Device Driver Programming

What's **not** in the Books

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Audience

- Not targeted at beginners in device driver programming
- At least basic skills and experience are assumed
- No discussion of basic device driver operation
- Covers OS/2 protected mode drivers only, OS/2 virtual DOS machines are not addressed

Paradigma

- OS/2 is used in highly dynamic environments now:
  - »Plug and Play« buses like
    - PCCard/Cardbus sockets
    - USB
    - Device bays with hot-swap features
  - Machines with power management
- Device drivers need to handle such hardware
- Programmers have to care about that

Device Driver Programming

Driver Identification

Driver Identification

- Device drivers shall identify themselves verbosely wherever this is possible:
  - in the device driver file (BldLevel)
  - in the resource manager tree (Hardware Manager)
  - in the PCCard manager (PC Card Director)
- This helps you both in development and support
- It gives users confidence in their system setup

Identification BldLevel

The information shown by the BldLevel utility is stored in the file description:

```
  DESCRIPTION "@#DANI:1.5#@##1## 17.9.2002 12:57:21
   Nachtigall::    ::1ß::@@  Adapter Driver for ST506/IDE DASD"
```

The result is then

```
Signature:     @#DANI:1.5#@##1## 17.9.2002 12:57:21
  Nachtigall::    ::1ß::@@  Adapter Driver for ST506/IDE DASD
Vendor:        DANI
Revision:      1.05
Date/Time:     17.9.2002 12:57:21
Build Machine: Nachtigall
File Version:  1.5.1
Description:   Adapter Driver for ST506/IDE DASD
```

Identification
Resource Manager

- Even if your driver doesn't handle any hardware, i.e. is a software-only driver, register it with the resource manager
- If your driver shows up in the resource manager device tree (check with RMView /D) then
  - you know that your initialization code is fine
  - the user knows that the driver is successfully loaded

Identification
Resource Manager

```
UCHAR DrvrNameTxt[]   = "DANIS506.ADD";
UCHAR DrvrDescrTxt[]  = "DMA Adapter Driver for ST506/IDE DASD";
UCHAR VendorNameTxt[]= "Dani";
DRIVERSTRUCT DriverStruct = {
   DrvrNameTxt,                 /* DriverName        */
   DrvrDescrTxt,                /* DriverDescription */
   VendorNameTxt,               /* VendorName        */
   CMVERSION_MAJOR,             /* MajorVersion      */
   CMVERSION_MINOR,             /* MinorVersion      */
   YEAR,MONTH,DAY,              /* Date              */
   0,                           /* DriverFlags       */
   DRT_ADDDM,                   /* DriverType        */
   DRS_ADD,                     /* DriverSubType     */
   NULL                         /* DriverCallback    */
};
```

generates this RMView /D output:

```
Driver: DANIS506.ADD  -  DMA Adapter Driver for ST506/IDE DASD
Vendor: Dani  Version: 1.1  Date (MDY): 9/15/2002
Flag: STATIC    Type-Subtype: ADDDM - ADD
```

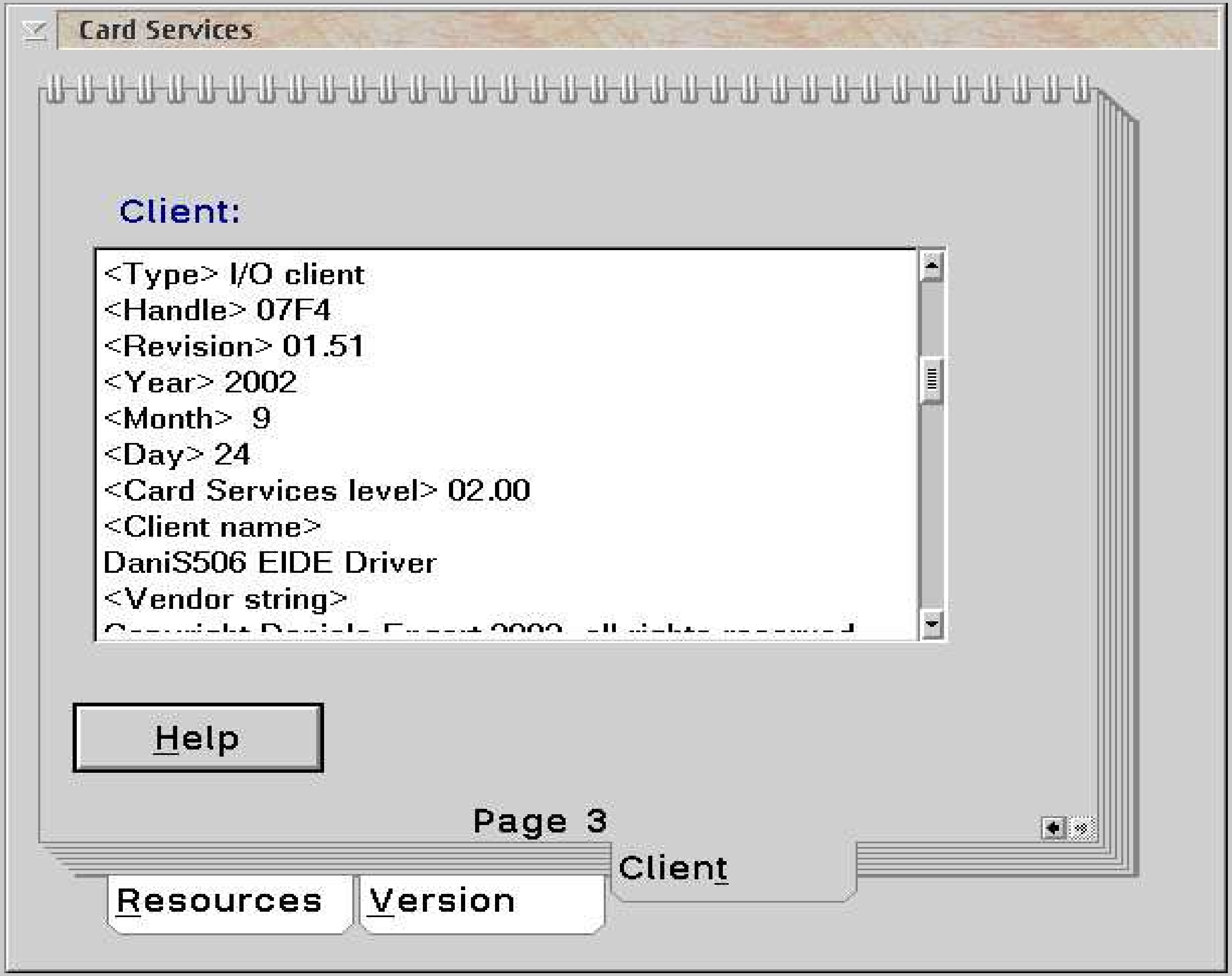
Identification
PC Card Director

A PCCard client driver registration like this one

```
struct CI_Info ClientInfo = {
  0,
  sizeof (ClientInfo),
  ATB_IOClient | ATB_Insert4Sharable | ATB_Insert4Exclusive,
  VERSION,
  0,
  ((YEAR - 1980) << 9) | (MONTH << 5) | DAY,
  offsetof (struct CI_Info, CI_Name),
  sizeof (ClientInfo.CI_Name),
  offsetof (struct CI_Info, CI_Vendor),
  sizeof(ClientInfo.CI_Vendor),
  "DaniS506 EIDE Driver",
  "Copyright Daniela Engert 2002, all rights reserved"
};
```

generates this output in PC Card Director

Identification PC Card Director



Client:

```
<Type> I/O client
<Handle> 07F4
<Revision> 01.51
<Year> 2002
<Month>  9
<Day> 24
<Card Services level> 02.00
<Client name>
DaniS506 EIDE Driver
<Vendor string>
```

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Device Driver Programming

Driver Interfaces

Driver Interfaces

- Drivers are DLL modules which are **not** linked against any other modules (except kernel)
- Drivers connect **dynamically** at runtime to kernel services or other OS/2 subsystems in kernel space
- Drivers must **not** assume that all subsystems are available on a given installation
- Connections are usually created by a registration/callback scheme

Driver Interfaces

- A driver **registers** to other services by IDC lookup (to other drivers) or device helper functions (to kernel services)
- if a driver offers services to other parts of the system it **exports** an entry point into its code
- if a driver uses services from other parts it **imports** an entry point into foreign code
- each service needs a full **specification**

Driver Interfaces

The minimum specification of a service requires:

- a registration method
  (IDC, device helper function, known location)
- a fully protyped service entry point
  (linkage, return type, argument types, ...)
- a list of execution contexts it may be called in
  (init time, task time, interrupt time, ...)
- a list of restrictions (if any)
  (duration, register usage, access privileges)
- a description of the functions provided

Driver Interfaces

Drivers implemented in C often require assembler stub functions which interface to the C language model to handle

- arguments passed in registers visa stack based arguments in C
- fully saved registers at the interface visa partially clobbered registers in C routines
- setup of DS to the driver's own default data segment
- setup of DS to the other driver's data segment

Driver Interfaces

Example:

```
int EntryPoint (int function, anytype *ptr);
```

Questions:

- is the function name _EntryPoint, ENTRYPOINT or @EntryPoint ?
- is the data segment already set up ?
- is a near or far return required ?
- is the pointer argument near or far ?
- what's the argument order ?
- who cleans up the arguments ?

Driver Interfaces

Driver entry points must be **fully** prototyped to avoid unexpected or faulty behaviour

wrong:

```
int EntryPoint (int function, anytype *ptr);
```

right:

```
int _far _cdecl _loadds EntryPoint (int function,
                                    anytype _far *ptr);
```

The calling convention, decoration, DS setup, and near/far attributes need to be specified to be independent of compiler options or models.

Driver Interfaces

Standard driver interfaces are

- Device helper entry point
- Strategy 1 entry point
- Interrupt handler entry points
- Timer handler entry point
- IDC entry point
- Context hook entry points

Driver Interfaces

The following driver interfaces are optional, but I consider them **mandatory**!

- Resource Manager services
- APM notifications
- PC Card/Cardbus services and notifications

You need them to adapt the driver operation to dynamic environments

Driver Interfaces

These driver interfaces are required for discovery of supported hardware

- Resource Manager services
- OEMHelp services

You need them to search in the OS/2 device database or to enumerate the PCI bus

Driver Interfaces

The following driver interfaces are required by particular classes of device drivers only

- Strategy 2 entry points (ADD/FLT/DMD)
- Strategy 3 entry points (DMD)
- NDIS2 entry points (MAC drivers)
- USB entry points (USB drivers)
- MM Stream entry points (Multimedia drivers)
- others

Strategy 1

- This entry point is exported to the OS/2 kernel in the device header structure
- Modern device drivers should request InitComplete and Shutdown notifications to attach to or detach from other services properly

Interrupt Handler

- You **must** handle shared interrupts
- PCI interrupts **may** be unshared
- the execution context of interrupt handlers is **restricted**
- the execution time of interrupt handlers must be **short**
- **defer** as much work as possible to task time handling (f.e. context hooks) - but decide wisely

Interrupt Handler

```
UCHAR SharingMode;

/* attach to interrupt in given sharing mode */

SharingMode = (IRQ->isShared) ? IRQMODE_SHARED : IRQMODE_UNSHARED;
rc = DevHelp_SetIRQ ((NPFN)IRQ->Handler, IRQ->Level, SharingMode);

/* if attach failed and sharing mode was "shared" try "unshared" */

if (rc && IRQ->isShared) {
  rc = DevHelp_SetIRQ ((NPFN)IRQ->Handler, IRQ->Level, IRQMODE_UNSHARED);

  /* if attach failed another time give up */

  if (!rc) {

    /* adjust actual sharing mode */
    IRQ->isShared = FALSE;

  }
}

/* rc == 0 if attach to interrupt succeeded */
```

Interrupt Handler

```
/* each IRQ entry point handles a list of instances hooked to this IRQ level */

USHORT FAR _loadds IRQEntry0() { return (HandleIRQ (IHdr[0].npInst) >> 1); }
USHORT FAR _loadds IRQEntry1() { return (HandleIRQ (IHdr[1].npInst) >> 1); }
USHORT FAR _loadds IRQEntry2() { return (HandleIRQ (IHdr[2].npInst) >> 1); }
USHORT FAR _loadds IRQEntry3() { return (HandleIRQ (IHdr[3].npInst) >> 1); }

USHORT NEAR HandleIRQ (PTRTYPE_INSTANCEDATA npInst) {
  USHORT Claimed = 0;

  /* walk list of instances attached to this IRQ */
  for (; NULL != npInst; npInst = npInst->npIntNext)
    Claimed |= npInst->IntHandler (npInst);

  return (~Claimed);
}

/* As long as the driver isn't prepared to handle interrupts          */
/* from a particular hardware we have to catch them anyway to prevent */
/* the OS/2 IRQ dispatcher from going mad!                            */

USHORT NEAR CatchInterrupt (PTRTYPE_INSTANCEDATA npInst) {
  if (npInst->CheckIRQ (npInst)) {
    DevHelp_EOI (npInst->IRQLevel);
    return (1);
  }
  return (0);
}
```

Interrupt Handler

```
USHORT NEAR Interrupt (PTRTYPE_INSTANCEDATA npInst){
  USHORT Claimed = 0;
  int    rcCheck;

  /* is the interrupt generated by hardware associated with this instance ? */
  /* if not, bail out early                                                 */

  if (!(rcCheck = CheckIRQ (npInst)))
    return (Claimed);

  /* so far, the interrupt is possibly from us                              */
  /* if we expect an interrupt or the interrupt is definitely from us,      */
  /* then handle it                                                         */
  /* up to this point, interrupts are still enabled in case of a shared IRQ */
  /* the following code is a section which must not be preempted            */

  DISABLE
  if ((npInst->Flags & WAIT_INTERRUPT) || (rcCheck == 1)) {
    npInst->Flags &= ~WAIT_INTERRUPT;

    /* there should be am IRQ timeout timer running */

    if (npInst->IRQTimerHandle) {
     ADD_CancelTimer (npInst->IRQTimerHandle); /* cancel the timer, got IRQ */
      npInst->IRQTimerHandle = 0;
      Claimed = 1;
    } /* else spurious */
```

Interrupt Handler

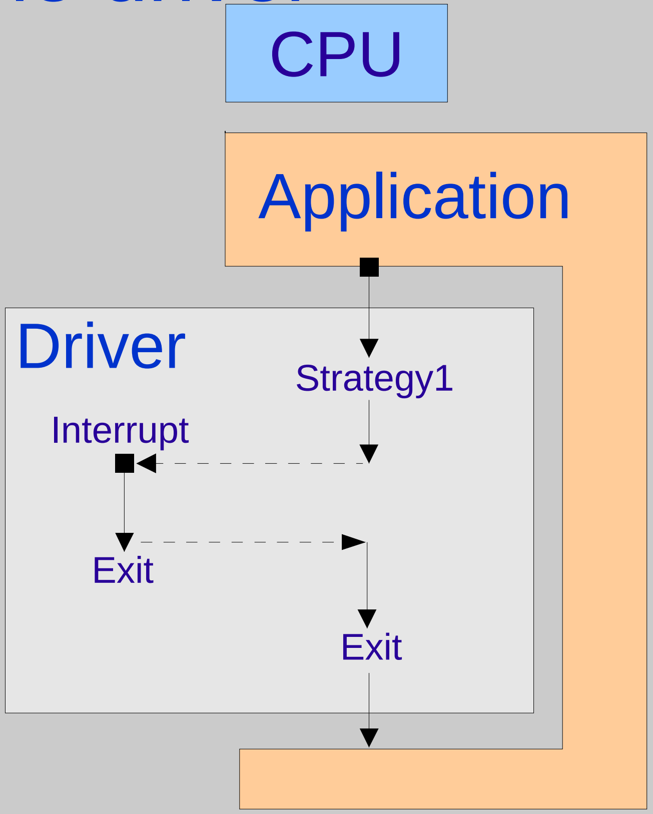
```
    /* reenable IRQ handling both globally and for this particular IRQ   */

    ENABLE
    DevHelp_EOI (npInst->IRQLevel);

    if (Claimed) {
      /* the actual handler code is running with interrupts enabled!     */

      HandleInterruptForInstance (npInst);

    }

    /* this is a *requirement* !                                         */
    /* if we fail to do so, the OS/2 IRQ dispatcher will shut down this  */
    /* IRQ line                                                          */

    Claimed = 1;

  } else {
    ENABLE
    /* spurious */
  }
  return (Claimed);
}
```

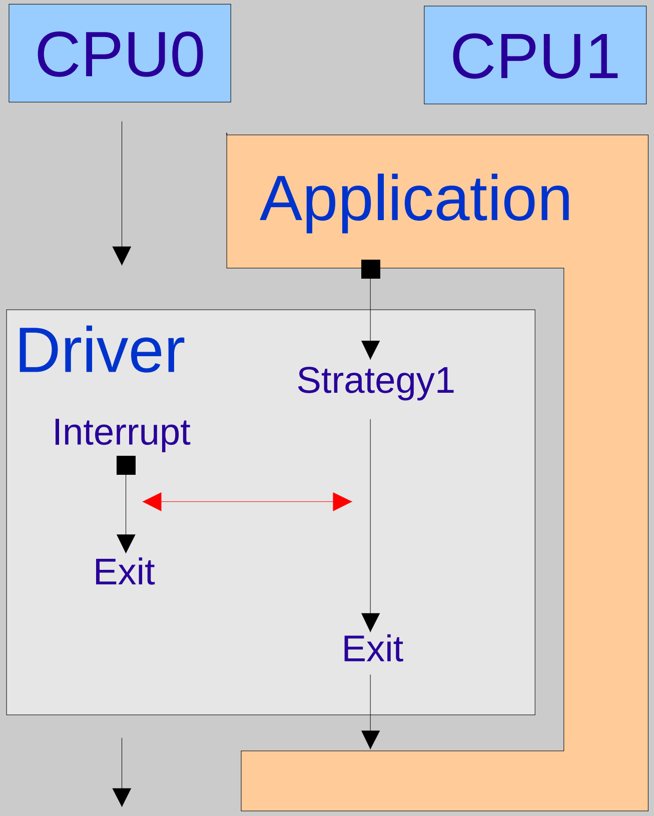
Interrupt Handler

- Interrupts **preempt** task time execution
- Interrupts **may** preempt interrupt time execution
- Interrupts may preempt their **own** interrupt handlers
- at each preemption, temporary resources (like memory mappings) may become **invalid**
- every preemption **costs** system resources (f.e. stack space)

Interrupts and SMP

On SMP systems interrupt handlers may execute **concurrently** with other parts of the same driver





Timer Handlers

- Timer handlers are in fact interrupt handlers, the same rules apply
- if you need multiple timers, the use of ADDCall.lib is recommended. It implements:
  - free running timers
  - one-shot timers
  - each timer may have different time intervals
  - each timer may have arguments

Timer Handlers

```
/* Expected interrupt timeout routine */
VOID FAR _cdecl IRQTimer (USHORT TimerHandle, ULONG Parameter1, ULONG Parameter2)
{
  /* cancelling the timer makes it an one-shot timer! */
  ADD_CancelTimer (TimerHandle);

  do something useful here
}

/* free running timer with a given call interval */
VOID FAR _cdecl Ticker (USHORT TimerHandle, ULONG Parameter1, ULONG Parameter2)
{
  do something useful here
}

{ /* Initialize timer pool */

  ADD_InitTimer (TimerPool, sizeof (TimerPool));

  /* start a timer to call function 'Ticker' with arguments arg1 and arg2 */
  /* repeatedly after each TICKER_INTERVAL milliseconds                   */

  ADD_StartTimerMS (&TickerHandle, TICKER_INTERVAL, (PFN)Ticker, arg1, arg2);

  /* stop all timer processing and destroy timer pool */

  ADD_DeInstallTimer();
}
```

IDC Entry Point

- The presence of an IDC entry point and its location within the driver's default code segment is advertised in the device driver header structure
- you need to specify in which execution contexts your IDC services may be called
- if you allow calls in interrupt context the same rules as for interrupt handlers apply
- most likely you need an assembler stub

IDC Entry Point

```
         EXTRN   _IDCHandler:NEAR/FAR

; VOID NEAR/FAR _cdecl IDCHandler (/* any argument type */)

; IDC stub to C handler routines
; needs to be located in the driver default code segment

         PUBLIC _IDCStub
_IDCStub PROC FAR

         PUSH ES
         PUSH DS
         PUSHAD

; handle arguments here to match the handler function prototype

         MOV  DS, CS:[_DSSel]
         CALL _IDCHandler

         POPAD
         POP  DS
         POP  ES
         RET

_IDCStub END

_DSSel   DW   SEG _DATA
```

Context Hooks

- Context hooks do deferred task time processing of interrupt time events (similar to DPCs in WindowsNT)
- Context hooks are excecuted after all interrupt processing at the next schedule point
- Context hooks can be armed only once until the next execution of the context hook code, multiple invocations need to be queued
- most likely you need an assembler stub

Context Hooks

```
        EXTRN   _CxtHookHandler:NEAR/FAR

; context hook handler entry points need to be located in the
; default code segment!

; VOID NEAR/FAR _cdecl CtxHookHandler (/* any argument type */)

        PUBLIC _CtxHookStub

_CtxHookStub PROC FAR

        PUSH ES
        PUSH DS
        PUSHAD

        PUSH EAX   ; stack frame is compatible to any data type
        MOV  DS, CS:[_DSSel]
        CALL _CtxHookHandler
        ADD  SP, 4

        POPAD
        POP  DS
        POP  ES
        RET

_CtxHookStub ENDP

_DSSel  DW   SEG _DATA
```

APM Events

- APM event callbacks are possibly called in interrupt context, so the general interrupt handling rules apply
- if necessary, defer APM processing to task time by using a context hook (f.e. device reinitialization after system resume)
- the OS/2 APM subsystem may not be available even if APM is active; the driver needs to handle this scenario gracefully

APM Registration

```
/* attach to APM at processing of the InitComplete request packet */

{
  UCHAR noAPM;

  /* attach to APM */

  if (!(noAPM = APMAttach())) {

    /* if attached, register for suspend and resume */

    APMRegister ((PAPMHANDLER)APMEventHandler,
                  APM_NOTIFYSETPWR | APM_NOTIFYNORMRESUME |
                  APM_NOTIFYCRITRESUME | APM_NOTIFYSTBYRESUME,
                  0);

    /* prepare driver to deal with APM notifications */

  } else {

    /* prepare driver to deal with APM events (like suspend) even if it */
    /* doesn't see any notifications about them!                        */

  }
}
```

APM Registration

```
USHORT FAR _cdecl APMEventHandler (PAPMEVENT Event) {
  USHORT Message = (USHORT)Event->ulParm1;
  USHORT PowerState;

  if (Message == APM_SETPWRSTATE) {
    PowerState = (USHORT)(Event->ulParm2 >> 16);
    if (PowerState != APM_PWRSTATEREADY)
      return (APMSuspend (PowerState));
  } else if ((Message == APM_NORMRESUMEEVENT) ||
             (Message == APM_CRITRESUMEEVENT) ||
             (Message == APM_STBYRESUMEEVENT)) {
    PowerState = 0;
    return (APMResume());
  }
  return 0;
}

USHORT NEAR APMSuspend (USHORT PowerState) {
  if (PowerState == APM_PWRSTATESUSPEND) {
    /* prepare hardware and software for suspend */
  }
  return 0;
}

USHORT NEAR APMResume() {
  /* restore/reinitialize hardware and software after resume */
  return 0;
}
```

PCCard/Cardbus

- The card services subsystem is optional, the driver needs to be prepared not to find it
- the minimum set of card service events to be handled is
  - CLIENTINFO (identify as client driver)
  - CARD_INSERTION
  - CARD_REMOVAL
- you may decide to handle more events
- most likely you need an assembler stub

Card Services Registration

```
/* Attach to PCMCIA.SYS
 * check for presence of card service
 * allocate a context hook for deferred processing of events
 * register driver with card services
 * scan sockets for PCCards already inserted (no card insertion events
   will be generated!)
 */

USHORT NEAR PCMCIASetup() {
  if (SELECTOROF(CSIDC.ProtIDCEntry) != NULL)
    return (FALSE);    /* already initialized */

  if (!DevHelp_AttachDD (PCMCIA_DDName, (NPBYTE)&CSIDC) &&
       CardServicesPresent() &&
      !DevHelp_AllocateCtxHook ((NPFN)&CSHookHandler, (PULONG)&CSCtxHook) &&
      !CSRegisterClient()) {
    int Socket;

    for (Socket = 0; Socket < NumSockets; Socket++)
      if (0 == CSCardPresent (Socket)) {
        PCCardPresent |= (1 << Socket);
      }
    return (FALSE);
  }
  return (TRUE);
}
```

Card Services Events

```
VOID NEAR _cdecl CSCallbackHandler (USHORT Socket, USHORT Event, PUCHAR Buffer)
{
  /* release resources if a card removal event occurs */
  /* acquire resources if card insertion event occurs */

  switch (Event) {
    case CARD_REMOVAL:
      if (!InitComplete) return;
      PCCardPresent &= ~(1 << Socket);
      CSUnconfigure (Socket);
      CardRemoval (Socket);
      return;

    case CARD_INSERTION:
      if (!InitComplete) return;
      if (CSConfigure (Socket) == 0) {
        PCCardPresent |= (1 << Socket);
        CardInsertion (Socket);
      }
      return;

    case CLIENTINFO:
      /* fill client info structure */
      return;

    /* handle other events if required */
  }
}
```

Card Services Events

```
USHORT NEAR CardRemoval (USHORT Socket) {
  /* handle removal of a PCCard
   * - detach hardware from the supporting driver code
   * - release resources allocated to the hardware being removed
   * - prepare driver to handle calls directed at removed hardware *gratiously*
   */
  return (0);
}

USHORT NEAR CardInsertion (USHORT Socket) {
  /* handle insertion of a PCCard (part I)
   * - allocate resources to the hardware being inserted
   * - make a *short* test if hardware is supported and healthy
   * - release resources if test fails
   */

  if (test passed) {
    /* defer full initialization (make take long) */

    DevHelp_ArmCtxHook (Socket, CSCtxHook);

  } else {
    /* release resources */

    CSUnconfigure (Socket);
  }
  return (0);
}
```

Card Services Events

```
USHORT NEAR _fastcall CardInsertionDeferred (USHORT Socket) {

   /* handle insertion of a PCCard (part II)
    * - full initialization of the newly inserted PCCard
    * - release resources if initialization fails
    */

   if (initialized) {

    /* attach hardware to the supporting driver code */

   } else {

     /* release resources */

     CSUnconfigure (Socket);
   }
   return (0);
}
```

Card Services Stub

```
; VOID FAR   _cdecl CSCallbackStub()
; VOID NEAR _cdecl CSCallbackHandler (USHORT Socket, USHORT Event,
;                                      PUCHAR Buffer)
        PUBLIC _CSCallbackStub

_CSCallbackStub PROC FAR

        PUSHF
        PUSHA
        PUSH   DS
        PUSH   ES              ; setup buffer pointer
        PUSH   BX
        AND    AX, 00FFh
        PUSH   AX              ; set up event number,
        PUSH   CX              ; socket number
        MOV    AX, _DATA       ; and data segment
        MOV    DS, AX
        CALL   _CSCallbackHandler
        ADD    SP, 3*2

        POP    ES
        POP    DS
        POPA
        POPF
        RET

_CSCallbackStub ENDP
```

Resource Management

- From a device driver's view, resource manager offers two basic services:
  - maintaining and validating hardware resources
  - maintaining and looking up the device database
- the former is mandatory, the latter is optional

Resource Management

- As a bare minimum, your driver must register with Resource Manager if it stays resident
- for users, this is the only way to find out if a driver is actually loaded by means of tools provided by a standard OS/2 installation (i.e. RMView /D)
- for developers, this is the easiest way to find out which hardware resources a driver is operating on

Resource Management
Resources

- every device driver creates a driver object in RM. Software only drivers are done here.
- for each device, drivers allocate hardware resource objects in RM and check for collisions
- in case of success, drivers:
  - create an adapter object for each hardware instance they handle and assign them to the driver object
  - assign hardware resources to the adapter objects
  - possibly create and assign device objects

Resource Management
Hardware Look-up

- Device drivers may look up the OS/2 device database for supported hardware
- this database is updated at each boot or on demand by means of the snooper drivers (SNOOP.LST)
- the hardware look-up may be for **exact** matches of device identifiers (PnP, PCI, EISA) or for **compatible** devices (f.e. »looks like an IDE port«)

OEMHelp Services

- OEMHelp provides access to configuration type BIOS services:
  - query video info
  - query MCA and ESCD info
  - enumerate and configure PCI adapters
- the OEMHelp PCI functions are more appropriate for device discovery in case of class specific drivers or info not maintained by the snoopers

OEMHelp Services

- OEMHelp may be called at DEVICE init time (ring 3) through regular 16-bit DosCalls
- OEMHelp needs to be called at BASEDEV init or task time (ring 0) through an IDC interface. This requires an assembler stub.

OEMHelp Services

```
CHAR     OEMHLP_DDName[9] = "OEMHLP$ ";
IDCTABLE OemHlpIDC        = { 0 };

UCHAR SetupOEMHlp() {
  if ((SELECTOROF(OemHlpIDC.ProtIDCEntry) != NULL) &&
      (OemHlpIDC.ProtIDC_DS != NULL))
    return (0);     /* alread initialized */

  /* Setup Global OEMHlp Variables */
  if (DevHelp_AttachDD (OEMHLP_DDName, (NPBYTE)&OemHlpIDC))
    return (1);     /* Couldn't find OEMHLP's IDC */

  if ((SELECTOROF(OemHlpIDC.ProtIDCEntry) == NULL) ||
      (OemHlpIDC.ProtIDC_DS == NULL))
    return (1);     /* Bad Entry Point or Data Segment */
  return (0);
}

/* example */
{
  RP_GENIOCTL IOCtlRP;

  /* Setup IO Control Packet here */

  return (CallOEMHlp ((PRPH)&IOCtlRP));
}
```

OEMHelp Services

```
; USHORT FAR _fastcall CallOEMHlp (PRPH pRPH);

@CallOEMHlp PROC FAR
         PUSH  BP
         MOV   BP, SP
         PUSH  SI
         PUSH  DI
         LES   BX, DWORD PTR [BP+6]
         TEST  WORD PTR [_OemHlpIDC.Entry], -1
         JNZ   DoOEMHlp

         MOV   AX, 8100h
         MOV   WORD PTR ES:[BX+3], AX
         JMP   SHORT CallOEMHlpEnd
DoOEMHlp:
         PUSH  [_OemHlpIDC.Entry]
         PUSH  DS
         MOV   DS, [_OemHlpIDC.DSeg]
         CALL  DWORD PTR [BP-8]
         POP   DS
         ADD   SP, 4
         MOV   AX, WORD PTR ES:[BX+3]
CallOEMHlpEnd:
         AND   AX, 8000h
         POP   DI
         POP   SI
         LEAVE
         RET   4
@CallOEMHlp ENDP
```