

SpaceFibre Router IP Core

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

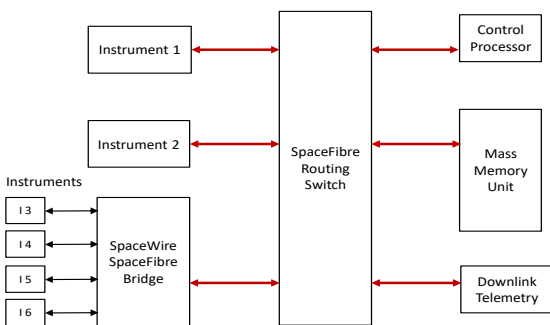
The SpaceFibre router supports up to 64 virtual networks that behave like independent SpaceWire networks working at multi-gigabit rates. The virtual networks can be set statically through FPGA programming or can be dynamically modified using the configuration port and the RMAP protocol, via SpaceFibre.

The IP Core has been optimised to work with Xilinx radiation-tolerant FPGAs using any number of virtual channels per port, each with its own quality of service parameters.

SpaceFibre Networks

SpaceFibre (SpFi) is a very high-speed serial link designed specifically for use onboard spacecraft (ECSS-E-ST-50-11C). SpaceFibre carries user data in packets which have the same format as SpaceWire packets (ECSS-E-ST-50-12C), making **SpaceFibre and SpaceWire compatible at the network level**. This means that applications developed for SpaceWire can be readily transferred to and run over a SpaceFibre network or mixed SpaceWire and SpaceFibre network. SpaceFibre provides a **low-latency broadcast capability** which can be used to distribute spacecraft time, signal events, report errors, etc. and carry SpaceWire time-codes.

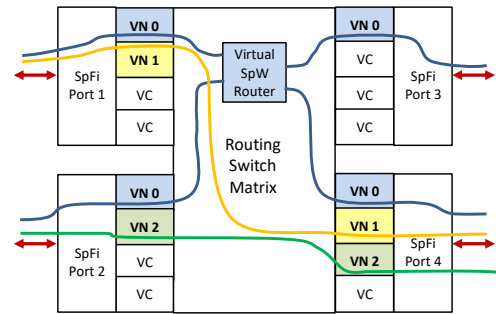
The SpaceFibre network layer is responsible for transferring packets over a SpaceFibre link or network. The packet format is very simple: <Destination Address> <Cargo> <End of Packet Marker>. The information to be sent is put in one or more packets as the cargo. The destination address holds the path or logical address; the routing concepts being the same as SpaceWire. 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. 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 (VN0) and two instrument data flows (VN1 and VN2) are assigned to virtual networks in the top four ports of the previous SpaceFibre Routing Switch.

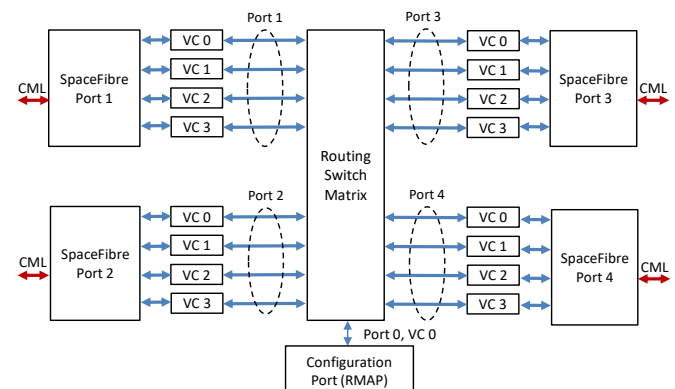
Router Architecture

The router architecture is built around a non-blocking routing switch matrix with a configurable number of ports. Each port implements several 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 in a different port.

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

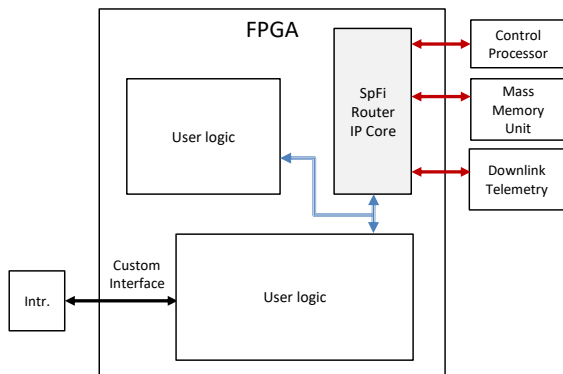
Packets belonging to different virtual networks never interfere with one another and do not impact the throughput and latency of the routing switch matrix. On the other hand, when multiple packets in the same virtual network need to be transferred to the same output port, packet-by-packet, round robin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

The following 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.

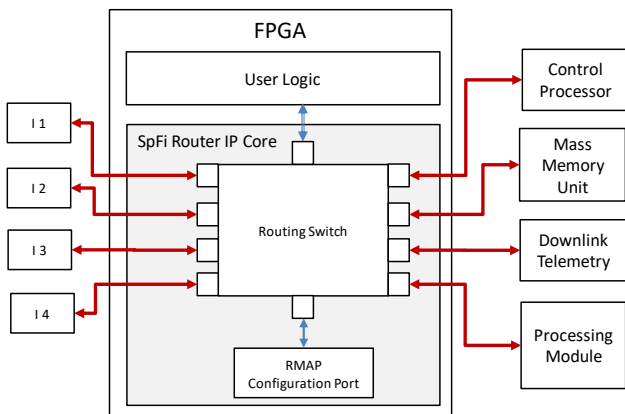


Example Use Cases

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).
- **Includes the SpaceWire and SpaceFibre interface IPs.**
- Supports lane rates of up to **6.25 Gbit/s in Kintex UltraScale** and 3.125 Gbit/s in Virtex-5QV.
- **Validated in major Xilinx FPGA families.**
- **Guaranteed timing closure** in Virtex-5QV with EDAC enabled and worst-case conditions.
- **Deterministic, low-latency switching.**

- 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.
- Includes a **configuration port (Port 0) with RMAP protocol**.
- Supports an **arbitrary number of ports** (up to 32) which can be SpaceFibre, SpaceWire and internal (FIFO-like) ports.
- Each SpaceFibre port can have a **different number of Virtual Channels**.
- **Supports path and logical addressing**, and group and regional adaptive routing.
- 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 mapped to any virtual network.
- **Automatic broadcasting of Broadcast messages** (SpaceFibre) and time-codes (SpaceWire).
- **Internal timer** tracks the time being distributed over the network.
- **Highly configurable**, giving flexibility through generics in the VHDL code.
- 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.
- 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. The table below shows the results for different number of SpW and SpFi ports, including the additional RMAP configuration port.

	XQRKU060 ⁽¹⁾			Virtex-5QV		
	LUT	DFF	BRAM	LUT	DFF	BRAM
2 SpFi/2 VCs + 2 SpW	3 %	1 %	1 %	13 %	11 %	9 %
4 SpFi/4 VCs + 4 SpW	8 %	4 %	4 %	38 %	30 %	23 %
8 SpFi/4 VCs + 4 SpW	18 %	7 %	7 %	76 %	60 %	39 %

⁽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 Kintex-7 & UltraScale (Vivado) and Virtex-5QV (ISE) that can directly be implemented in the FPGA for easy adoption. A comprehensive end-user test bench for ModelSim/Questa 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.