The EXFILT Project

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Contents

Chapter 1

Threats and Risks

1.1 Threats

- loss of customer data
- loss of corporate data
- theft of capital equipment
- business disruption
- reduced productivity
- increased expense
- regulatory violation
- loss of public trust
- stock loss

Risk = probability x cost

1.1.1 Incoming Threats

1.1.2 Insider Threats

ISO 17799 Code of Practice or Information Security Management Internal Controls (COSO) Committee of Sponsoring Organizations of the Treadway Commission (CobiT) Control Objective for Information and related Technology

Chapter 2

Background

- **Packet filtering** `https://www.youtube.com/watch?v=XHlqiqPvKw8`

- **Wireshark tutorial** `https://www.youtube.com/watch?v=Lu05owzpSb8`

- **Art of Packet Analysis** `https://www.youtube.com/watch?v=Qd6uDg9OGxM`

- **ARP protocol** `https://www.youtube.com/watch?v=TOyZ6TWQdM`

Chapter 3

Computer Software Prototype

The goal is to set up two laptops. One is configured as a THREAT machine, the second is configured as the EXFILT machine.

To configure the user machine we need to install Ubuntu, hardwire the THREAT machine to the EXFILT machine with a crossover cable, and set up a lan between the two machines.

For the THREAT machine, the steps are:

1. Download and burn Ubuntu CD

2. Install Ubuntu from the CD

3. Connect the crossover cable

4. set hostname to THREAT

    (a) edit /etc/hostname
    (b) edit /etc/hosts
        - 127.0.0.1 localhost
        - 127.0.1.1 THREAT
        - 10.0.0.2 THREAT
    (c) edit /etc/network/interfaces

        ```
        auto eth0
        iface eth0 inet static
        address 10.0.0.2
        gateway 10.0.0.1
        netmask 255.255.255.0
        broadcast 10.0.0.255
        ```

5. turn on manual network management

    - edit /etc/NetworkManager/NetworkManger.conf
        - comment out dns by putting # as first character of the line

　　　　　　　　– set managed=true (says WE are managing the connection)

　6. Set up the lan

　　　(a) sudo ifconfig eth0 10.0.0.2 netmask 255.255.255.0 up

　　　(b) sudo route add default gw 10.0.0.1

Notice that the THREAT machine has a single IP address of 10.0.0.2 and routes traffic to 10.0.0.1

　SNORT Malware
　https://github.com/rshipp/awesome-malware-analysis
　For the EXFILT machine, the steps are:

　1. Download and burn Ubuntu CD

　2. Install Ubuntu from the CD

　3. set hostname to EXFILT

　4. Connect the crossover cable

　5. Set up the lan

　　　(a) sudo ifconfig eth1 10.0.0.1 netmask 255.255.255.0 up

　　　(b) sudo route add default gw 192.168.1.1

Notice that the EXFILT machine has 2 IP addresses. The first address is 10.0.0.1 which is on the crossover lan. But EXFILT also has a wireless address on the 192.168.1 subnet (WLAN1)

　　With this setup all traffic from the THREAT machine is routed through the EXFILT machine. We need to set up EXFILT to act as the router on the 10.0.0 subnet.

3.0.3   EXFILT Router setup

- eth1 lan crossover network 10.0.0.0/8

- wlan1 wireless outside network 192.168.1.0/8

- EXFILT = 10.0.0.1, THREAT = 10.0.0.2

3.0.4   EXFILT software setup

```
sudo apt-get install -y flex bison libpcap-dev libpcre3 libpcre3-dev libdnet
```

```
tcpdump-4.7.4.tar.gz (http://www.tcpdump.org)
tar -zxf tcpdump-4.7.4.tar.gz
cd tcpdump-4.7.4
./configure && make && sudo make install
```

```
wget https://www.snort.org/downloads/snort/daq-2.0.4.tar.gz
```

```
tar -zxf daq-2.0.4.tar.gz
cd daq-2.0.4
./configure && make && sudo make install

http://code.google.com/p/libdnet
tar -zxf libdnet-1.12.tgz
cd libdnet-1.12
./configure && make && sudo make install

wget https://www.snort.org/downloads/snort/snort-2.9.7.2.tar.gz
tar -zxf snort-2.9.7.2.tar.gz
cd snort-2.9.7.2
./configure --enable-sourcefire && make && sudo make install

sudo cp /usr/local/lib/libdnet.1.0.1 /usr/local/lib/libdnet.so.1.0.1
sudo /sbin/ldconfig
sudo updatedb
snort -v -i wlan1
```
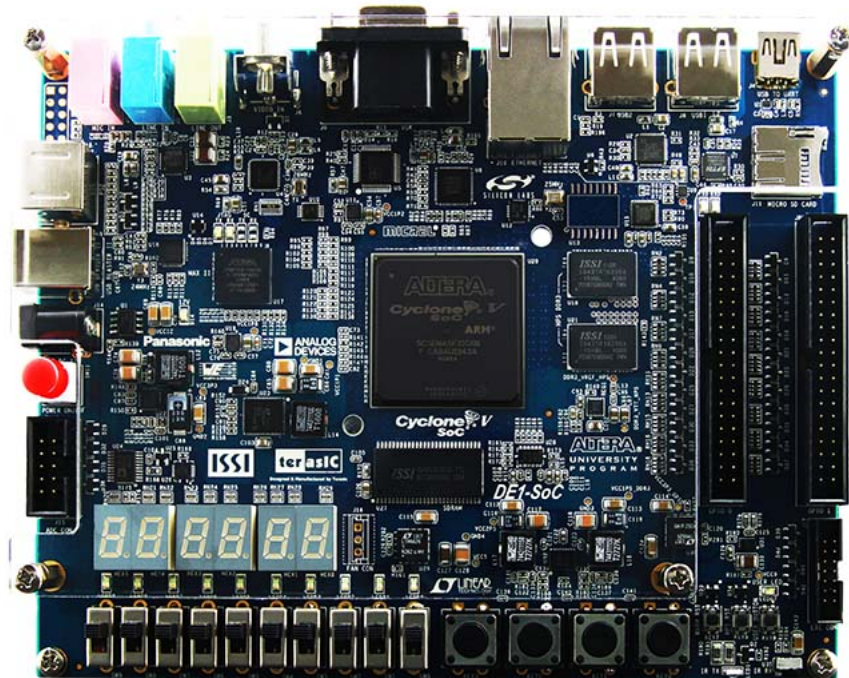
Chapter 4

FPGA Hardware Implementation

4.1   FPGA

VHDL Basics and FPGA Implementation course
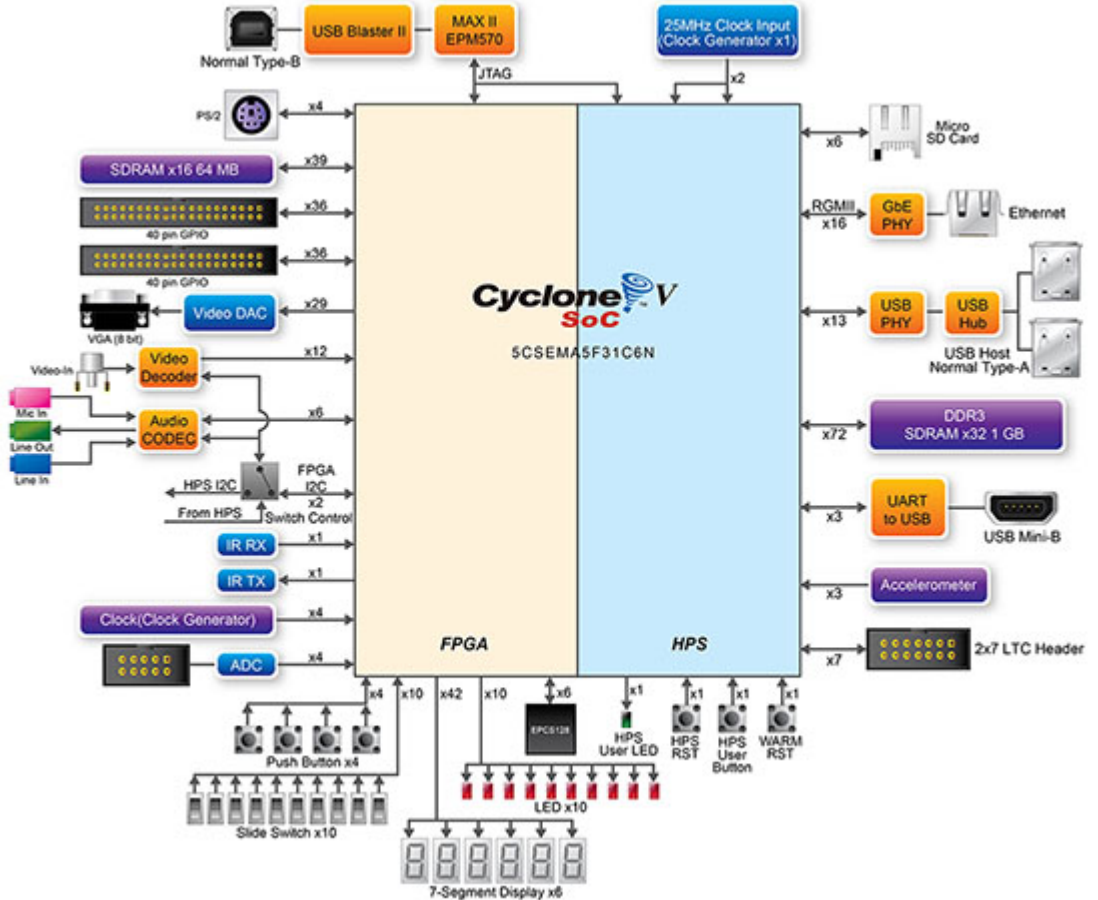
4.1.1   Hardware Tradeoff Matrix[4]

	x86	GPU	DSP	FPGA	μC
embed	maybe	hard	easy	easy	easy
low power	unusual	nope	sometimes	sometimes	yes
float op	good	excellent	excellent	possible	nope
int op	excellent	excellent	excellent	excellent	mediocore
control flow	excellent	challenging	air	challenging	excellent
io	mediocore	nope	ok	ginormous	ok
pipelining	nope	nope	nope	yes	nope
programmable	easy	medium	medius	challenging	easy
timing control	medium	what?	fair	excellent	fair

    state machines / random numbers PSHDL / myHDL / Verilog / VHDL
    Xilinx / Altera / Actel (microsem) / Lattice

Ethernet hardware chip news.thomasnet.com/fullstory/hardwired-tcp-ip-ic-offloads-stack-for-high-speed-internet-490029

4.1.2   FPGA Development Boards[4]

	actel	altera	xilinx
cheap	PSHDL board	DE0-Nano bemicro CV	Papilo One (Spartan 3) mojo Vs (spartan 6) XuLA2-LX25
powerful SoC	igloo 2 boards smartfusion2 starter kit SmartFusion Starter kit	cyclone 5/arria EBV SoCrates	artix/kintex/virtex MicroZedBoard parallella
CPU+FPGA	Daenkrake		Logi

deny by default

disaster recovery

stealing backups recovery plan

software user-mode kernel-mode hypervisor firmware microcode hardware physics

hardware exfilt: http://es.slideshare.net/ortegaalfredo/deep-submicronbackdoorsortegasyscan2014slides
modify chip to detect sequence toggle hardware line (e.g. led) to generate radio freq listen
with radio

infilltration

size of information key is easy... use blinds database is hard ... large volume

cloud?

sysadmin attacks (snowden/anthem)

fpga/asic runtime reconfigurable systems `http://media.ccc.de/browse/congress/2013/30C3_-_5443_-_en_-_`
`http://byterazor.federationhq.de/download/handout_30C3.pdf`

fpga 50 dollars serial cable logic analyzer VHDL / Verilog `http://tama-www.informatik.uni-hamburg.ed/vhdl/`

www.altera.com 6Gbps (starter kit)

regular, random machine audits (aka drug policy) work from home? Ring-level security policy? finding out (e.g. watermarks, RFID tags) dual computer policy? (plugged USB/secure only networking/loctite screws)

> ”Many businesses erro by putting too much faith in technology alone, or by
> starting a security program with a technology blitz. The best security technology
> in the world won't produce a good return on investment without the foundation
> of security processes, policies, and education. Instead, businesses should start
> by evaluating employee behavior and the associated risks based on factors such
> as the locale and the threat landscape. Then treat education, security training,
> and business processes can be scuplted around that intelligence. At that point,
> appropriate investments in security technology can be applied” [2]

outsiders let inside ”cleaner attacks”/”copier attacks”/”video stream encrypt”

BYOD mobility cloud internet wifi USB unauthorized software email

provisioning privileged account management managing access

4.2   DE1 gpio test

```
GPIO1 is the GPIO connector nearest outside edge of board.
GPIO1 layout is (pin 1 is near USB port, on inside edge of connector)
   pin 1          pin 2
   pin 3          pin 4
   pin 5          pin 6
   pin 7          pin 8
   pin 9          pin 10
   pin 11 (VCC5V)  pin 12 (GND)
   pin 13         pin 14
   pin 15         pin 16
   pin 17         pin 18
   pin 19         pin 20
   pin 21         pin 22
   pin 23         pin 24
   pin 25         pin 26
   pin 27         pin 28
   pin 29 (VCC3.3) pin 30 (GND)
   pin 31         pin 32
   pin 33         pin 34
   pin 35         pin 36
   pin 37         pin 38
   pin 39         pin 40


Wire from GPIO1 pin 1 to LED-diode+
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[0] should turn OFF this LED

Wire from GPIO1 pin 2 to LED-diode+
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[1] should turn OFF this LED

Wire from GPIO1 pin 3 to LED-diode+
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[2] should turn OFF this LED

Wire from GPIO1 pin 4 to LED-diode+
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[3] should turn ON this LED
```

```vhdl
library ieee;
use ieee.std_logic_1164.all;

ENTITY TPDblink IS
 PORT (
  KEY: in std_logic_vector(3 downto 0);
  GPIO_1: out std_logic_vector(35 downto 0));
end ENTITY TPDblink;

architecture TPDblinkarch of TPDblink is
 begin
  process(KEY)
   variable result: std_logic_vector(35 downto 0)
       := "111111111111111111111111111111111111";
   begin
 if KEY(0)='1' THEN
     result(0) := '1';
else
  result(0) := '0';
end if;
if KEY(1)='1' THEN
     result(1) := '1';
else
  result(1) := '0';
end if;
if KEY(2)='1' THEN
     result(2) := '1';
else
  result(2) := '0';
end if;
if KEY(3)='1' THEN
     result(3) := '0';
else
  result(3) := '1';
end if;
         GPIO_1 <= result;
  end process;
end architecture TPDblinkarch;

#***************************************************************
# This .sdc file is created by Terasic Tool.
# Users are recommended to modify this file to match users logic.
#***************************************************************


#***************************************************************
# Create Clock
```

```
#****************************************************************
create_clock -period 20.000ns [get_ports CLOCK_50]
create_clock -period 20.000ns [get_ports CLOCK2_50]
create_clock -period 20.000ns [get_ports CLOCK3_50]
create_clock -period 20.000ns [get_ports CLOCK4_50]

# for enhancing USB BlasterII to be reliable, 25MHz
create_clock -name {altera_reserved_tck} -period 40 {altera_reserved_tck}
set_input_delay -clock altera_reserved_tck -clock_fall 3 [get_ports altera_reserved_td
set_input_delay -clock altera_reserved_tck -clock_fall 3 [get_ports altera_reserved_tm
set_output_delay -clock altera_reserved_tck 3 [get_ports altera_reserved_tdo]

#****************************************************************
# Create Generated Clock
#****************************************************************
derive_pll_clocks




#****************************************************************
# Set Clock Latency
#****************************************************************




#****************************************************************
# Set Clock Uncertainty
#****************************************************************
derive_clock_uncertainty




#****************************************************************
# Set Input Delay
#****************************************************************




#****************************************************************
# Set Output Delay
#****************************************************************




#****************************************************************
# Set Clock Groups
```

```
#****************************************************************



#****************************************************************
# Set False Path
#****************************************************************



#****************************************************************
# Set Multicycle Path
#****************************************************************



#****************************************************************
# Set Maximum Delay
#****************************************************************



#****************************************************************
# Set Minimum Delay
#****************************************************************



#****************************************************************
# Set Input Transition
#****************************************************************



#****************************************************************
# Set Load
#****************************************************************



#===============================================================
# Build by Terasic System Builder
#===============================================================
```

```
set_global_assignment -name FAMILY "Cyclone V"
set_global_assignment -name DEVICE 5CSEMA5F31C6
set_global_assignment -name TOP_LEVEL_ENTITY "TPDblink"
set_global_assignment -name ORIGINAL_QUARTUS_VERSION 14.0
set_global_assignment -name LAST_QUARTUS_VERSION 14.1.0
set_global_assignment -name PROJECT_CREATION_TIME_DATE "21:01:14 FEBRUARY 27,2015"
set_global_assignment -name DEVICE_FILTER_PACKAGE FBGA
set_global_assignment -name DEVICE_FILTER_PIN_COUNT 896
set_global_assignment -name DEVICE_FILTER_SPEED_GRADE 6


#=============================================================
# ADC
#=============================================================
set_location_assignment PIN_AJ4 -to ADC_CS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_CS_N
set_location_assignment PIN_AK4 -to ADC_DIN
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_DIN
set_location_assignment PIN_AK3 -to ADC_DOUT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_DOUT
set_location_assignment PIN_AK2 -to ADC_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_SCLK


#=============================================================
# Audio
#=============================================================
set_location_assignment PIN_K7 -to AUD_ADCDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_ADCDAT
set_location_assignment PIN_K8 -to AUD_ADCLRCK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_ADCLRCK
set_location_assignment PIN_H7 -to AUD_BCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_BCLK
set_location_assignment PIN_J7 -to AUD_DACDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_DACDAT
set_location_assignment PIN_H8 -to AUD_DACLRCK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_DACLRCK
set_location_assignment PIN_G7 -to AUD_XCK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_XCK


#=============================================================
# CLOCK
#=============================================================
set_location_assignment PIN_AF14 -to CLOCK_50
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK_50
set_location_assignment PIN_AA16 -to CLOCK2_50
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK2_50
set_location_assignment PIN_Y26 -to CLOCK3_50
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK3_50
set_location_assignment PIN_K14 -to CLOCK4_50
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK4_50

#==============================================================
# SDRAM
#==============================================================
set_location_assignment PIN_AK14 -to DRAM_ADDR[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[0]
set_location_assignment PIN_AH14 -to DRAM_ADDR[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[1]
set_location_assignment PIN_AG15 -to DRAM_ADDR[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[2]
set_location_assignment PIN_AE14 -to DRAM_ADDR[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[3]
set_location_assignment PIN_AB15 -to DRAM_ADDR[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[4]
set_location_assignment PIN_AC14 -to DRAM_ADDR[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[5]
set_location_assignment PIN_AD14 -to DRAM_ADDR[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[6]
set_location_assignment PIN_AF15 -to DRAM_ADDR[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[7]
set_location_assignment PIN_AH15 -to DRAM_ADDR[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[8]
set_location_assignment PIN_AG13 -to DRAM_ADDR[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[9]
set_location_assignment PIN_AG12 -to DRAM_ADDR[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[10]
set_location_assignment PIN_AH13 -to DRAM_ADDR[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[11]
set_location_assignment PIN_AJ14 -to DRAM_ADDR[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[12]
set_location_assignment PIN_AF13 -to DRAM_BA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_BA[0]
set_location_assignment PIN_AJ12 -to DRAM_BA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_BA[1]
set_location_assignment PIN_AF11 -to DRAM_CAS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CAS_N
set_location_assignment PIN_AK13 -to DRAM_CKE
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CKE
set_location_assignment PIN_AG11 -to DRAM_CS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CS_N
set_location_assignment PIN_AH12 -to DRAM_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CLK
set_location_assignment PIN_AK6 -to DRAM_DQ[0]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[0]
set_location_assignment PIN_AJ7 -to DRAM_DQ[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[1]
set_location_assignment PIN_AK7 -to DRAM_DQ[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[2]
set_location_assignment PIN_AK8 -to DRAM_DQ[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[3]
set_location_assignment PIN_AK9 -to DRAM_DQ[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[4]
set_location_assignment PIN_AG10 -to DRAM_DQ[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[5]
set_location_assignment PIN_AK11 -to DRAM_DQ[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[6]
set_location_assignment PIN_AJ11 -to DRAM_DQ[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[7]
set_location_assignment PIN_AH10 -to DRAM_DQ[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[8]
set_location_assignment PIN_AJ10 -to DRAM_DQ[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[9]
set_location_assignment PIN_AJ9 -to DRAM_DQ[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[10]
set_location_assignment PIN_AH9 -to DRAM_DQ[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[11]
set_location_assignment PIN_AH8 -to DRAM_DQ[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[12]
set_location_assignment PIN_AH7 -to DRAM_DQ[13]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[13]
set_location_assignment PIN_AJ6 -to DRAM_DQ[14]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[14]
set_location_assignment PIN_AJ5 -to DRAM_DQ[15]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[15]
set_location_assignment PIN_AB13 -to DRAM_LDQM
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_LDQM
set_location_assignment PIN_AE13 -to DRAM_RAS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_RAS_N
set_location_assignment PIN_AK12 -to DRAM_UDQM
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_UDQM
set_location_assignment PIN_AA13 -to DRAM_WE_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_WE_N

#===============================================================
# I2C for Audio and Video-In
#===============================================================
set_location_assignment PIN_J12 -to FPGA_I2C_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to FPGA_I2C_SCLK
set_location_assignment PIN_K12 -to FPGA_I2C_SDAT
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to FPGA_I2C_SDAT

#==============================================================
# SEG7
#==============================================================
set_location_assignment PIN_AE26 -to HEX0[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[0]
set_location_assignment PIN_AE27 -to HEX0[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[1]
set_location_assignment PIN_AE28 -to HEX0[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[2]
set_location_assignment PIN_AG27 -to HEX0[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[3]
set_location_assignment PIN_AF28 -to HEX0[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[4]
set_location_assignment PIN_AG28 -to HEX0[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[5]
set_location_assignment PIN_AH28 -to HEX0[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[6]
set_location_assignment PIN_AJ29 -to HEX1[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[0]
set_location_assignment PIN_AH29 -to HEX1[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[1]
set_location_assignment PIN_AH30 -to HEX1[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[2]
set_location_assignment PIN_AG30 -to HEX1[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[3]
set_location_assignment PIN_AF29 -to HEX1[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[4]
set_location_assignment PIN_AF30 -to HEX1[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[5]
set_location_assignment PIN_AD27 -to HEX1[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[6]
set_location_assignment PIN_AB23 -to HEX2[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[0]
set_location_assignment PIN_AE29 -to HEX2[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[1]
set_location_assignment PIN_AD29 -to HEX2[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[2]
set_location_assignment PIN_AC28 -to HEX2[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[3]
set_location_assignment PIN_AD30 -to HEX2[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[4]
set_location_assignment PIN_AC29 -to HEX2[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[5]
set_location_assignment PIN_AC30 -to HEX2[6]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[6]
set_location_assignment PIN_AD26 -to HEX3[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[0]
set_location_assignment PIN_AC27 -to HEX3[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[1]
set_location_assignment PIN_AD25 -to HEX3[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[2]
set_location_assignment PIN_AC25 -to HEX3[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[3]
set_location_assignment PIN_AB28 -to HEX3[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[4]
set_location_assignment PIN_AB25 -to HEX3[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[5]
set_location_assignment PIN_AB22 -to HEX3[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[6]
set_location_assignment PIN_AA24 -to HEX4[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[0]
set_location_assignment PIN_Y23 -to HEX4[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[1]
set_location_assignment PIN_Y24 -to HEX4[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[2]
set_location_assignment PIN_W22 -to HEX4[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[3]
set_location_assignment PIN_W24 -to HEX4[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[4]
set_location_assignment PIN_V23 -to HEX4[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[5]
set_location_assignment PIN_W25 -to HEX4[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[6]
set_location_assignment PIN_V25 -to HEX5[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[0]
set_location_assignment PIN_AA28 -to HEX5[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[1]
set_location_assignment PIN_Y27 -to HEX5[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[2]
set_location_assignment PIN_AB27 -to HEX5[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[3]
set_location_assignment PIN_AB26 -to HEX5[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[4]
set_location_assignment PIN_AA26 -to HEX5[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[5]
set_location_assignment PIN_AA25 -to HEX5[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[6]


#=============================================================
# IR
```

```
#=============================================================
set_location_assignment PIN_AA30 -to IRDA_RXD
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to IRDA_RXD
set_location_assignment PIN_AB30 -to IRDA_TXD
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to IRDA_TXD


#=============================================================
# KEY
#=============================================================
set_location_assignment PIN_AA14 -to KEY[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[0]
set_location_assignment PIN_AA15 -to KEY[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[1]
set_location_assignment PIN_W15 -to KEY[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[2]
set_location_assignment PIN_Y16 -to KEY[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[3]


#=============================================================
# LED
#=============================================================
set_location_assignment PIN_V16 -to LEDR[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[0]
set_location_assignment PIN_W16 -to LEDR[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[1]
set_location_assignment PIN_V17 -to LEDR[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[2]
set_location_assignment PIN_V18 -to LEDR[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[3]
set_location_assignment PIN_W17 -to LEDR[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[4]
set_location_assignment PIN_W19 -to LEDR[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[5]
set_location_assignment PIN_Y19 -to LEDR[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[6]
set_location_assignment PIN_W20 -to LEDR[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[7]
set_location_assignment PIN_W21 -to LEDR[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[8]
set_location_assignment PIN_Y21 -to LEDR[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[9]


#=============================================================
# PS2
#=============================================================
set_location_assignment PIN_AD7 -to PS2_CLK
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_CLK
set_location_assignment PIN_AD9 -to PS2_CLK2
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_CLK2
set_location_assignment PIN_AE7 -to PS2_DAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_DAT
set_location_assignment PIN_AE9 -to PS2_DAT2
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_DAT2


#===========================================================
# SW
#===========================================================
set_location_assignment PIN_AB12 -to SW[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[0]
set_location_assignment PIN_AC12 -to SW[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[1]
set_location_assignment PIN_AF9 -to SW[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[2]
set_location_assignment PIN_AF10 -to SW[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[3]
set_location_assignment PIN_AD11 -to SW[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[4]
set_location_assignment PIN_AD12 -to SW[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[5]
set_location_assignment PIN_AE11 -to SW[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[6]
set_location_assignment PIN_AC9 -to SW[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[7]
set_location_assignment PIN_AD10 -to SW[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[8]
set_location_assignment PIN_AE12 -to SW[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[9]


#===========================================================
# Video-In
#===========================================================
set_location_assignment PIN_H15 -to TD_CLK27
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_CLK27
set_location_assignment PIN_D2 -to TD_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[0]
set_location_assignment PIN_B1 -to TD_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[1]
set_location_assignment PIN_E2 -to TD_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[2]
set_location_assignment PIN_B2 -to TD_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[3]
set_location_assignment PIN_D1 -to TD_DATA[4]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[4]
set_location_assignment PIN_E1 -to TD_DATA[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[5]
set_location_assignment PIN_C2 -to TD_DATA[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[6]
set_location_assignment PIN_B3 -to TD_DATA[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[7]
set_location_assignment PIN_A5 -to TD_HS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_HS
set_location_assignment PIN_F6 -to TD_RESET_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_RESET_N
set_location_assignment PIN_A3 -to TD_VS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_VS


#=============================================================
# VGA
#=============================================================
set_location_assignment PIN_B13 -to VGA_B[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[0]
set_location_assignment PIN_G13 -to VGA_B[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[1]
set_location_assignment PIN_H13 -to VGA_B[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[2]
set_location_assignment PIN_F14 -to VGA_B[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[3]
set_location_assignment PIN_H14 -to VGA_B[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[4]
set_location_assignment PIN_F15 -to VGA_B[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[5]
set_location_assignment PIN_G15 -to VGA_B[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[6]
set_location_assignment PIN_J14 -to VGA_B[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[7]
set_location_assignment PIN_F10 -to VGA_BLANK_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_BLANK_N
set_location_assignment PIN_A11 -to VGA_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_CLK
set_location_assignment PIN_J9 -to VGA_G[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[0]
set_location_assignment PIN_J10 -to VGA_G[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[1]
set_location_assignment PIN_H12 -to VGA_G[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[2]
set_location_assignment PIN_G10 -to VGA_G[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[3]
set_location_assignment PIN_G11 -to VGA_G[4]
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set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[4]
set_location_assignment PIN_G12 -to VGA_G[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[5]
set_location_assignment PIN_F11 -to VGA_G[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[6]
set_location_assignment PIN_E11 -to VGA_G[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[7]
set_location_assignment PIN_B11 -to VGA_HS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_HS
set_location_assignment PIN_A13 -to VGA_R[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[0]
set_location_assignment PIN_C13 -to VGA_R[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[1]
set_location_assignment PIN_E13 -to VGA_R[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[2]
set_location_assignment PIN_B12 -to VGA_R[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[3]
set_location_assignment PIN_C12 -to VGA_R[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[4]
set_location_assignment PIN_D12 -to VGA_R[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[5]
set_location_assignment PIN_E12 -to VGA_R[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[6]
set_location_assignment PIN_F13 -to VGA_R[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[7]
set_location_assignment PIN_C10 -to VGA_SYNC_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_SYNC_N
set_location_assignment PIN_D11 -to VGA_VS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_VS


#=============================================================
# HPS
#=============================================================
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[0]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[3]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[4]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[5]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[6]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[7]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[8]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[9]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[10]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[11]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[12]
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set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[13]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[14]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_BA[0]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_BA[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_BA[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[0]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[3]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[0]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[3]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[4]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[5]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[6]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[7]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[8]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[9]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[10]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[11]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[12]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[13]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[14]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[15]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[16]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[17]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[18]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[19]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[20]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[21]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[22]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[23]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[24]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[25]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[26]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[27]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[28]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[29]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[30]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[31]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_CAS_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_CKE
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_CS_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ODT
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_RAS_N
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set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_WE_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_RESET_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_RZQ
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DD
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_GTX_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_INT_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_MDC
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_MDIO
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DV
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_EN
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_NCSO
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_GPIO[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_GPIO[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_GSENSOR_INT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C1_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C1_SDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C2_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C2_SDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C_CONTROL
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_KEY
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_LED
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_CMD
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_MISO
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_MOSI
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_SS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_UART_RX
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_UART_TX
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_CLKOUT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DIR
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_NXT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_STP
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_CONV_USB_N

#============================================================
# GPIO_0, GPIO_0 connect to GPIO Default
#============================================================
set_location_assignment PIN_AC18 -to GPIO_0[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[0]
set_location_assignment PIN_Y17 -to GPIO_0[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[1]
set_location_assignment PIN_AD17 -to GPIO_0[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[2]
set_location_assignment PIN_Y18 -to GPIO_0[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[3]
set_location_assignment PIN_AK16 -to GPIO_0[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[4]
set_location_assignment PIN_AK18 -to GPIO_0[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[5]
set_location_assignment PIN_AK19 -to GPIO_0[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[6]
set_location_assignment PIN_AJ19 -to GPIO_0[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[7]
set_location_assignment PIN_AJ17 -to GPIO_0[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[8]
set_location_assignment PIN_AJ16 -to GPIO_0[9]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[9]
set_location_assignment PIN_AH18 -to GPIO_0[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[10]
set_location_assignment PIN_AH17 -to GPIO_0[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[11]
set_location_assignment PIN_AG16 -to GPIO_0[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[12]
set_location_assignment PIN_AE16 -to GPIO_0[13]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[13]
set_location_assignment PIN_AF16 -to GPIO_0[14]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[14]
set_location_assignment PIN_AG17 -to GPIO_0[15]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[15]
set_location_assignment PIN_AA18 -to GPIO_0[16]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[16]
set_location_assignment PIN_AA19 -to GPIO_0[17]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[17]
set_location_assignment PIN_AE17 -to GPIO_0[18]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[18]
set_location_assignment PIN_AC20 -to GPIO_0[19]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[19]
set_location_assignment PIN_AH19 -to GPIO_0[20]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[20]
set_location_assignment PIN_AJ20 -to GPIO_0[21]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[21]
set_location_assignment PIN_AH20 -to GPIO_0[22]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[22]
set_location_assignment PIN_AK21 -to GPIO_0[23]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[23]
set_location_assignment PIN_AD19 -to GPIO_0[24]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[24]
set_location_assignment PIN_AD20 -to GPIO_0[25]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[25]
set_location_assignment PIN_AE18 -to GPIO_0[26]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[26]
set_location_assignment PIN_AE19 -to GPIO_0[27]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[27]
set_location_assignment PIN_AF20 -to GPIO_0[28]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[28]
set_location_assignment PIN_AF21 -to GPIO_0[29]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[29]
set_location_assignment PIN_AF19 -to GPIO_0[30]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[30]
set_location_assignment PIN_AG21 -to GPIO_0[31]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[31]
set_location_assignment PIN_AF18 -to GPIO_0[32]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[32]
set_location_assignment PIN_AG20 -to GPIO_0[33]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[33]
set_location_assignment PIN_AG18 -to GPIO_0[34]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[34]
set_location_assignment PIN_AJ21 -to GPIO_0[35]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[35]


#==============================================================
# GPIO_1, GPIO_1 connect to GPIO Default
#==============================================================
set_location_assignment PIN_AB17 -to GPIO_1[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[0]
set_location_assignment PIN_AA21 -to GPIO_1[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[1]
set_location_assignment PIN_AB21 -to GPIO_1[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[2]
set_location_assignment PIN_AC23 -to GPIO_1[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[3]
set_location_assignment PIN_AD24 -to GPIO_1[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[4]
set_location_assignment PIN_AE23 -to GPIO_1[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[5]
set_location_assignment PIN_AE24 -to GPIO_1[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[6]
set_location_assignment PIN_AF25 -to GPIO_1[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[7]
set_location_assignment PIN_AF26 -to GPIO_1[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[8]
set_location_assignment PIN_AG25 -to GPIO_1[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[9]
set_location_assignment PIN_AG26 -to GPIO_1[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[10]
set_location_assignment PIN_AH24 -to GPIO_1[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[11]
set_location_assignment PIN_AH27 -to GPIO_1[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[12]
set_location_assignment PIN_AJ27 -to GPIO_1[13]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[13]
set_location_assignment PIN_AK29 -to GPIO_1[14]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[14]
set_location_assignment PIN_AK28 -to GPIO_1[15]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[15]
set_location_assignment PIN_AK27 -to GPIO_1[16]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[16]
set_location_assignment PIN_AJ26 -to GPIO_1[17]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[17]
set_location_assignment PIN_AK26 -to GPIO_1[18]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[18]
set_location_assignment PIN_AH25 -to GPIO_1[19]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[19]
set_location_assignment PIN_AJ25 -to GPIO_1[20]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[20]
set_location_assignment PIN_AJ24 -to GPIO_1[21]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[21]
set_location_assignment PIN_AK24 -to GPIO_1[22]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[22]
set_location_assignment PIN_AG23 -to GPIO_1[23]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[23]
set_location_assignment PIN_AK23 -to GPIO_1[24]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[24]
set_location_assignment PIN_AH23 -to GPIO_1[25]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[25]
set_location_assignment PIN_AK22 -to GPIO_1[26]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[26]
set_location_assignment PIN_AJ22 -to GPIO_1[27]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[27]
set_location_assignment PIN_AH22 -to GPIO_1[28]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[28]
set_location_assignment PIN_AG22 -to GPIO_1[29]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[29]
set_location_assignment PIN_AF24 -to GPIO_1[30]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[30]
set_location_assignment PIN_AF23 -to GPIO_1[31]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[31]
set_location_assignment PIN_AE22 -to GPIO_1[32]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[32]
set_location_assignment PIN_AD21 -to GPIO_1[33]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[33]
set_location_assignment PIN_AA20 -to GPIO_1[34]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[34]
set_location_assignment PIN_AC22 -to GPIO_1[35]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[35]


#===============================================================
# End of pin assignments by Terasic System Builder
#===============================================================


set_global_assignment -name PARTITION_NETLIST_TYPE SOURCE -section_id Top
set_global_assignment -name PARTITION_FITTER_PRESERVATION_LEVEL PLACEMENT_AND_ROUTING -
set_global_assignment -name PARTITION_COLOR 16764057 -section_id Top
```

```
set_global_assignment -name MIN_CORE_JUNCTION_TEMP 0
set_global_assignment -name MAX_CORE_JUNCTION_TEMP 85
set_global_assignment -name POWER_PRESET_COOLING_SOLUTION "23 MM HEAT SINK WITH 200 LFPM AIRFLOW"
set_global_assignment -name POWER_BOARD_THERMAL_MODEL "NONE (CONSERVATIVE)"
set_global_assignment -name SOURCE_FILE TPDblink.qsf
set_global_assignment -name SDC_FILE TPDblink.SDC
set_global_assignment -name BDF_FILE TPDbnor.bdf
set_instance_assignment -name PARTITION_HIERARCHY root_partition -to | -section_id Top

\section{Chord Keyboard test}
\begin{verbatim}

GPIO1 is the GPIO connector nearest outside edge of board.
GPIO1 layout is (pin 1 is near USB port, on inside edge of connector)

Note that the VCC and GND pins are skipped in the GPIO number scheme.
This is certain to cause a bit of confusion.

    PHYSICAL PIN NUMBERS                 GPIO PIN NUMBERS
    ---------------------------          --------------------------
    pin 1            pin 2               pin 0           pin 1
    pin 3            pin 4               pin 2           pin 3
    pin 5            pin 6               pin 4           pin 5
    pin 7            pin 8               pin 6           pin 7
    pin 9            pin 10              pin 8           pin 9
    pin 11 (VCC5V)   pin 12 (GND)
    pin 13           pin 14              pin 10          pin 11
    pin 15           pin 16              pin 12          pin 13
    pin 17           pin 18              pin 14          pin 15
    pin 19           pin 20              pin 16          pin 17
    pin 21           pin 22              pin 18          pin 19
    pin 23           pin 24              pin 20          pin 21
    pin 25           pin 26              pin 22          pin 23
    pin 27           pin 28              pin 24          pin 25
    pin 29 (VCC3.3) pin 30 (GND)
    pin 31           pin 32              pin 26          pin 27
    pin 33           pin 34              pin 28          pin 29
    pin 35           pin 36              pin 30          pin 31
    pin 37           pin 38              pin 32          pin 33
    pin 39           pin 40              pin 34          pin 35

Chord Keyboard connector layout (DB25 connector)

   1   2   3   4   5   6   7   8   9   10   11   12   13
      14   15   16   17   18   19   20   21   22   23   24   25
```

```
pin  1 GND                      +-----------------------+
pin  2 F2 FA                    | F1 | F3 | F5 | F7 | F9 |
pin  3 F1 F9                    +-----------------------+
pin  4 T4 F8                    | F1 | F3 | F5 | F7 | F9 |
pin  5 T3 F7                    +-----------------------+
pin  6 T2 F6          +----+
pin  7 GND            | T4 |
pin  8 Select Left    +----+
pin  9 Select Right   | T3 |
pin 11 +5V            +----+
pin 15 parity         | T2 |
pin 16    F3          +----+
pin 17    F4          | T1 |
pin 18 T1 F5          +----+


(NOTE: GPIO physical pin 3 == GPIO1 logical pin 2 == GPIO(2))
Wire from GPIO1 (physical pin 3,  logical 2)  to DB25 pin 2
Wire from GPIO1 (physical pin 4,  logical 3)  to DB25 pin 3
Wire from GPIO1 (physical pin 5,  logical 4)  to DB25 pin 4
Wire from GPIO1 (physical pin 6,  logical 5)  to DB25 pin 5
Wire from GPIO1 (physical pin 7,  logical 6)  to DB25 pin 6
Wire from GPIO1 (physical pin 9,  logical 8)  to DB25 pin 8
Wire from GPIO1 (physical pin 10, logical 9)  to DB25 pin 9
Wire from GPIO1 (physical pin 11, +5V)        to DB25 pin 11
Wire from GPIO1 (physical pin 12, GND)        to DB25 pin 1, DB25 pin 7
(NOTE: We don't skip 11, 12 as logical pins, see prior diagram)
Wire from GPIO1 (physical pin 19, logical 16) to DB25 pin 16
Wire from GPIO1 (physical pin 20, logical 17) to DB25 pin 17
Wire from GPIO1 (physical pin 21, logical 18) to DB25 pin 18
```

The keyboard has a SELECT LEFT (GPIO logical 8) and SELECT RIGHT (GPIO logical 9). We have to set 8 and 9 to read a key. In particular, to read F2, F1, T4, T3, T2, and T1

```
    GPIO_1(8) <= '0';
    GPIO_1(9) <= '1';
```

To read F3, F4, F5, F6, F7, F8, F9, and FA

```
    GPIO_1(8) <= '1';
    GPIO_1(9) <= '0';
```

Thus reading the key requires two physical reads.

```
library ieee;
use ieee.std_logic_1164.all;
```

```
ENTITY TPDblink IS
 PORT (
  LEDR: out std_logic_vector(9 downto 0);
  GPIO_1: inout std_logic_vector(35 downto 0));
end ENTITY TPDblink;

architecture TPDblinkarch of TPDblink is
 begin
  process(GPIO_1)
    -- the 10 LEDs on the board
    variable lights: std_logic_vector(9 downto 0) := "1111111111";
    constant lighton:  std_logic := '0';
    constant lightoff: std_logic := '1';
    -- F1 F3 F5 F7 F9 (upper row)
    -- F2 F4 F6 F8 FA (lower row)
    -- T4 T3 T2 T1 (thumb keys)
    -- keynamePinNumber: GPIO pin number
    constant F2FApin2:     Integer := 2;
    constant F1F9pin3:     Integer := 3;
    constant T4F8pin4:     Integer := 4;
    constant T3F7pin5:     Integer := 5;
    constant T2F6pin6:     Integer := 6;
    constant T1F5pin18:    Integer := 18;
    constant   F4pin17:    Integer := 17;
    constant   F3pin16:    Integer := 16;
    constant paritypin15:  Integer := 15;
    constant SELLEFTpin8:  Integer := 8;
    constant SELRIGHTpin9: Integer := 9;
    constant GNDpin1:      Integer := 12;
    constant GNDpin7:      Integer := 12;
    constant FiveVpin11:   Integer := 11;
    constant keydown: std_logic := '1';
    constant keyup:   std_logic := '0';

    begin
      -- GPIO_1(8) <= '0'; -- F2 F1 T4 T3 T2 T1
      -- GPIO_1(9) <= '1';
      GPIO_1(8) <= '1'; -- F3 F4 F5 F6 F7 F8 F9 FA
      GPIO_1(9) <= '0';
      if (GPIO_1(F1F9pin3) = keydown)
        then lights(0) := lighton; else lights(0) := lightoff; end if;
      if (GPIO_1(F2FApin2) = keydown)
        then lights(1) := lighton; else lights(1) := lightoff; end if;
      if (GPIO_1(F3pin16) = keydown)
        then lights(2) := lighton; else lights(2) := lightoff; end if;
      if (GPIO_1(F4pin17) = keydown)
```

```
      then lights(3) := lighton; else lights(3) := lightoff; end if;
    if (GPIO_1(T1F5pin18) = keydown)
      then lights(4) := lighton; else lights(4) := lightoff; end if;
    if (GPIO_1(T2F6pin6) = keydown)
      then lights(5) := lighton; else lights(5) := lightoff; end if;
    if (GPIO_1(T3F7pin5) = keydown)
      then lights(6) := lighton; else lights(6) := lightoff; end if;
    if (GPIO_1(T4F8pin4) = keydown)
      then lights(7) := lighton; else lights(7) := lightoff; end if;
    LEDR <= lights;
  end process;
end architecture TPDblinkarch;
```

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