

SpaceFibre Router IP Core

The STAR-Dundee SpaceFibre Router IP Core provides a highly flexible SpaceFibre router comprising a number of SpaceFibre interfaces and a fully configurable, non-blocking, high performance, routing switch.

The SpaceFibre router supports up to 64 virtual networks that behave like independent SpaceWire networks working at multi-gigabit rates. The virtual networks can be set statically through FPGA programming or can be dynamically modified using the configuration port and the RMAP protocol, via SpaceFibre.

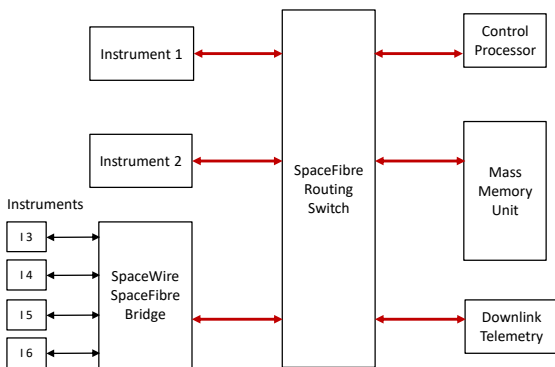
The IP Core has been optimised to work with high-performance radiation-tolerant FPGAs using up to eight virtual channels per port, each with its own quality of service parameters. The IP Core can also be implemented in radiation-tolerant ASIC technologies.

SpaceFibre Networks

SpaceFibre (SpFi) is a very high-speed serial link designed specifically for use onboard spacecraft (ECSS-E-ST-50-11C). SpaceFibre carries SpaceWire packets over virtual channels and provides a broadcast feature similar to SpaceWire time-codes but offering much more capability. SpaceFibre is compatible with the packet level of the SpaceWire standard (ECSS-E-ST-50-12C).

The SpaceFibre network layer is responsible for transferring packets over a SpaceFibre link or network. The information to be sent is packaged in the same format as SpaceWire: <Destination Address> <Cargo> <End of Packet Marker>. It uses the same routing concepts as SpaceWire including both path and logical addressing.

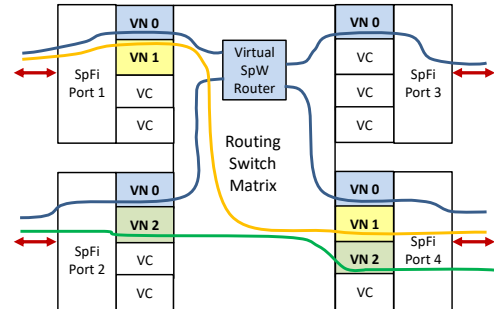
The following figure shows an example onboard network using SpaceFibre.



The control processor is used to configure and control all on-board data-handling equipment. It therefore needs a connection to every instrument and to the mass memory. This could be provided using a separate command and control network, but it would result in additional mass and power consumption. The addition of a SpaceFibre router connected to all of the on-board equipment allows the control processor to send commands and receive information from all of the on-board data handling units.

Each SpaceFibre link implements multiple virtual channels, each one with specific quality of service parameters. For example, the bandwidth allocation parameter of each virtual channel can be set to the expected bandwidth of each instrument so they do not interfere with one another or with the control network. Virtual

networks are built from the interconnection between virtual channels of different ports. These operate like SpaceWire networks.



The figure above shows an example of how the control network and two instrument data flows are assigned to virtual networks in the top four ports of the previous SpaceFibre Routing Switch.

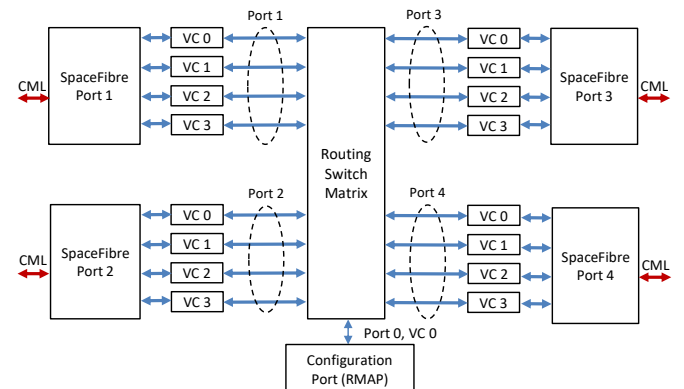
Router Architecture

The router architecture is built around a non-blocking routing switch matrix with a configurable number of ports. Each port implements a number of virtual channels. Each virtual channel has an associated virtual network number.

The switch matrix interconnects one or more virtual channels with the same virtual network number. Each of these virtual channels must be located in a different port.

When a packet arrives to a virtual channel, the output port is selected using path or logical addressing, indicated by the leading byte of each packet and the configuration of the internal routing table. The virtual channel in the output port that has the same virtual network number is selected. In case there is the output does not have a virtual channel with the same virtual network number, the packet is spilled.

Packets belonging to different virtual networks never interfere with one another and do not impact the throughput and latency within the routing switch matrix. On the other hand, when multiple packets in the same virtual network need to be transferred to the same output port, packet-by-packet, round robin arbitration is performed, similarly to a SpaceWire router.

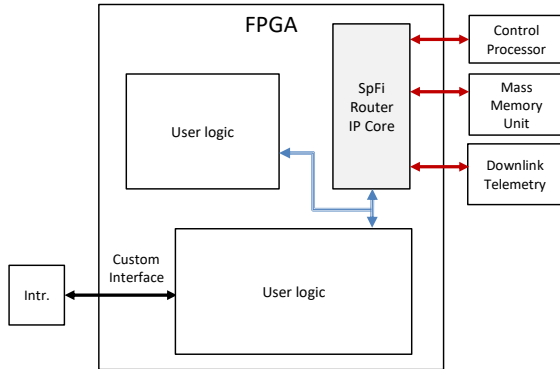


The figure above shows a simplified router architecture with four ports, each with four virtual channels, plus a configuration port. The configuration port allows the RMAP protocol to be used to configure

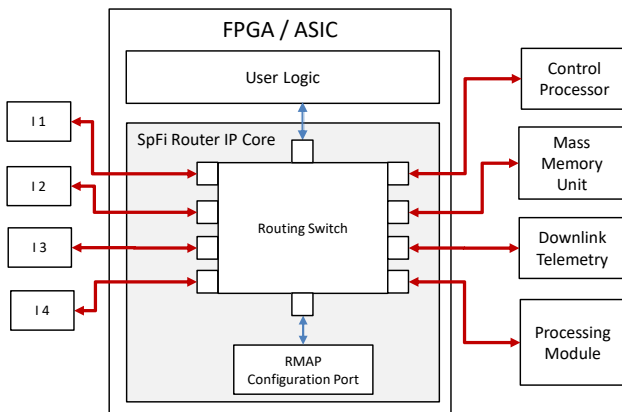
the routing table, the virtual networks, the SpaceFibre links and their corresponding quality of service.

Example Use Cases

The high flexibility of the SpaceFibre Router IP Core ensures different user needs can be accommodated with ease. Two examples of very different use cases are presented below.



The figure above shows a small 4-port SpFi router with pre-programmed static virtual networks and quality of service settings. Most of the FPGA resources are used for the user logic, which interfaces to the SpFi Router using one or more virtual channels of the same internal port. This solution allows SpaceFibre routing capabilities to be added to the data handling network using the same FPGA dedicated to controlling a high speed instrument.



This second use case describes a larger 10-port router that handles the interconnections of the whole data handling network. The virtual networks can be re-configured dynamically by the control processor depending on the current system operational mode, using the configuration port and the RMAP protocol. An internal port can also be used to access custom user logic.

IP Core Features

The STAR-Dundee SpaceFibre Router IP core has the following features:

- Compliant with the SpaceFibre standard, including the SpaceFibre network layer (ECSS-E-ST-50-11C).
- Supports an arbitrary number of SpaceFibre, SpaceWire and internal (FIFO-like) ports. Does not include the SpW interface.
- Each SpFi port can have a different number of Virtual Channels
- Deterministic low latency switching
- Automatic broadcasting of Broadcast messages (SpFi) and Time-Codes (SpW)
- Includes a configuration port (Port 0) with RMAP protocol

- Supports path and logical addressing, and group and regional adaptive routing
- Full non-blocking switch matrix. Packet arbitration only takes place when two or more virtual channels request the same output port within the same virtual network
- Packet by packet round robin arbitration within each virtual network
- Automatic packet spill on time-out event caused by unexpected packet blocking, using a configurable virtual channel time-out period
- Supports up to 64 virtual networks
- Each virtual channel of each port can be configured to belong to any virtual network
- Internal timer tracks the time being distributed over the network
- Highly configurable, giving flexibility through generics in the VHDL code, including number of ports and virtual channels
- Supports lane rates up to 3.125 Gbit/s in RTG4 or Virtex-5QV and 6.25 Gbit/s in Kintex UltraScale
- Guaranteed timing closure in RTG4 or Virtex-5QV with EDAC and SET filter enabled and worst-case conditions
- Different options for the configuration of virtual networks and other parameters:
 - Fixed at FPGA programming using VHDL constants
 - Changed dynamically with user logic via VHDL ports
 - Changed dynamically using RMAP protocol via SpaceWire or SpaceFibre
- Validated in major FPGA families (e.g. Xilinx Kintex) including radiation-hard devices, e.g. Microsemi RTG4
- Designed by the team who created the SpaceFibre standard

Resource Usage and Performance

The actual resources used by the complete SpaceFibre Router design depend on the FPGA and the specific user configuration. For the Xilinx FPGAs, the table below shows the percentage results for different number of SpW and SpFi ports, including the additional RMAP configuration port. The SpFi IP Cores are also included.

	Virtex-5QV			Kintex UltraScale 060 ¹		
	LUT	DFF	BRAM	LUT	DFF	BRAM
2 SpFi/2 VCs + 2 SpW	13 %	11 %	9 %	3 %	1 %	1 %
4 SpFi/4 VCs + 4 SpW	38 %	30 %	23 %	8 %	4 %	4 %
8 SpFi/4 VCs + 4 SpW	76 %	60 %	39 %	18 %	7 %	7 %

¹ TMR has not been applied to the design

IP Core Delivery Files

The STAR-Dundee SpaceFibre Router IP Core comes with a reference design for RTG4 (Liberio), Virtex-5QV (ISE), Kintex-7 & UltraScale (Vivado) that can directly be implemented in the FPGA for easy adoption. A comprehensive end-user test bench for ModelSim/Quarta simulators is also provided.

Licensing

The STAR-Dundee SpaceFibre Router IP Core is available under license. For more information on IP cores, license, or if you have specific or custom requirements, please contact us.