Writing and Debugging EBC Drivers

Michael Kinney
Principal Engineer
Intel

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Agenda

- **A Brief History of EBC**
- EBC Overview
- Designing and Implementing EBC Drivers
- Testing and Debugging EBC Drivers
- EBC Performance Guidelines
- Summary

Motivation and Goals

- Option ROM Cost w/ Multiple Images
  - For EFI 1.02 this was Itanium and IA-32
  - Costs continue to increase as EFI adds CPU architectures
- Design Goals
  - Simple instruction set
    - Lightweight efficient interpreter
  - Share a common call stack
    - Low overhead on calls
  - Share all data structures.
    - No translations required on EBC ⇔ native transitions
  - No library dependencies
  - No C coding restrictions

Options

- JAVA and Forth
  - Rejected due to large libraries
- IA-32 Interpreter
  - Rejected due to the size/complexity of the interpreter
  - Requires updates for new IA-32 instructions
- Remote Procedure Call (RPC) like mechanism
  - PRO: Can handle mixed CPU arch sizes
  - CON: Does not support all C constructs
  - CON: Function call overhead to transpose
  - CON: Difficult to share data structures
    - EFI System Table, Boot Services Table, Protocol Interfaces
  - EFI 1.02 Specification included some support
- EBC Instruction Set with Natural Addressing
  - PRO: Simple instruction set, no library dependencies
  - PRO: Share common stack and data structures
  - CON: Minor C coding restrictions

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Natural Addressing

```
typedef struct {
  UINT64  BufferLength;
  VOID    *Buffer;
  UINT16  Checksum;
} MY_STRUCT;
```

	Byte Offset	
Field	32-bit	64-bit
BufferLength	0	0
Buffer	8	8
Checksum	12	16

- All fields are fixed size except INTN, UINTN, and pointers
- Byte Offset = C + N * Size of pointer in bytes
  - BufferLength: Offset = 0 + 0 * sizeof(VOID *) = 0 or 0
  - Buffer: Offset = 8 + 0 * sizeof(VOID *) = 8 or 8
  - Checksum Offset = 8 + 1 * sizeof(VOID *) = 12 or 16
- Encode both C and N into the instruction
  - C and N replace traditional offset field for address modes

Executing EBC Images

- EBC Interpreter
  - Implemented as a UEFI Driver
  - Typically stored in system FLASH (~10 KB compressed)
- Thunks
  - Native code that transfers control to/from EBC functions
  - Translates from native CPU ABI to EBC ABI (stack based)
  - Translates from EBC ABI (stack based) to native CPU ABI
- EBC executables use PE/COFF image format
- EBC executables loaded with EFI Boot Service LoadImage()
  - LoadImage() must support native and EBC images
  - Thunk to image entry point created by LoadImage()
- EBC executables started with EFI Boot Service StartImage()
  - Calls entry point thunk
- Thunks to exported functions created dynamically
  - Startup code contains BREAK instructions to create thunks
  - Function pointer references detected by compiler
    - Assignment or static initialization of protocol functions

EBC Images in PCI Option ROMs

- PCI Bus Driver discovers PCI Option ROMs
- PCI Option ROMs support multiple UEFI Images
  - UEFI Images may be compressed
- UEFI images dispatched by PCI Bus Driver
  - Non-UEFI images, including legacy, are ignored
  - UEFI Drivers dispatch in the order they appear
  - PCI Bus Driver calls LoadImage() and StartImage()
- Bus Specific Driver Override Protocol
  - Produced by PCI Bus Driver
  - Consumed by EFI Boot Service ConnectController()
  - Specifies priority order of Driver Binding Protocols
- Recommendations
  - Legacy Option ROM image first
  - Native UEFI Drivers next
  - EBC UEFI Drivers last
  - Compress driver images

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When to use EBC

- Add-in Video Adapters
- Add-in Disk Controllers
- Not used for NICs (UNDI)
  - UNDI is runtime which must be native.
- Reduce driver image footprint
  - Adapters supporting multiple CPU types
    - IA-32 and IPF
    - IA-32 and X64
    - X64 and IPF
    - IA-32, X64, and IPF
- Reduce adapter SKUs

EBC Development Checklist

- Implement and Test Native Driver
- EBC Development Environments
- EBC Target Environments
- Driver Design Steps
- Driver Implementation Steps
- Portability Considerations

EBC Development Environments

- EDK on TianoCore.org
  - https://edk.tianocore.org/files/documents/16/313/Edk-Dev-Snapshot-20061228.zip
  - Config.env: EFI_GENERATE_INTERMEDIATE_FILE = YES
- Intel® C Compiler for EFI Byte Code Version 1.2 Build 20040123
  - Common Flags:
    - /W3 /WX /FAcs /Fa
  - http://www3.intel.com/cd/software/products/asmo-na/eng/compilers/efibc/219678.htm
- Microsoft* Linker Version 7.10.3077 and above
  - Common Flags:
    - /MACHINE:EBC /OPT:REF /ENTRY:EfiStart
    - /SUBSYSTEM:EFI_BOOT_SERVICE_DRIVER
    - EbcLib.lib
  - Microsoft* Visual Studio .NET 2003
  - Microsoft* Visual Studio 2005
  - Windows* DDK 3790.1830

EBC Target Environments

- UEFI Compliant Platforms
- EDK – DUET Platform
  - Boots UEFI environment on legacy platform
- EDK – NT32 Platform
  - UEFI Emulation environment for Windows
  - Not useful for drivers that touch hardware

Driver Implementation Steps

- Create Driver Directory
- Design Private Context Data Structure
- Add Source Files to Driver Directory
- Add .INF File to Driver Directory
- Add .INF file to .DSC file in Build Directory
- Run nmake to build driver

DEMO: Build EBC SampleDriver
DEMO: Build EBC HelloWorld

Portability Considerations

- Do Not Assume Max Number of Children
- Do Not Use Fixed Memory Addresses
- Do Not Use Assembly
- Do Not Use Floating Point Arithmetic
- Some Minor EBC Porting Considerations
- Bus Drivers Should Support Producing 1 Child at a time if possible (improves boot performance)

Common EBC Source Porting Issues

- EfiMain() and EfiStart() are reserved words
- Function Declarations
  - Must match Function Prototype if present
    - All parameter types and return types
- Pre-Init Data Structures
  - Function pointer fields must match declaration
  - Data fields can not reference sizeof()
  - EFI_STATUS indirectly references sizeof() for EBC
- case statement can not reference sizeof()
  - EFI_STATUS indirectly references sizeof() for EBC

DEMO: PortDemo1 PortDemo2

Common EBC Execution Issues

- Incorrect result of op between variable and immediate data
  - Workaround: Type convert immediate data to UINTN
- Incorrect result of arithmetic calculations
  - INTN and UINT8
  - INTN and UINT16
  - INTN and UINT32
  - UINTN and INT64
  - Workaround: Type convert fixed size to natural
- Incorrect CMP instruction generation
  - Workaround: Not an issue if UEFI base types are used

DEMO: PortDemo3

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Testing Recommendations

- UEFI Self Certification Tests (SCTs)
- Test Functions with EFI Shell Commands
- Check for Leaks with EFI Shell Commands
- Install EFI Compliant Operating System
- Boot EFI Compliant Operating System
- Debug Macros Identify Critical Failures
- Use Same Techniques on all CPU Types
  - IA-32, Itanium® Processor Family, x64, EBC

Debug Methods

- DEBUG()/ASSERT() Macros
- POST Card
- UART Serial Port
- VGA Display
- EBC Debugger

Debug Macros

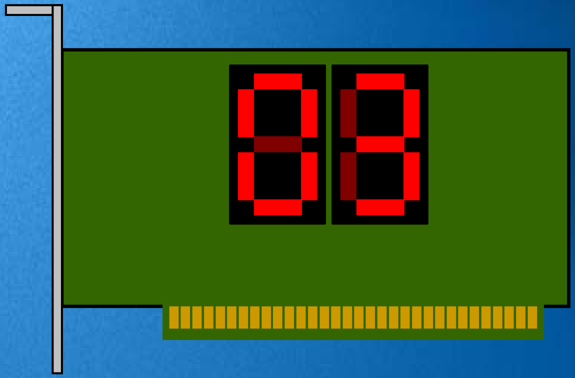
- ASSERT (Expression)
  - If Expression is FALSE, then print file name and line number and halt.
- ASSERT_EFI_ERROR (Status)
  - If Status is not EFI_SUCCESS, then print file name and line number and halt.
- CR (Record, Type, Field, Signature)
  - ASSERT()s if Data Structure Signature does not match
- EFI_BREAKPOINT ()
  - Generate a CPU break point instruction

Debug Macros

- **DEBUG (ErrorLevel, String, …)**
  - Print String if ErrorLevel is active.

•EFI_D_ERROR	0x80000000
•EFI_D_INIT	0x00000001
•EFI_D_WARN	0x00000002
•EFI_D_INFO	0x00000040
•EFI_D_BLKIO	0x00001000
•EFI_D_UNDI	0x00010000

When DEBUG() is not Available



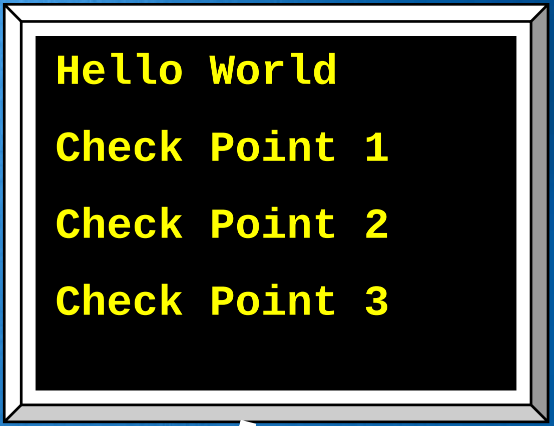
- POST Card (I/O 0x80)
  - PCI Root Bridge I/O Protocol
  - PCI I/O Protocol

```
Value = 0x03;
Status = PciIo->Io.Write (
                     PciIo,                       // This
                     EfiPciIoWidthUint8,          // Width
                     EFI_PCI_IO_PASS_THROUGH_BAR, // BAR
                     0x80,                        // Offset
                     1,                           // Count
                     &Value                       // Buffer
                     );
```

CAUTION

May not work on all platforms
May produce unpredictable results
Must be removed from production drivers

When DEBUG() is not Available



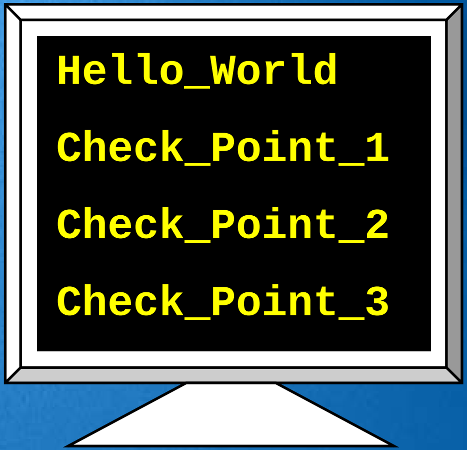
```
Hello World
Check Point 1
Check Point 2
Check Point 3
```

- UART (COM1 I/O 0x3F8-0x3FF)
- UART (Platform Specific MMIO)
  - PCI Root Bridge I/O Protocol
  - PCI I/O Protocol

```
Status = PciIo->PollIo (PciIo, EfiPciIoWidthUint8,
                        EFI_PCI_IO_PASS_THROUGH_BAR,
                        0x3FD, 0x20, 0x20, 1000000, &Lsr);
Status = PciIo->Io.Write (PciIo, EfiPciIoWidthUint8,
                          EFI_PCI_IO_PASS_THROUGH_BAR,
                          0x3F8, 1, &Data);
```

May not work on all platforms
May produce unpredictable results
Must be removed from production drivers

When DEBUG() is not Available



```
Hello_World
Check_Point_1
Check_Point_2
Check_Point_3
```

- VGA (MMIO 0xB8000-0xBFFFF)
  - PCI Root Bridge I/O Protocol
  - PCI I/O Protocol

```
VideoAddress   = 0xB8000 + (Row * 80 + Column) * 2;
VideoCharacter = 0x0700 | Character;
Status = PciIo->Mem.Write (PciIo, EfiPciIoWidthUint16,
                           EFI_PCI_IO_PASS_THROUGH_BAR,
                           VideoAddress, 1, &VideoCharacter);
```

CAUTION

May not work on all platforms
May produce unpredictable results
Must be removed from production drivers

EBC Debugger Demo

- Compile with /FAcs and /Fa
  - Generates .COD files with mixed source/asm
- Link with /MAP:mapfile
  - Generate .MAP file of functions in EBC driver
- Config.env
  - EFI_GENERATE_INTERMEDIATE_FILE = YES

DEMO: EBC Debugger

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EBC Performance Guidelines

- Do as little work in EBC driver as possible
  - Use EFI Boot Services
  - Use EFI Runtime Services
  - Use Protocols produced by other drivers
- Perform operations at largest size possible

DEMO: BadPerf and GoodPerf

EBC Performance Guidelines

- EFI Boot Services
  - CopyMem(), SetMem()
- PCI I/O Services
  - PollMem() and PollIo()
  - Mem.Read(), Mem.Write(), Io.Read(), Io.Write()
    - Supports Buffer, FIFO, and Fill operations
    - EfiPciIoWidthUintX, EfiPciIoWidthFifoUnitX, EfiPciIoWidthFillUintx
  - Pci.Read() and Pci.Write()
    - Use buffer to perform many PCI cycles at once
  - CopyMem()
    - Video scroll operations when HW engine no available
  - Map(), UnMap()
    - Perform double buffering as required in native code

DEMO: CirrusLogic

Summary

- Use EFI Driver Writer's Guide for UEFI 2.0
  - Draft Version 0.94
- Implement and Test Native Driver First
- Be aware of EBC Source Portability Issues
  - No assembly or floating point support
- Call External Services for Performance
  - UEFI Boot Services
  - UEFI Protocols
- Use EBC Debug Methods and EBC Debugger
- Validate with SCTs, EFI Shell, and OS Install/Boot
- Follow EBC Option ROM Recommendations
  - EBC Images Last
  - Use UEFI Compression to reduce size

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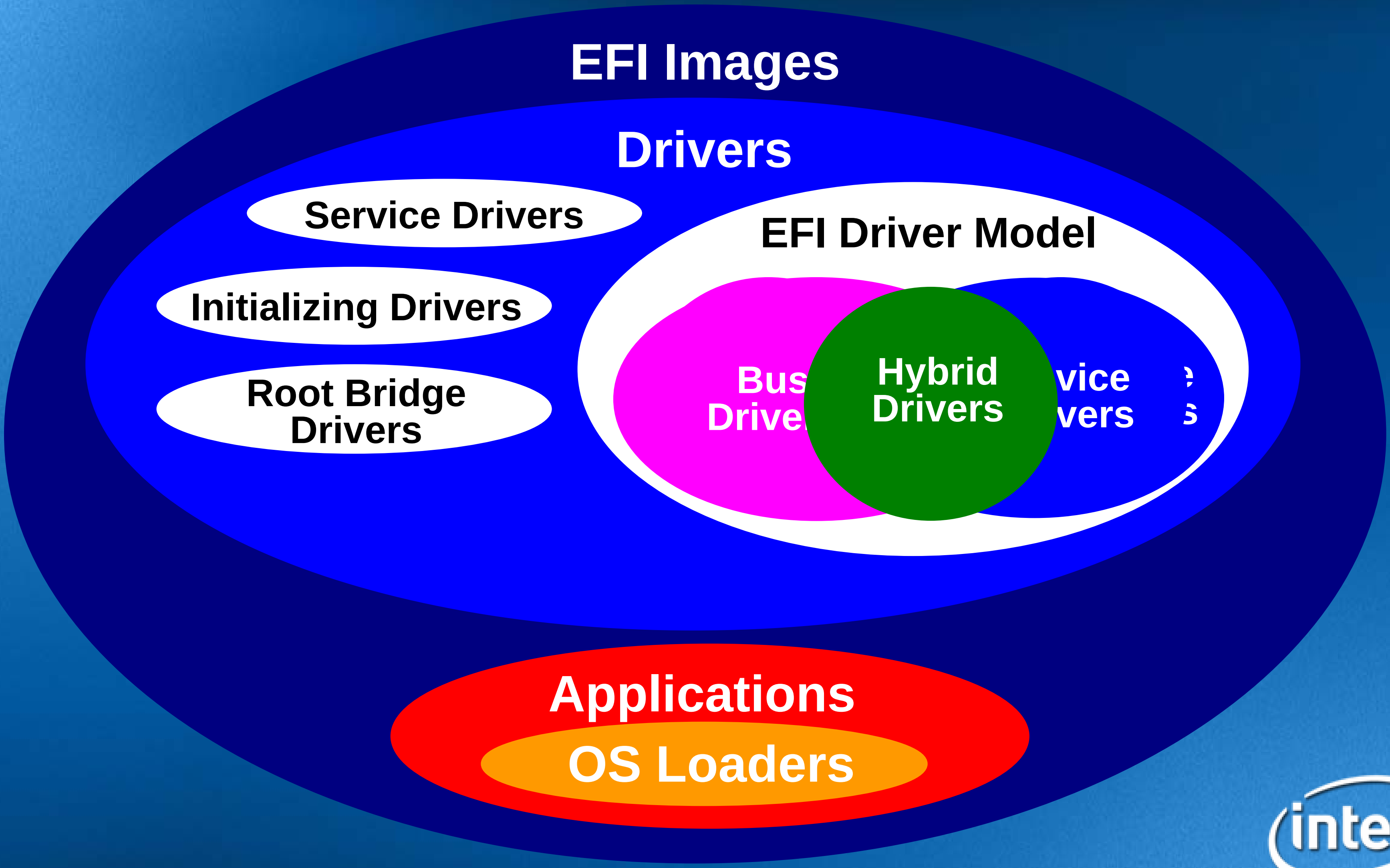
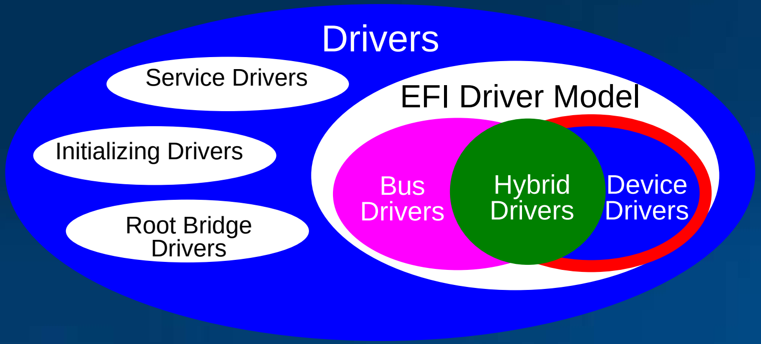
Definitions

- EFI Image
  - **Executable Image in a PE32 Image Format**
- EFI Driver
  - EFI Image that Typically Manages Physical Devices
  - Many Types are Possible
- Handle
  - Object Containing One or More Protocols
- Protocol
  - Object Containing Functions and Data
- Controller
  - Physical Device that is Managed by an EFI Driver
- Event
  - Object that may be Signaled or Waited Upon
  - Synchronous and Asynchronous Notifications

UEFI Driver Types



Device Driver

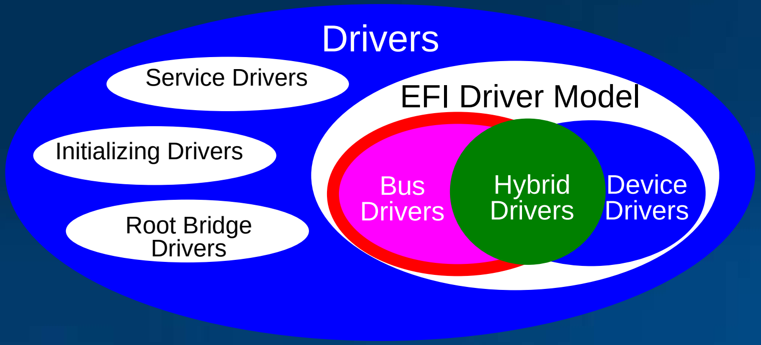


- Manages a Controller or Peripheral Device
- Start() Does Not Create Any Child Handles
- Start() Produces One or More I/O Protocols
  - Installed onto the Device’s Controller Handle

Examples:

PCI Video Adapters
USB Host Controllers
USB Keyboards / USB Mice
PS/2 Keyboards / PS/2 Mice

Bus Driver



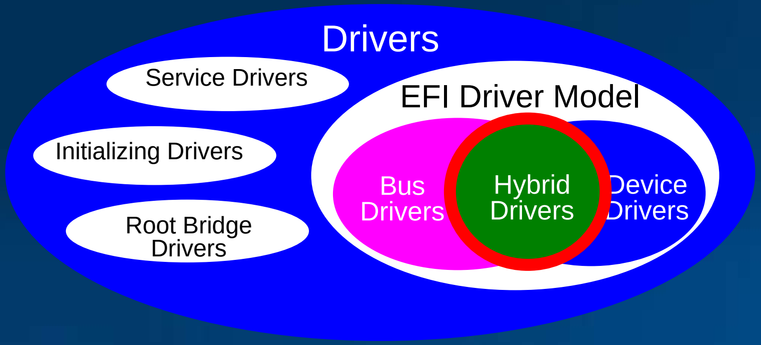
- Manages and Enumerates a Bus Controller
- Start() Creates One or More Child Handles
- Start() Produces Bus Specific I/O Protocols
  - Installed onto the Bus's Child Handles

Examples:

PCI Network Interface Controllers

Serial UART Controllers

Hybrid Driver



- Manages and Enumerates a Bus Controller
- Start() Creates One or More Child Handles
- Start() Produces Bus Specific I/O Protocols
  - Installed onto the Bus's Controller Handle
  - Installed onto Bus's Child Handles

Examples:

PCI SCSI Host Controllers

PCI Fiber Channel Controllers

Driver Design Steps

- Determine Driver Type
- Identify Consumed I/O Protocols
- Identify Produced I/O Protocols
- Identify EFI Driver Model Protocols
- Identify Additional Driver Features
- Identify Target Platforms
  - IA-32
  - Itanium Processor Family
  - EFI Byte Code (EBC)

Driver Design Checklist

	PCI Video	PCI RAID
Driver Type	Device	Hybrid
I/O Protocols Consumed	PCI I/O Device Path	PCI I/O Device Path
I/O Protocols Produced	GOP	SCSI Pass Thru Block I/O
Driver Binding	✓	✓
Component Name	✓	✓
Driver Configuration		✓
Driver Diagnostics	✓	✓
Unloadable	✓	✓
Exit Boot Services Event	sometimes	sometimes
Runtime		
Set Virtual Address Map Event		