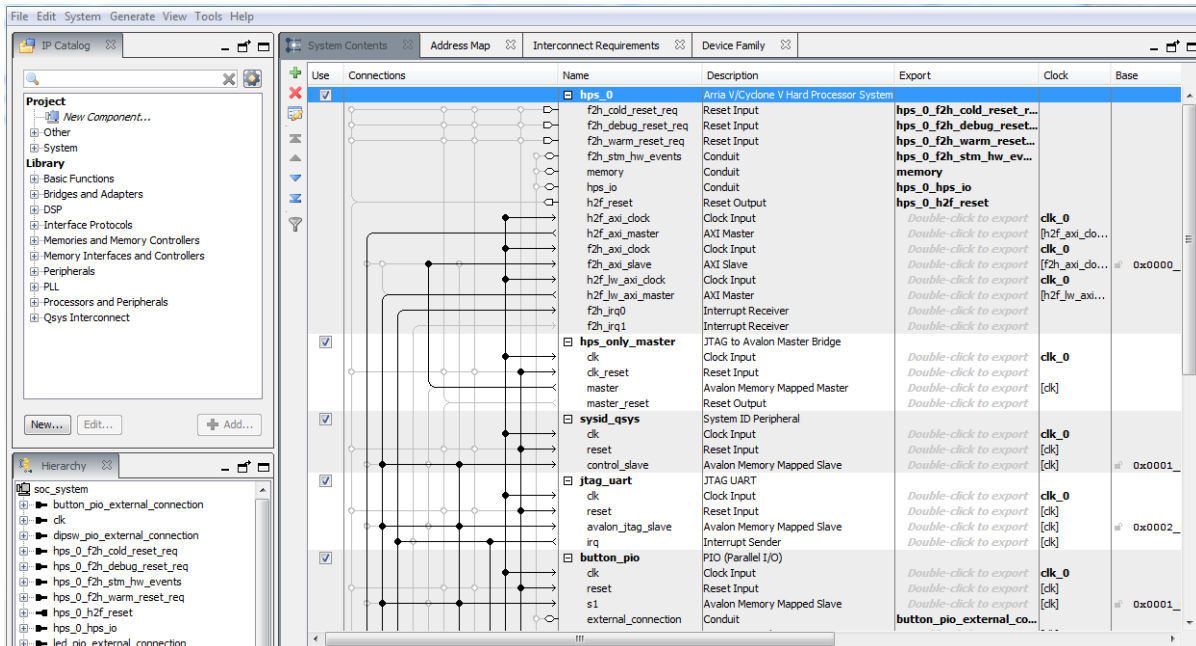
Getting Started

1. Make a copy of the Cyclone V Golden Hardware Reference Design (GHRD) from your Cyclone V SoC Development Kit installation location or download the latest Cyclone V GHRD design example from the [Rocketboards website](#) to your project location.
2. Download the [AN 706 design files](#) (an706-design-files.zip) provided.
3. Open the GHRD project within the Intel Quartus Prime Standard Edition software.

Generating the Initial HDL in Platform Designer (Standard)

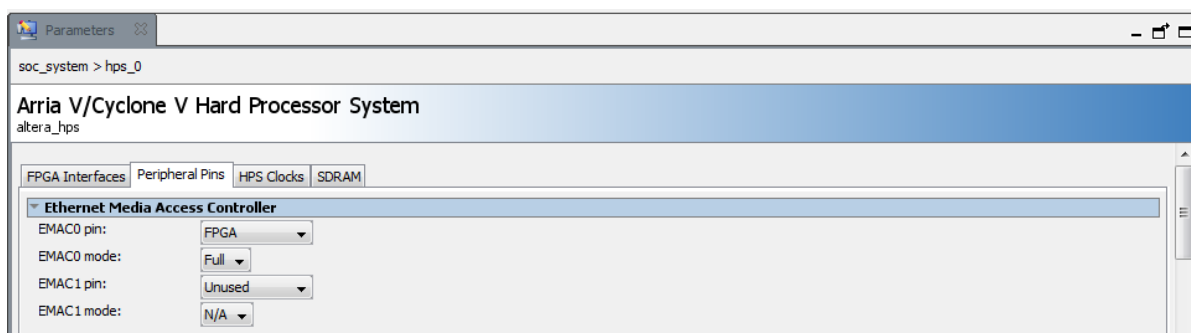
1. In the Intel Quartus Prime Standard Edition navigation bar, select **Tools > Platform Designer (Standard)**.
2. In the Platform Designer (Standard) window, select **File > Open > soc_system.qsys**.
3. In the **System Contents** tab, double click on `hps_0` to open the **HPS Parameters** window.

Figure 2: System Contents Window



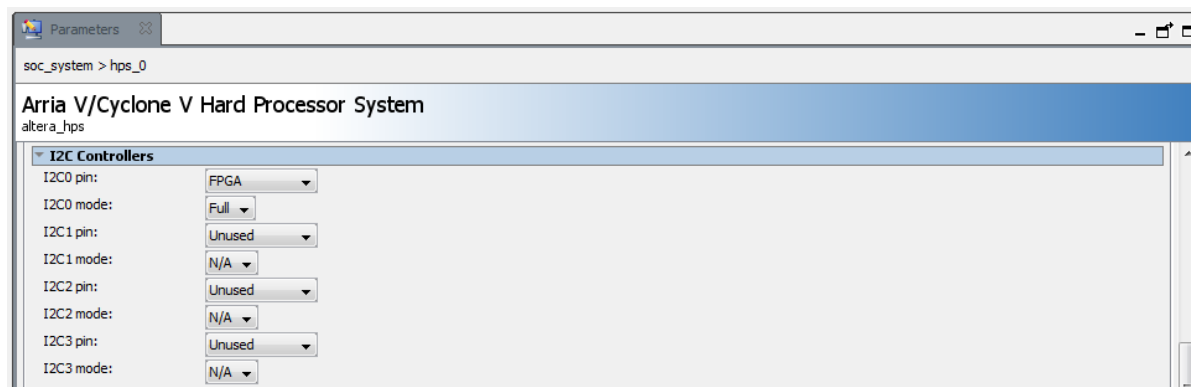
4. On the **Peripheral Pins** tab, under the **Ethernet Media Access Controller** section, click on the **EMAC0 pin** pull-down and select **FPGA**. The **EMAC0 mode** pull-down automatically displays **Full** to indicate **GMII** mode. Select the **EMAC1 pin** pull-down as **Unused**.

Figure 3: Selecting FPGA for EMAC0 Pin in the HPS Parameters Window



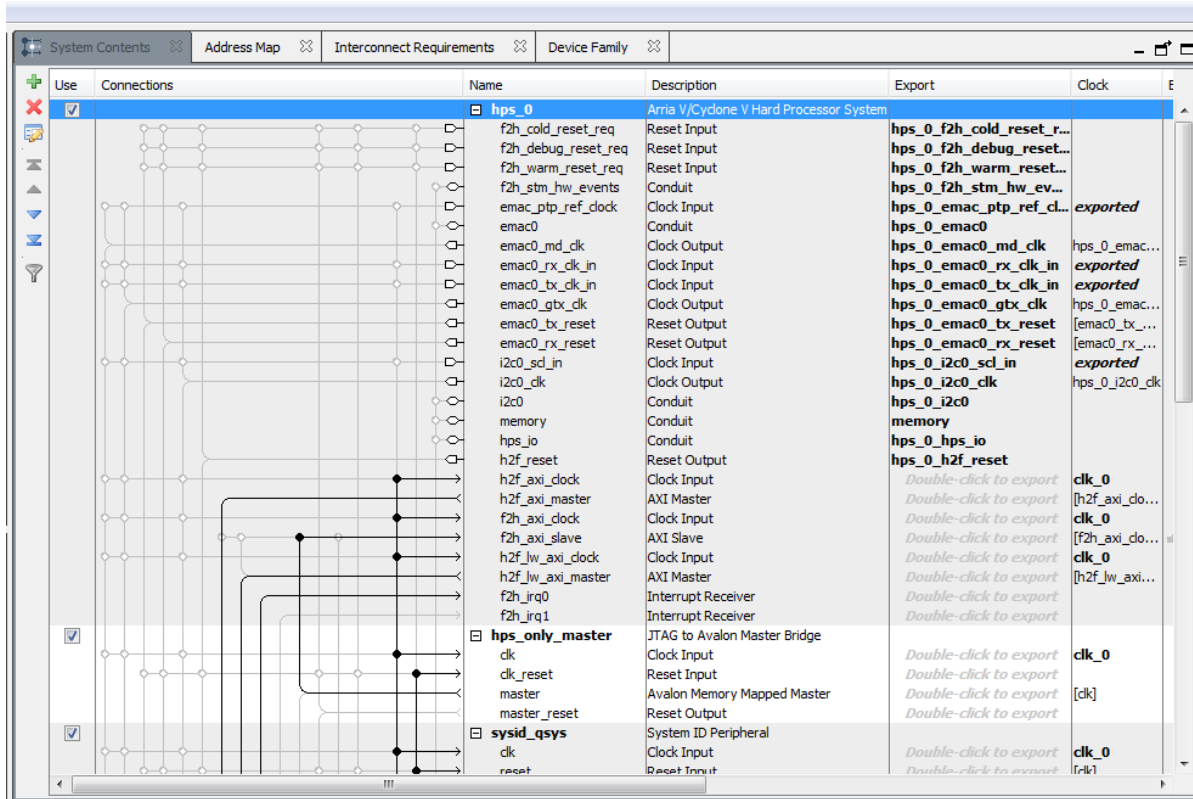
5. On the **Peripheral Pins** tab, scroll down to the **I2C Controllers** section, click on the **I2C0 pin** pull-down and select **FPGA**. The **I2C0 mode** pull-down automatically displays **Full**.

Figure 4: Selecting FPGA for I2C0 Pin in the HPS Parameters Window



6. Return to the **System Contents** tab and in the **Export** column, double-click on the EMAC0 and I2C0 signal pins to export them as conduits.

Figure 5: Exporting Pins in System Contents Window



7. Select **Generate > Generate HDL** from the Platform Designer (Standard) menu bar. In the project directory, replace the top level RTL file, `ghrd_top.v`, with the generated Verilog file. Platform Designer (Standard) exposes the following EMAC0 and I2C0 interfaces in the file:

Table 3: EMAC0 Signals in the FPGA Domain

Signal	Width	Direction	Description
emac0_phy_txd_o	8	Out	PHY Transmit Data
emac0_phy_txen_o	1	Out	PHY Transmit Data Enable
emac0_phy_txer_o	1	Out	PHY Transmit Error
emac0_phy_rxdv_i	1	In	PHY Receive Data Valid
emac0_phy_rxer_i	1	In	PHY Receive Error
emac0_phy_rxd_i	8	In	PHY Receive Data
emac0_phy_col_i	1	In	PHY Collision Detect

Signal	Width	Direction	Description
emac0_phy_crs_i	1	In	PHY Carrier Sense
emac0_gmii_mdo_o	1	Out	MDIO signal data out
emac0_gmii_mdo_o_e	1	Out	MDIO signal output enable
emac0_gmii_mdi_i	1	In	MDIO signal input
emac0_gmii_mdc_o	1	Out	Management Data Clock
emac0_clk_rx_i	1	In	PHY RX reference clock
emac0_clk_tx_i	1	In	PHY TX reference clock
emac0_phy_txclk_o	1	Out	Transmit clock output to the PHY
emac0_rst_clk_tx_n_o	1	Out	Transmit clock reset output to the FPGA interface
emac0_rst_clk_rx_n_o	1	Out	Receive clock reset output

Table 4: I2C0 Signals in the FPGA Domain

Signal	Width	Direction	Description
i2c0_out_data	1	Out	Outgoing I ² C data enable
i2c0_sda	1	In	Incoming I ² C data
i2c0_clk_clk	1	Out	Outgoing I ² C clock enable
i2c0_scl_in_clk	1	In	Incoming I ² C clock source

Related Information

- **Ethernet Media Access Controller**

Refer to the interface descriptions in the "Ethernet Media Access Controller" chapter of the *Cyclone V Hard Processor System Technical Reference Manual* for more detailed GMII interface signal descriptions.

- **I²C Controller**

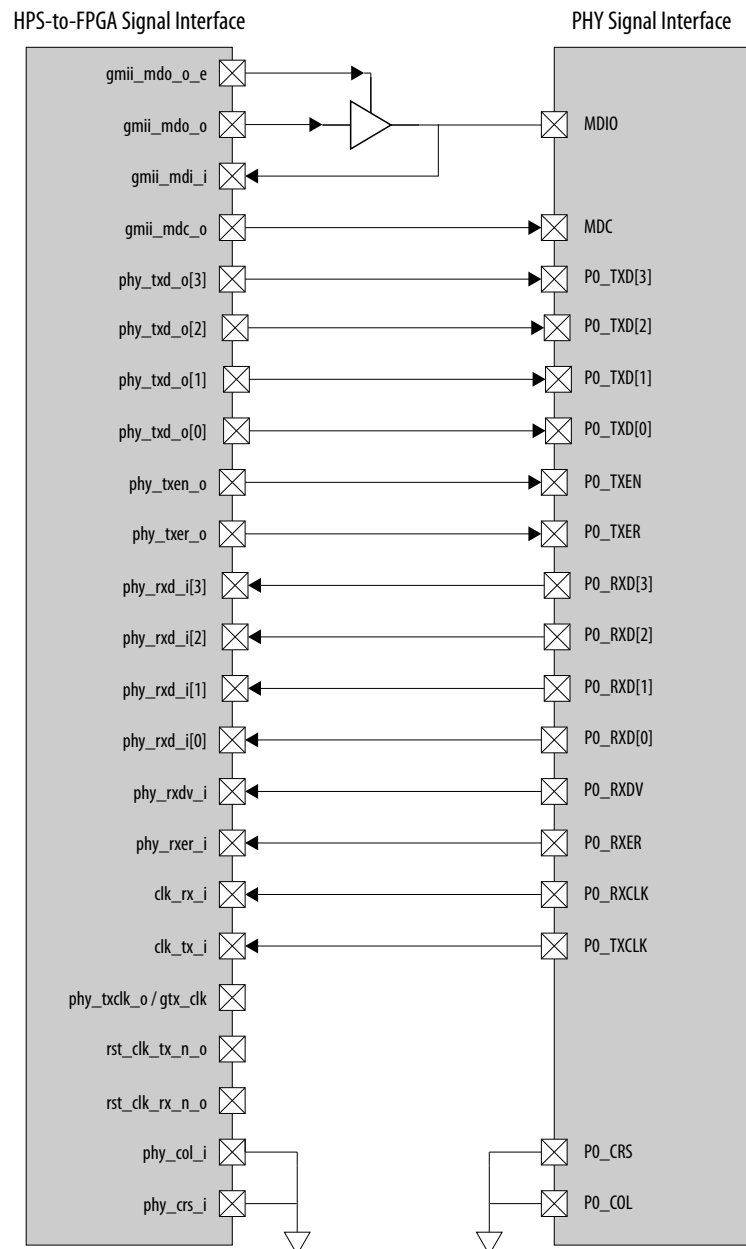
Refer to the interface descriptions in the "I²C Controller" chapter of the *Cyclone V Hard Processor System Technical Reference Manual* for more detailed I²C interface signal descriptions.

Top Level Routing

The top level RTL file defines the pin connections from the Cyclone V HPS EMAC0 to the Renesas MII PHY on the Cyclone V SoC development board.

Note: Because MII is a 4-bit data width protocol, connect only the lower 4-bits, `emac0_phy_txd_o[3:0]` and `emac0_phy_rxd_i[3:0]`, of EMAC0's RX and TX interface from the FPGA.

Figure 6: Routing of the EMAC0 FPGA Interface to the On-board MII PHY



HPS I2C0 is routed through the FPGA interface and acts as a master to various on-board I²C slaves:

- Two Octal Digital Power Supply Managers with EEPROM
- LCD
- RTC
- EEPROM

Note: A bi-directional buffer, `ALT_IOBUF`, must be added in the design to connect the I²C signals to an external open drain IO. The buffer can be included by instantiating `ALT_IOBUF` in `ghrd_top.v`.

The following Verilog code shows the `ALT_IOBUF` instantiation for an I²C interface implemented through the FPGA:

```
ALT_IOBUF scl_iobuf (.i(1'b0), .oe(scl_o_e), .o(scl_o), .io(fpga_i2c_scl)); //  
declared bi-directional buffer for scl  
ALT_IOBUF sda_iobuf (.i(1'b0), .oe(sda_o_e), .o(sda_o), .io(fpga_i2c_sda)); //  
declared bi-directional buffer for sda
```

Related Information

[ALT_IOBUF Primitive](#)

Refer to the `ALT_IOBUF` primitive information for more information.

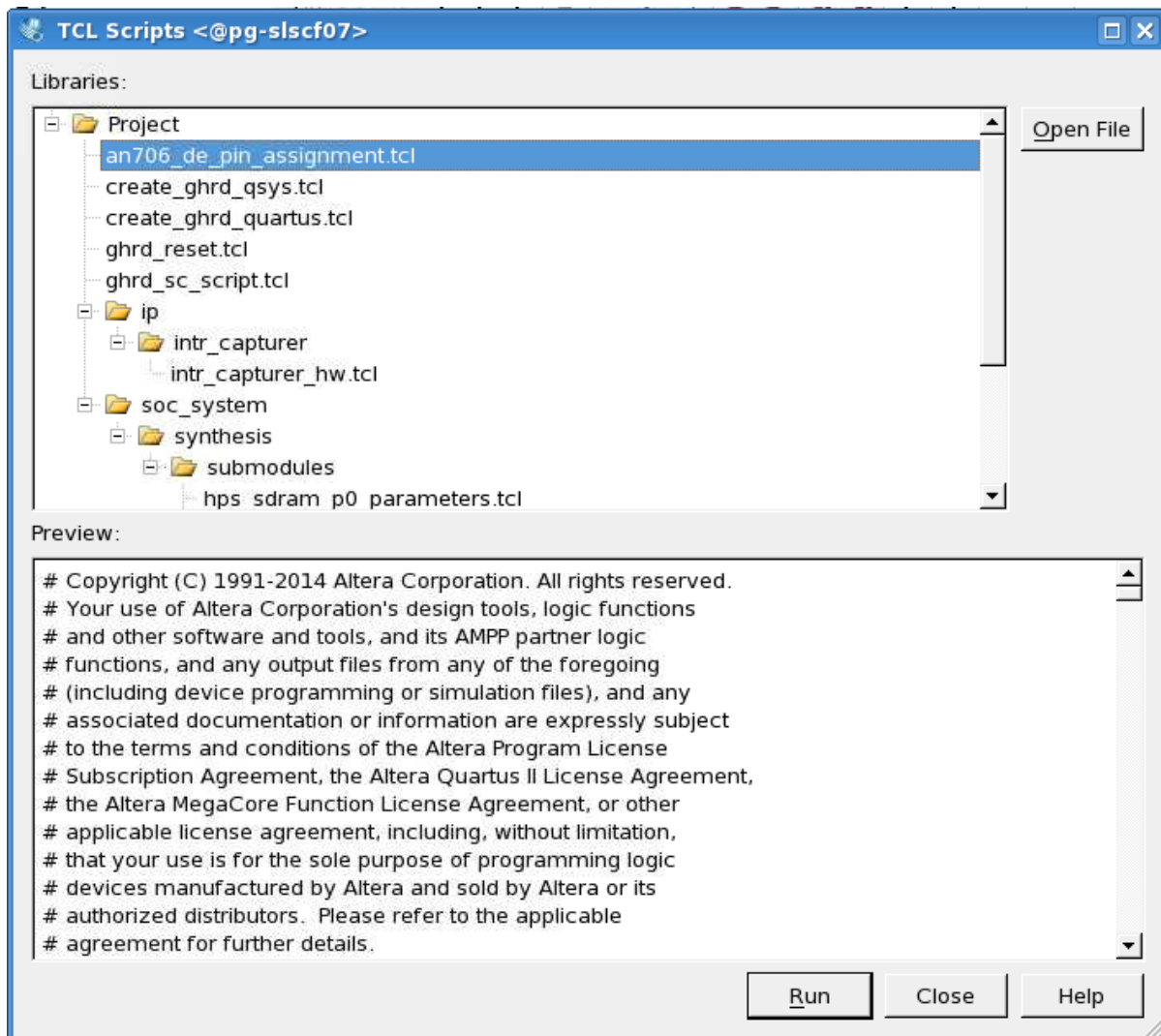
Timing Constraint Configuration

Replace the `soc_system_timing.sdc` file in your project directory with the `soc_system_timing.sdc` file provided in the project folder. This new file is customized for the EMAC0 and I2C0 interface being tested on the Cyclone V SoC development board.

Adding Pin Assignments in Intel Quartus Prime Standard Edition

1. Copy `an706_de_pin_assignment.tcl` from the [AN 706 design files](#) into your project directory.
2. In the Intel Quartus Prime Standard Edition menu bar, select **Tools > Tcl Scripts**
3. In the Tcl Scripts window, choose `an706_de_pin_assignment.tcl` and select **Run**.

Figure 7: Selecting pin_assignment.tcl in the Tcl Scripts Window



The `an706_de_pin_assignment.tcl` script automatically assigns EMAC0 and I2C0 signal pins to their related FPGA pin location.

Table 5: Pin Assignments for EMAC0 and I2C0

Signal	Direction	Pin Location
enet1_rx_clk	Input	PIN_Y24
enet1_rx_d[0]	Input	PIN_AB23
enet1_rx_d[1]	Input	PIN_AA24

Signal	Direction	Pin Location
enet1_rx_d[2]	Input	PIN_AB25
enet1_rx_d[3]	Input	PIN_AE27
enet1_rx_dv	Input	PIN_Y23
enet1_rx_error	Input	PIN_AE28
enet1_tx_clk_fb	Input	PIN_W25
enet1_tx_d[0]	Output	PIN_W20
enet1_tx_d[1]	Output	PIN_Y21
enet1_tx_d[2]	Output	PIN_AA25
enet1_tx_d[3]	Output	PIN_AB26
enet1_tx_en	Output	PIN_AB22
enet1_tx_error	Output	PIN_AG5
enet_dual_resethn	Output	PIN_AJ1
enet_fpga_mdc	Output	PIN_H12
enet_fpga_mdio	Bidirectional	PIN_H13
fpga_i2c_scl	Bidirectional	PIN_G7
fpga_i2c_sda	Bidirectional	PIN_F6

Hardware Programming File Compilation and Generation

After the Platform Designer (Standard) system is set up, the top level RTL file updated, the related signal pin location assigned and timing constrained, the design can be compiled and the SOF programming file generated.

In the Intel Quartus Prime Standard Edition software navigation bar, select **Processing > Start Compilation** to generate the SOF programming file.

SD Card Image Updates

Update the default SD card image with the generated preloader binary, u-boot image file and DTB file following the steps described below:

1. With your Linux machine, prepare the SD card by following the information in [GSRD-Booting Linux Using Prebuilt SD Card Image](#). Untar the `sd_image.bin.tar.gz` file and program the image file, `sd_image.bin` into the SD card.
2. Replace the `preloader-mkimage.bin`, `u-boot.img` and `socfpga.dtb` in the SD card.

Note: Information provided regarding SD card changes, preloader and Linux software file changes and preloader generation are applicable to this reference design only.

Preloader Generation

Because this design example modifies the default GHRD Platform Designer (Standard) file, it is essential to re-generate the preloader with the preloader generator.

Related Information

[GSRD - Generating and Compiling the Preloader](#)

Refer to this location for information on how to generate and compile the preloader.

U-boot Setup

Go to file location `u-boot-socfpga/include/configs/socfpga_cyclone.h`. The EMAC0 parameters associated with the interface speed must be configured to MII in the `socfpga_cyclone.h` file in the u-boot source. Change the `#define` for `CONFIG_EMAC_BASE` and `CONFIG_PHY_INTERFACE_MODE` to the following:

```
#define CONFIG_EMAC_BASE                CONFIG_EMAC0_BASE
#define CONFIG_PHY_INTERFACE_MODE      SOCFPGA_PHYSEL_ENUM_MII
```

Related Information

[Preloader and U-Boot Customization](#)

Refer to this location for information on how to customize u-boot.

Device Tree Setup

Generate the device tree. EMAC0 is enabled in the device tree source, as shown below, and the I2C0 code source maintains its default settings.

```
aliases {
    ethernet0 = "/soc/ethernet@ff700000";
};
ethernet@ff700000 {
    compatible = "altr,socfpga-stmmac", "snps,dwmac-3.70a",
    "snps,dwmac";
    reg = <0xff700000 0x2000>;
    interrupts = <0x0 0x73 0x4>;
    interrupt-names = "macirq";
    mac-address = [00 00 00 00 00 00];
    clocks = <0xd>;
    clock-names = "stmmaceth";
    status = "okay";
    phy-mode = "mii";
    phy-add r= <0xffffffff>;
    snsp,
};
```

Related Information

[GSRD User Manual - Device Tree Generator](#)

Refer to this location for information on device tree generation.

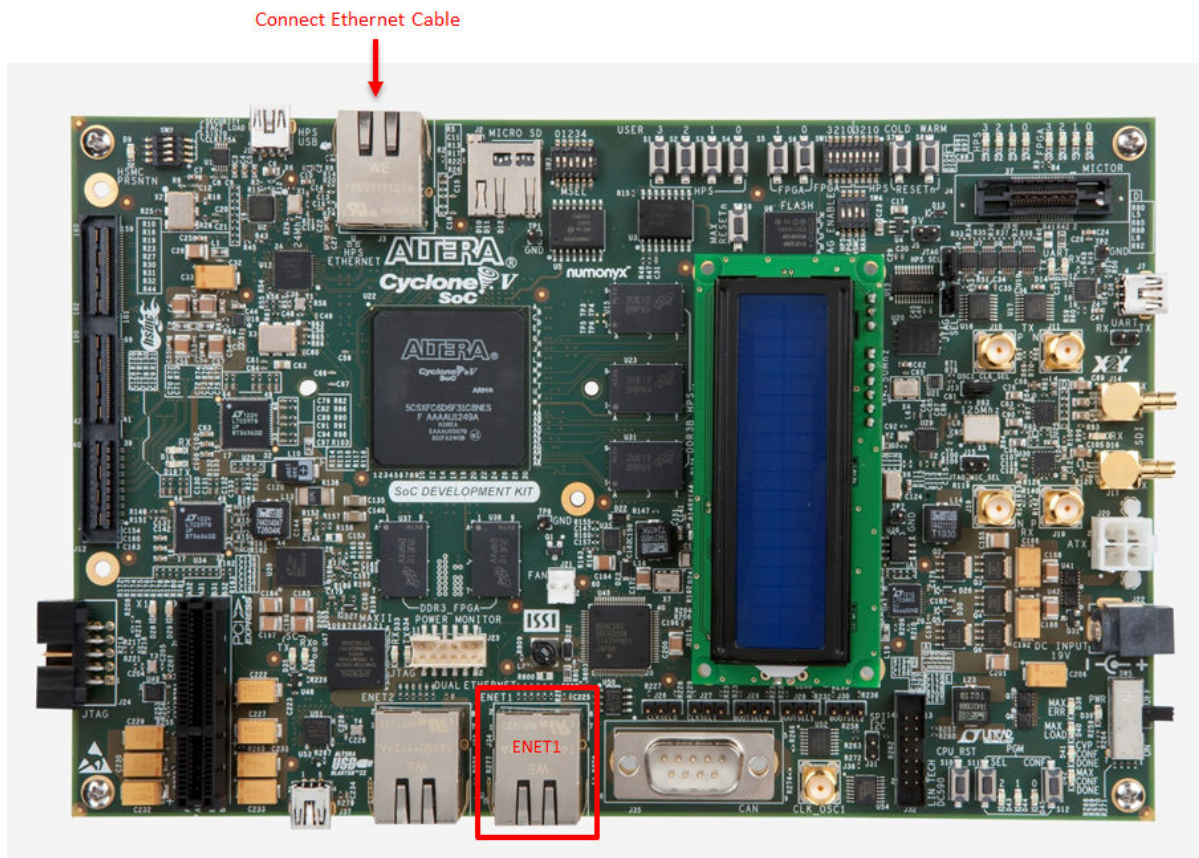
Board Setup and Booting Linux from the SD Card

Before you begin

Board setup is based on the *GSRD Getting Started Guides*.

1. Connect Ethernet Cable to the ENET1 Ethernet port.

Figure 8: Ethernet Connection on Cyclone V SoC Development Board



2. Slot in the SD card and power on the board.
3. Program the FPGA .sof file and perform a warm reset on the Cyclone V HPS component to reload the SD card image.
4. The kernel automatically enables and initializes EMAC0 then executes the dynamic host configuration protocol (DHCP) to obtain an IP address.
5. When the boot process has completed, login as root at the kernel terminal.

Figure 9: Kernel Login Example

```
libphy: stmmac: probed
eth0: PHY ID b8242824 at 0 IRQ 0 (stmmac-0:00) active
eth0: PHY ID b8242824 at 1 IRQ 0 (stmmac-0:01)
eth0: PHY ID 00000000 at 6 IRQ 0 (stmmac-0:06)
eth0: PHY ID ff5f521e at 7 IRQ 0 (stmmac-0:07)
stmmac - user ID: 0x10, Synopsys ID: 0x37
Ring mode enabled
DMA HW capability register supported
Enhanced/Alternate descriptors
Enabled extended descriptors
RX Checksum Offload Engine supported (type 2)
TX Checksum insertion supported
```



```
Configuring network interfaces... eth0: device MAC address c6:1d:a4:1a:a4:e8
udhcpd (v1.20.2) started
Sending discover...
libphy: stmmac-0:00 - Link is Up - 100/Full
Sending discover...
Sending select for 137.57.118.160...
Lease of 137.57.118.160 obtained, lease time 86400
/etc/udhcpd.d/50default: Adding DNS 137.57.116.2
/etc/udhcpd.d/50default: Adding DNS 137.57.137.2
/etc/udhcpd.d/50default: Adding DNS 137.57.64.1
done.
```

Related Information

- [GSRD User's Manual - Getting Started Guides](#)
Refer to this location for information on board setup in the GSRD User's Manual - Getting Started Guides.
- [GSRD - SD Card](#)
Refer to this location for information on updating the SD Card.

Sample Application Example

The default kernel image contains many useful commands and built-in tools, such as `ethtools` and `mii-tools`. Some examples are illustrated in this section.

EMAC Test

Examples of commands that can be executed on EMAC0 are:

```
>udhcpd
```

Activate the dhcp server to request an IP address.

Figure 10: `udhcpd` Command Output

```
Configuring network interfaces... eth0: device MAC address c6:1d:a4:1a:a4:e8
udhcpd (v1.20.2) started
Sending discover...
libphy: stmmac-0:00 - Link is Up - 100/Full
Sending discover...
Sending select for 137.57.118.160...
Lease of 137.57.118.160 obtained, lease time 86400
/etc/udhcpd.d/50default: Adding DNS 137.57.116.2
/etc/udhcpd.d/50default: Adding DNS 137.57.137.2
/etc/udhcpd.d/50default: Adding DNS 137.57.64.1
done.
```

```
>ifconfig eth0
```

Initialize and enable or disable the network interface.

Figure 11: `ifconfig eth0` Command Output

```

root@socfpga:~# ifconfig eth0
eth0      Link encap:Ethernet  HWaddr c6:1d:a4:1a:a4:e8
          inet addr:137.57.118.54  Bcast:0.0.0.0  Mask:255.255.255.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1628 errors:0 dropped:0 overruns:0 frame:0
          TX packets:7 errors:4 dropped:0 overruns:0 carrier:4
          collisions:0 txqueuelen:1000
          RX bytes:158838 (155.1 KiB)  TX bytes:2030 (1.9 KiB)
          Interrupt:147

```

```
>ethtool eth0
```

Display and allow edits to the EMAC device parameters.

Figure 12: `ethtool eth0` Command Output

```

root@socfpga:~# ethtool eth0
Settings for eth0:
    Supported ports: [ TP AUI BNC MII FIBRE ]
    Supported link modes:   10baseT/Half 10baseT/Full
                           100baseT/Half 100baseT/Full
    Supported pause frame use: No
    Supports auto-negotiation: Yes
    Advertised link modes:  10baseT/Half 10baseT/Full
                           100baseT/Half 100baseT/Full
    Advertised pause frame use: No
    Advertised auto-negotiation: Yes
    Speed: 100Mb/s
    Duplex: Full
    Port: MII
    PHYAD: 0
    Transceiver: external
    Auto-negotiation: on
    Supports Wake-on: d
    Wake-on: d
    Current message level: 0x0000003f (63)
                           drv probe link timer ifdown ifup
    Link detected: yes

```

I²C Test

The I²C interface can be tested using the following commands:

```
>i2cdetect -l
```

List the detected HPS I²C ports.

```
>i2cdetect -r 0
```

List the I²C slave devices connected to the HPS. "UU" is defined as device busy.

Figure 13: i2cdetect Command Outputs

```

root@socfpga_cyclone5:~# i2cdetect -l
i2c-0  i2c          Synopsys DesignWare I2C adapter          I2C adapter
root@socfpga_cyclone5:~# i2cdetect -r 0
WARNING! This program can confuse your I2C bus, cause data loss and worse!
I will probe file /dev/i2c-0 using read byte commands.
I will probe address range 0x03-0x77.
Continue? [Y/n] y
    0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --
10:  --  --  --  --  --  --  --  17  --  --  --  --  --  --  --  --
20:  --  --  --  --  --  --  --  --  UU  --  --  --  --  --  --  --
30:  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --
40:  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --
50:  --  UU  --  --  --  55  --  --  --  --  --  5b  5c  --  5e  --
60:  --  --  --  --  --  --  66  --  UU  --  --  --  --  --  --  --
70:  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --  --

```

```
>i2cset -y 0 0x66 0x10 0x55
```

I2C0 writes the data value 0x55 to the data address 0x10 of slave device at 0x66. The command is written in the order: device address, data address, data value.

```
>i2cget -y 0 0x66 0x10
```

Return data value at address 0x10 of the device slave at address 0x66.

Figure 14: i2cset and i2cget Commands

```

root@socfpga_cyclone5:~# i2cset -y 0 0x66 0x10 0x55
root@socfpga_cyclone5:~# i2cget -y 0 0x66 0x10
0x55

```

```
>i2cdump -y 0 0x66
```

Register data dump from 0x00 to 0xFF. "XX" is defined as a non-valid address.

Figure 15: i2cdump Command Output

```

root@socfpga_cyclone5:~# i2cdump -y 0 0x66
No size specified (using byte-data access)
 0 1 2 3 4 5 6 7 8 9 a b c d e f 0123456789abcdef
00: 47 02 32 a1 4d ad f8 22 42 bc 52 14 39 22 42 bc G??M??"B?R?9"B?
10: 55 14 39 00 c2 c0 00 00 00 07 c2 c0 00 00 00 0c U?9.??...???.??
20: 4d fc ad 2c ed 90 00 01 2a 29 3f 3c 8e 3f b4 9b M??,??.*?)?<????
30: 00 89 36 00 00 00 XX 00 00 00 00 00 00 00 00 00 .?6...X.....
40: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
50: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 XX 00 .....X.
60: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
70: 00 00 00 00 00 00 00 00 00 00 00 00 XX 00 00 00 .....X....
80: 20 XX f3 5d a1 81 03 00 10 0e XX XX 50 9a 02 bc X?]???.??XXP???.
90: 55 b5 6f 00 00 00 62 00 00 00 00 00 00 00 00 00 U?o...b.....
a0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
b0: 00 00 00 00 00 00 00 00 00 00 00 00 00 XX 00 00 .....X..
c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
f0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....

```

Reference Documents

A summary list of the reference documents and sites mentioned in this application note follows:

Related Information

- [HPS-to-FPGA Application Note \(AN 706\) Design Example](#)
- [Cyclone V SoC Development Kit](#)
- [Golden System Reference Design User's Manual](#)
- [Compiling Golden Hardware Reference Design](#)
- [Ethernet Media Access Controller](#)
In the *Cyclone V Hard Processor System Technical Reference Manual*
- [I²C Controller](#)
In the *Cyclone V Hard Processor System Technical Reference Manual*
- [ALT_IIOBUF Primitive](#)
- [GSRD-Bootting Linux Using Prebuilt SD Card Image](#)
- [GSRD - Generating and Compiling the Preloader](#)
- [Preloader and U-Boot Customization](#)
- [GSRD User Manual - Device Tree Generator](#)
- [GSRD User's Manual - Getting Started Guides](#)
- [GSRD - SD Card](#)
- [RocketBoards website](#)
- [General-Purpose I/O Interface](#)
In the *Cyclone V Hard Processor System Technical Reference Manual*

AN 706 Revision History

Date	Version	Changes
May 2018	2018.05.07	<ul style="list-style-type: none">SD/MMC can route signals to the FPGAClarify that CAN is only supported by the Cyclone V SoC device family
July 2014	2014.07.17	<ul style="list-style-type: none">Modified URLs of RocketBoards pages to version-specific links.Corrected AN 706 design example URL.Added steps to the <i>Board Setup and Booting Linux from the SD Card</i> section.
July 2014	2014.07.03	Initial Release