Accelerating Option Development With the TURBOchannel Developer's Kit

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Digital's TRI/ADD Program

Overview

- Review of the TURBOchannel
- TURBOchannel Developer's Kit
- TURBOchannel Interface ASIC (TcIA)

TURBOchannel Platforms

- **DECstation/DECsystem 5000 Family**
  - Model 200 was first TURBOchannel system, with 3 slots
  - Models 1xx (3 slots), Personal DECstation (2 slots) followed
  - Model 240 is highest performance DS5000
- **VAXstation 4000 Family**
  - Models 60 and 90 use TURBOchannel Adapter
- **DEC 3000 AXP Workstation/Server Family**
  - Models 500/500S with 6 slots
  - Models 400/400S with 3 slots
  - Model 300 with 2 slots and motherboard graphics

Digital's I/O - from Unibus to TURBOchannel

	Unibus	Q-bus	TURBOchannel
Date introduced	1970	1975	1990
Topology	Bus (symmetric)	Bus (symmetric)	Interconnect (asymmetric)
Type	Backplane/cable	Backplane	Mezzanine
Protocol	Asynchronous	Asynchronous	Synchronous, 12.5 - 25 MHz
Primary application	I/O and memory	I/O and memory	I/O (memory on an option)
Maximum peak data rate	2- Mbytes/sec	3+ Mbytes/sec	100 Mbytes/sec
Address & Data Lines	18 address and 16 data	21 address/16 data	32 address/data
Control Lines	22	22	12
Base Address	Jumpers	Jumpers	System dependent
Vector	Jumpers	Jumpers	System dependent
Firmware on board?	No	No	Yes
Mechanical size	One or more Quad	Dual/Quad	Single, Double, Triple
I/O interface logic	MSI parts	MSI; DCxxx parts	PALs/Transceivers; TcIA
Complexity of interface	Medium complexity	Simple, few parts	Simple, but fast

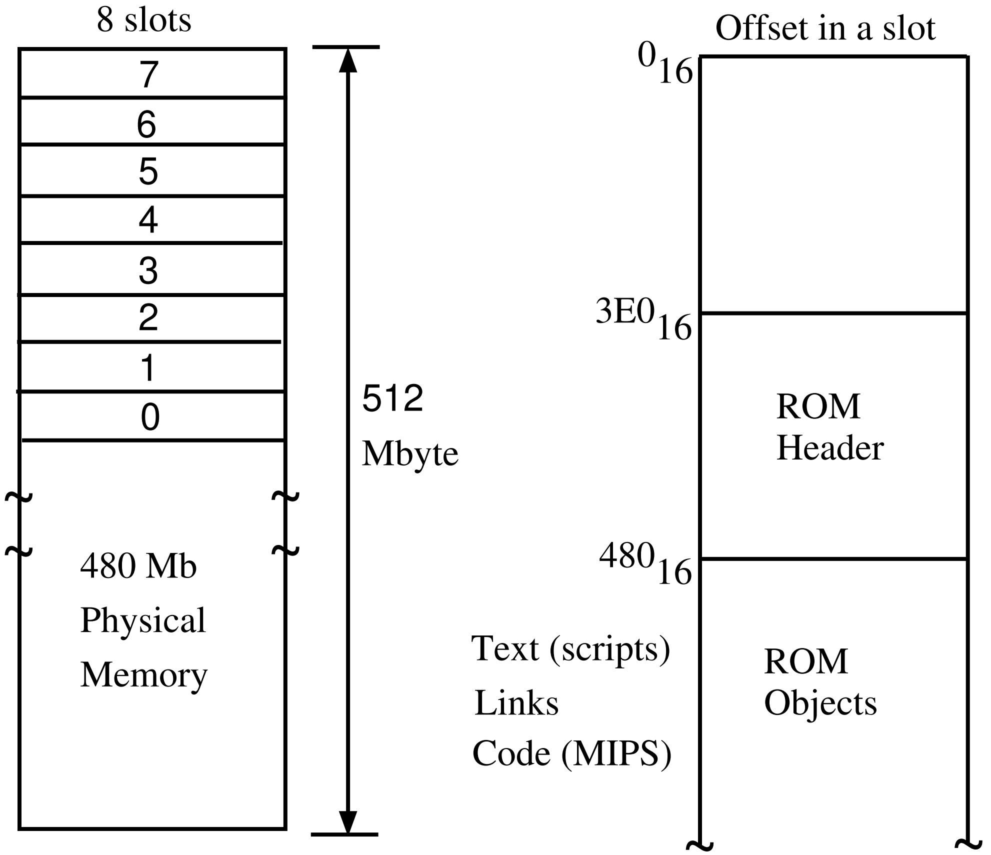
TURBOchannel Characteristics

- **Mechanical**
  - Single, Double and Triple Widths
  - Active Components on one side only
  - Can stack or edge-mount daughter boards for additional space
- **Electrical**
  - 44 Signal pins
  - Fixed frequency, 12.5 to 25 MHz clock
- **Protocol**
  - Synchronous
  - PIO and DMA transactions
- **Firmware (ROM) on board with**
  - Module ID, including manufacturer
  - Scripts (string of module test commands, ASCII)
  - Links (pointer to another object)
  - Executable MIPS code (power-on self test, bootstrap, etc)

Another View of TURBOchannel Characteristics

1. Mechanical
2. Electrical
   } Qbus, Unibus, BI
3. Software-
   a. Address space
   b. Software/firmware

Example: DECstation 5000 Model 200



TURBOchannel Specifications Status

- **Version 3 now formal specification, includes updated mechanical specification**
- **Controlled by the TURBOchannel Industry Group**
- **Printed documentation available from Integrated Test Solutions**
- **PostScript™ documentation files available via anonymous ftp from:**

gatekeeper: 16.1.0.2

See file:

gatekeeper:pub/DEC/TriAdd/README_turbo3

TURBOchannel Specifications Version 3 Changes

Proposals passed by the TURBOchannel Industry Group include:

- **Hardware**
  - Clarifications to Protocol and Timing
  - Block I/O write added
  - Revised parity
  - Byte masking for I/O reads added
  - Update to mechanical drawings
- **Firmware**
  - Extra REX memory region added
  - TCF1 (TURBOchannel Firmware version 1) defined with
    - . New Block I/O write enable/disable
    - . New Parity enable/disable/test
    - . New malloc callback
    - . Get System ID changes
- **System Parameters moved to separate document**

TURBOchannel Industry Group

- **Formal owners of the TURBOchannel specification**
- **Nine companies now own the specification:**
  - ACC Systems
  - Avnet Computers
  - Design Analysis Associates
  - Digital Equipment Corporation
  - Genroco, Inc
  - Kubota Pacific
  - MAGMA
  - Olivetti Research
  - VME Microsystems, Inc

TURBOchannel Industry Group

- **Bylaws of the TURBOchannel Industry Group Available**
- **For information on the TURBOchannel Industry Group, contact:**

Bill Fletcher, Chairman
TURBOchannel Industry Group
c/o Design Analysis Associates
75 West 100 South
Logan, UT 84321

Telephone: (801) 753-2212
FAX: (801) 753-7669

Available TURBOchannel Interfaces

- **Final edition of the TRI/ADD Program Shippable Products Catalog** (Jan 1993)
  - 9 new TURBOchannel product listings, including Real Time Clock
  - New format for both US and European paper sizes
- **PostScript™ file available via anonymous ftp from:**

gatekeeper: 16.1.0.2

File:

gatekeeper:pub/DEC/TriAdd/TAcatalog.ps

or:

gatekeeper:pub/DEC/TriAdd/TAcatalog.ps.Z (compressed file)

Goal of the Kit

To give hardware and software engineers a jump-start in the development of new TURBOchannel options.

Strategy

- Well-documented, fully-functional TURBOchannel sample board - performs all TURBOchannel functions, including interrupt and conflict
- Hardware documentation to understand how the board was built
- All firmware for the on-board ROM
- Software tools used in ROM image generation (assumes a RISC ULTRIX environment)
- Drivers and test programs for all TURBOchannel system environments

What's new in the Kit?

- **Documentation updates**
- **New documentation files**
  - Version 3 TURBOchannel Specifications
  - DEC 3000 AXP Service Guides and Macrocoder's Manual
  - TURBOchannel firmware Questions and Answers
- **Firmware updates**
- **Software tools updates**
- **New Drivers and test programs for**
  - MIPS and Alpha OSF/1
  - VAX and Alpha OpenVMS

Kit Contents

1. **TURBOchannel sample board (CB)**
2. **Hard copy documentation**
3. **One TK50**

Kit Contents

1. TURBOchannel sample board (CB)

- Single-width TURBOchannel option module
- LEDs on bulkhead end
- Single socketed part, the ROM

  Allows different firmware to be developed and loaded for testing.

  Firmware can also be loaded from local disk or over Ethernet from another system during development.

Anti-static strap and screwdriver included for installation.

TURBOchannel Sample Board (CB) functions

- **4 basic TURBOchannel transactions**
  - I/O read
  - I/O write
  - DMA read (one word only)
  - DMA write (one word only)
- **2 additional functions**
  - Interrupt request
  - Force "conflict" on next PIO
- **4 registers**
  - 32-bit data and address registers
  - 16-bit LED/CSR register: 4 LEDs go to control bits, 4 LEDS available
  - 1-bit test register (write to set, read to clear)
- **32 Kbyte ROM**
  - Board ID
  - Init, cnfg and test code
  - Scripts and links

Kit Contents

2. Hard copy documentation

- Developer's Tools Overview
- Module Installation Guide
- Channel Board (CB) Functional specification
  - Functional Description
  - Programming the CB
  - Assembly drawing
  - Schematic
  - PAL equations
  - External bill of materials
- ROM Developer's Guide
- Channel Board (CB) Software

Kit Contents

3. TK50 contents

- CB module directory tree
- ROM development directory tree
- Documentation directory
- Version 3 TURBOchannel Specifications directory

TK50 Contents

CB module directory tree

- ULTRIX and OSF/1 directory trees
  - Alpha OSF/1 cb driver
  - MIPS OSF/1 cb driver
  - MIPS ULTRIX cb driver
  - Common test programs
- VMS directory tree
  - Alpha OpenVMS CB driver
  - VAX OpenVMS CB driver
  - Common test programs
- Firmware directory tree
  - cnfg, init, t and scripts/links directories
  - All executable code goes into a single object

TK50 Contents

ROM development directory tree

- "dummy" (generic) option directory tree
  - cnfg, t and scripts/links directories like CB
  - boot and crt directories with example code
  - Code goes into multiple objects
- Firmware tools directory tree
  - Convert scripts and links into "object code"
  - Convert object code into ROM objects
  - Create files for loading ROMs from ROM images

TK50 Contents

Documentation directory (19 Mb!)

- CB Board Functional Specification (PostScript™)
- CB Board Installation Procedure (PostScript™)
- DEC 3000 AXP Service Guides for Models 500/500S, 400/400S, 300 (PostScript™)
- DEC 3000 AXP Macrocoder's Manual (PostScript™)
- DECstation/DECsystem 5000 ROM Appendix (PostScript™)
- TURBOchannel firmware Questions and Answers (text)

TK50 Contents

Version 3 TURBOchannel Specifications directory

- README file describing the rest of the files (text)
- All sections of the Specifications (PostScript™)
- System Parameters document (PostScript™)

So What?

How does this "stuff" help a TURBOchannel module developer?

It helps you with

- Hardware Development
- Firmware Development
- Software Development

Hardware Development Help

- **The CB board itself**
- **TURBOchannel Specifications**
  - Describes hardware environment
  - Documents all transactions
- **Kit Documentation**
  - IOPAL & DMAPAL (22V10s)
    - . State diagrams
    - . PAL equations
  - Board layout*
  - Schematic
  - Bill of materials

*Note comment on DC loading. Use care in layout for critical signals.

Firmware Development Help

- **TURBOchannel Specifications**
  - Describes firmware environment
  - Documents firmware call interface
  - Lists all callbacks available to firmware

- **Kit Documentation**
  - eoc: executable object compiler
  - sc: scripts compiler
  - convert: executable image to ROM files

Firmware Development Help

- **Firmware examples (assumes MIPS ULTRIX)**
  - **Sample board firmware**
    - . Makefiles
    - . Header files
    - . ROM header & trailer
    - . Scripts and links
    - . Code for: init, cnfg, t (no boot)

    Use as-is or modify for experimentation
  - **"dummy option" firmware**
    - . Makefiles
    - . More header files
    - . Generic ROM header and trailer
    - . Example scripts and links
    - . Additional code files

  Useful starting point for firmware for a new TURBOchannel option

Firmware Development Help

- **Tools (assumes MIPS ULTRIX)**
  - eoc: executable object compiler
  - sc: scripts compiler
  - convert: executable image to ROM files

Software Development Help

- **Documentation directory tree**
  - System hardware documentation
  - Operating System driver documentation
- **Device drivers and test programs**
  - For all Operating Systems supporting TURBOchannel
    - . ULTRIX and OSF/1 versions for MIPS and Alpha AXP architectures
    - . OpenVMS versions for VAX and Alpha AXP architectures

      (Details on following slides)
  - Exercise all functions of the sample board
  - A starting point for experimenting with the sample board
  - A starting point for new drivers

Software Development Help

ULTRIX and OSF/1 drivers

- Available for MIPS ULTRIX, MIPS OSF/1, Alpha AXP OSF/1
- Well documented
- Source code very similar so differences may be easily identified
- Exercise all board functions
  - Read and write using either DMA or PIO
  - Shows virtual to physical to TURBOchannel address translation for DMA
  - Uses timer to increment LEDS (start/stop via ioctls)
  - Can read registers and ROM through ioctls
  - Test interrupt with an ioctl
  - Map to sample board address space using mmap code
- MIPS OSF/1 version is a loadable driver; future Alpha AXP OSF/1 loadable driver support should be similar
- Text and PostScript™ installation instruction files included

Software Development Help

ULTRIX and OSF/1 test programs

- Common for all 3 Operating Systems
- Makefile will compile on all 3 Operating Systems
- Exercise all functions of the drivers
- Programs for:
  - Read, write and interrupt tests (PIO & DMA)
  - Register display using ioctls
  - Register display using mmap call
  - ROM read, decode and display
  - Start LED increment
  - Stop LED increment

Software Development Help

OpenVMS device drivers

- Available for VAX and Alpha AXP OpenVMS
- Well documented
- Exercise all board functions
  - Read and write using either DMA or PIO
  - Shows virtual to physical to TURBOchannel address translation for DMA
  - Test interrupt with READPBLK

Software Development Help

OpenVMS test programs

- DMA read and write test
- PIO read and write test
- Interrupt test

Availability

The TURBOchannel Specifications and the TURBOchannel Developer's Kit are available from:

Integrated Test Solutions
2352 Main Street, Suite 201
Concord Office Park
Concord, MA 01742

Telephone: (508) 897-0028
FAX: (508) 897-0171

Why a TURBOchannel Interface ASIC (TcIA)?

To give hardware designers a "known-good", low-cost, small real-estate, high performance interface to the TURBOchannel to help in the development of new options.

TcIA Characteristics

- **Physical**
  - Plastic Quad Flat Pack
  - 160 pins
  - 0.65 mm pin pitch
  - 28 mm x 28 mm
  - Under 3 Watts at full TURBOchannel speed (25Mhz)
- **Logical**
  - Separate "transmit" and "receive" engines
  - TURBOchannel and option sides may run in separate time domains
  - Support for PIO, Simple DMA and Intelligent DMA

TcIA Functions

- **Support for Programmed I/O Devices**
  - Synchronous or asynchronous with respect to TURBOchannel clock
  - Provides 8 read/write general-purpose outputs
  - Provides 4 readable inputs that can be used to generate a TURBOchannel interrupt
  - Optional TURBOchannel parity generation and checking
  - I/O address latching

TcIA Functions

- **Support for Simple DMA Devices**
  - Word-addressable transmit and receive pointers
  - 15-word transmit and receive FIFOs
  - Transmit and receive scatter/gather tables
  - Byte and half-word data with unpacking and packing of data

TcIA Functions

- **Support for Intelligent Controllers**
  - External addresses are supplied by the option for DMA reads and writes
  - Supports option addresses of up to 32 bits
  - Word count and burst size supplied by the option
  - Byte and half-word data with unpacking and packing of data

Availability

Information on the TURBOchannel Interface ASIC is available from:

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