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Analog Devices TigerSHARC Link

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Summary

This application note describes a full-featured transmitter/receiver macro that can communicate with Spartan™-II, Spartan-IIE, Spartan-3, Virtex™, Virtex-E, Virtex-II, and Virtex-II Pro™ FPGA families via the Analog Devices ADSP-TS101S TigerSHARC™ link-port function.

Introduction

The Analog Devices TigerSHARC Digital Signal Processors (DSPs) contain an optional link-port function that is intended for communication between DSPs, but can also be used to communicate with Virtex series FPGAs. This is extremely useful when a system is designed around these two components. The macro described herein is a full featured transmitter/receiver compatible with ADSP-TS101S devices that allow bidirectional double data rate (DDR) communication of 128-bit words over an 8-bit link at speeds of up to 125 megabits per second (Mb/s) per line (125 megabytes per second (MB/s) total) in a Virtex-E -7 or a Spartan-3 -5 device and 167 Mb/s per line (167 MB/s total) in a Virtex-II -5 or a Virtex-II Pro -5 device. Full details on the link port characteristics are available from Analog Devices at:

<http://www.analog.com/processors/resources/technicalLibrary/manuals/index.html>

Note: The macro described herein is intended for use in systems where the clock rate is the same or very close (within 1,000 ppm) in the devices at each end of the link.

Circuit Description

The macro consists of three parts: the receiver, the transmitter, and the controlling state machine. The macro basics are shown in **Figure 1**. The local (FPGA) clock is running at twice the link frequency, but it should be noted that the link uses double data rate techniques, i.e., data is transferred on each clock edge. For example, with a local clock of 150 MHz, the link port will be running DDR at 150 Mb/s per line.

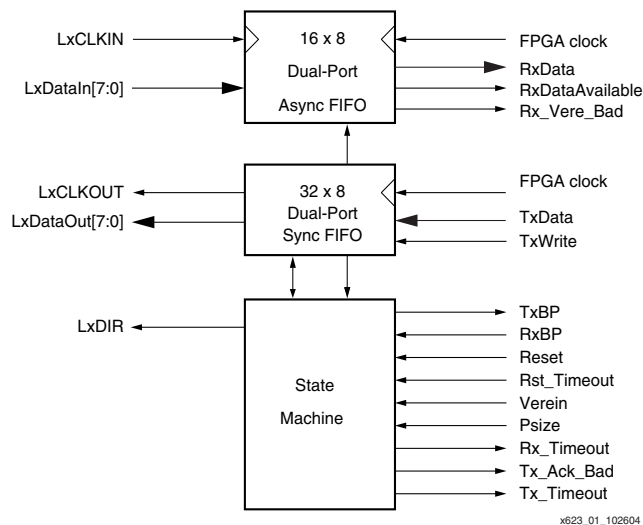


Figure 1: Link-Port Macro Diagram

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Receiver

When the macro is in receiver mode, the incoming data is clocked into a small dual-port FIFO. Eight bits are clocked in by the rising edge of the incoming clock and eight bits by the falling edge. This data is almost immediately clocked out of the FIFO synchronous to the FPGA clock and is presented byte-wide to the user's system with data valid timing. Data transfers are shown in [Figure 2](#), which shows the case where the VERE function (described below) is not used. [Figure 3](#) shows the case where the VERE function is enabled. The assumption here is that the user logic will always be capable of accepting incoming data, or that a FIFO external to the macro is available. Example designs of FIFOs that work with the link-port macro are given in the reference design .zip file described in [Design Files](#).

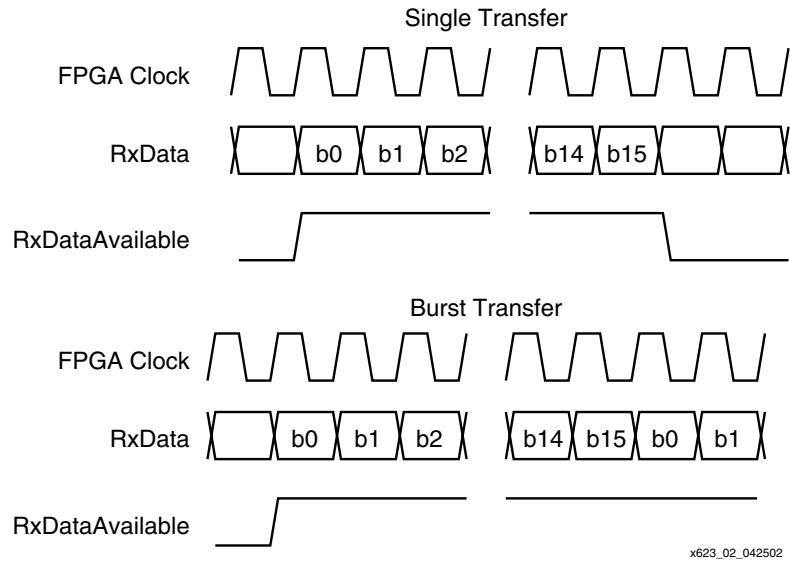


Figure 2: Data Valid Timing (no VERE)

One characteristic of the link-port protocol is that it can be used with or without the transmission of a verification byte. This VERE function is turned on or off via registers in the ADSP-TS101S device, or by setting the signal "Verein" of the FPGA macro to 1. The VERE byte is not directly available to the user, but when the function is enabled, the output Rx_Vere_Bad of the macro indicates whether the last received 128-bit data was correctly received or not. The timing for this signal is shown in [Figure 3](#).

It is recommended to enable the VERE function for two reasons. The first is to ensure data integrity, and the second is to minimize the possibility of data overrun, which could occur between two systems that do not have exactly the same clock. The byte received immediately following the VERE byte is undefined in the spec, and so is not useful as data, but very useful for rate adaption. If the FPGA clock is running slower than the link clock, there will be only one "blank" receive cycle during burst transfers every now and then. If the FPGA clock is running synchronously to the DSP, the received word will always be followed by a VERE byte, followed by a dummy byte. RxDataAvailable will be Low for both these bytes, as shown in [Figure 3](#). If the FPGA clock is running slightly faster than the DSP clock, the VERE byte will be followed by one or two dummy bytes. If the FPGA clock is running slightly slower than the DSP clock, the VERE byte will be followed either by a dummy byte or by the first byte of the next word in a burst transfer. Thus, rate adaption is provided for in all three cases when the VERE function is enabled, thus avoiding the overrun that could occur otherwise.

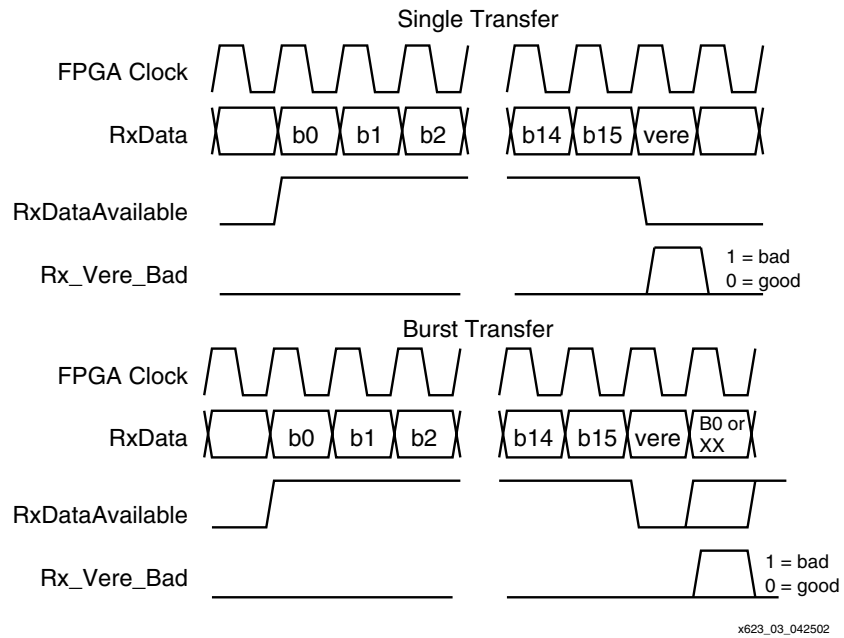


Figure 3: Data Valid Timing (with VERE)

Transmitter

Data (128-bit) for transmission is written to the macro using the timing shown in Figure 4.

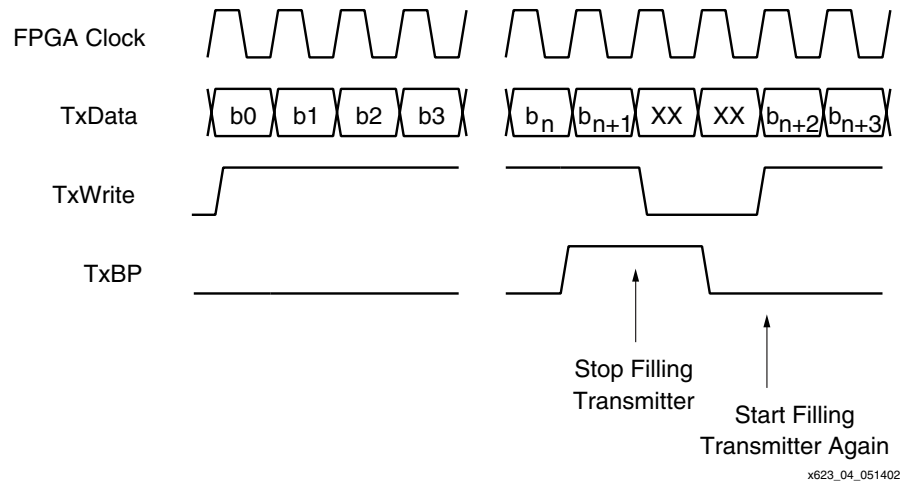


Figure 4: Transmitter Timing

The input path is a shallow synchronous FIFO of 32 or 64 bytes that generates a back-pressure signal (TxBP) when it is getting full. The user should not continue to write data when this back-pressure signal is High or data will be lost. The user also needs to ensure that data is written in multiples of 16 bytes, because there is no mechanism built into the macro to check for this and it is otherwise possible that an underrun could occur. If the VERE data verification function has been enabled, then the VERE byte is calculated by the macro and is automatically inserted into the transmitted data as per the link-port specification. Note that the VERE function can only be enabled or disabled for both the transmitter and the receiver. The parameter cannot be individually used for the transmitter or the receiver.

State Machine

The state machine manages the receive and transmit functionality of the macro and provides additional feedback signals to the user. Inputs to the state machine include the Verein input described above that enables (High) or disables (Low) the VERE function. There is also a "PSIZE" input that serves the same purpose as the PSIZE register bit in the ADSP-TS101S device. When this is set Low, a maximum burst size of 64 transmissions is allowed, and when set High, the burst size is set to infinity. There is an output signal called "Tx_Ack_Bad" that indicates when the connectivity check specified by the link-port protocol has failed. This would typically indicate a bad connection between systems.

Time-outs for both receiver and transmitter are also built in per the link-port specification. These outputs will go High when a receive or transmit time-out has occurred. They are reset by setting the "rst_timeout" input High for one clock cycle. If this input is unused, it should be connected to a logic 0 for correct operation. These signals are not used internally to the macro.

Clocking Considerations

The FPGA clock should be connected via a global buffer, but this is not so obvious for the incoming link clock (LxCLKIN). This clock signal is fairly lightly loaded, with around ten clock loads and six logic loads. The clock loads are used to clock in data, so ideally the clock would be passed through a DLL/DCM to minimize the hold time at the pins. However, the signal is non-continuous, and so this is not possible. If the clock is passed through a global buffer, then the hold time at the inputs will be quite long at 1 ns to 2 ns, which is not a problem at low link frequencies, but starts to become important over 100 Mb/s. The solution chosen is, therefore, to use the clock signal directly and to apply a MAXSKEW or USELOWSKEWLINES constraint to the net, to ensure that race conditions are avoided. This is applied to the design via a .ucf constraint file, an example of which is given in the design .zip file in **Design Files**.

Top Level

The top level design to use the macro is shown in **Figure 5**. This basically combines the input and output data busses into one bidirectional bus using 3-state buffers in the IOBs of the FPGA. An example is given in the design .zip file. The output signals, i.e., LxData[7:0], LxDIR, and LxClockout are driven by flip-flops in the IOBs of the FPGA to minimize skew between the clock and the data signals. The control signal LxDIR is only used when using an external buffer for level translation, which is typically not necessary. The transmission standard for the FPGA can be any of the supported standards, but would typically be 3.3V LVTTTL signaling as this is used by the ADSP-TS101S. There are no constraints on where the link port pins should be located on the device, other than they should be placed as close together as possible.

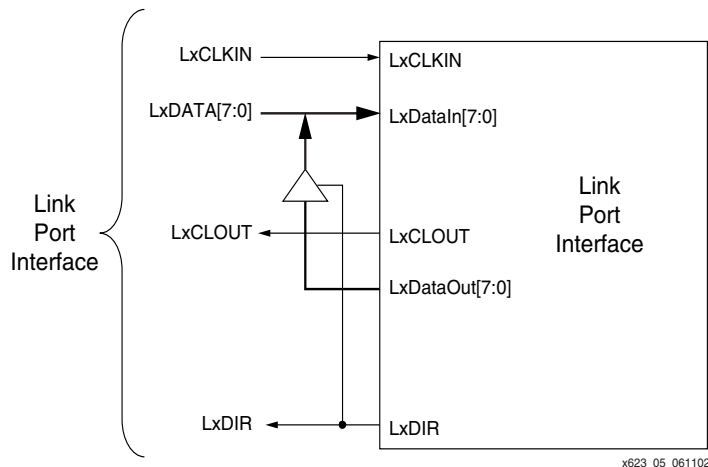


Figure 5: Top-Level Design Diagram

Design Files

The macro design files are written for Virtex, Virtex-E, Virtex-II, and Virtex-II Pro devices. These design files are available in both Verilog and VHDL from the Xilinx website ([xapp634.zip](#)). See the **readme.txt** file enclosed in the zip file for the latest details.

Conclusion

Spartan and Virtex series devices can be easily interfaced with Analog Devices ADSP-TS101S devices, using the macro described in this application note for the embedded link port function, at link speeds of up to 150 Mb/s. This allows the rapid and transparent transfer of data between the DSP and the FPGA in applications where, for instance, an algorithm is shared between software and hardware.

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
06/21/02	1.0	Initial Xilinx release.
03/17/04	1.1	Deleted text from Transmitter section. Updated Web links. Added Spartan-3 devices to mentioned Xilinx FPGA families.
10/26/04	1.2	Revised Figure 1 .