מנהל התקנים

DMA

גישה ישירה לזיכרון

Device Manager

פסיקות

INTERRUPTS

ניהול ציוד היקפי

שאול קובל מערכות מחשבים

Introduction to Systems Programming

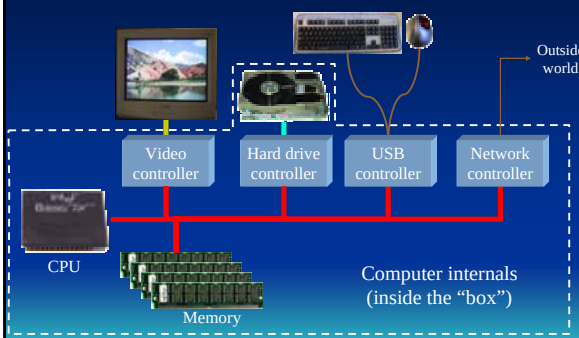
מבוא לתכנות מערכות

Input-Output קלט פלט

Devices, Controllers, and I/O Architectures

ארכיטקטורה של קלט/פלט ,
מערכות ובקרים

Components of a simple PC



מבנה מחשב PC בסיסי

I/O Device Types

- Block Devices
  - block size of 512-32768 bytes
  - block can be read/written individually
  - typical: disks / floppy / CD
- Character Devices
  - delivers / accepts a sequential stream of characters
  - non-addressable
  - typical: keyboard, mouse, printer, network
- Other: Monitor, Clock

Interrupt Controllers

- Device interrupts are fed to the processor using a special piece of hardware
- standard for this device is the Intel 8259 interrupt controller, and has been since early PCs

IRQ

- The IRQ is a number set in the computer for the interrupt request.
- assigned to devices to allow it to "interrupt", or send a signal, to the computer when it is finished processing.
- In older computers, you had to manually set the IRQ values for devices.
- Newer computers and operating systems use plug'n'play, which allows you to not need to set IRQ values.

Device	Data rate
Keyboard	10 bytes/sec
Mouse	100 bytes/sec
56K modem	7 KB/sec
Telephone channel	8 KB/sec
Dual ISDN lines	16 KB/sec
Laser printer	100 KB/sec
Scanner	400 KB/sec
Classic Ethernet	1.25 MB/sec
USB (Universal Serial Bus)	1.5 MB/sec
Digital camcorder	4 MB/sec
IDE disk	5 MB/sec
40x CD-ROM	6 MB/sec
Fast Ethernet	12.5 MB/sec
ISA bus	16.7 MB/sec
EIDE (ATA-2) disk	16.7 MB/sec
FireWire (IEEE 1394)	50 MB/sec
XGA Monitor	60 MB/sec
SONET OC-12 network	78 MB/sec
SCSI Ultra 2 disk	80 MB/sec
Gigabit Ethernet	125 MB/sec
Ultrium tape	320 MB/sec
PCI bus	528 MB/sec
Sun Gigaplane XB backplane	20 GB/sec

Typical Data Rates

מהירות טיפוסית של מעבר נתונים

Why Interrupts Are Used to Process Information

- one thing at a time
- *appear* to do many things at once
- multitasking operating system like Windows
- the processor
- two basic ways that the processor could do this:
  - Polling: turns going to each device and asking if they have anything they need it to do.
  - Interrupting: let the devices request them when they need its attention
- software interrupts. used by various software programs in response to different events that occur as the operating system and applications run

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Polling & Interrupts

- how does the CPU know that a particular device is ready or requires attention?
- these requests are, generally, asynchronous
- software program must include routines to handle these requests
- 2 techniques are available to service external devices:
  - Polling
  - Interrupts

לכידות ופסיקות

- איך המעבד יודע שרכיב או ציוד היקפי מוכן (סיים את עבודתו) או דורש שרות של המעבד ?
- הבקשות הם בדרך כלל אסינכרונית (אין התאמת שעונים).
- התוכנה חייבת לכלול פרוצדורות לטיפול באותם בקשות.
- ישנם 2 טכניקות למתן שרות לאותם רכיבים או ציוד:
  - סריקה לצורך לכידה
  - פסיקות

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Polling & Interrupts

- **Polling**:
  - **CPU periodically polls** ALL external devices & takes action if required
- **Interrupts:**
  - **external device** indicates request for attention by **sending a signal** via a control line
  - it stops the current CPU activity and responds to the device that requested attention

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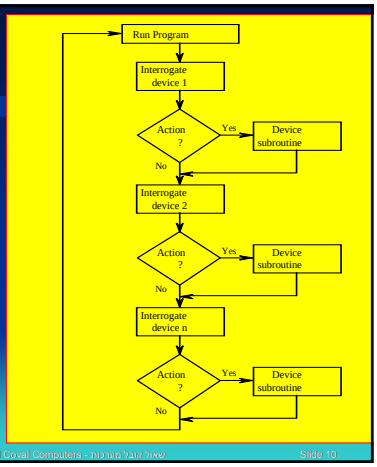
Polling

- must be written in the main program (by a programmer, in advance)
- high level language used



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Polling

- If, after interrogating, attention is required from a particular device – an appropriate subroutine is called & executed (it does not take long)
- when finished – the CPU returns to the main program
- if the frequency of polling is high – a significant overhead is incurred on a CPU
- If, however, the frequency of polling is low - events may be undetected - data lost due to latency etc.

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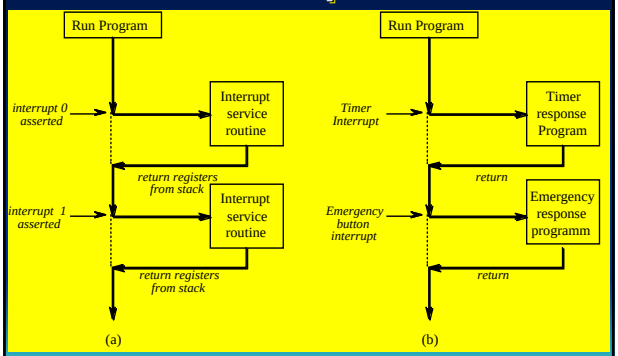
Interrupts



- a) generic b) specific

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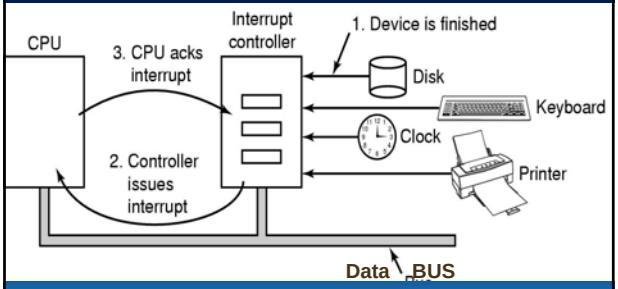
- special circuitry within a mP carries interrupt signals: **Interrupt Request Line (IRL)**
- The external device sends a logic signal to the CPU when it requires attention
- The CPU completes current instruction first, before transferring control to - the **Interrupt Service Routine (ISR)**
- **ISR** – is a software routine but it is called by hardware
- **ISR** can occur anywhere in the main program

Interrupts



How interrupts happen. Connections between devices and interrupt controller actually use interrupt lines on the bus rather than dedicated wires

IRQ Lines and the System Bus

- The devices that use interrupts trigger them by signaling over lines provided on the ISA system bus.
- some of them are only used internally by the system, and therefore they are not given wires on the system bus. These are interrupts 0, 1, 2, 8 and 13, and are never available to expansion cards (remember, IRQ2 is now wired to IRQ9 on the motherboard).

Priority Interrupt

- priority level
- an old PC/XT, the priority of the interrupts is 0, 1, 2, 3, 4, 5, 6, 7.
- On a modern machine
- second set of eight interrupts is piped through the IRQ2 channel
- priorities become 0, 1, (8, 9, 10, 11, 12, 13, 14, 15), 3, 4, 5, 6, 7.

IRQs 8 to 15 take the place of IRQ2.

Non-Maskable Interrupts (NMI)

- can be used for serious conditions that demand the processor's immediate attention.

Interrupts, Multiple Devices and Conflicts

- is not feasible for more than one device to use an interrupt at one time,

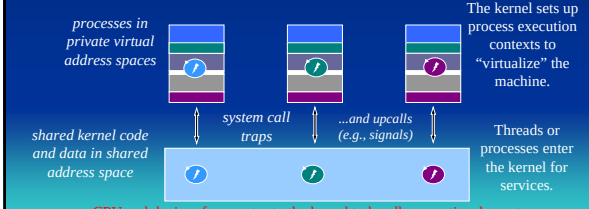
The Nature of Resource Conflicts

some of the ways that resource conflicts manifest themselves.

- System hangs or lockups, particularly while using a peripheral device.
- (Memory) parity errors on parity-enabled systems.
- Noise or other problems from sound cards.
- Junk being printed on your printer.
- The mouse pointer hanging and refusing to move, or moving in a stuttering fashion.
- Error messages from Windows 95, messages about the PC not operating at maximum performance, or the system dropping to "Safe Mode" or "MS-DOS Compatibility Mode".
- Errors and crashes of applications for no apparent reason.

Resource Conflict Resolution

- general steps that can be followed to fix this sort of problem
  - Determine what all the devices in the system are using for resources.
  - Identify the conflicting devices.
  - Change the resource settings on one or more of the devices so they are no longer conflicting



CPU and devices force entry to the kernel to handle exceptional events.

Summary of IRQs and Their Typical Uses

IRQ	Bus Line?	Priority	Typical Default Use	Other Common Uses
0	no	1	System timer	None
1	no	2	Keyboard controller	None
2	no (rerouted)	n/a	None; cascade for IRQs 8-15. Replaced by IRQ 9	Modems, very old (EGA) video cards, COM3 (third serial port), COM4 (fourth serial port)
3	8/16-bit	11	COM2 (second serial port)	COM4 (fourth serial port), modems, sound cards, network cards, tape accelerator cards
4	8/16-bit	12	COM1 (first serial port)	COM3 (third serial port), modems, sound cards, network cards, tape accelerator cards

IRQ	Bus Line?	Priority	Typical Default Use	Other Common Uses
5	8/16-bit	13	Sound card	LPT2 (second parallel port), LPT3 (third parallel port), COM3 (third serial port), COM4 (fourth serial port), modems, network cards, tape accelerator cards, hard disk controller on old PC/XT
6	8/16-bit	14	Floppy disk controller	Tape accelerator cards
7	8/16-bit	15	LPT1 (first parallel port)	LPT2 (second parallel port), COM3 (third serial port), COM4 (fourth serial port), modems, sound cards, network cards, tape accelerator cards
8	no	3	Real-time clock	None
9	16-bit only	4		Network cards, sound cards, SCSI host adapters, PCI devices, rerouted IRQ2 devices

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IRQ	Bus Line?	Priority	Typical Default Use	Other Common Uses
10	16-bit only	5		Network cards, sound cards, SCSI host adapters, secondary IDE channel, quaternary IDE channel, PCI devices
11	16-bit only	6		Network cards, sound cards, SCSI host adapters, VGA video cards, tertiary IDE channel, quaternary IDE channel, PCI devices
12	16-bit only	7	PS/2 mouse	Network cards, sound cards, SCSI host adapters, VGA video cards, tertiary IDE channel, PCI devices
13	no	8	Floating Point Unit (FPU / NPU / Math Coprocessor)	None
14	16-bit only	9	Primary IDE channel	SCSI host adapters
15	16-bit only	10	Secondary IDE channel	Network cards, SCS

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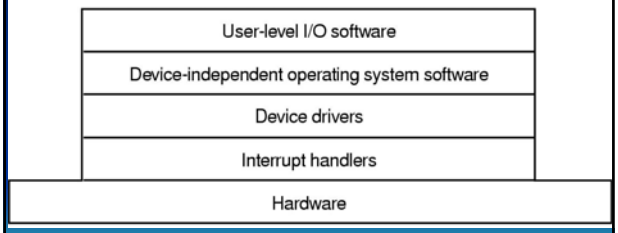
I/O Software Layers



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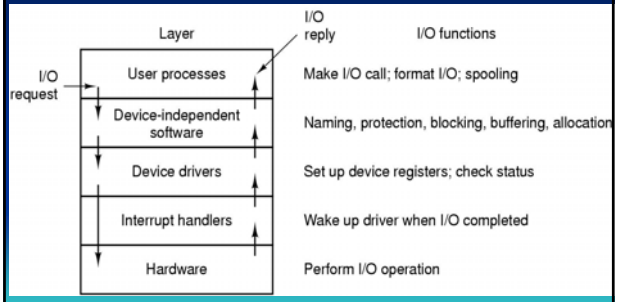
Layers of the I/O system



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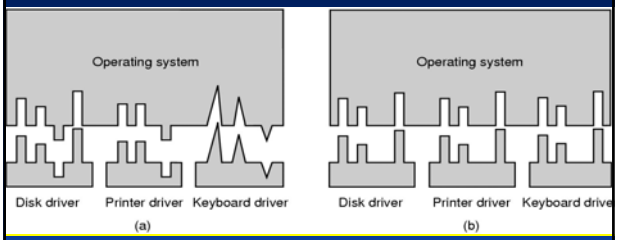
Device-Independent Interface



(a) Without a standard driver interface
(b) With a standard driver interface

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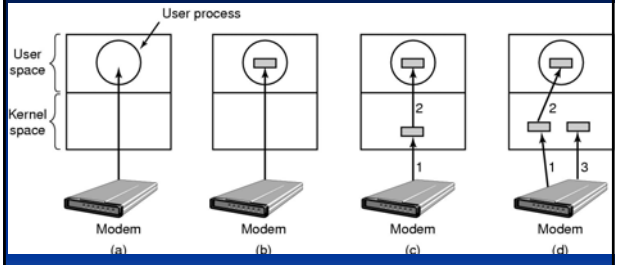
Buffering



(a) Unbuffered input
(b) Buffering in user space
(c) Buffering in the kernel followed by copying to user space
(d) Double buffering in the kernel

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Buffering Options

- No buffering: lots of context switching.
- User space buffering (**read** syscall for **n** bytes):
  - buffer needs to be pinned in memory
- Kernel buffer with copy: only kernel page needs to be pinned.
  - What happens with characters received during copy?
- Best: double buffering in kernel: while kernel buffer 0 is being copied, buffer 1 accepts new characters. Then they switch roles.

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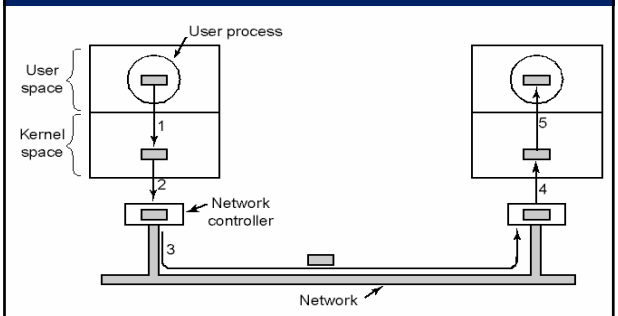
Networking may involve many copies



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Interrupt procedure

- The main program continues to run until the first interrupt is asserted in the interrupt request line (IRL)
- The interrupt hardware latches the signal and interrupts the CPU activity
- The execution starts when the CPU finishes its current job
- when the interrupt service routine (ISR) has finished – the CPU returns to the main program (status - when left - preserved in the registers)

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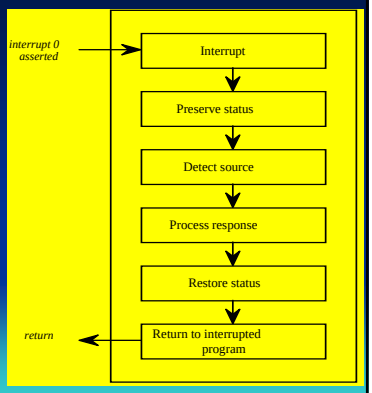
Interrupt Service Routine

- The interrupt must not lead to loss of data
- The content of certain registers is saved to memory. These are:
  - program counter
  - process status
  - accumulator



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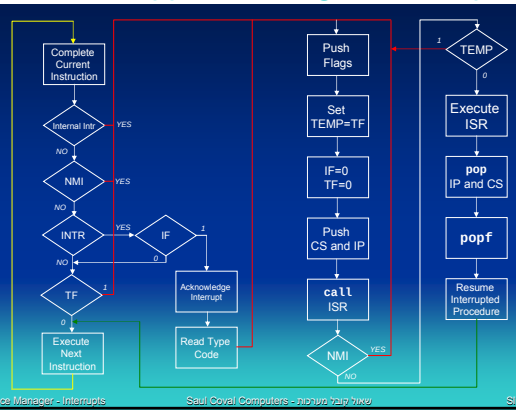
What Happens During an Interrupt ?



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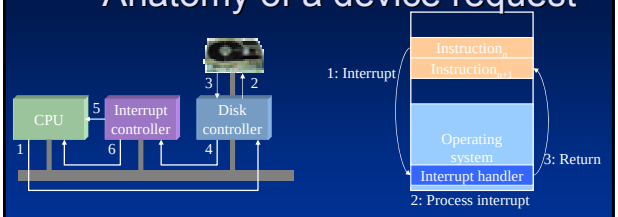
Anatomy of a device request



- Left: sequence as seen by hardware
  - Request sent to controller, then to disk
  - Disk responds, signals disk controller which tells interrupt controller
  - Interrupt controller notifies CPU
- Right: interrupt handling (software point of view)

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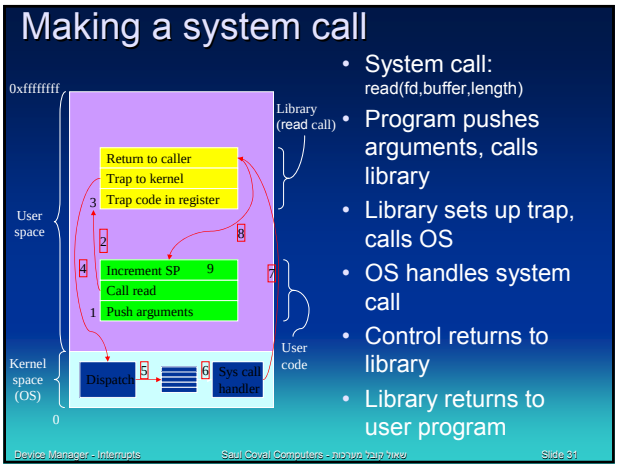
Making a system call
0xffffffff
User space
Kernel space (OS)
0
Library (read call)
User code
Return to caller
Trap to kernel
Trap code in register
Increment SP
Call read
Push arguments
Dispatch
Sys call handler
1
2
3
4
5
6
7
8
9
• System call: read(fd,buffer,length)
• Program pushes arguments, calls library
• Library sets up trap, calls OS
• OS handles system call
• Control returns to library
• Library returns to user program
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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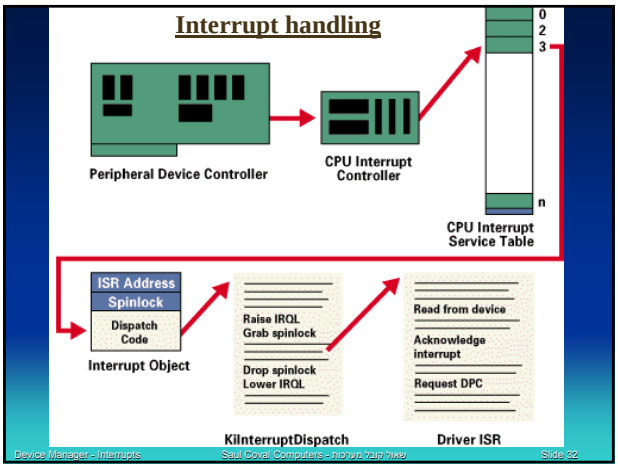
Interrupt handling
Peripheral Device Controller
CPU Interrupt Controller
CPU Interrupt Service Table
0
2
3
n
ISR Address
Spinlock
Dispatch Code
Interrupt Object
Raise IRQL
Grab spinlock
Drop spinlock
Lower IRQL
KiInterruptDispatch
Read from device
Acknowledge interrupt
Request DPC
Driver ISR
Device Manager - Interrupts
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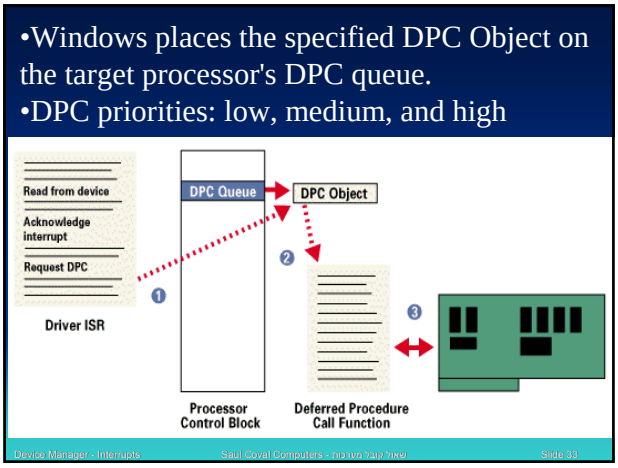
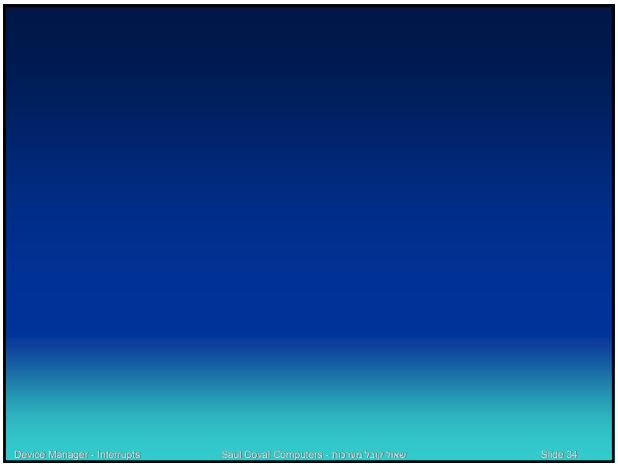
Slide 32


•Windows places the specified DPC Object on the target processor's DPC queue.
•DPC priorities: low, medium, and high
Read from device
Acknowledge interrupt
Request DPC
Driver ISR
DPC Queue
DPC Object
Processor Control Block
Deferred Procedure Call Function
1
2
3
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 33


Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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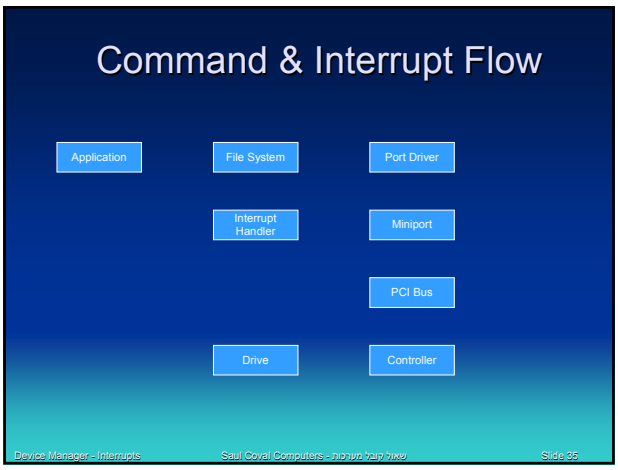
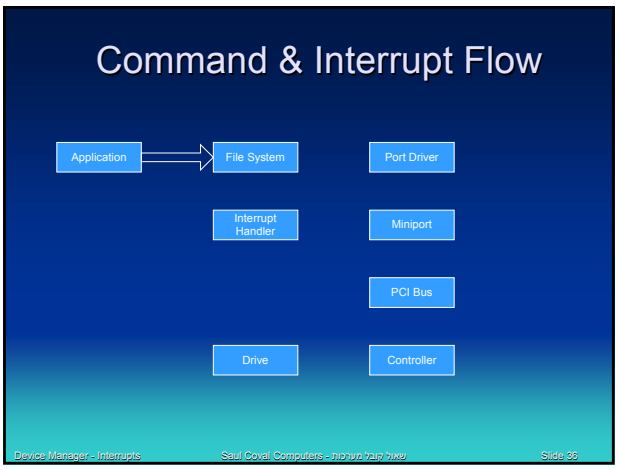

Command & Interrupt Flow
Application
File System
Port Driver
Interrupt Handler
Miniport
PCI Bus
Drive
Controller
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 35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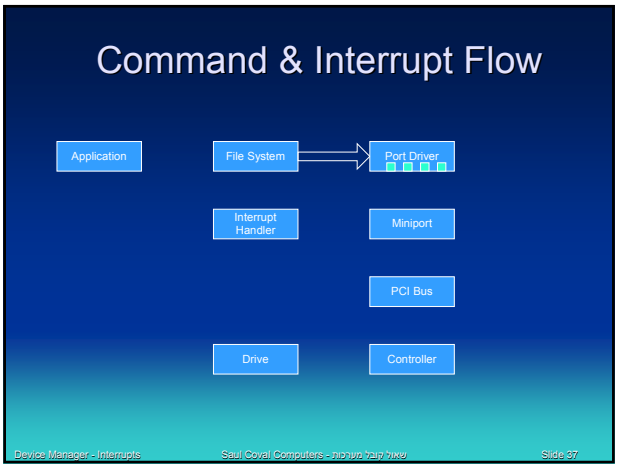
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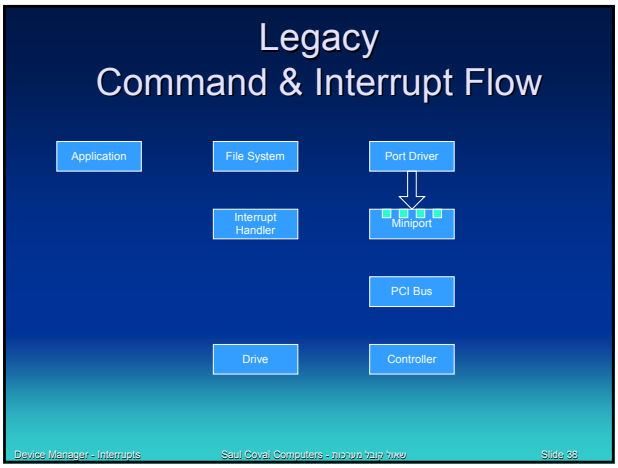
Legacy
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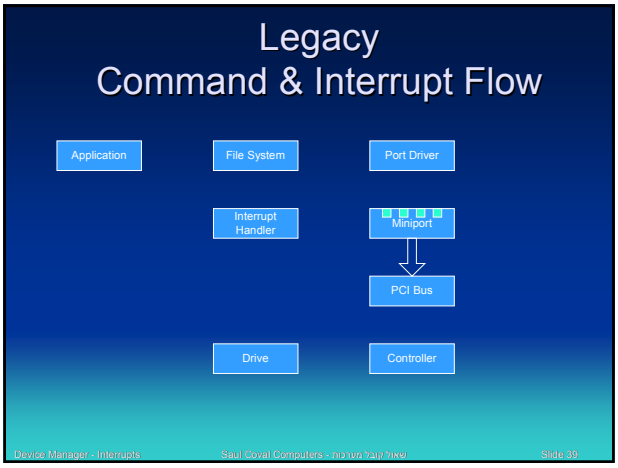
Slide 38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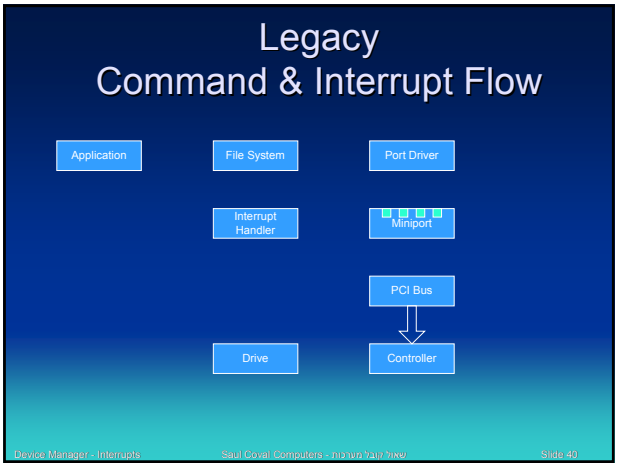
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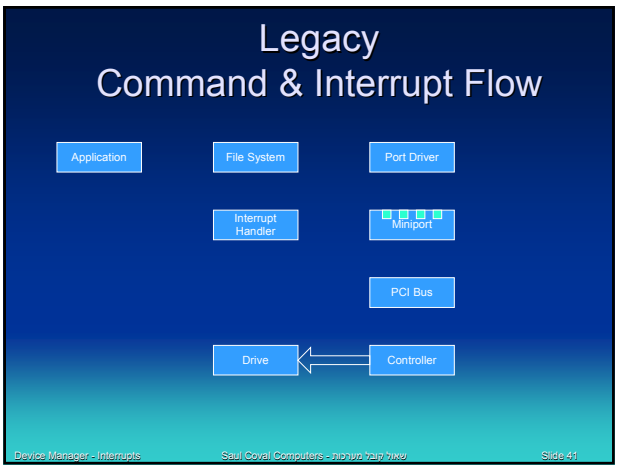
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Saul Coval Computers - שאול קובל מערכות
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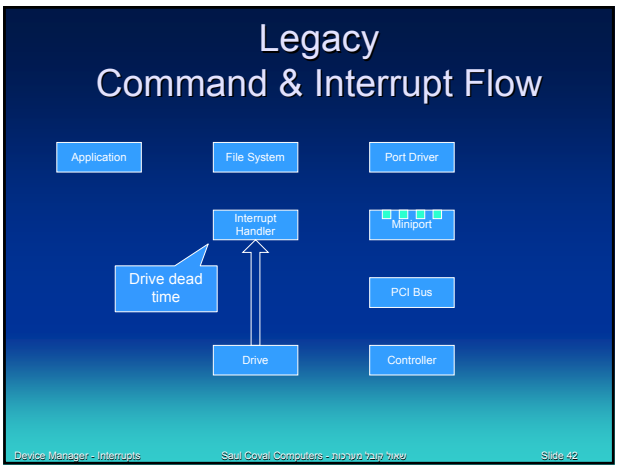
Legacy
Command & Interrupt Flow
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Port Driver
Interrupt Handler
Miniport
Drive dead time
PCI Bus
Drive
Controller
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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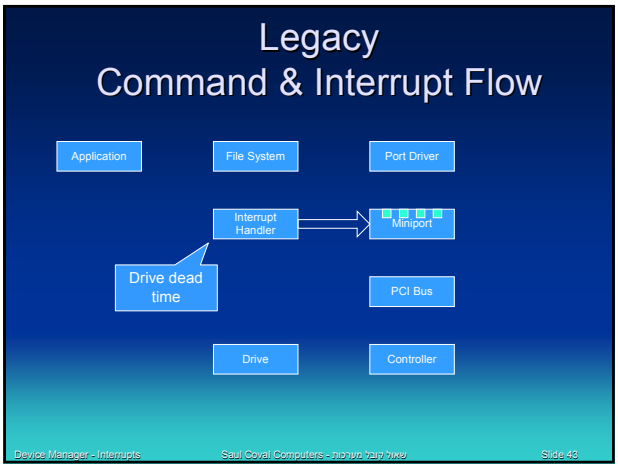
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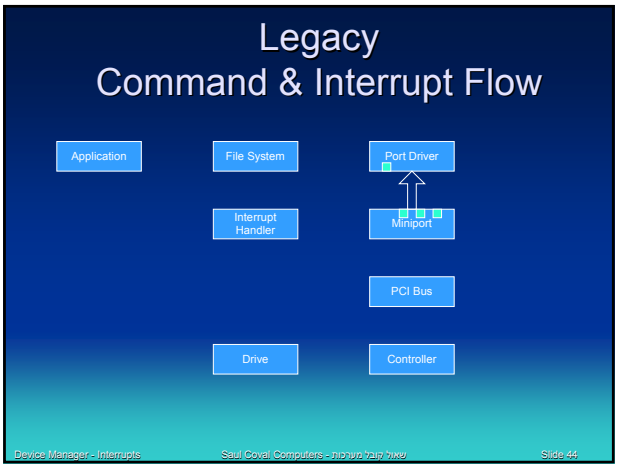
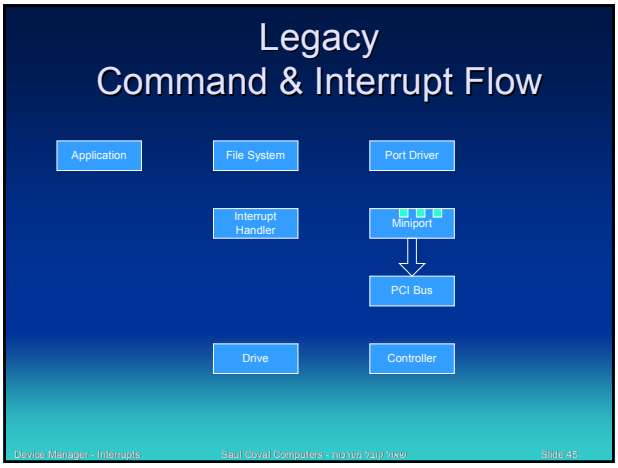
Saul Coval Computers - שאול קובל מערכות
Slide 43


Legacy
Command & Interrupt Flow
Application
File System
Port Driver
Interrupt Handler
Miniport
PCI Bus
Drive
Controller
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 44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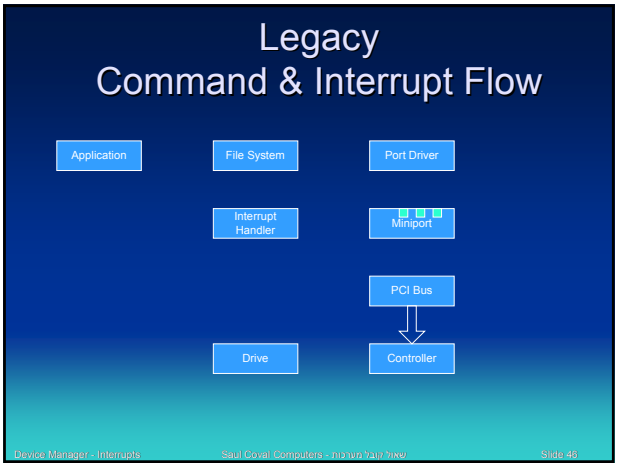
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 45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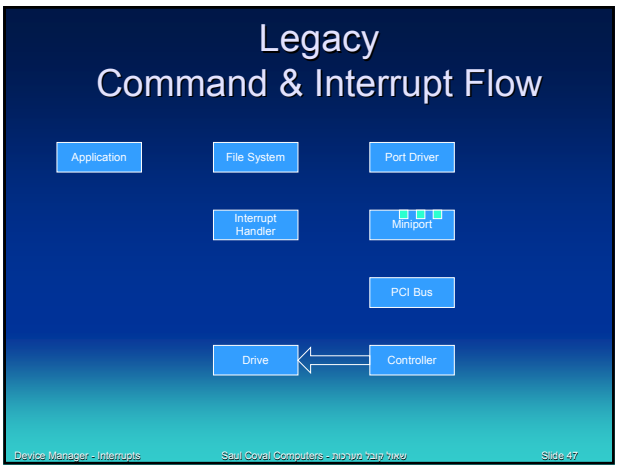
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 46


Legacy
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Application
File System
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Interrupt Handler
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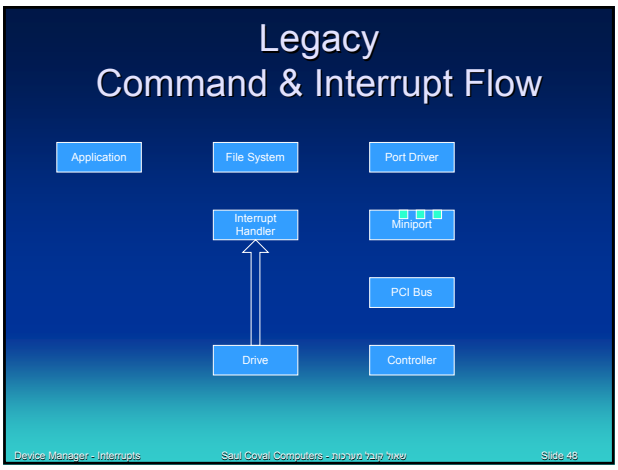
Drive
Controller
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 47


Legacy
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File System
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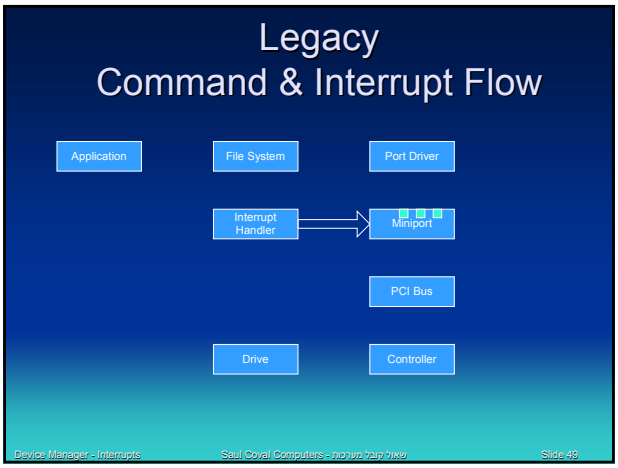
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 48


Legacy
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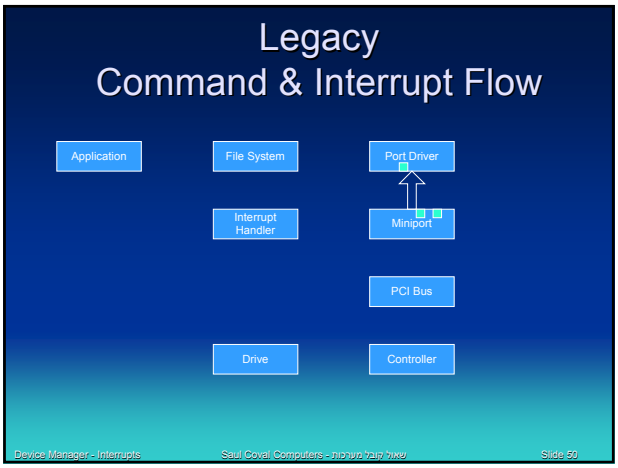
Saul Coval Computers - שאול קובל מערכות
Slide 49


Legacy
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File System
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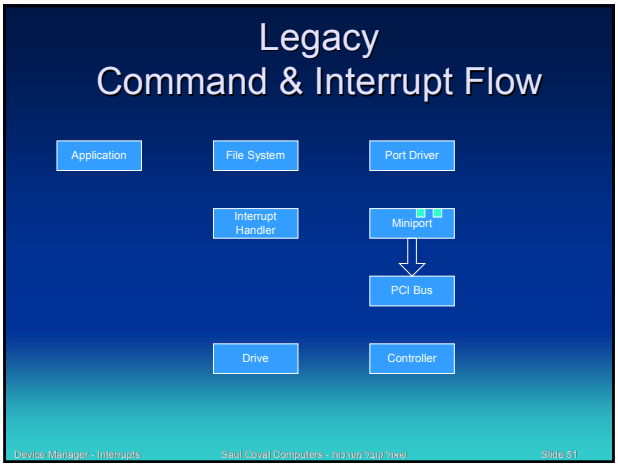
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 50


Legacy
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File System
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Interrupt Handler
Miniport
PCI Bus
Drive
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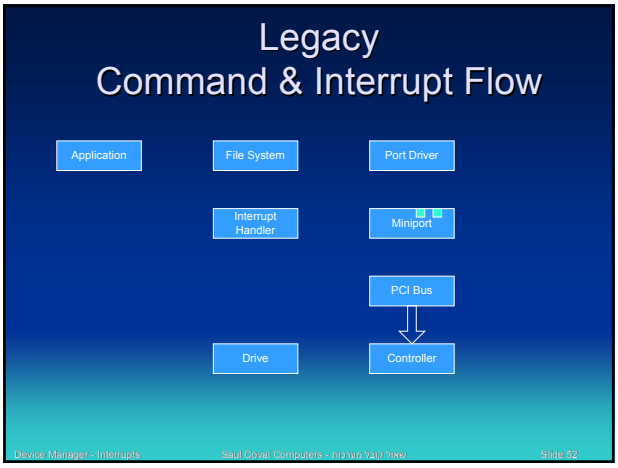
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 51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File System
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Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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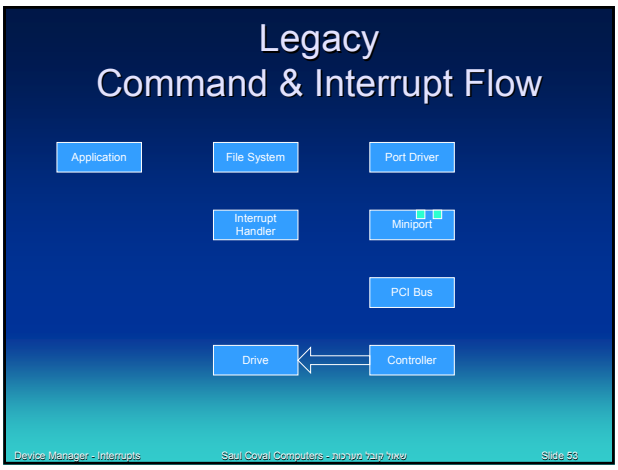
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Interrupt Handler
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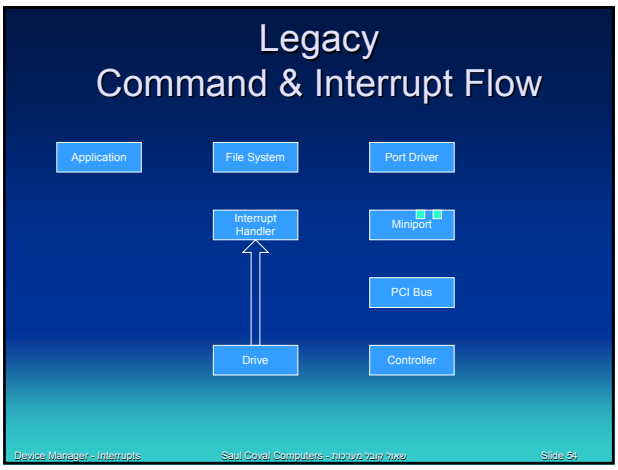
Drive
Controller
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 53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Drive
Controller
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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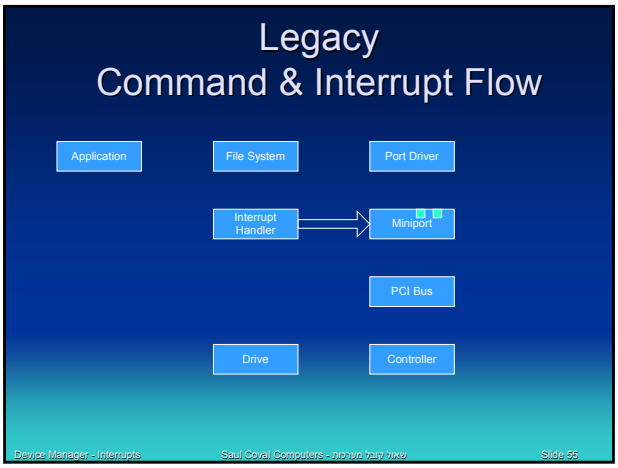
Legacy
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File System
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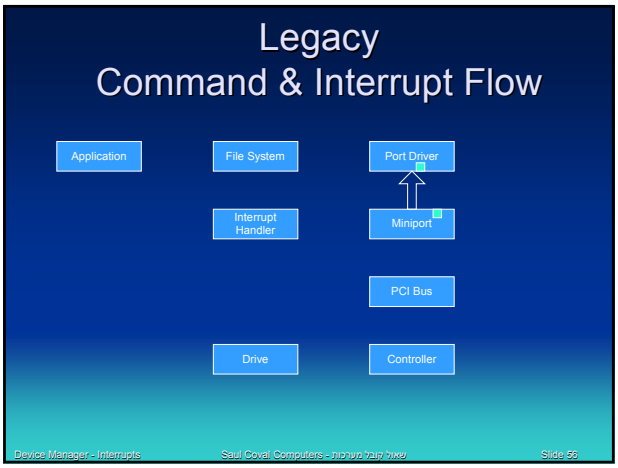
Controller
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 55


Legacy
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Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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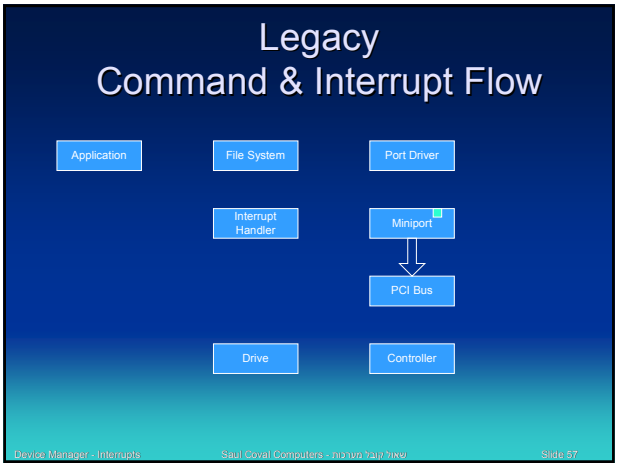
Legacy
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Application
File System
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Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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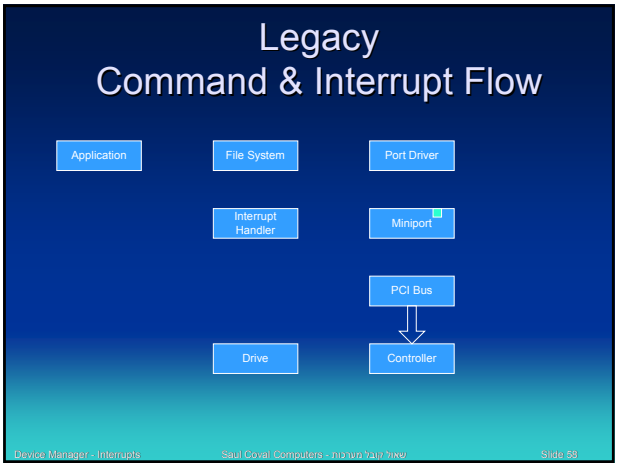
Legacy
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File System
Port Driver
Interrupt Handler
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PCI Bus
Drive
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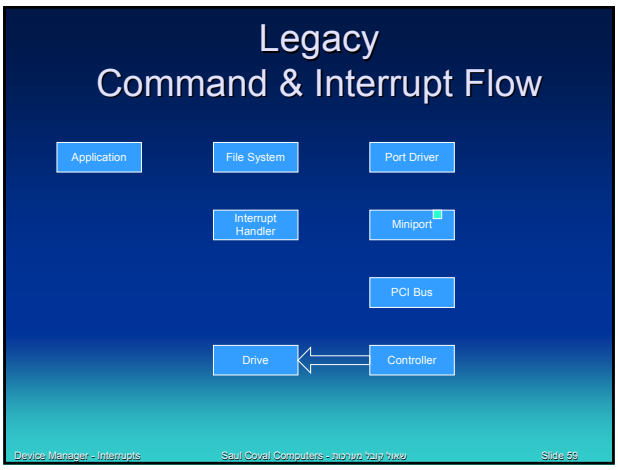
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 58


Legacy
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File System
Port Driver
Interrupt Handler
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Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
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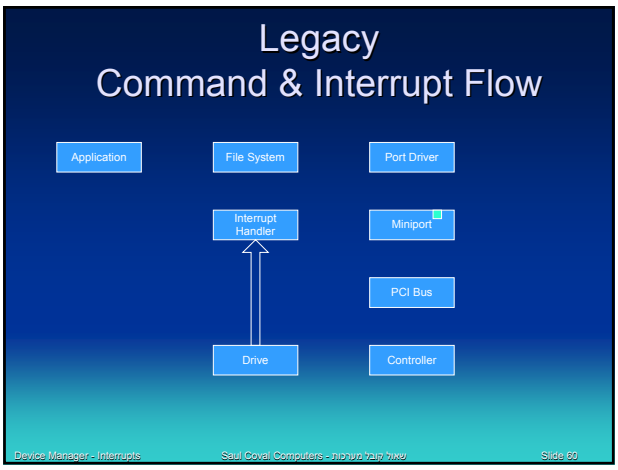
Legacy
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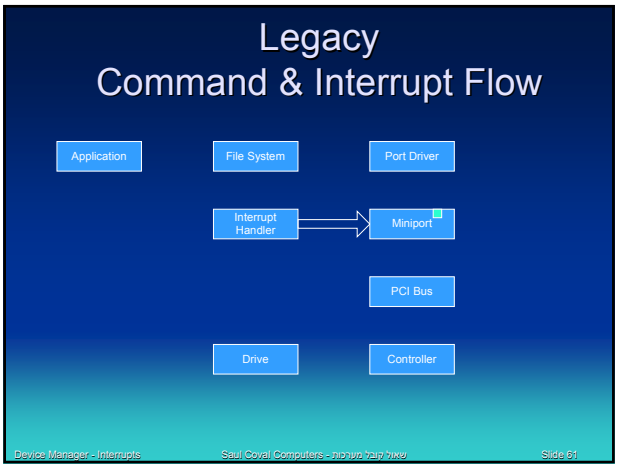
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 60


Legacy
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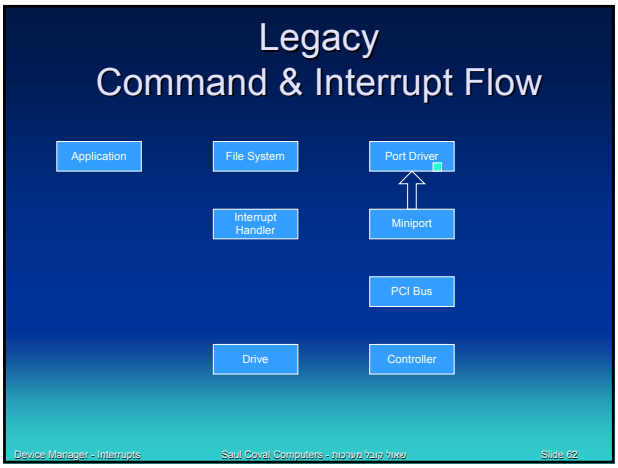
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 61


Legacy
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File System
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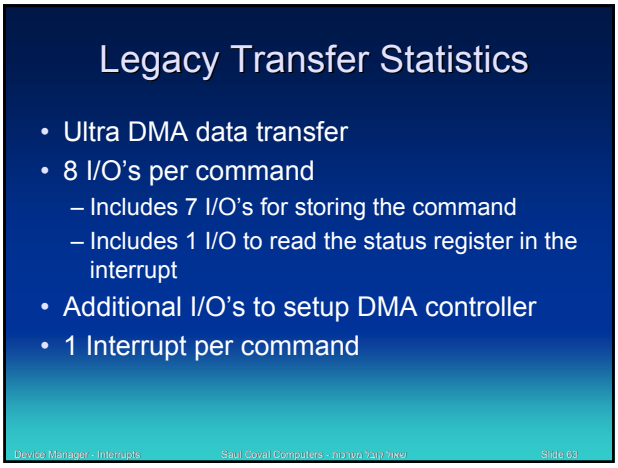
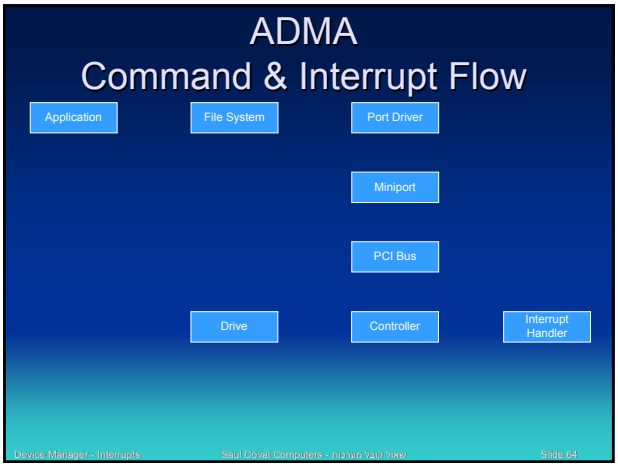
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 62


Legacy Transfer Statistics
• Ultra DMA data transfer
• 8 I/O's per command
– Includes 7 I/O's for storing the command
– Includes 1 I/O to read the status register in the interrupt
• Additional I/O's to setup DMA controller
• 1 Interrupt per command
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 63


ADMA
Command & Interrupt Flow
Application
File System
Port Driver
Miniport
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Drive
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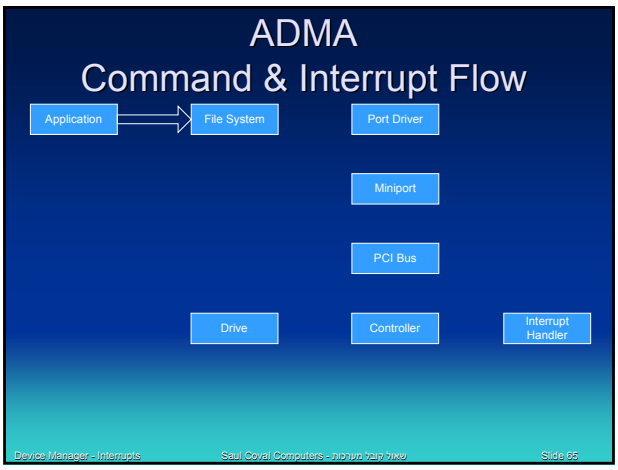
Interrupt Handler
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 64


ADMA
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Application
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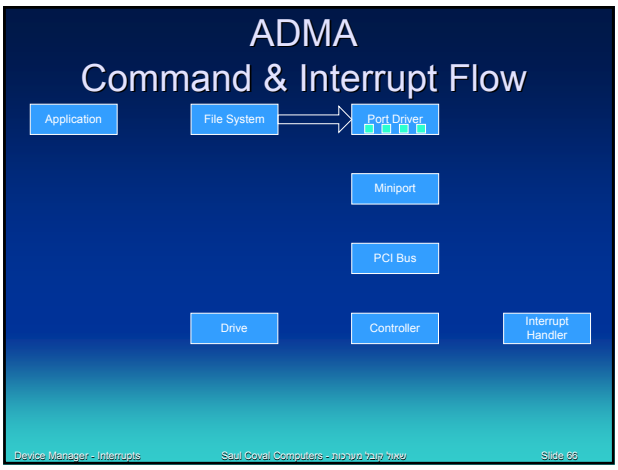
Interrupt Handler
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 65


ADMA
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Application
File System
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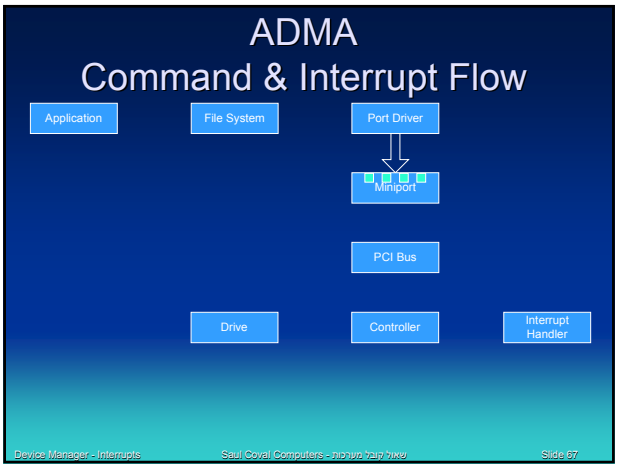
Interrupt Handler
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 66


ADMA
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File System
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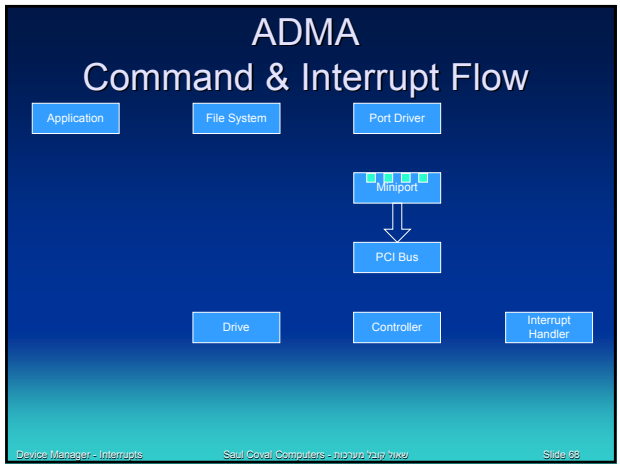
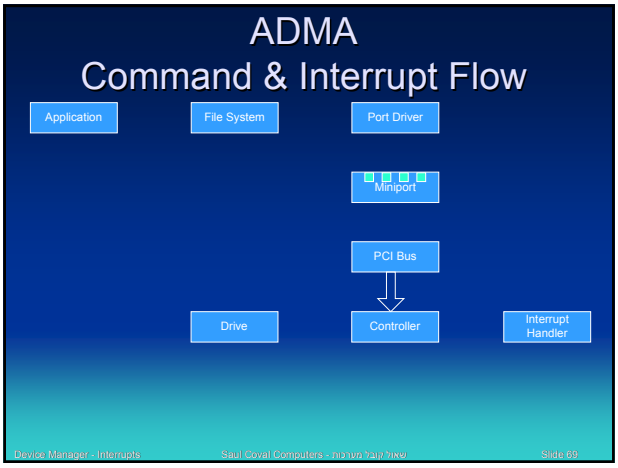
Controller
Interrupt Handler
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 67


ADMA
Command & Interrupt Flow
Application
File System
Port Driver
Miniport
PCI Bus
Drive
Controller
Interrupt Handler
Device Manager - Interrupts
Saul Coval Computers - שאול קובל מערכות
Slide 68


ADMA
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Interrupt Handler
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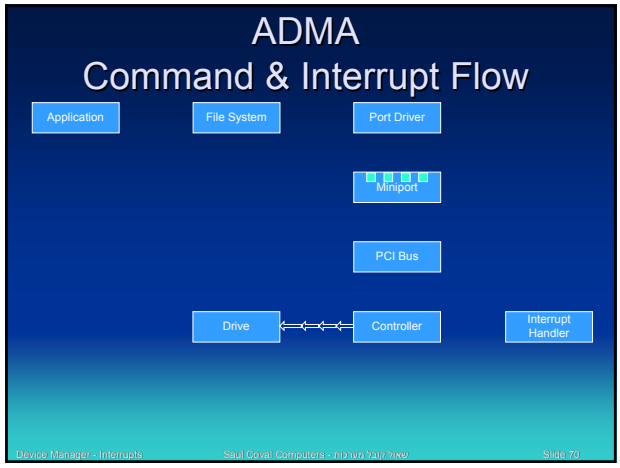
Saul Coval Computers - שאול קובל מערכות
Slide 69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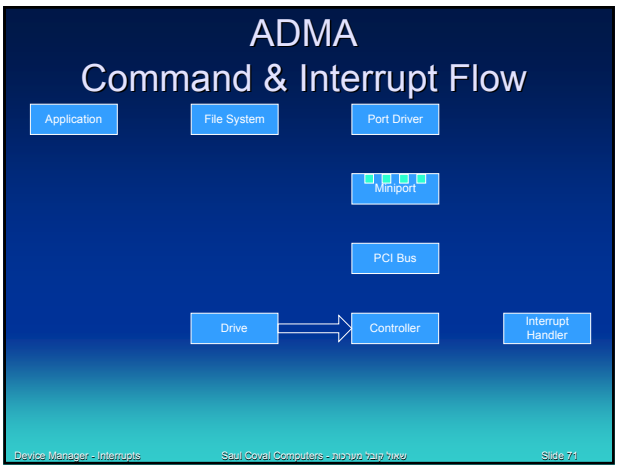
Saul Coval Computers - שאול קובל מערכות
Slide 70


ADMA
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Interrupt Handler
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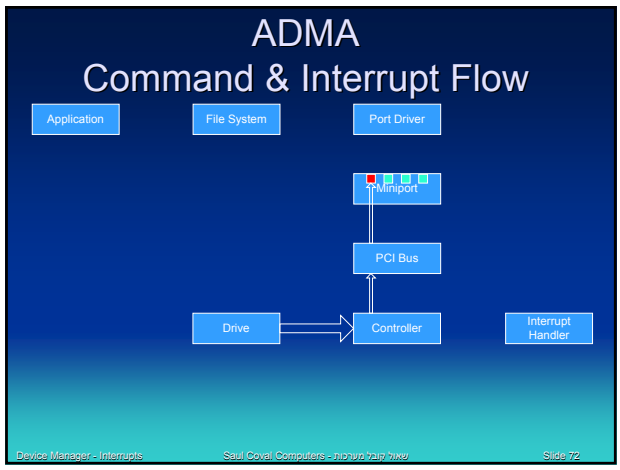
Saul Coval Computers - שאול קובל מערכות
Slide 71


ADMA
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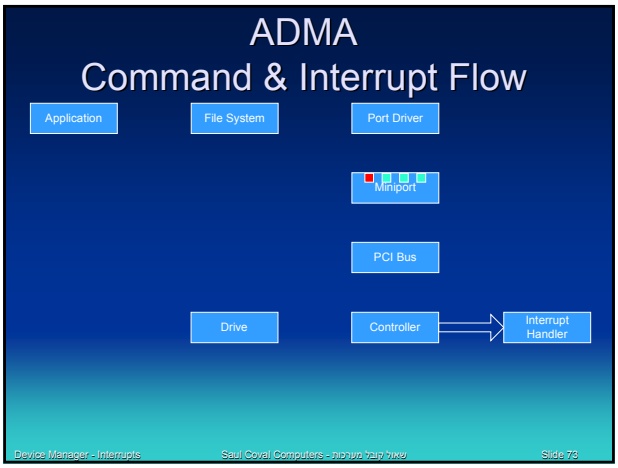
Saul Coval Computers - שאול קובל מערכות
Slide 72


ADMA
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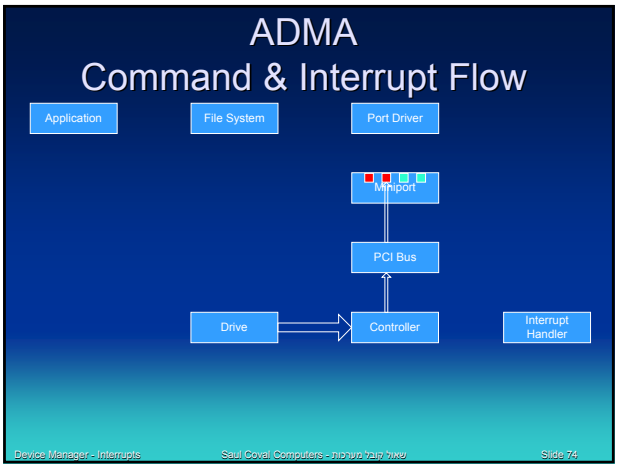
Saul Coval Computers - שאול קובל מערכות
Slide 73


ADMA
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Saul Coval Computers - שאול קובל מערכות
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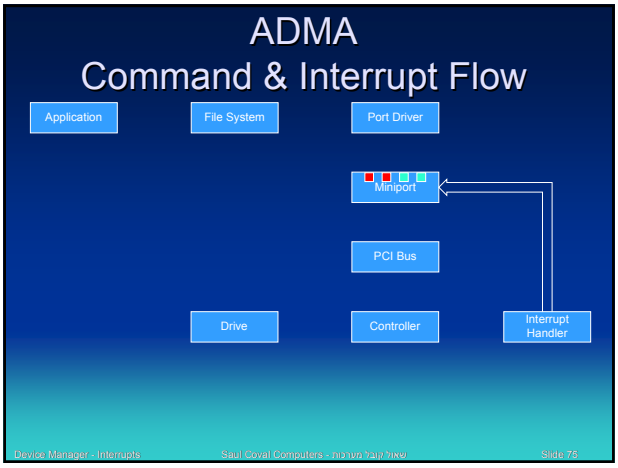
ADMA
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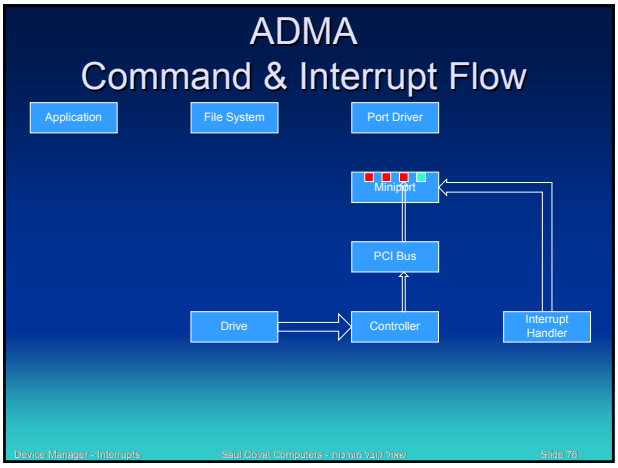
Saul Coval Computers - שאול קובל מערכות
Slide 75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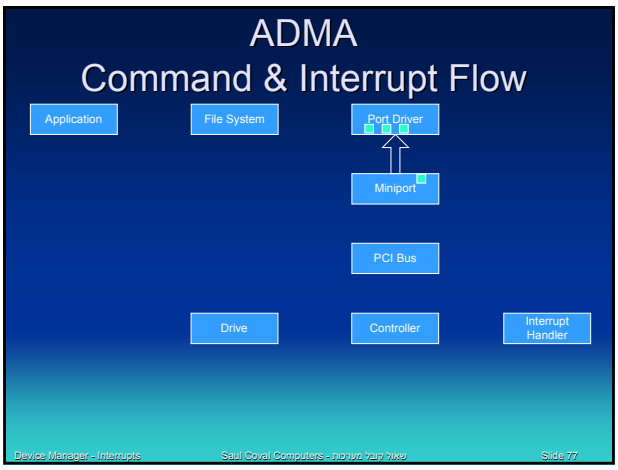
Saul Coval Computers - שאול קובל מערכות
Slide 76


ADMA
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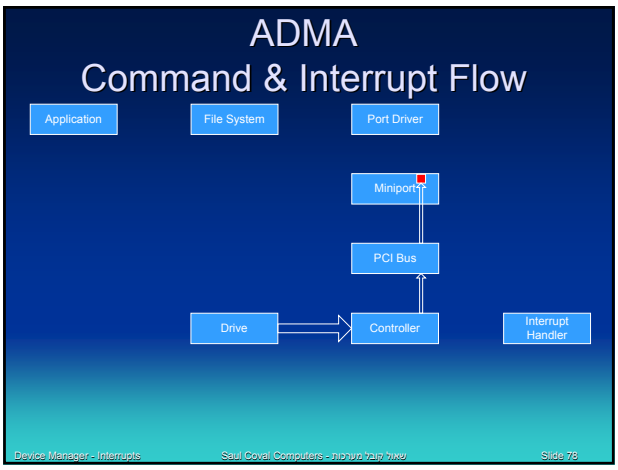
Slide 77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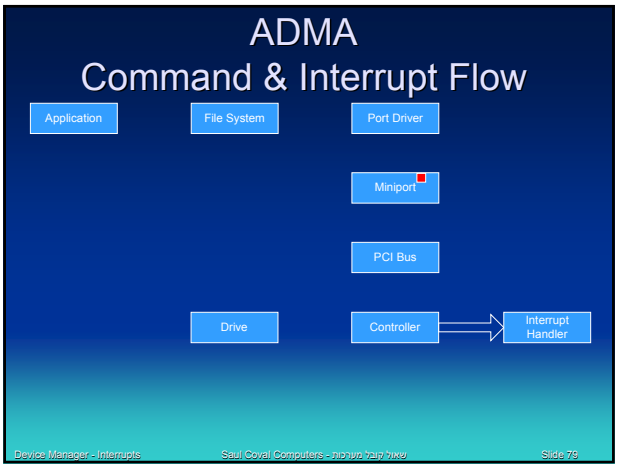
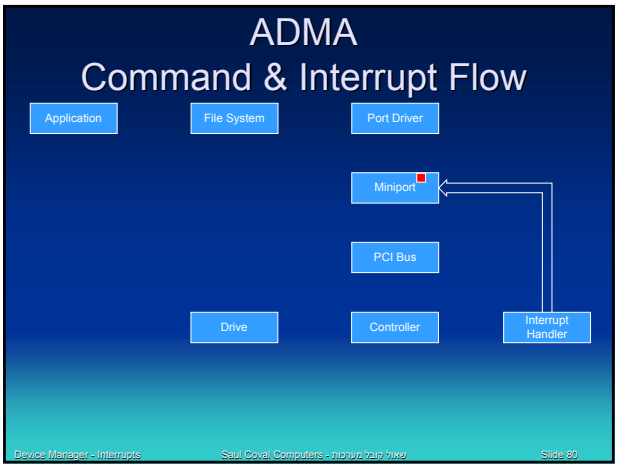
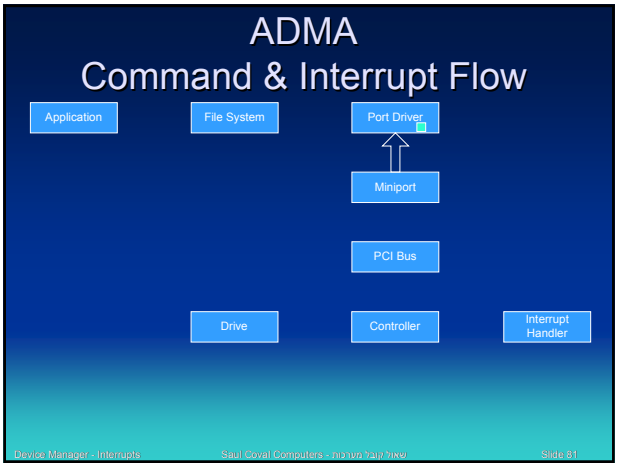
Saul Coval Computers - שאול קובל מערכות
Slide 78



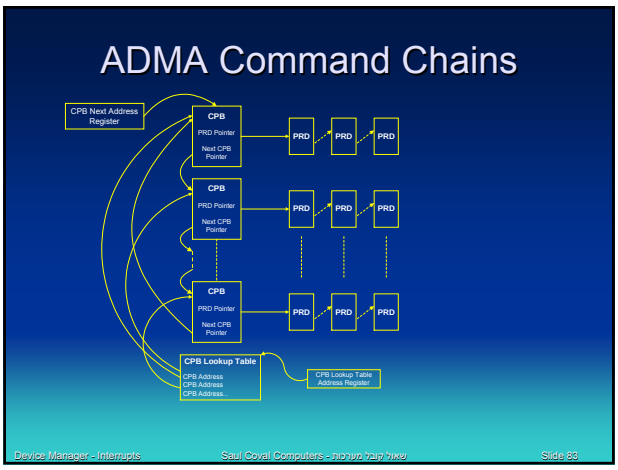


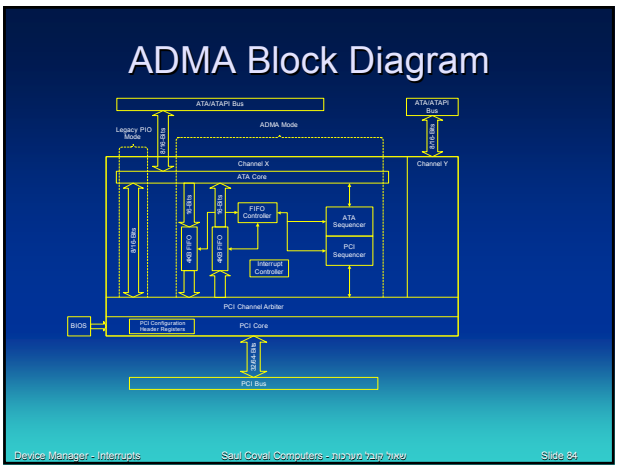


ADMA Transfer Statistics

- Ultra DMA data transfer
- No I/O
  - ADMA registers are memory mapped
  - ADMA uses normal PCI memory reads and writes to retrieve commands
- 1 Interrupt per group of I/O requests
  - Commands that complete while an ADMA interrupt is processed will not generate an additional interrupt

Device Manager - Interrupts Saul Coval Computers - שאול קובל מערכות Slide 82





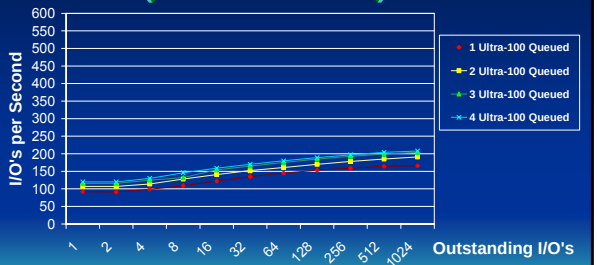
Test Conditions

- System (Micron)
  - 500Mhz P3
  - 192MB RAM
  - NT 4.0 SP6
  - Intel 82801 Chipset
  - 33Mhz PCI slot on a 66Mhz bus
  - Micron Northbridge
- Iometer
  - Fileserver access pattern
  - 100% Random, 80% Reads, 60% 4k blocks (remainder spread from 512 bytes to 64kbytes)
- Process
  - Boot using motherboard controller (same drive for all tests)
  - UDMA-100 card has for drives attached
  - ADMA card is in the same slot using the same 4 drives

Device Manager - Interrupts Saul Coval Computers - שאול קובל מערכות Slide 86

File Server Access Pattern

Ultra-100 Addin Card (Queued Drives)



Ultra-100 controller using drives that support queueing. The Ultra-100 controller does not using the queing capability of the drive.

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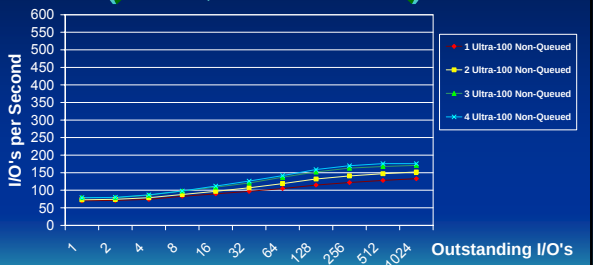
File Server Access Pattern

Ultra-100 Addin Card (Non-Queued Drives)



Ultra-100 controller using drives that do not support queueing.

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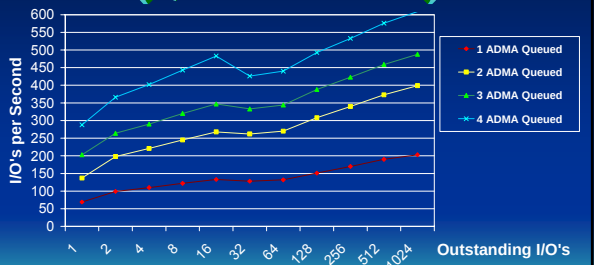
File Server Access Pattern

ADMA Controller (Queued Drives)



ADMA controller using drive queing capability

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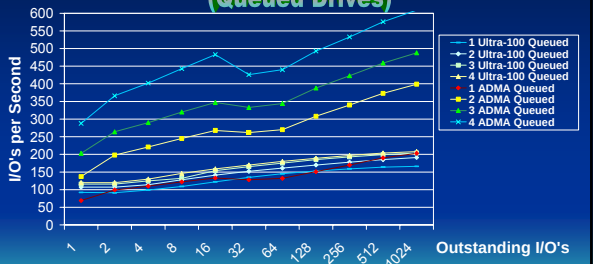
File Server Access Pattern

Controller Comparison Ultra-100/ADMA (Queued Drives)



Overlay of Ultra-100 controller using drives that support queing with ADMA controller using queued capability. The Ultra-100 controller does not using the queing capability of the drive.

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Interprocess communication

- Processes want to exchange information with each other
- Many ways to do this, including
  - Network
  - Pipe (special file): A writes into pipe, and B reads from it

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