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# SMPTE 2022-1/2 CBR MPEG2 Over IP with Forward Error Correction

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## Summary

This application note covers the design considerations of a video over IP networks system using the performance features of the LogiCORE™ IP SMPTE 2022-1/2 Video Over IP transmitter and receiver cores [Ref 1]. The design demonstrates a constant bit rate (CBR) MPEG2 transport stream (TS) over a dual gigabit Ethernet link with forward error correction (FEC). The software application is based on the Xilinx SMPTE 2022 reference design format.

The reference design consists of two platforms: the transmitter and the receiver. Both platforms use the provided DVB-ASI block to receive or transmit the serial video stream using the SDI port of an Inrevium TB-FMCH-3GSDI2A 3G/HD/SD-SDI mezzanine card. For transmit transactions, the DVB-ASI block converts the received serial video stream to an AXI4 interface stream which is delivered to the SMPTE 2022-1/2 Video Over IP transmitter core. For receive transactions, the DVB-ASI block converts the AXI4 interface stream from the SMPTE 2022-1/2 Video Over IP receiver core to an ASI stream for transmitting from the SDI port.

On the transmit platform, the incoming AXI4 interface video stream is multiplexed and encapsulated into user-configured IP datagram packets by the SMPTE 2022-1/2 Video Over IP transmitter core and sent by a Tri-Mode Ethernet MAC v8.0 core [Ref 2] which interfaces with an Inrevium TB-FMCL-GLAN-B dual gigabit Ethernet PHY mezzanine card. The transmitted packet is transferred through a 1G Ethernet cable to the receive platform.

On the receive platform, the Ethernet datagram packets are collected by the Tri-Mode Ethernet MAC core. The SMPTE 2022-1/2 Video Over IP receiver core filters the datagram based on user-configured parameters on the selected RTP header, de-encapsulates and de-multiplexes the datagram packets into individual streams (channels) and outputs the streams to the DVB-ASI block for transmitting from the ASI port.

The Ethernet datagram packets are buffered in DDR3 SDRAM on both the transmit and receive platforms. The DDR traffic passes through the Advanced Microcontroller Bus Architecture (AMBA® protocol) Advanced eXtensible Interface (AXI) interconnect to the AXI4 memory controller on the Kintex®-7 FPGA. A MicroBlaze™ processor is included in the design to initialize the cores and read the status of the entire platform.

The reference design is targeted for the Xilinx Kintex-7 FPGA KC705 evaluation kit [Ref 3], which uses the Kintex-7 XC7K325T-2FFG900 FPGA [Ref 4] and the Inrevium TB-FMCH-3GSDI2A [Ref 5] and TB-FMCL-GLAN-B [Ref 6] mezzanine cards.

## Included Systems

The reference design was created and built using the Vivado® Design Suite, System Edition 2013.4. The design also includes software built using the Xilinx Software Development Kit (SDK) 2013.4. The software runs on the MicroBlaze processor subsystem and implements control and status functions. Complete project files for Vivado Design Suite and the SDK are provided with this application note to allow examination and rebuilding of the design or to use it as a template for starting a new design. See [Reference Design, page 23](#).

## Introduction

The reference design covers the 1G SMPTE 2022-1/2 Video Over IP cores with hitless protection implementation on the KC705 evaluation board. In this design, the DVB-ASI block was added to interface to the TB-FMCH-3GSDI2A SDI mezzanine board which receives or transmits the video TS through the ASI port. The top-level representation of the video over IP system is shown in [Figure 1](#).

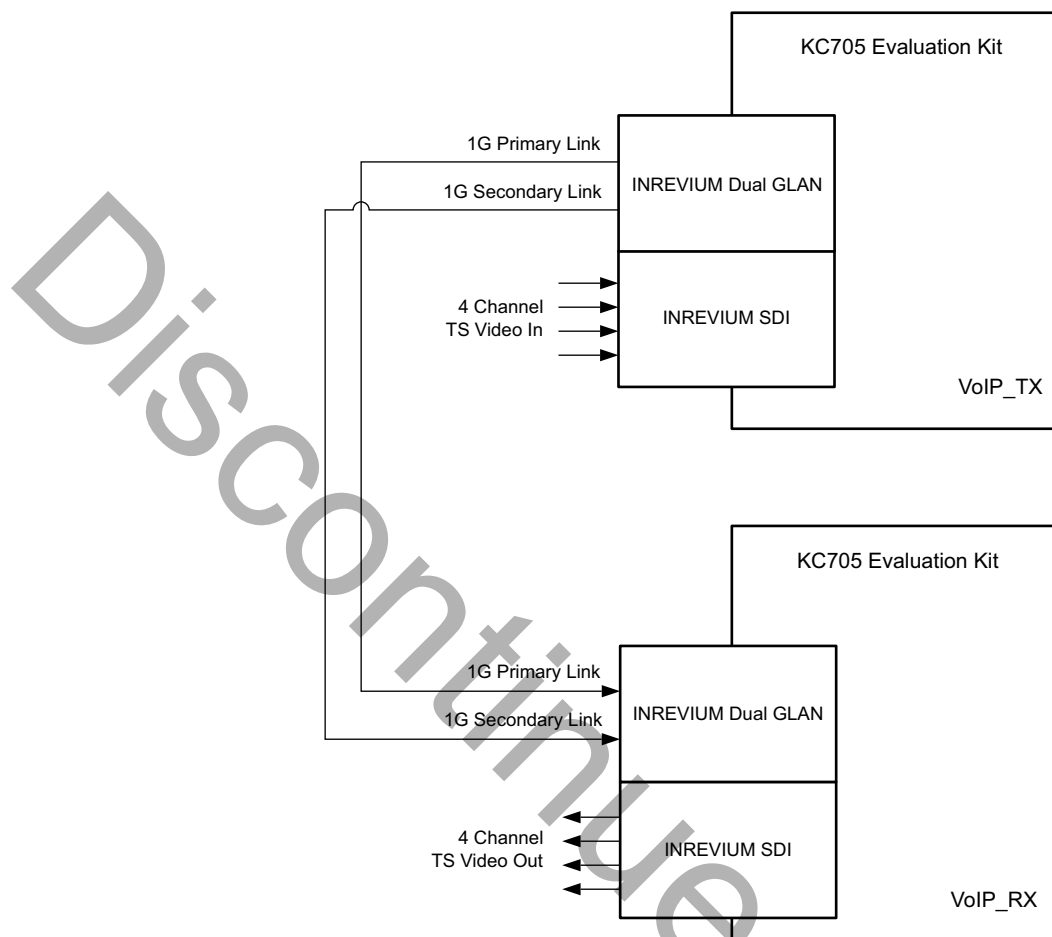


Figure 1: Top-Level Video Over IP System on KC705 Evaluation Board

The transmit platform is shown in [Figure 2](#) and the receive platform is shown in [Figure 3](#).

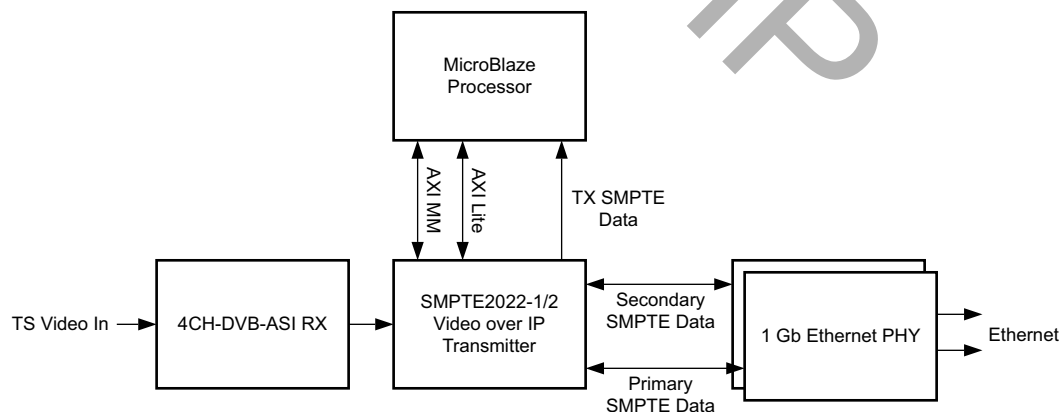
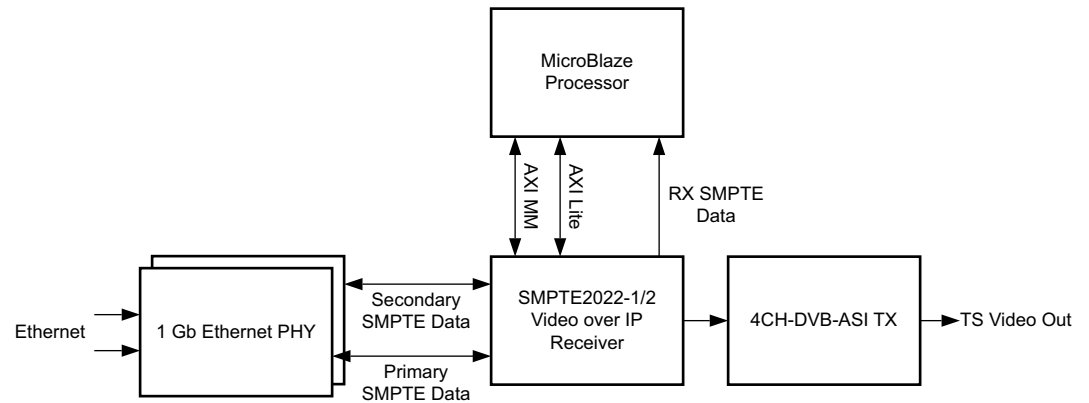


Figure 2: Transmit Platform Diagram



**Figure 3: Receive Platform Diagram**

High-level control of the system is provided by a simplified embedded MicroBlaze processor subsystem containing I/O peripherals and processor support blocks. A clock generator and processor system reset block supply clocks and resets for the system, respectively. This logic is contained in the customized `axilite_bridge` core. [Figure 4](#) shows a block diagram of the MicroBlaze processor subsystem.

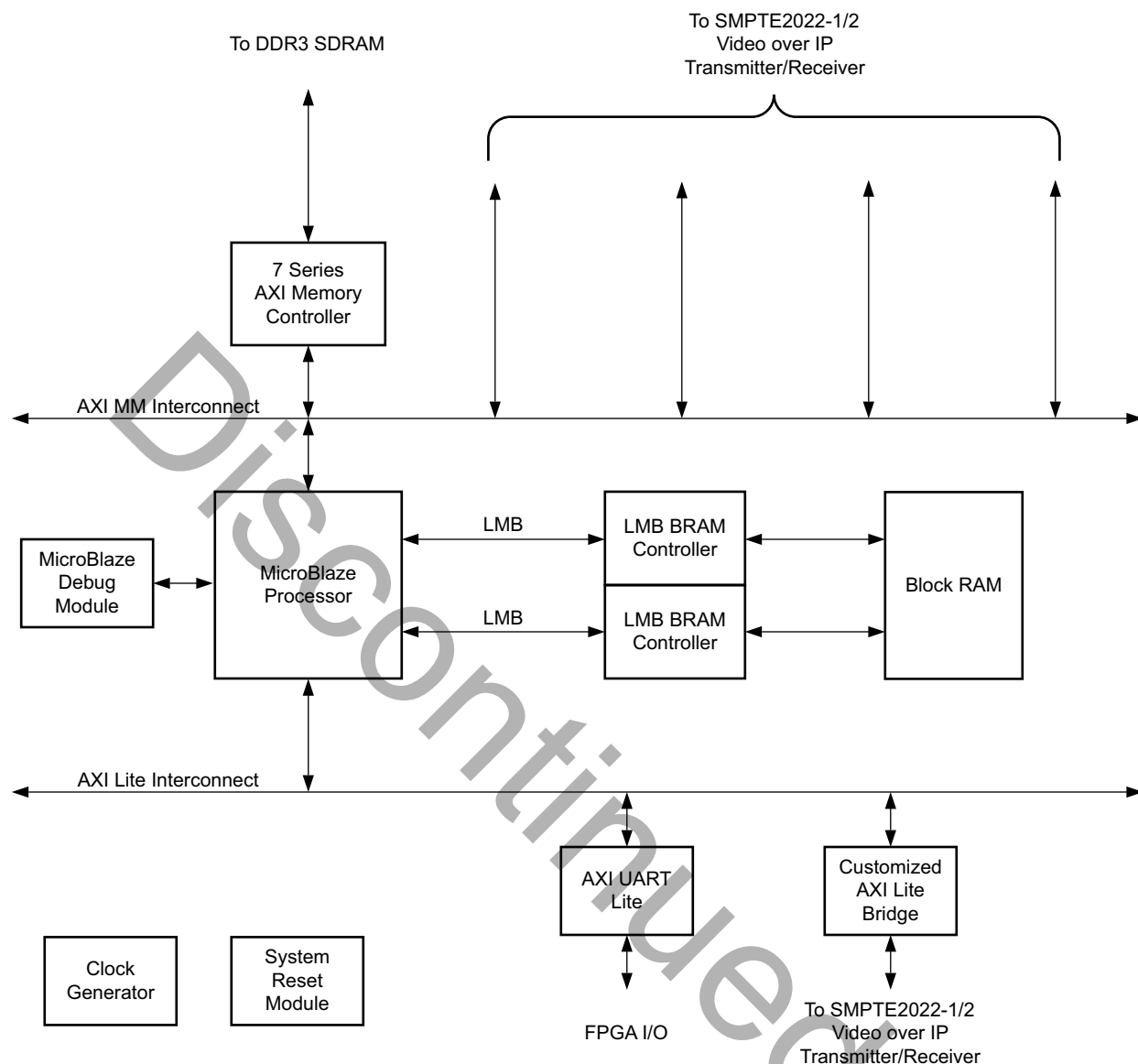


Figure 4: MicroBlaze Processor Subsystem Diagram

Table 1 shows the address map of the MicroBlaze processor subsystem.

Table 1: MicroBlaze Processor Subsystem Address Map

Peripherals	Instance	Base Address	High Address
lmb_bram_if_ctrl	ilmb_bram_if_ctrl	0x00000000	0x0001FFFF
lmb_bram_if_ctrl	dlmb_bram_if_ctrl	0x00000000	0x0001FFFF
mig_7series	mig_1	0xC0000000	0xFFFFFFFF
axi_uartlite	axi_uartlite_1	0x40600000	0x4060FFFF
axilite_bridge	smpte2022_axilite	0x70E00000	0x70E0FFFF

## Hardware Requirements

The hardware requirements for the reference design are:

- Two Xilinx Kintex-7 FPGA KC705 evaluation kits, Rev 1.0 or 1.1
- Two Inrevium 3GSDI FMC Connectivity mezzanine cards (TB-FMCH-3GSDI2A)
- Two Inrevium 1000 Base-T Ethernet FMC Connectivity mezzanine cards (TB-FMCL-GLAN-B)
- Ethernet cable
- Vivado Design Suite 2013.4
- SDK 2013.4

## Reference Design Specifics

Other than the SMPTE 2022-1/2 Video Over IP transmitter and receiver cores, the reference design includes these cores:

- AXI4 Interconnect
- MicroBlaze Processor
- MicroBlaze Processor Debug Module
- Local Memory Bus
- LMB BRAM Interface Controller
- Block RAM
- Clocking Wizard
- Processor System Reset Module
- AXI UART Lite
- SMPTE2022 AXI4-Lite Bridge (customized)
- MIG 7 Series
- Tri-Mode Ethernet MAC

## Hardware System Specifics

This section describes the high-level features of the reference design, including how the main IP blocks are configured.

### Video Over IP System

The reference design implements the SMPTE 2022-1/2 Video Over IP cores as modules for broadcast applications that require bridging between broadcast connectivity standards and a gigabit Ethernet Network. The cores are intended for developing Internet protocol based systems to reduce the overall cost in broadcast facilities for distribution and routing of audio and video data. The TS data are mapped into media datagram payloads as per SMPTE 2022-2. The systematically-generated redundant forward error correction datagrams are formatted according to SMPTE 2022-1. IP/UDP/RTP protocols provide standard headers when transporting the media and FEC datagrams over the IP network.

To support the system functions correctly, the bandwidth available in the network must meet what is required to support the stream generated by the system. The overhead size required for media datagram generation is 54 Bytes due to the IP/UDP/RTP and SMPTE 2022-2 headers.

### SMPTE 2022-1/2 Video Over IP Transmitter

The SMPTE 2022-1/2 Video Over IP transmitter in the reference design is configured to accept four channels of TS input from the SMPTE TS receiver. The transmitter connects to a dual port gigabit Ethernet MAC (Tri Mode Ethernet MAC) through an AXI4-Stream data interface for two links (hitless protection). The transmitter also connects to a customized IP core in the MicroBlaze processor subsystem through an AXI4-Lite control interface. The transmitter core does not have native register access support. Thus, a customized IP core called `smpte2022_axilite` is created for the register access. The transmitter core uses three AXI4 external master connectors to access the DDR3 SDRAM through the AXI4 interconnect. The initial memory map address range is fixed from `0xC0000000` up to a user-determined value based on the FEC and RTP packet allocation. The maximum user address is `0xFFFFFFFF`.

The transmitter also contains an AXI4-Lite interface which allows dynamic control of the parameters within the core from a processor. For more information about the registers, see *LogiCORE IP SMPTE 2022-1/2 Video Over IP Transmitter v1.0 Product Guide* (PG180) [Ref 8].

The registers are categorized into two main sections: the general space and the channel space. The parameters in the general space apply to all of the channels. The parameters in the channel space apply to an individual channel. The channel space register is divided into two sections where the parameters are set based on either the respective links and channel or the respective channel only. In this reference design, four channels are supported and all of the parameters are differentiated by the UDP destination port and the primary and secondary links are differentiated by the IP Address. See [Software Configuration, page 9](#) for details.

For the general registers, normal address read and write access is applied. For the channel registers, follow these steps to update the registers:

1. Select either the primary or secondary link to be configured using the most significant bit of the register address `base_addr + 0x00C`
2. Set the channel to be configured at register address `base_addr + 0x00C`
3. Configure the channel-specific register.
4. Pulse bit 1 of register address `base_addr + 0x000` to commit the channel registers change.
5. Repeat [step 1](#) through [step 4](#) for another channel or registers (see [Figure 5](#)).

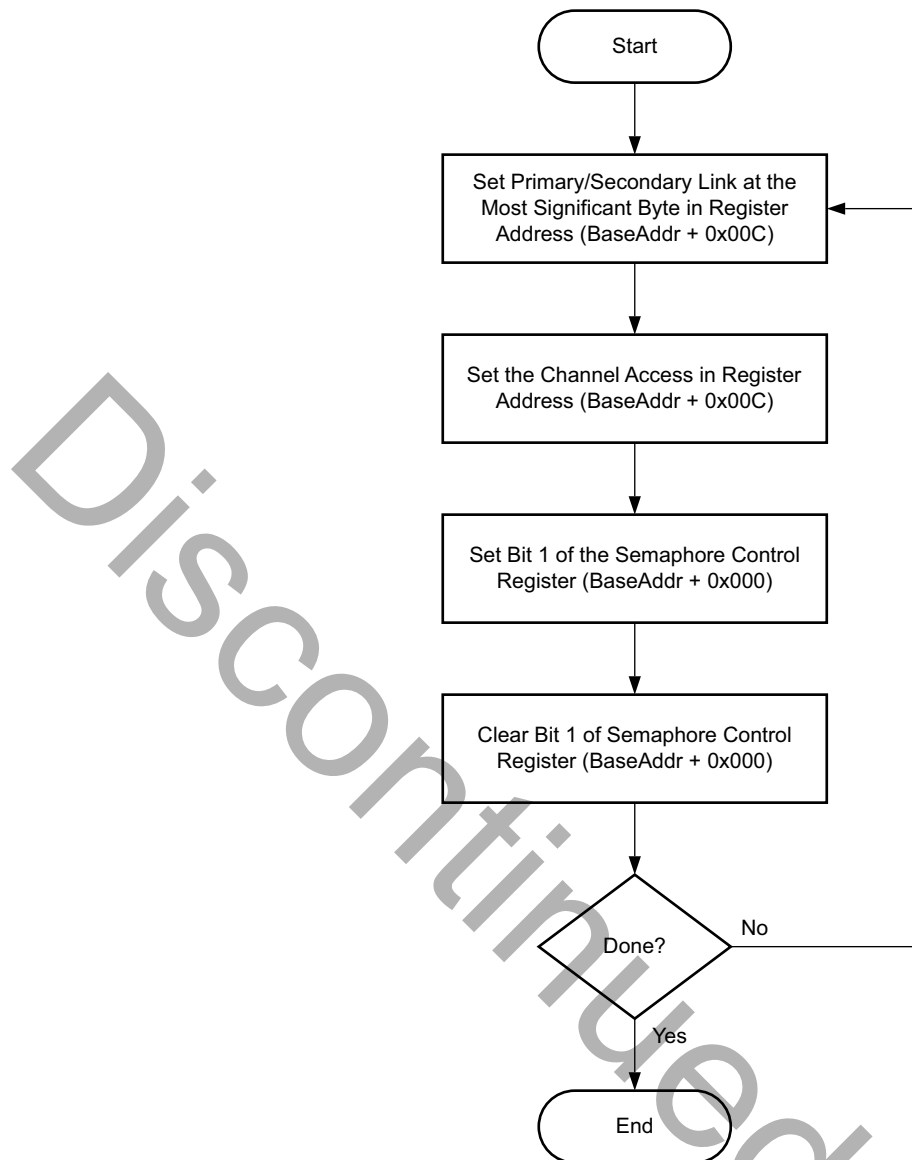


Figure 5: Channel Register Configuration Flow Chart

## SMPTE 2022-1/2 Video Over IP Receiver

The SMPTE 2022-1/2 Video Over IP receiver in the reference design is configured to stream four channels of TS output to the DVB-ASI port. The receiver connects to a dual port gigabit Ethernet MAC through an AXI4-Stream for two links (hitless protection). The receiver also connects to a customized IP core in the MicroBlaze processor subsystem through an AXI4-Lite control interface. The receiver core does not have native register access support. Thus, a customized IP core called `smp2e2022_bridge` is created for register access. The receiver core uses two AXI4 external master connectors to access the DDR3 SDRAM through an AXI4 interconnect. The initial memory map address range is fixed from `0xC0000000` up to a user-determined value based on the FEC and RTP packet allocation. The maximum user address is `0xFFFFFFFF`.

The receiver contains an AXI4-Lite interface which allows dynamic control of the parameters within the core from a processor. For more information about the registers, see *Logicore IP SMPTE 2022-1/2 Video Over IP Receiver v1.0 Product Guide* (PG181) [Ref 9].

The registers are categorized into two main sections: the general space and the channel space. The parameters in the general space apply to all of the channels. The parameters in the channel space apply to an individual channel. The channel space register is divided into two sections where the parameter are set based on either the respective links and channel or the respective channel only. In this reference design, four channels are supported and all of the parameters are differentiated by the UDP destination port and the primary and secondary links are differentiated by the IP address. refer to [Software Configuration, page 9](#) for details.

For the general registers, normal address read and write access is applied. For the channel registers, use the same method described in the [SMPTE 2022-1/2 Video Over IP Transmitter](#) section. See [Figure 5](#).

## AXI4 Interconnect (AXI\_MM)

This AXI4 interconnect instance provides the high  $F_{MAX}$  and throughput needed for the design by providing a 128-bit core data width and running at 200 MHz. The AXI4 interconnect core data width and clock frequency matches the capabilities of the attached AXI4 MIG so that width and clock converters are not required between them. Setting the AXI4 Interconnect core data width and clock frequency below the native width and clock frequency of the memory controller creates a bandwidth bottleneck within the system. To help meet the timing requirements of a 256-bit AXI4 interface at 200 MHz, a rank of register slices are enabled between the AXI\_MM interconnect and the AXI4 MIG. Together, the AXI4 interconnect and AXI4 MIG form a 4-port AXI4 multi-port memory controller (MPMC) connected to four AXI4 external master connectors. The configuration of this AXI4 interconnect is consistent with the system performance optimization recommendations for an AXI4 MPMC-based system as described in *AXI Reference Guide (UG761)* [\[Ref 10\]](#).

## MIG 7 Series

The 7 series FPGAs AXI4 memory controller (a block that integrates the MIG tool into the Vivado IDE) forms the single slave connected to the AXI4 Interconnect. The memory controller AXI4 interface is 128 bits wide, runs at 200 MHz, and disables narrow burst support for optimal throughput and timing. This configuration matches the native AXI4 interface clock and width corresponding to a 64-bit DDR3 DIMM with an 800 MHz memory clock which is the nominal performance of the memory controller for a Kintex-7 device with a -2 speed grade. Register slices are enabled to ensure that the interface meets timing at 200 MHz. These settings help ensure that a high degree of transaction pipelining is active to improve system throughput. See the *7 Series FPGAs Memory Interface Solutions v2.0 User Guide (UG586)* [\[Ref 11\]](#) for more information about the memory controller.

## AXI4 Interconnect (AXI4-Lite)

The MicroBlaze processor data peripheral (DP) interface master writes to and reads from all AXI4-Lite slave registers in the design for control and status information. These interconnects are 32 bits and do not require high  $F_{MAX}$  and throughput. Therefore, a separate AXI4 interconnect with a lower  $F_{MAX}$  requirement is used. Because high throughput is not required, this block is configured for shared-access mode allowing for the optimization of area over performance. Also, this interconnect is clocked at 100 MHz to allow the use of synchronous integer ratio clock converters in the AXI4 interconnect which offer lower latency and less area than asynchronous clock converters. The slaves on the AXI4-Lite interconnect are MDM, AXI4 UART (AXI4-Lite) and a customized IP core to the SMPTE 2022-1/2 Video Over IP transmitter or receiver core.

## Tri-Mode Ethernet MAC

The Tri-Mode Ethernet MAC instance on the transmitter side has its AXI4-Stream transmit interface connected to the output of the SMPTE 2022-1/2 Video Over IP transmitter. The Tri-Mode Ethernet MAC instance on the receiver side has its AXI4-Stream receive interface



connected to the input of the SMPTE 2022-1/2 Video Over IP receiver. The Tri-Mode Ethernet MAC core interfaces to the Dual Port Gigabit Ethernet PHY (Inrevium TB-FMCL-GLAN-B FMC mezzanine card). See PG051, *LogiCORE IP Tri-Mode Ethernet MAC Product Guide* (PG051) [Ref 12] for more information.

## Software Configuration

The software application initializes the video over IP transmitter and receiver systems. After the software initialization, commands can be selected from the menu at the UART display.

Application-level software and the drivers for controlling the system are written in C. Alternatively, drivers and application software can be written directly to the IP control registers.

The software configures the values for the transmitter general space registers as shown in Table 2. The configuration for the transmitter primary and secondary channel access registers is shown in Table 3 and Table 4. The configuration for the receiver general space registers is shown in Table 5. The configuration for the receiver primary and secondary channel access registers is shown in Table 6 and Table 7. The base address of the register set is the AXI4-Lite bridge base address (0x70E00000). Registers not shown in the tables are not initialized and remain at their respective default values.

Table 2: Initialized Transmitter General Space Register Values

Offset	Register Name	Value
0x00000000	0x10 Primary Mac Address (Low)	0x000000AA
	0x14 Primary Mac Address (High)	0x00000000
	0x18 Secondary Mac Address (Low)	0x000000CC
	0x1C Secondary Mac Address (High)	0x00000000

Table 3: Initialized Transmitter Primary Channel Access Register Values

Offset	Register Name	Value			
		Channel 0	Channel 1	Channel 2	Channel 3
0x00000080	0x00 ip_header	0x00006480			
	0x04 vlan_tag_info	0x0000AB00	0x0000AB10	0x0000AB20	0x0000AB30
	0x08 dest_mac_low_addr	0x000000FF			
	0x0C dest_mac_high_addr	0x00000000			
	0x10 dest_ip_host_low_addr	0xC0A80064			
	0x20 src_ip_host_low_addr	0xC0A80032			
	0x30 udp_src_port	0x00000010	0x00000020	0x00000030	0x00000040
	0x34 udp_dest_port	0x00000010	0x00000020	0x00000030	0x00000040
0x00000100	0x18 ssrc	0x12345600	0x12345610	0x12345620	0x12345630
	0x1C fec_config	0x00000000			
	0x20 fec_col_offset	0x00000000			
	0x24 fec_L_value	0x00000004			
	0x28 fec_D_value	0x00000004			
	0x2C FEC BaseAddress	0xC0000000	0xC0AC0000	0xC1580000	0xC2040000

Table 4: Initialized Transmitter Secondary Channel Access Register Values

Offset	Register Name	Value			
		Channel 0	Channel 1	Channel 2	Channel 3
0x00000080	0x00	ip_header			
	0x04	0x0000AB00	0x0000AB10	0x0000AB20	0x0000AB30
	0x08	dest_mac_low_addr			
	0x0C	dest_mac_high_addr			
	0x10	dest_ip_host_low_addr			
	0x20	src_ip_host_low_addr			
	0x30	0x00000010	0x00000020	0x00000030	0x00000040
0x00000100	0x34	0x00000010	0x00000020	0x00000030	0x00000040
	0x18	0x12345600	0x12345610	0x12345620	0x12345630
	0x1C	fec_config			
	0x20	fec_col_offset			
	0x24	fec_L_value			
	0x28	fec_D_value			
	0x2C	FEC BaseAddress			

Table 5: Initialized Receiver General Space Register Values

Offset	Register Name	Value
0x00000000	0x10	Primary Mac Address (Low)
	0x14	Primary Mac Address (High)
	0x18	Secondary Mac Address (Low)
	0x1C	Secondary Mac Address (High)
	0x28	packet_delay
	0x30	reorder_delay
	0x34	fec_base_addr
	0x38	fec_pool_size

Table 6: Initialized Receiver Primary Channel Access Register Values

Offset	Register Name	Value			
		Channel 0	Channel 1	Channel 2	Channel 3
0x00000080	0x00	ip_header			
	0x04	ip_header_parameter			
	0x08	0x0000AB00	0x0000AB10	0x0000AB20	0x0000AB30
	0x0C	dest_ip_host_low_addr			
	0x1C	src_ip_host_low_addr			
	0x2C	0x00000010	0x00000020	0x00000030	0x00000040
	0x30	0x00000010	0x00000020	0x00000030	0x00000040

Table 6: Initialized Receiver Primary Channel Access Register Values (Cont'd)

Offset		Register Name	Value			
			Channel 0	Channel 1	Channel 2	Channel 3
0x00000100	0x08	recovey_enable	0x00000003	0x00000003	0x00000003	0x00000003
	0x0C	match_sel	0x0000003E	0x0000003E	0x0000003E	0x0000003E
	0x10	ssrc	0x12345600	0x12345610	0x12345620	0x12345630
	0x18	playout_delay	0x00465000			
	0x2C	chan_buf_base_addr	0xC0000000	0xC6000000	0xCC000000	0xD2000000
	0x30	chan_pkt_buf_size	0x0000FFFF			

Table 7: Initialized Receiver Secondary Channel Access Register Values

Offset		Register Name	Value			
			Channel 0	Channel 1	Channel 2	Channel 3
0x00000080	0x00	ip_header				
	0x04	ip_header_parameter				
	0x08	vlan_tag_info	0x0000AB00	0x0000AB10	0x0000AB20	0x0000AB30
	0x0C	dest_ip_host_low_addr	0xC0A80066			
	0x1C	src_ip_host_low_addr	0xC0A80034			
	0x2C	udp_src_port	0x00000010	0x00000020	0x00000030	0x00000040
	0x30	udp_dest_port	0x00000010	0x00000020	0x00000030	0x00000040
0x00000100	0x08	recovery_enable				
	0x0C	match_sel				
	0x10	ssrc				
	0x18	playout_delay				
	0x2C	chan_buf_base_addr				
	0x30	chan_pkt_buf_size				

Figure 6 shows the video over IP transmitter and receiver overall software process.

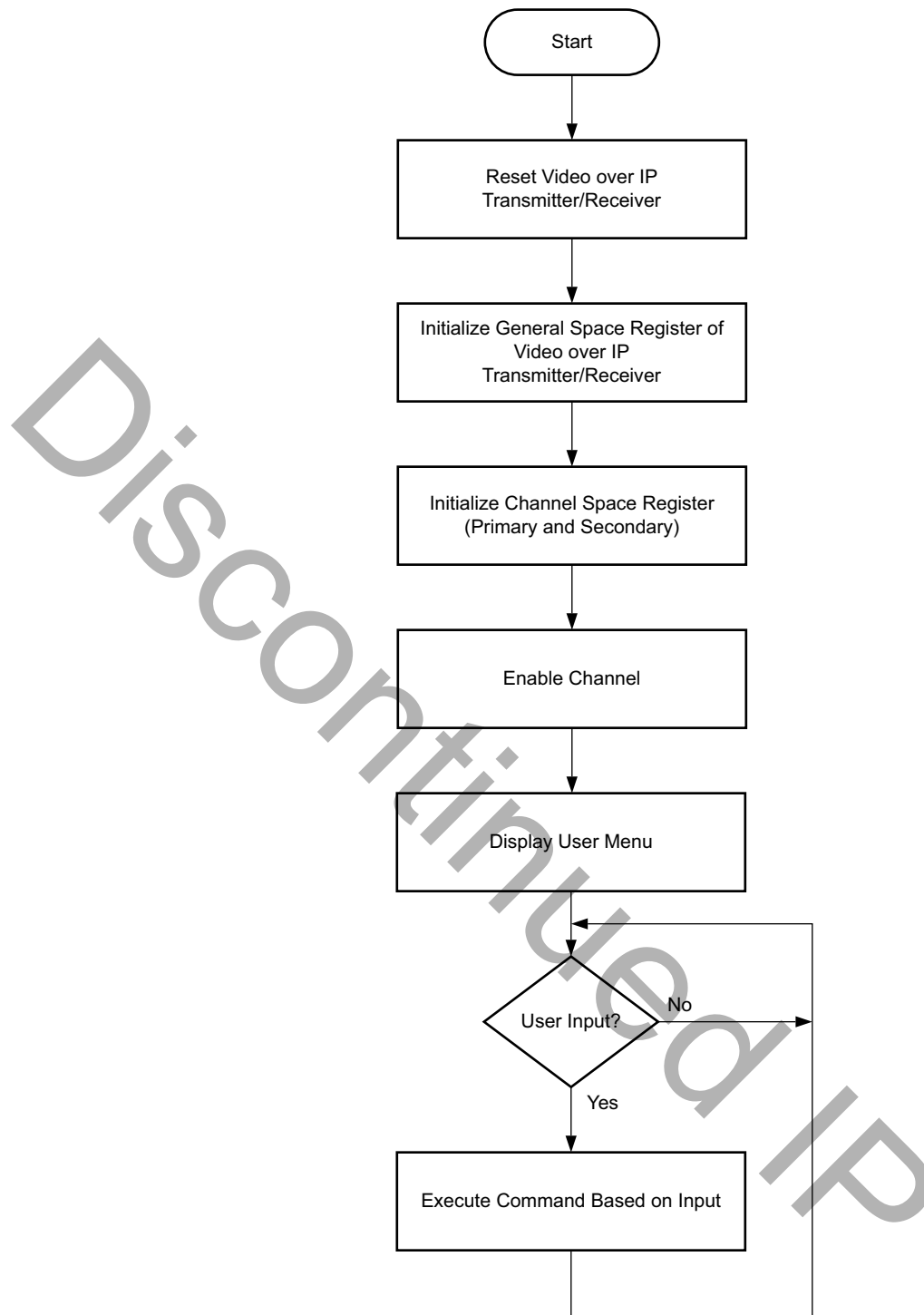


Figure 6: Video Over IP Transmitter and Receiver Overall Software Process

## Executing the Reference Design in Hardware

This section provides instructions to execute the reference design in hardware. This reference design runs on the Kintex-7 FPGA KC705 Evaluation Kit, the Inrevium 3G/HD/SD-SDI (TB-FMCH-3GSDI2A) and the Inrevium 1000 Base-T Ethernet (TB-FMCL-GLAN-B) mezzanine cards shown in [Figure 7](#) and [Figure 8](#).

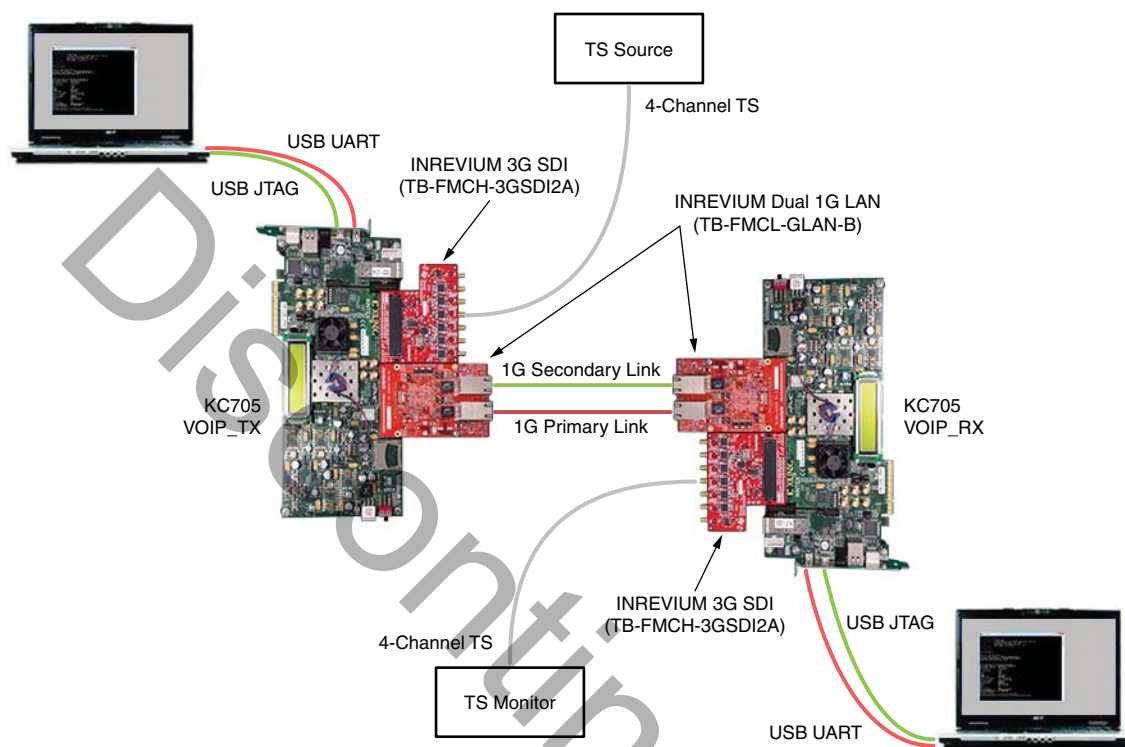


Figure 7: Video Over IP System

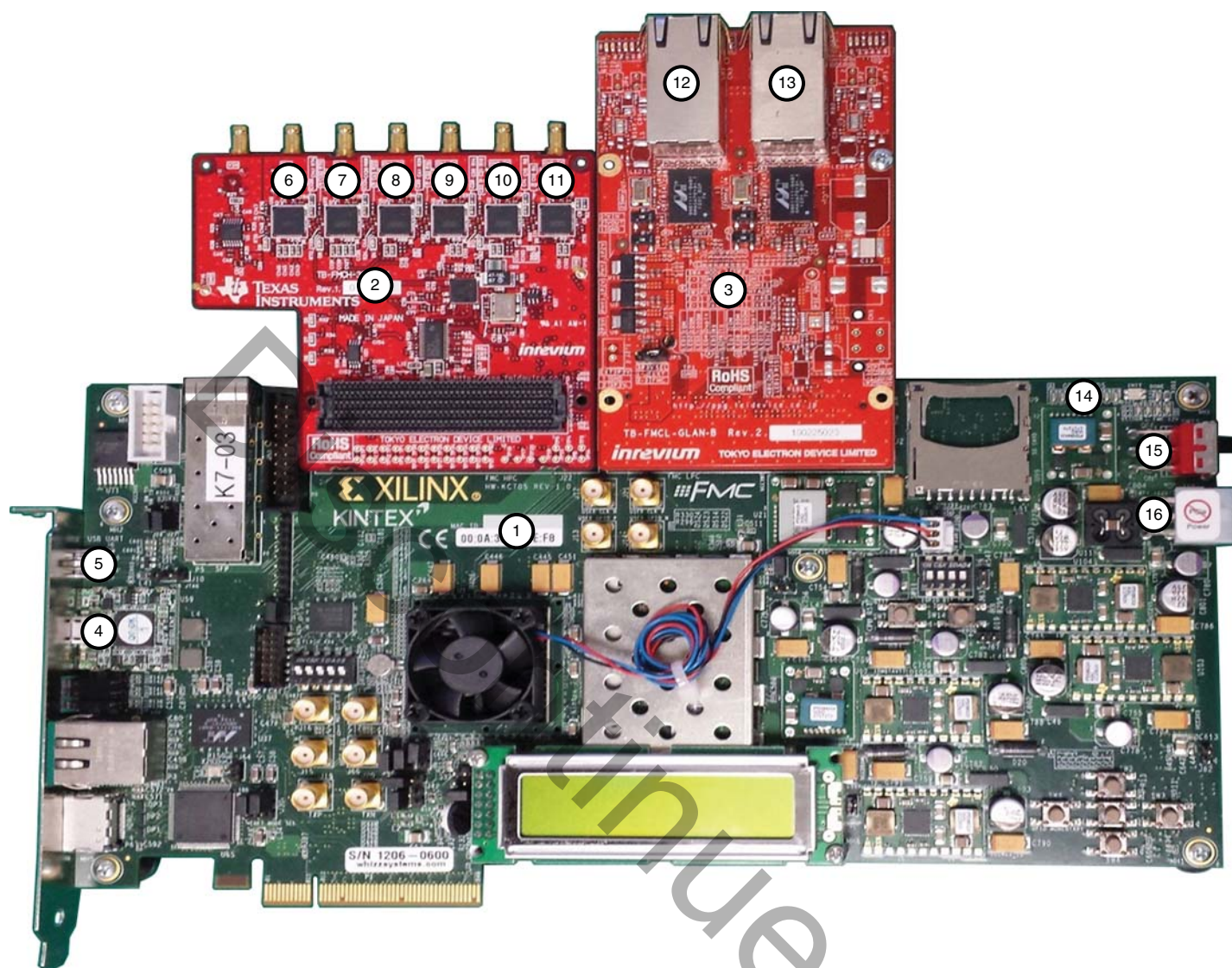


Figure 8: KC705, TB-FMCH-3GSDI2A and TB-FMCL-GLAN-B Boards

In these instructions, numbers in parentheses correspond to callout numbers in [Figure 8](#).

1. Connect a USB cable from the host PC to the USB JTAG port (4). Ensure the appropriate device drivers are installed.
2. Connect a second USB cable from the host PC to the USB UART port (5). Ensure that USB UART drivers described in [Hardware Requirements, page 5](#) have been installed.
3. Connect a TB-FMCH-3GSDI2A board (2) to the HPC-FMC connector of the KC705 boards.
4. Connect a TB-FMCL-GLAN-B board (3) to the LPC-FMC connector of the KC705 boards.
5. Connect one end of the Ethernet LAN cable to the GLAN port 1 (13) for the primary link and another Ethernet LAN cable to the GLAN port 2 (12) for Secondary Link.
6. Connect a power supply to the J49 (16) connector of the KC705 boards.
7. Set the KC705 board power switch (15) to the ON position.
8. Make sure that the HW-KC705 board revision numbers (1) are the same for both the transmit and receive platforms.



9. On the video over IP transmitter board, connect the TS source cables to the specified 3G/HD/SD DIN connectors:
  - Channel 0 to connector 2 (10)
  - Channel 1 to connector 4 (8)
  - Channel 2 to connector 5 (7)
  - Channel 3 to connector 6 (6)
10. On the video over IP receiver board, connect the TS monitor cables to the specified 3G/HD/SD DIN connectors:
  - Channel 0 to connector 1 (11)
  - Channel 1 to connector 4 (8)
  - Channel 2 to connector 5 (7)
  - Channel 3 to connector 6 (6)
11. Start a terminal program (HyperTerminal, for example) on the host PC with these settings:
  - Baud Rate: **115200**
  - Data Bits: **8**
  - Parity: **None**
  - Stop Bits: **1**
  - Flow Control: **None**

## Executing the Reference System Using the Pre-Built Bitstream and Compiled Software Application

This section details the steps necessary to execute the system using the files in the `ready_for_download` directory:

1. Launch the Xilinx Microprocessor Debugger by selecting **Start > All Programs > Xilinx Design Tools > Vivado 2013.4 > SDK**.
2. In the Xilinx command shell window, change to the `ready_for_download` directory:  
 VoIP\_TX:  

```
>cd <unzip dir>/KC705_SMPTE2022_12_4Ch/  
kc705_smp2e2022_12_4ch_tx/ready_for_download
```

 VoIP\_RX:  

```
>cd <unzip dir>/KC705_SMPTE2022_12_4Ch/  
kc705_smp2e2022_12_4ch_rx/ready_for_download
```
3. Download the bitstream to the FPGA:  

```
XMD% fpga -f download.bit
```
4. Exit the XMD command prompt:  

```
XMD% exit
```

**Note:** Start-up order is not critical.

## Running the Hardware and Software

### Transmitter

A HyperTerminal screen displaying the video over IP transmitter initialization sequence is shown in [Figure 9](#). All four channels are initialized with a different configuration.



Xilinx Inc.  
V\_SMPTE2022\_12\_TX 1G  
Vivado Reference Design  
Created: November 21, 2013  
Copyright (c) 2013 Xilinx, Inc.  
All rights reserved.

VoIP TX Reset

VoIP TX Initializing...  
Primary MAC Address: 00-00-00-00-00-AA  
Secondary MAC Address: 00-00-00-00-00-CC  
VoIP TX Initialization done

Initializing for Primary Channel 1  
Dest MAC Address: 00-00-00-00-00-FF  
TS Packet Size: 188 Bytes  
TS Packets: 7 Packets  
IP Version: IPv4  
TTL: 128  
TOS: 100  
VLAN: Disabled  
VLAN Tag: 0xAB00  
Source IP Addr: 192.168.0.50  
Dest IP Addr: 192.169.0.100  
Source Port: 0x0010  
Dest Port: 0x0010  
SSRC: 0x12345600  
FEC (1D) : On  
FEC (2D) : On  
FEC Size: 5x20  
Block Align: Block Aligned  
FEC BASEADDRESS: 0xC0000000  
Channel Enable  
Primary Channel 1 Initialization Done  
TS Configuration for Primary 1 Initialization Done

Initializing for Secondary Channel 1  
Dest MAC Address: 00-00-00-00-00-EE  
TS Packet Size: 188 Bytes  
TS Packets: 0 Packets  
IP Version: IPv4  
TTL: 128  
TOS: 100  
VLAN: Disabled  
VLAN Tag: 0xAB00  
Source IP Addr: 192.168.1.50  
Dest IP Addr: 192.169.1.100  
Source Port: 0x0010  
Dest Port: 0x0010  
SSRC: 0x12345600  
FEC (1D) : On  
FEC (2D) : On  
FEC Size: 5x20  
Block Align: Block Aligned  
FEC BASEADDRESS: 0xC0000000  
Channel Enable  
Secondary Channel 1 Initialization Done  
TS Configuration for 1 Initialization Secondary Done

Figure 9: VOIP\_TX Initializing Channel 1 Hyperterminal Output



Five options are displayed on the HyperTerminal screen as shown in Figure 10:

- 1 = Reset core
- 2 = Initialize Core (general space registers only)
- s = Configure channel (opens “Select Channel” submenu)
- p = Probe Current Settings (displays status of selected registers in general space)
- ? = Display current menu

```

-----
-- VoIP TX Main Menu --
-----

Select option
1 = Reset Core
2 = Initialize Core
s = Configure Channel
p = Probe Current Settings
? = help
-----

```

Figure 10: VOIP\_TX Main Menu Hyperterminal Output

Selecting option **s** produces the Select Channel menu as shown in Figure 11:

```

Select Channel
Primary Channels
1 = Channel 1
2 = Channel 2
3 = Channel 3
4 = Channel 4

Secondary Channels
5 = Channel 1
6 = Channel 2
7 = Channel 3
8 = Channel 4

m = Main Menu
-----

```

Figure 11: VOIP\_TX Select Channel Menu Hyperterminal Output

Options allow the choice of one of the 4 channels (either Primary or Secondary link) or to return to the main menu:

Primary Channel:

- 1 = Channel 1
- 2 = Channel 2
- 3 = Channel 3
- 4 = Channel 4

Secondary Channel:

- 5 = Channel 1
- 6 = Channel 2
- 7 = Channel 3
- 8 = Channel 4

m = Main menu

After selecting any of the channels, the Select Option submenu is displayed as shown in Figure 12.

```

Select Option
1 = Channel Init
2 = Channel Enable/Disable
3 = Change Host IP Address
4 = VLAN En/Disable
5 = Change VLAN Tag
6 = Set Dest MAC Addr
7 = Set Dest IP Addr
8 = Set Source UDP Port
9 = Set Dest UDP Port
0 = Set SSRC
a = Set Packet Size
b = FEC On/Off
c = Toggle FEC Level
d = Set Column FEC
e = Set Row FEC
f = Toggle Block Alignment
g = Set Number of TS Packets
p = Probe Status
m = Main Menu
s = Channel Select
-----

```

Figure 12: VOIP\_TX Select Option Submenu Hyperterminal Output


One of twenty options in the menu list can be chosen:

- 1 = Channel Init (configure target channel registers)
- 2 = Channel Enable/Disable
- 3 = Change Host IP Address
- 4 = VLAN Enable/Disable
- 5 = Change VLAN Tag
- 6 = Set Destination MAC Addr
- 7 = Set Destination IP Addr
- 8 = Set Source UDP Port
- 9 = Set Destination UDP Port
- 0 = Set SSRC
- a = Set Packet Size
- b = FEC On/Off (toggle FEC engine)
- c = Toggle FEC Level
- d = Set Column FEC
- e = Set Row FEC
- f = Toggle Block Alignment
- g = Set Number of TS Packets
- p = Probe Status
- m = Main menu
- s = Channel Select

To transmit video over network, enable the channel by selecting option **2** from the menu. The channel is not automatically enabled during initialization.

### Receiver

A HyperTerminal screen showing the video over IP receiver output display is shown in [Figure 13](#). All four channels are initialized with a different configuration.



```

Xilinx Inc.
V_SMPTE2022_12_RX IG
Vivado Reference Design
Created: November 21, 2013
Copyright (c) 2013 Xilinx, Inc.
All rights reserved.

VoIP RX Reset

VoIP RX Initializing...
Primary MAC Address: 00-00-00-00-00-EE
Secondary MAC Address: 00-00-00-00-00-FF
Packet Delay:      8000
Reorder Delay:     1
FEC Base Address:  0xDC000000
FEC Pool Size:     921600
VoIP RX Initialization done

Initializing Channel 1
Primary Stream Configure
IP Version:        IPv4
VLAN:              Disable
VLAN Tag:          0xAB00
Dest IP Addr:      192.169.0.100
Host IP Addr:      192.168.0.50
Dest Port:         0x0010
Source Port:       0x0010
SSRC:              0x12345600

Match Select:
SSRC:              On
Dest UDP:          On
Source UDP:        On
Dest IP:           Off
Src IP:            Off
VLAN:              Off

Secondary Stream Configure
IP Version:        IPv4
VLAN:              Disable
VLAN Tag:          0xAB00
Dest IP Addr:      192.169.1.100
Host IP Addr:      192.168.1.50
Dest Port:         0x0010
Source Port:       0x0010

Match Select:
SSRC:              On
Dest UDP:          On
Source UDP:        On
Dest IP:           Off
Src IP:            Off
VLAN:              Off

General Channel Setting:
Playout Delay:     9000
Channel Buffer Address: 0xc0000000
Channel Buffer Size: 65535
Channel Enabled

Channel 1 Initialization Done
  
```

**Figure 13: VOIP\_RX Initializing Channel 1 Hyperterminal Output**

Six options are displayed on the HyperTerminal screen as shown in [Figure 14](#):

- 1 = Reset core
- 2 = Initialize core general space registers
- 3 = Secondary Link Enable/Disable
- s = Configure channel (opens Select Channel submenu)
- p = Probe Current Settings (displays status of selected registers in general space)
- ? = Display current menu

```

-----
-- VoIP RX Main Menu --
-----

Select option
1 = Reset Core
2 = Initialize Core
3 = Secondary On/Off
s = Configure Channel
p = Probe Current Settings
? = help
-----

```

Figure 14: VOIP\_RX Main Menu Hyperterminal Output

Selecting option **s** produces the Select Channel menu as shown in Figure 15:

```

-----
Select Channel
Primary Channels
1 = Channel 1
2 = Channel 2
3 = Channel 3
4 = Channel 4

Secondary Channels
5 = Channel 1
6 = Channel 2
7 = Channel 3
8 = Channel 4

m = Main Menu
-----

```

Figure 15: VOIP\_RX Select Channel Menu Hyperterminal Output

Options allow the choice of one of the 4 channels (either Primary or Secondary link) or to return to the main menu:

Primary Channel:

- 1 = Channel 1
- 2 = Channel 2
- 3 = Channel 3
- 4 = Channel 4

Secondary Channel:

- 5 = Channel 1
- 6 = Channel 2
- 7 = Channel 3
- 8 = Channel 4

m = Main menu

After selecting any of the channels, the Select Option submenu is displayed as shown in Figure 16.

```

-----
Select Option
1 = Channel Init
2 = Channel Enable/Disable
p = Probe Status
m = Main Menu
s = Channel Select
-----

```

Figure 16: VOIP\_RX Select Option Submenu Hyperterminal Output

One of five options in the menu list can be chosen:

- 1 = Channel Init (configure target channel registers)
- 2 = Channel Enable/Disable
- p = Probe Status
- m = Main menu
- s = Channel Select

## Rebuilding and Compiling the Reference Design

This section covers rebuilding the hardware design. Before rebuilding the project, ensure that the licenses for the SMPTE 2022-1/2 Video Over IP Transmitter and Receiver cores and the Tri-Mode Ethernet MAC are installed.

**Note:** To ensure that no compilation errors occur due to long file paths, unzip the project files as close as possible to the root directory. For example, with a typical Windows installation, unzip the files at C:\.

### Generating the Programming File with Vivado Design Suite 2013.4

- At the Tcl Console, change to the workspace directory by typing:  
 VoIP\_TX:  

```
>cd <unzip_dir>/KC705_SMPTE2022_12_4Ch/kc705_smpte2022_12_4ch_tx
```

 VoIP\_RX:  

```
>cd <unzip_dir>/KC705_SMPTE2022_12_4Ch/kc705_smpte2022_12_4ch_rx
```
- To create, compile and generate the project bitstream, run the `all.tcl` script by typing at the Tcl Console:  

```
>source all.tcl
```

### Compiling the Software with SDK

- After the bitstream generation (`all.tcl` script) is complete, open the implemented design by clicking **Open Implemented Design** under the Implementation tab on the right.
- Click **Open Block Design** under the IP integrator tab on the right, then click `system_basic.bd`.
- At the Sources tab, expand the hierarchy of the project, right-click `i_system_basic` and select **Export Hardware for SDK**.
- A window appears. Set the workspace and export path to:  
 VoIP\_TX:  

```
<unzip_dir>\KC705_SMPTE2022_12_4Ch\kc705_smpte2022_12_4ch_tx\SW\SDK_workspace
```

 VoIP\_RX:  

```
<unzip_dir>\KC705_SMPTE2022_12_4Ch\kc705_smpte2022_12_4ch_rx\SW\SDK_workspace
```
- Ensure that all check boxes are selected and Click **OK**.
- Import the board support package (BSP) and software applications into the workspace by selecting **File > Import > General > Existing Projects**.
- Click **Next**, then browse to:  
 VoIP\_TX:  

```
<unzip_dir>\KC705_SMPTE2022_12_4Ch\kc705_smpte2022_12_4ch_tx\SW\SDK_workspace
```

 VoIP\_RX:  

```
<unzip_dir>\KC705_SMPTE2022_12_4Ch\kc705_smpte2022_12_4ch_tx\SW\SDK_workspace
```

8. Click **OK**.
9. Ensure that all check boxes are selected.
10. Click **Finish**.

The BSP and software applications compile at this step. The process takes 2 to 5 minutes. The existing software applications can now be modified and new software applications can be created in the SDK.

## Running the Hardware and Software through the SDK

1. Open the JTAG configuration by selecting **Xilinx Tools > Configure JTAG Settings** (Figure 17).

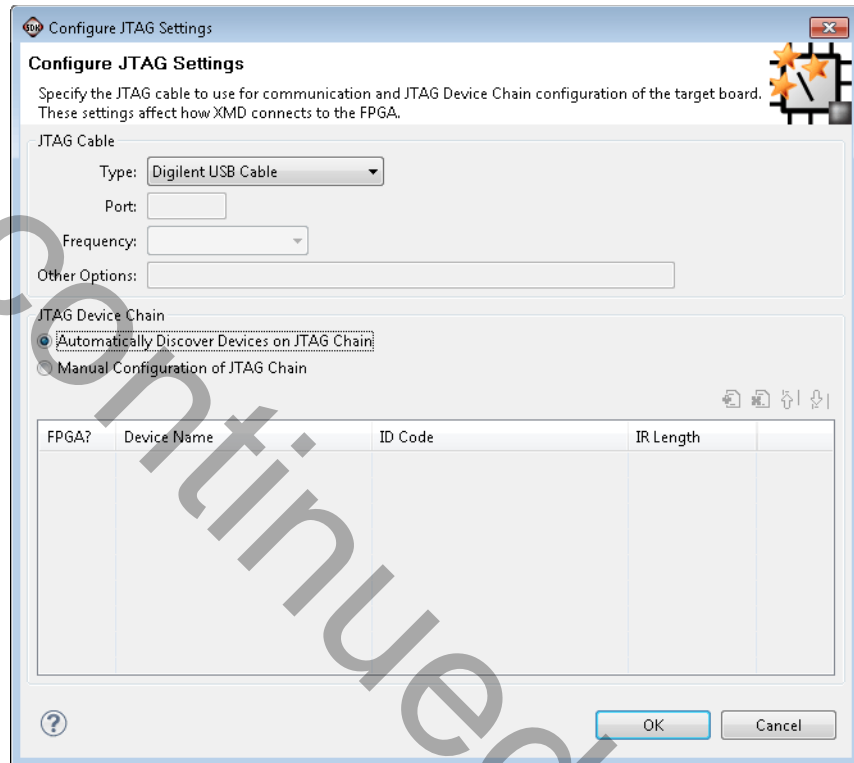


Figure 17: JTAG Configuration Settings

2. Select the **Digilent USB Cable** in Type field
3. Click **Automatically Discover Devices on JTAG Chain**.

**Note:** Two workstations are needed when running from the SDK, one for the transmitter and another for the receiver, because the debugger can only connect to one Digilent USB Cable at a time.

4. Click **OK**.
5. Select **Xilinx Tools > Program FPGA**.
6. Click **Program**.
7. In the Project Explorer window, right-click and select:

VoIP\_TX:

**voip\_rx\_main > Run As > Launch on Hardware**

VoIP\_RX:

**voip\_tx\_main > Run As > Launch on Hardware**

**Note:** The choice is provided whether to run the software application either from MIG or block RAM by editing the linker script. The default setting in the linker script is to execute the software application from block RAM.

## Debug

Upon completion of the reference design setup, check these items to ensure proper operation:

### Transmitter

- Ensure that the two LEDs on the two RJ45 ports of the Inrevium TB-FMCL-GLAN-B board are ON indicating transmission from the board for two links (primary and secondary):
  - **LED Right:** 1GBASE-TX link/speed
  - **LED Left:** Transmit activity
- Ensure that the LEDs (D2, D4, D8 and D9) on the Inrevium TB-FMCH-3GSDI2A board are OFF indicating there are streams present at the board.
- Ensure that the user-defined LEDs (GPIO LEDs, item 14, [Figure 8, page 14](#)) for port 0, 6 and 7 of the KC705 evaluation kit board are ON:
  - **GPIO LED 0:** DDR initialization complete
  - **GPIO LED 6:** 100 MHz Locked
  - **GPIO LED 7:** 200 MHz Locked

### Receiver

- Ensure that the LED (right) on the two RJ45 ports of the Inrevium TB-FMCL-GLAN-B board are ON indicating 1GBASE-TX link/speed for the two links (primary and secondary).
- Ensure that the RX and Duplex LEDs on the TB-FMCL-GLAN-B board are ON indicating packets are present. See the *TB-FMCL-GLAN-B Hardware User Manual* [\[Ref 7\]](#).
- Ensure that the user-defined LEDs (GPIO LEDs, item 14, [Figure 8, page 14](#)) for port 0, 6 and 7 of the KC705 evaluation kit board are ON:
  - **GPIO LED 0:** DDR initialization complete
  - **GPIO LED 6:** 100 MHz Locked
  - **GPIO LED 7:** 200 MHz Locked

## Reference Design

The reference design files for this application note can be downloaded from:

<https://secure.xilinx.com/webreg/clickthrough.do?cid=352502>, registration required.

[Table 8](#) shows the reference design checklist.

**Table 8: Reference Design Checklist**

Parameter	Description
<b>General</b>	
Developer name	Muhammad Ilias, Gilbert Magnaye, Myo Tun Aung, Josh Poh, Tom Sun
Target devices (stepping level, ES, production, speed grades)	Kintex-7 XC7K325T-2FFG900
Source code provided	Yes
Source code format	VHDL (some sources are encrypted)
Design uses code/IP from existing Xilinx application note/reference designs, CORE Generator™ software, or third party	Yes, core generated from Vivado IP catalog

Table 8: Reference Design Checklist (Cont'd)

Parameter	Description
<b>Simulation</b>	
Functional simulation performed	N/A
Timing simulation performed	N/A
Test bench used for functional and timing simulations	N/A
Test bench format	N/A
Simulator software/version used	N/A
SPICE/IBIS simulations	N/A
<b>Implementation</b>	
Synthesis software tools/version used	Vivado 2013.4
Implementation software tools/versions used	Vivado 2013.4
Static timing analysis performed	Yes (passing the implementation stage)
Hardware Verification	
Hardware verified	Yes
Hardware platform used for verification	Kintex-7 FPGA KC705 evaluation kit Rev 1.0 and 1.1

## Notes

### Software Application

The software application can be set to run from either DDR (`mig_1`) or block RAM (`lmb_subsys_ilmb_bram_if_cntlr_lmb_subsys_dlmb_bram_if_cntlr`) by properly setting values in the linker script (`lscript.ld`).

### Video Over IP Receiver

The tready control generator module (`tready_ctrl.vhd`) is instantiated in the design to regulate the data ready signal by ensuring that the buffered packets level in the SMPTE 2022-1/2 Video Over IP receiver core is greater or equal to that set in the playout delay register.

## Conclusion

This application note describes a video over IP network system using various Xilinx IP cores. The reference design demonstrates the ability of the SMPTE 2022-1/2 Video Over IP cores to encapsulate and de-encapsulate multiple transport streams into a TS per IP configuration (user-configured values) and transport them through a 1 Gb/s Ethernet pipe. The utilization of the Ethernet bandwidth is over 90% with 125 Mb/s TS Video Streams for each of four channels, with an FEC size of 4 x 4 with TS per IP of 1 and TS size of 188 bytes. The Reference Design can perform recovery of a limited number of Ethernet packets when impairment is introduced into the network with the forward error correction engine turned on.



## References

This application note uses these references:

1. SMPTE 2022-1/2 Video Over IP Core [product page](#)
2. Tri-Mode Ethernet MAC Core [product page](#)
3. Kintex-7 FPGA KC705 Evaluation Kit [product page](#)
4. *7 Series FPGAs Configuration User Guide* ([UG470](#))
5. Inrevium TB-FMCH-3GSDI2A 3G/HD/SD 3GSDI FMC Connectivity mezzanine card [product page](#)
6. Inrevium TB-FMCL-GLAN-B 1000 Base-T Ethernet FMC Connectivity mezzanine card [product page](#)
7. TB-FMCL-GLAN-B [Hardware User Manual](#)
8. *LogiCORE IP SMPTE 2022-1/2 Video Over IP Transmitter v1.0 Product Guide* ([PG180](#))
9. *LogiCORE IP SMPTE 2022-1/2 Video Over IP Receiver v1.0 Product Guide* ([PG181](#))
10. *AXI Reference Guide* ([UG761](#))
11. *7 Series FPGAs Memory Interface Solutions v2.0 User Guide* ([UG586](#))
12. *LogiCORE IP Tri-Mode Ethernet MAC Product Guide* ([PG051](#))

## Revision History

The following table shows the revision history for this document.

Date	Version	Description of Revisions
09/30/2015	1.1	Updated for Table 4 and VOIP_TX Main Menu Hyperterminal Output option.
12/18/2013	1.0	Initial Xilinx release.

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