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

- 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**
  - 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
- **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

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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
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** 0x00000004
- **EFI_D_BLKIO** 0x00000100
- **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, EfiPciIoWidthUint8, EFI_PCI_IO_PASS_THROUGH_BAR, 0x80, 1, &Value);

May not work on all platforms
May produce unpredictable results
Must be removed from production drivers
When DEBUG() is not Available

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

May not work on all platforms
May produce unpredictable results
Must be removed from production drivers
When DEBUG() is not Available

- 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, EFI_PciIoWidthUint16, 
                         EFI_PCI_IO_PASS_THROUGH_BAR, 
                         VideoAddress, 1, &VideoCharacter);

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

- Compile with /FAs 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
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

- Service Drivers
- Initializing Drivers
- Root Bridge Drivers

EFI Driver Model
- Hybrid Drivers
- Bus Device Drivers
- Device Drivers

EFI Images

Applications
- OS Loaders
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

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

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*Designing and Implementing EFI Drivers*