LogiCORE IP CAN v4.2

User Guide

UG765 June 22, 2011

XILINX®

Revision History

This table shows the revision history for the CAN User Guide.

Date	Version	Revision
9/21/10	1.0	First release of the core with AXI interface support. The previous release of this document was ug186.
6/22/11	2.0	Updated for core version 4.2 and 13.2 design tools.

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Preface

About This Guide

The *CAN v4.2 User Guide* provides information about generating the Xilinx® LogiCORE™ IP CAN core, customizing and simulating the core with the provided example design, and running the design files through implementation using the Xilinx tools.

Guide Contents

These chapters are included in this guide:

- Preface, About This Guide, introduces the organization and purpose of this User Guide, provides links to additional resources, and contains a list of acronyms.
- Chapter 1, Introduction, describes the core and related information, including recommended design experience, additional resources, technical support, and submitting feedback to Xilinx.
- Chapter 2, Licensing the Core, provides information about licensing the core.
- Chapter 3, Quick Start Example Design, provides instructions to quickly generate the core and run the example design through implementation and simulation.
- Chapter 4, Detailed Example Design, describes the demonstration test bench in detail and provides instructions for how to customize the demonstration test bench for use in an application.

Additional Resources

To find additional documentation, see the Xilinx website at:

www.xilinx.com/support/documentation/index.htm.

To search the Answer Database of silicon, software, and IP questions and answers, or to create a technical support WebCase, see the Xilinx website at:

www.xilinx.com/support.

List of Acronyms

Acronym	**Spelled Out**
AXI	Advanced eXtensible Interface
BRPR	Baud Rate Prescaler Register
BTR	Bit Timing Register
CAN	Controller Area Network
FIFO	First In First Out
FPGA	Field Programmable Gate Array
GUI	Graphical User Interface
HDL	Hardware Description Language
ICR	Interrupt Clear Register
IES	Incisive Enterprise Simulator
IP	Intellectual Property
ISE®	Integrated Software Environment
ISR	Interrupt Status Register
RX	Receive
SDF	Standard Delay Format
TX	Transmit
UCF	User Constraints File
VCS	Verilog Compiled Simulator (Synopsys)
VHDL	VHSIC Hardware Description Language (VHSIC an acronym for Very High-Speed Integrated Circuits)
XST	Xilinx Synthesis Technology

Chapter 1

Introduction

The Xilinx® LogiCORE™ IP CAN v4.2 core is a compact, full-featured targeted design platform that conforms to *ISO 11898-1*, *CAN2.0A* and *CAN2.0B* standards. Bit rates of up to 1 Mb/s are supported. The core size can be optimized using parameterized configurations for acceptance filtering and FIFO depth. The example design in this guide is provided in both Verilog and VHDL.

This chapter introduces the CAN core and provides related information, including system requirements, recommended design experience, additional resources, technical support, and submitting feedback to Xilinx.

About the Core

The CAN core is a Xilinx CORE Generator™ IP core, included in the latest IP Update on the Xilinx IP Center. For detailed information about the core, see www.xilinx.com/xlnx/xebiz/designResources/ip_product_details. For information about licensing options, see Chapter 2, Licensing the Core.

System Requirements

Operating System Requirements

For a list of operating system requirements, see the ISE Design Suite 13: Release Notes Guide at the web page 13.2 Release Notes/Known Issues.

Software

- ISE® software v13.2
- Mentor Graphics ModelSim v6.6d
- Cadence Incisive Enterprise Simulator (IES) v10.2
- Synopsys VCS and VCS MX 2010.06

Recommended Design Experience

Although the CAN core is a fully-verified targeted design platform, the challenge associated with implementing a complete CAN design varies, depending on the application requirements. For best results, previous experience with building high-performance FPGA designs using Xilinx implementation software and a user constraints file (UCF) is recommended.

Contact your local Xilinx representative for assistance in evaluating your specific requirements.

Additional Core Resources

For detailed information and updates related to the CAN core, see the following documents, located on the CAN product page:

www.xilinx.com/xlnx/xebiz/designResources/ip_product_details.

- *CAN Data Sheet*
- *CAN Release Notes*

Updates to this document are also available at the CAN product page.

Technical Support

For technical support, visit www.support.xilinx.com. Questions are routed to a team of engineers with expertise using the CAN core.

Xilinx will provide technical support for use of this product as described in this guide. Xilinx cannot guarantee timing, functionality, or support of this product for designs that do not follow these guidelines.

Feedback

Xilinx welcomes comments and suggestions about the CAN core and the documentation supplied with the core.

Core

For comments or suggestions about the CAN core, submit a WebCase from www.support.xilinx.com/. Be sure to include this information:

- Product name
- Core version number
- Explanation of your comments

Document

For comments or suggestions about this document, submit a WebCase from www.support.xilinx.com/. Be sure to include this information:

- Document title
- Document number
- Page number(s) to which your comments refer
- Explanation of your comments

Chapter 2

Licensing the Core

This chapter provides instructions for obtaining a license for the CAN core, which you must do before using the core in your designs. The CAN core is provided under the terms of the Xilinx LogiCORE Site License Agreement, which conforms to the terms of the SignOnce IP License standard defined by the Common License Consortium. Purchase of the core entitles you to technical support and access to updates for one year.

Before you Begin

This chapter assumes that you have installed all required software specified on the CAN product page.

License Options

The CAN core provides three licensing options. After installing the required Xilinx® ISE® software and IP Service Packs, choose a license option.

Simulation Only

The Simulation Only Evaluation license key is provided with the Xilinx CORE Generator™ tool. This key lets you assess core functionality with either the example design provided with the CAN core, or alongside your own design and demonstrates the various interfaces to the core in simulation. (Functional simulation is supported by a dynamically generated HDL structural model.)

Full System Hardware Evaluation

The Full System Hardware Evaluation license is available at no cost and lets you fully integrate the core into an FPGA design, place-and-route the design, evaluate timing, and perform functional simulation of the CAN core using the example design and demonstration test bench provided with the core.

In addition, the license key lets you generate a bitstream from the placed and routed design, which can then be downloaded to a supported device and tested in hardware. The core can be tested in the target device for a limited time before timing out (ceasing to function), at which time it can be reactivated by reconfiguring the device.

Cannot use this in production programs.

Full

The Full license key is available when you purchase the core and provides full access to all core functionality both in simulation and in hardware, including:

- Gate-level functional simulation support
- Back annotated gate-level simulation support
- Functional simulation support
- Full-implementation support including place and route and bitstream generation
- Full functionality in the programmed device with no time-outs

Obtaining Your License Key

This section contains information about obtaining a simulation, full system hardware, and full license keys.

Simulation License

No action is required to obtain the Simulation Only Evaluation license key; it is provided by default with the Xilinx CORE Generator software.

Full System Hardware Evaluation License

To obtain a Full System Hardware Evaluation license, perform these steps:

1. Navigate to the CAN product page for this core.
2. Click Evaluate.
3. Follow the instructions to install the required Xilinx ISE software and IP Service Packs.

Obtaining a Full License

To obtain a Full license key, you must purchase a license for the core. After doing so, click the “Access Core” link on the Xilinx.com IP core product page for further instructions.

Installing Your License File

The Simulation Only Evaluation license key is provided with the ISE CORE Generator system and does not require installation of an additional license file. For the Full System Hardware Evaluation license and the Full license, an email will be sent to you containing instructions for installing your license file. Additional details about IP license key installation can be found in the ISE Design Suite Installation, Licensing and Release Notes document.

Quick Start Example Design

This chapter provides instructions to generate a CAN core quickly, run the design through implementation with the Xilinx tools, and simulate the example design using the provided demonstration test bench. See the example design in Chapter 4, Detailed Example Design.

Overview

Figure 3-1 illustrates the CAN example design.

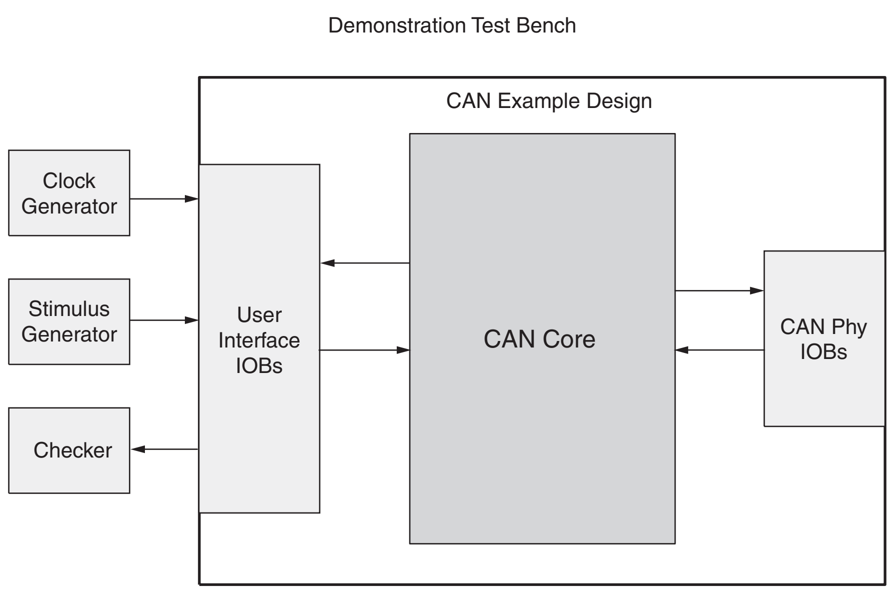

Figure 3-1: **Example Design**

The CAN example design consists of the following:

- CAN netlist
- HDL wrapper which instantiates the CAN netlist
- Customizeable demonstration test bench to simulate the example design

The CAN example design has been tested with Xilinx® ISE® software v13.2 and the Mentor Graphics ModelSim v6.6d simulator.

Generating the Core

This section describes how to generate a CAN core with default values using the Xilinx CORE Generator™ tool.

To generate the core:

1. Start the CORE Generator tool.

   For help starting and using the CORE Generator tool, see the *Xilinx CORE Generator Guide*, available from the ISE documentation web page.
2. Choose File → New Project.
3. Type a directory name.

   This example uses the directory name *design*.
4. Do the following to set project options:
   - Part Options
     - From Target Architecture, select the desired family. For a list of supported families, see the *CAN Data Sheet*.

     Note: If an unsupported silicon family is selected, the CAN core will not appear in the taxonomy tree.
   - Generation Options
     - For Design Entry, select either VHDL or Verilog.
5. After creating the project, locate the CAN core in the taxonomy tree under Automotive & Industrial >Automotive > CAN.
6. Double-click the core to display the main CAN configuration screen.

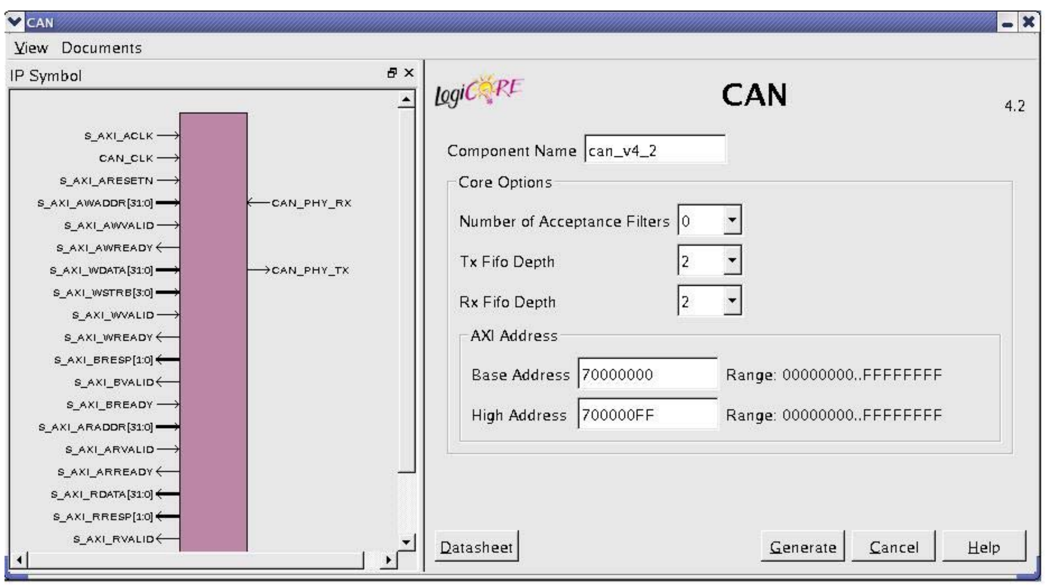

Figure 3-2: **CAN Main Screen**

7. In the Component Name field, enter a name for the core instance.

   This example uses the name *quickstart*.

8. After selecting the parameters from the GUI screens, click Finish.

   The core and its supporting files, including the example design, are generated in the project directory. For detailed information about the example design files and directories see Chapter 4, Detailed Example Design.

Implementing the Example Design

After generating a core with either a Full-System Hardware Evaluation or Full license, the netlists and example design can be processed by the Xilinx implementation tools. The generated output files include scripts to assist you in running the Xilinx software.

To implement the CAN example design, open a command prompt or terminal window and type these commands:

For Windows:

```
ms-dos> cd <proj_dir>\quickstart\implement
ms-dos> implement.bat
```

For Linux:

```
Linux-shell% cd <proj_dir>/quickstart/implement
Linux-shell% ./implement.sh
```

These commands execute a script that synthesizes, builds, maps, and places-and-routes the example design. The script then generates a post-par simulation model for use in timing simulation. The resulting files are placed in the results directory.

Simulating the Example Design

The CAN core provides a quick way to simulate and observe the behavior of the core by using the provided example design. There are two different simulation types: functional and timing. The simulation models provided are either in VHDL or Verilog, depending on the CORE Generator software Design Entry project option.

Setting up for Simulation

The Xilinx UNISIM and SIMPRIM libraries must be mapped into the simulator. If the UNISIM or SIMPRIM libraries are not set for your environment, go to the Synthesis and Simulation Guide in the Xilinx Software Manuals for assistance compiling Xilinx simulation models.

Simulation scripts are provided for ModelSim.

Functional Simulation

This section provides instructions for running a functional simulation of the CAN core using either VHDL or Verilog. Functional simulation models are provided when the core is generated. Implementing the core before simulating the functional models is not required.

To run a VHDL or Verilog functional simulation of the example design:

1. Set the current directory to:

   `<quickstart>`**`/simulation/functional/`**

2. Launch the simulation script.

   `ModelSim:` **`vsim -do simulate_mti.do`**

   `ncsim (ms-dos>):` **`simulate_ncsim.bat`**

   `ncsim (Linux-shell%):` ./**`simulate_ncsim.sh`**

The simulation script compiles the functional simulation models and demonstration test bench, adds relevant signals to the wave window, and runs the simulation. To observe the operation of the core, inspect the simulation transcript and the waveform.

Timing Simulation

Timing simulation is supported only for the Full-System Hardware Evaluation and Full license types, as the core cannot be implemented using a Simulation Only Evaluation license. This section contains instructions for running a timing simulation of the CAN core using either VHDL or Verilog. A timing simulation model is generated when the core is run through the Xilinx tools using the implement script. It is a requirement that the core is implemented before attempting to run timing simulation.

To run a VHDL or Verilog functional simulation of the example design:

1. Set the current directory to:

   `<quickstart>/simulation/timing/`

2. Launch the simulation script:

   `ModelSim:` **`vsim -do simulate_mti.do`**

   `ncsim (ms-dos>):` **`simulate_ncsim.bat`**

   `ncsim (Linux-shell%):` ./**`simulate_ncsim.sh`**

The simulation script compiles the timing simulation model and the demonstration test bench, adds relevant signals to the wave window, and runs the simulation. To observe the operation of the core, inspect the simulation transcript and the waveform.

Chapter 4

Detailed Example Design

This chapter provides detailed information about the example design, including a description of files and the directory structure generated by the Xilinx® CORE Generator™ software, the purpose and contents of the provided scripts, the contents of the example HDL wrappers, and the operation of the demonstration test bench.

- **<project directory>**
  Top-level project directory; name is user-defined
  - <project_directory>/<component name>
    Core release notes file
    - <component_name>/doc
      Product documentation
    - <component_name>example design
      Verilog and VHDL design files
    - <component_name>/implement
      Implementation script files
      - <component_name>/implement/results
        Results directory, created after implementation scripts are run, and contains implement script results
    - <component_name>/simulation
      Simulation scripts
      - <component_name>/simulation/functional
        Functional simulation files
      - simulation/timing
        Simulation files

Directory and File Contents

The CAN v4.2 core directories and their associated files are defined in the following sections.

<project directory>

The <project directory> contains all the CORE Generator software project files.

Table 4-1: **Project Directory**

Name	Description
<project_dir>	
<component_name>.ngc	Top-level netlist
<component_name>.v[hd]	Verilog or VHDL simulation model
<component_name>.xco	CORE Generator software project-specific option file; can be used as an input to the CORE Generator software.
<component_name>_flist.txt	List of files delivered with the core.
<component_name>.{veo|vho}	VHDL or Verilog instantiation template.

Directory and File Contents

<project_directory>/<component name>

The <component name> directory contains the release notes file provided with the core, which can include last-minute changes and updates.

Table 4-2: **Component Name Directory**

Name	Description
<project_dir>/<component_name>	
can_release_notes.txt	Core name release notes file.

Directory and File Contents

<component_name>example design

The example design directory contains the example design files provided with the core.

Table 4-3: **Example Design Directory**

Name	Description
<project_dir>/<component_name>/example_design	
<component_name>_top.ucf	Provides example constraints necessary for processing the CAN core using the Xilinx implementation tools.
<component_name>_top.v[hd]	The VHDL or Verilog top-level file for the example design; it instantiates the CAN core.
<component_name>.v	Top-level file for the example design. Only generated when Verilog design flow is selected.

Directory and File Contents

<component_name>/doc

The doc directory contains the PDF documentation provided with the core.

Table 4-4: **Doc Directory**

Name	Description
<project_dir>/<component_name>/doc	
ds798_can.pdf	CAN v4.2 Data Sheet
ug765_can.pdf	CAN v4.2 User Guide

Directory and File Contents

<component_name>/implement

The implement directory contains the core implementation script files. Generated for Full-System Hardware Evaluation and Full license types.

Table 4-5: **Implement Directory**

Name	Description
<project_dir>/<component_name>/implement	
implement.{bat | sh}	A Windows (.bat) or Linux script that processes the example design.
xst.prj	The XST project file for the example design that lists all of the source files to be synthesized. Only available when the CORE Generator software project option is set to ISE or Other.
xst.scr	The XST script file for the example design used to synthesize the core. Only available when the CORE Generator software Vendor project option is set to ISE or Other.

Directory and File Contents

<component_name>/implement/results

The results directory is created by the implement script, after which the implement script results are placed in the results directory.

Table 4-6: **Results Directory**

Name	Description
<project_dir>/<component_name>/implement/results	
Implement script result files.	

Directory and File Contents

<component_name>/simulation

The simulation directory contains the simulation scripts provided with the core.

Table 4-7: **Simulation Directory**

Name	Description
<project_dir>/<component_name>/simulation	
glbl.v	Verilog test file provided with the demonstration test bench.
can_v4_2_tb.v[hd]	Verilog/VHDL test file provided with the demonstration test bench.

Directory and File Contents

<component_name>/simulation/functional

The functional directory contains functional simulation scripts provided with the core.

Table 4-8: **Functional Directory**

Name	Description
<project_dir>/<component_name>/simulation/functional	
simulate_mti.do	A macro file for ModelSim that compiles the HDL sources and runs the simulation.
simulate_ncsim.sh	A macro file for Cadence IES that compiles the HDL sources and runs the simulation in a Linux environment.
simulate_ncsim.bat	A macro file for Cadence IES that compiles the HDL sources and runs the simulation in a Windows environment.
wave.do	A macro file for ModelSim that opens a wave window and adds key signals to the wave viewer. This file is called by the simulate_mti.do file and is displayed after the simulation is loaded.
wave.sv	A macro file for Cadence IES that opens a wave window and adds key signals to the wave viewer.

Directory and File Contents

simulation/timing

The timing simulation directory is generated only for Full-System Hardware Evaluation and Full-license types.

Table 4-9: **Timing Directory**

Name	Description
<project_dir>/<component_name>/simulation/timing	
simulate_mti.do	A macro file for ModelSim that compiles the post-par timing netlist, demonstration test bench files, and runs the simulation.
simulate_ncsim.sh	A macro file for Cadence IES that compiles the post-par timing netlist, demonstration test bench files, and runs the simulation in a Linux environment.
simulate_ncsim.bat	A macro file for Cadence IES that compiles the post-par timing netlist, demonstration test bench files, and runs the simulation in a Windows environment.
wave.do	A macro file for ModelSim that opens a wave window and adds key signals to the wave viewer. This file is called by the simulate_mti.do file and is displayed after the simulation is loaded.
wave.sv	A macro file for Cadence IES that opens a wave window and adds key signals to the wave viewer.

Directory and File Contents

Implementation Scripts

Note: Present only with a Full license.

The implementation script is either a shell script(.sh) or batch file (.bat) that processes the example design through the Xilinx tool flow. It is located at:

Linux

```
<project_dir>/<component_name>/implement/implement.sh
```

Windows

```
<project_dir>/<component_name>/implement/implement.bat
```

When the CORE Generator software is run with the Full System Hardware Evaluation, or Full license types, the implement script performs these steps:

- Synthesizes the HDL example design files using XST
- Runs NGDBuild to consolidate the core netlist and the example design netlist into the NGD file containing the entire design
- Maps the design to the target technology
- Place-and-routes the design on the target device
- Performs static timing analysis on the routed design using Timing Analyzer (TRCE)
- Generates a bitstream
- Enables Netgen to run on the routed design to generate a VHDL or Verilog netlist (as appropriate for the Design Entry project setting) and timing information in the form of SDF files

The Xilinx tool flow generates several output and report files. These are saved in the following directory which is created by the implement script:

```
<project_dir>/<component_name>/implement/results
```

Simulation Scripts

Functional Simulation

The test scripts are ModelSim macros that automate the simulation of the test bench. They are available from the following location:

```
<project_dir>/<component_name>/simulation/functional/
```

The test script performs these tasks:

- Compiles the structural UNISIM simulation model
- Compiles HDL Example Design source code
- Compiles the demonstration test bench
- Starts a simulation of the test bench
- Opens a Wave window and adds signals of interest (wave_mti.do/wave_ncsim.sv)
- Runs the simulation to completion

Timing Simulation

Note: Present only with a Full license.

The test scripts are a ModelSim or a Cadence IES macro that automates the simulation of the test bench. They are located in:

`<project_dir>/<component_name>/simulation/timing/`

The test script performs these tasks:

- Compiles the SIMPRIM based gate level netlist simulation model
- Compiles the demonstration test bench
- Starts a simulation of the test bench
- Opens a Wave window and adds signals of interest (wave_mti.do/wave_ncsim.sv)
- Runs the simulation to completion

Example Design Configuration

Figure 4-1 illustrates the example design configuration.

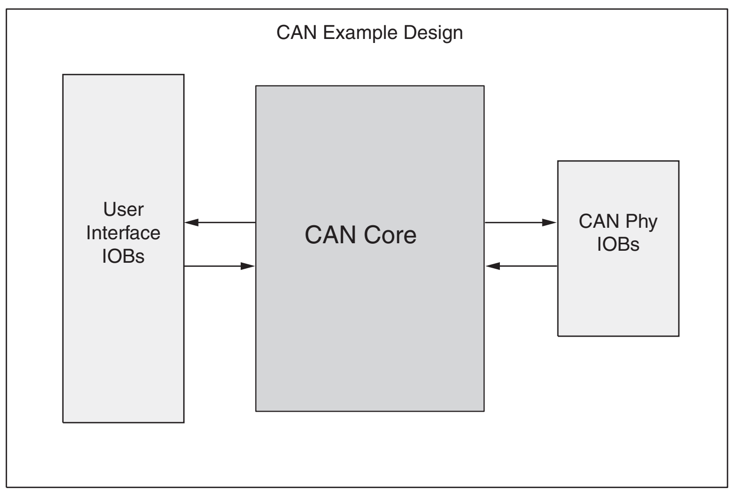

Figure 4-1: **Example Design Configuration**

The example design contains the following:

- An instance of the CAN core

  During simulation, the CAN core is instantiated as a black box and replaced with the CORE Generator software netlist during implementation and the gate-level simulation model.

- Input and output buffers for top-level port signal

Demonstration Test Bench

Figure 4-2 illustrates the demonstration test bench.

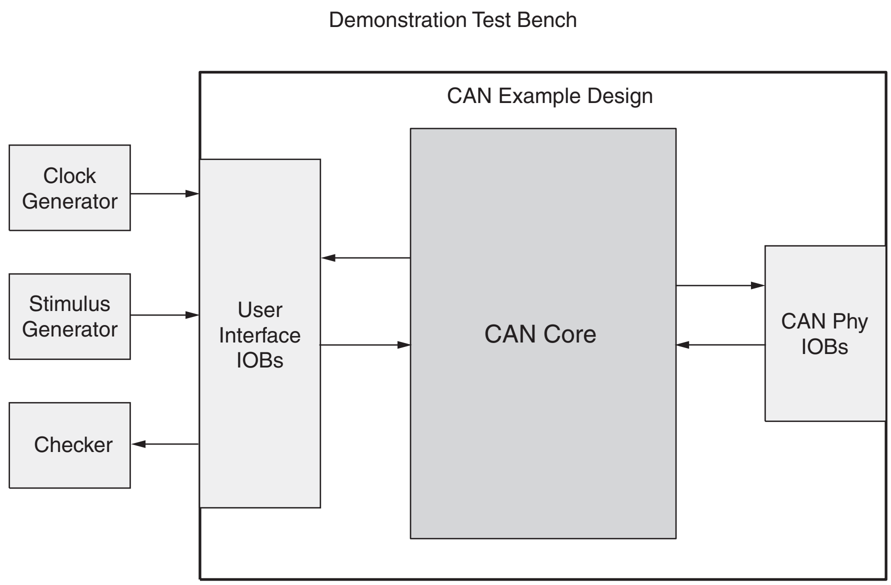

Figure 4-2: **Demonstration Test Bench**

Test Bench Functionality

The demonstration test bench is a straightforward VHDL or Verilog file to exercise the example design and the core itself.

The test bench consists of the following:

- Clock Generators
- Procedure to write to a Configuration Register memory location
- Procedure to read from a Configuration Register memory location
- Procedure to display the bits set in the Interrupt Status Register (ISR)

Core with No Acceptance Filtering

The demonstration test bench performs the following tasks:

- Input clock signals are generated.
- A reset is applied to the example design.
- The Baud Rate Prescalar register and Bit Timing registers are written to. These registers are read from and the values read are compared with the values written.
- The Interrupt Enable Register is written to enable interrupts for TXBFLL and RXOK bits. This register is read from and the value read is compared with the value written.
- The Mode Select Register is written to select Loop Back mode of operation. This register is read from and the value read is compared with the value written.
- The Software Reset Register is written to enable CEN bit. This register is read from and the value written is compared with the value read.

- Five messages are written in sequence:

1. The first message is written to the TXHPB and is a standard data frame.
2. The second message is written to the TX FIFO and is a standard data frame.
3. The third message is written to the TX FIFO and is a standard remote frame.
4. The fourth message is written to the TX FIFO and is an extended data frame.
5. The fifth message is written to the TX FIFO and is an extended remote frame.

   After each message is written, the test bench waits for the assertion of the interrupt line. When the interrupt line is asserted, the following conditions occur:

   - The bits set in the ISR are displayed.
   - The RX FIFO is read if the RXOK bit is set. The message received is compared with the message previously transmitted.
   - The ICR is written to. This clears the bits in the ISR that are set.

   With no acceptance filtering, all five messages are received in the RX FIFO.

Core with Acceptance Filtering

The demonstration test bench performs the following tasks:

- Input clock signals are generated.
- A reset is applied to the example design.
- The Baud Rate Prescalar register and Bit Timing registers are written to. These registers are read from and the values read are compared with the values written.
- The Interrupt Enable Register is written to enable interrupts for TXBFLL and RXOK bits. This register is read from and the value read is compared with the value written.
- Acceptance Filter ID Register 1 and Acceptance Filter Mask Register 1 are written to. These registers are read from and the values read are compared with the values written.
- The Acceptance Filter Register is written to enable Acceptance Filter pair 1. This register is read from and the value read is compared with the value written.
- The Mode Select Register is written to select Loop Back mode. This register is read from and the value read is compared with the value written.
- The Software Reset Register is written to enable CEN bit. This register is read from and the value written is compared with the value read.
- Five messages are written in a sequence.

1. The first message is written to the TXHPB and is a standard data frame.
2. The second message is written to the TX FIFO and is a standard data frame.
3. The third message is written to the TX FIFO and is a standard remote frame.
4. The fourth message is written to the TX FIFO and is an extended data frame.
5. The fifth message is written to the TX FIFO and is an extended remote frame.

   After each message is written, the test bench waits for the interrupt line to be asserted. When the interrupt line is asserted, these conditions occur:

   - The bits in the ISR that are set are displayed.
   - The RX FIFO is read if the RXOK bit is set. The message that is received is compared with the message that was transmitted.
   - The ICR is written to. This clears the bits in the ISR that are set.

- After the fourth message is transmitted and received, the Interrupt Enable Register is written to enable interrupts for TXOK, RXOK and TXBFLL. This register is read from and the value read is compared with the value written.
- The fifth message does not pass acceptance filtering. Only the TXOK bit in the ISR is set when the ISR is asserted.

Customizing the Demonstration Test Bench

This section describes the variety of demonstration test bench customization options that can be used for individual system requirements.

Changing the Data

You can change the contents of the message written to the TX FIFO / TX HPB by changing the procedure call that writes to the TX FIFO and the TX HPB memory locations. The relevant fields in the checkers must also be changed to ensure that the message read from the RX FIFO matches the message that was transmitted.

Changing the CAN Parameters

The values written to the BRPR and the BTR registers can be changed for appropriate bit timing values. The test bench operates in the Loop Back mode of operation.

Changing the Test Bench Structure

You can add messages using these steps.

1. Write the message to the TX FIFO.
2. Wait for an interrupt and process the interrupt.
3. Read the received message from the RX FIFO.