Generic Audio Driver for Windows CE 6.0

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Structure

- **Generic Audio Driver**
  - Project description
  - Overall design
  - **Control Framework**
    - Overall design
    - Sample driver
  - **Generic Wavedev2**
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    - Sample implementations
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Generic Audio Driver Description

- **Problem**

  The need to support multiple audio codec drivers on multiple platforms under WinCE 6.0.

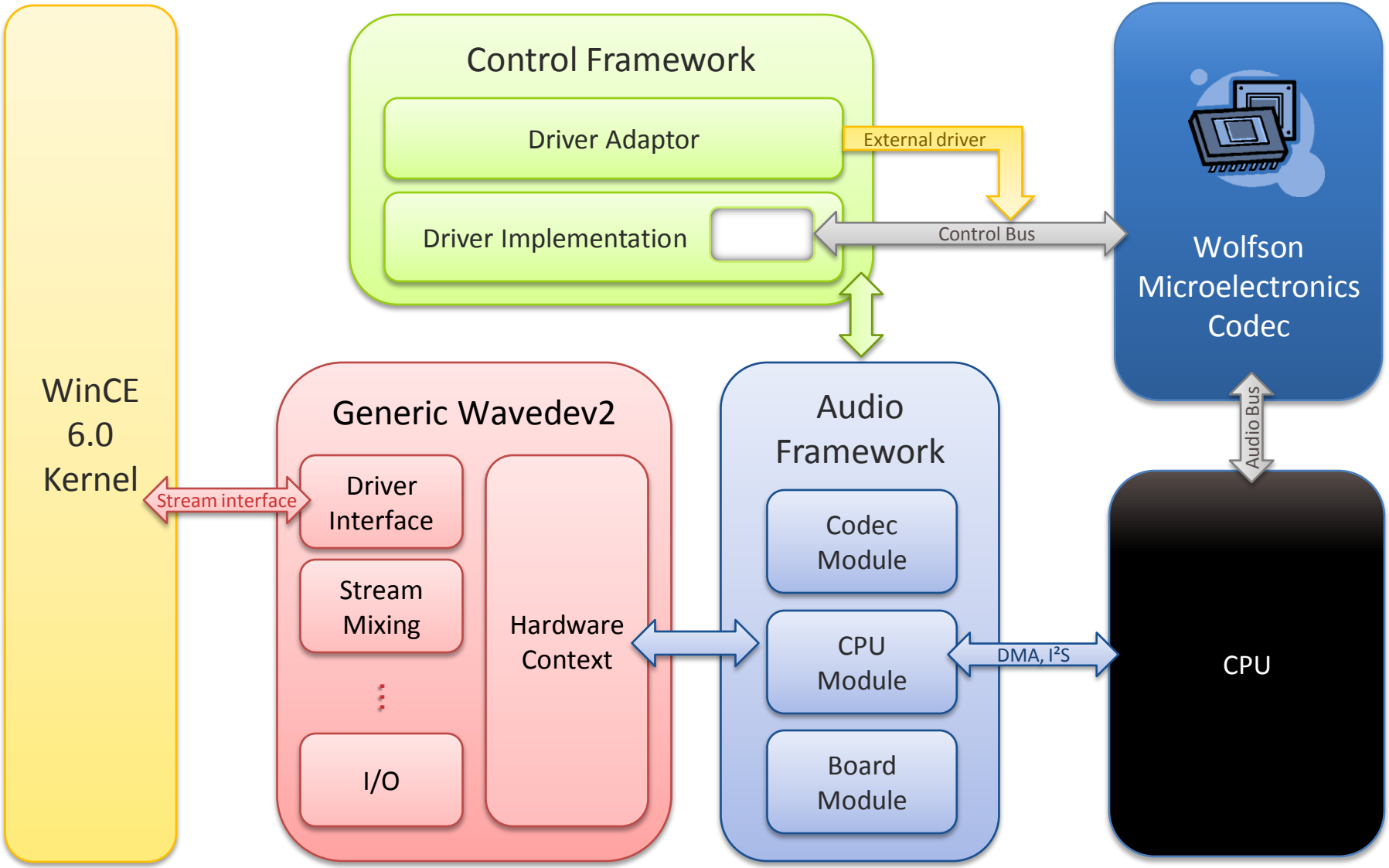
- **Previous situation**

  Different platform vendors use different audio drivers. Linux example: four distinct drivers for WM8731.

  Leads to poor code re-use, maintenance/bug tracking difficulties, complicated new platform/codec support, ...

- **Solution**
  - Use standard WinCE 6.0 approach to audio drivers – Generic Wavedev2.
  - Separate chip control from audio data – Control Framework.
  - Separate CPU, board and codec – Audio Framework.

Overall Design



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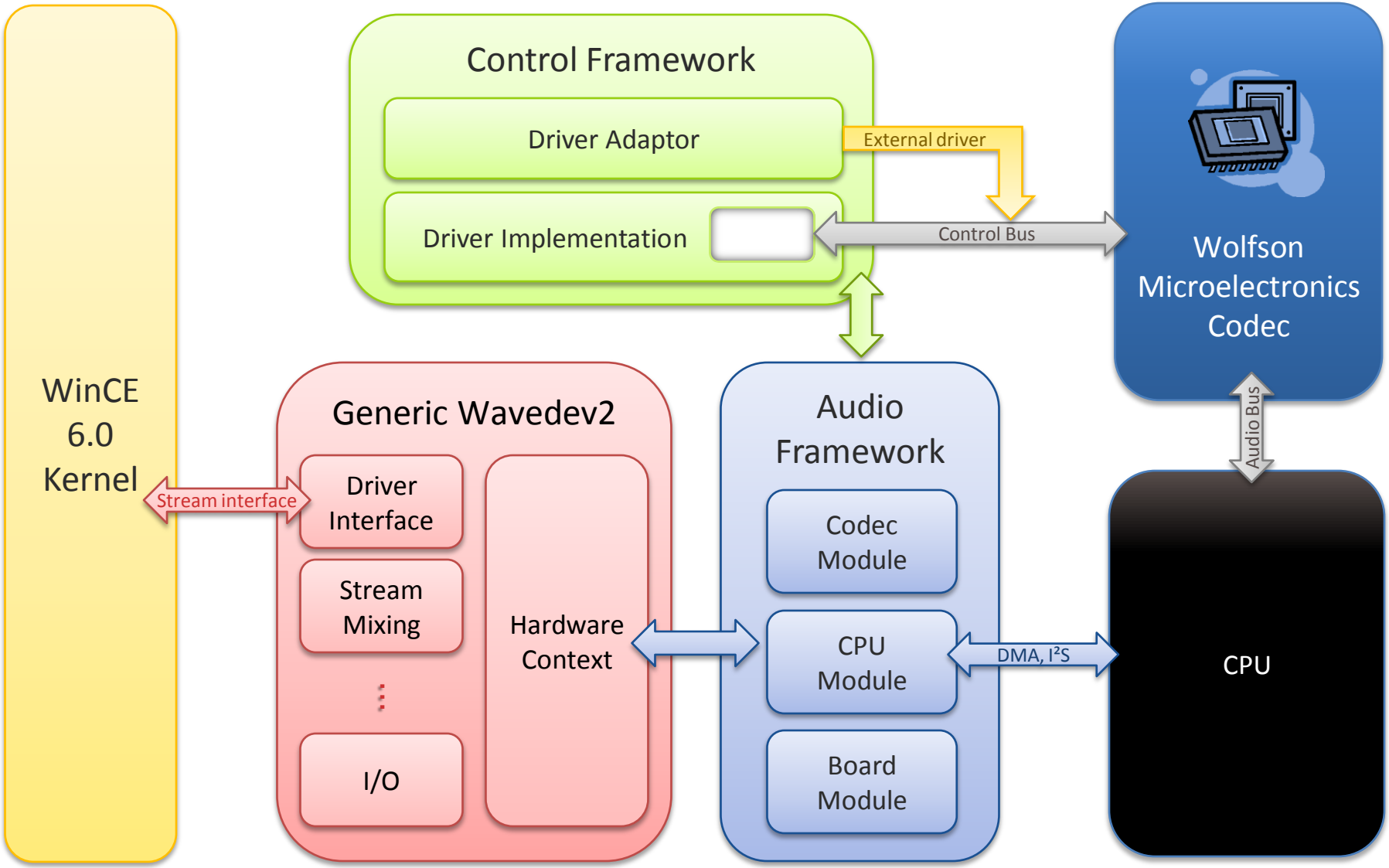

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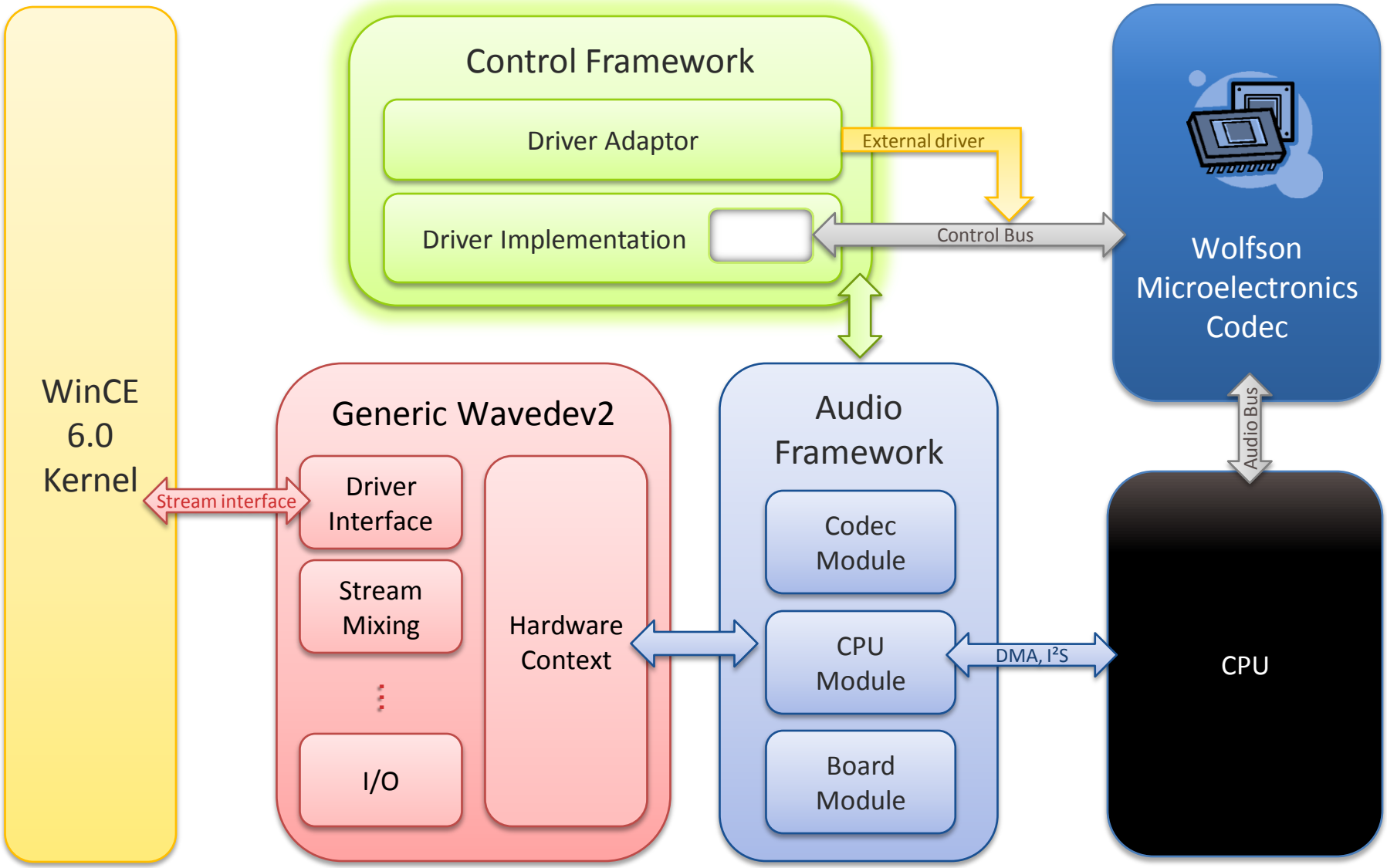
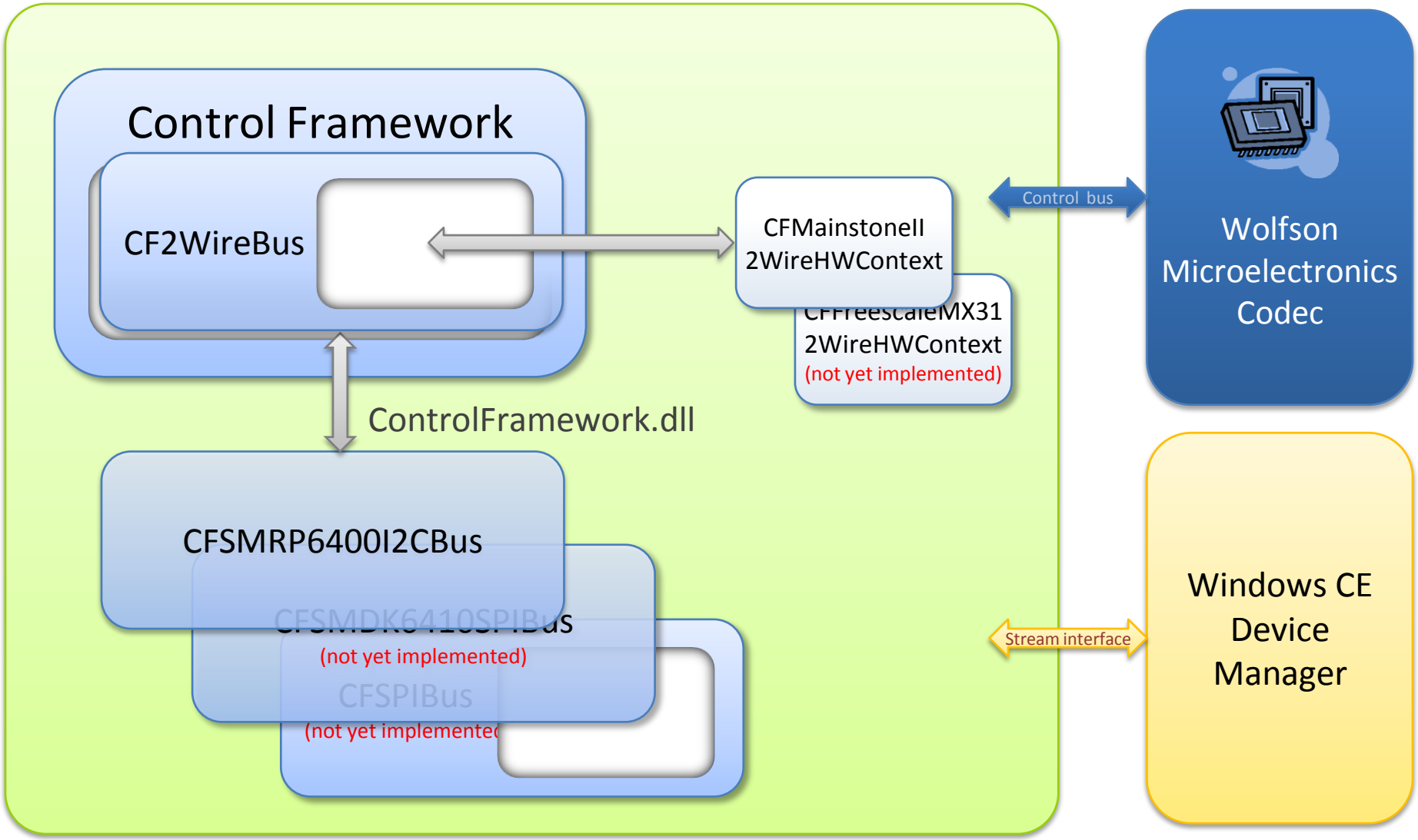


Control Framework

- Provides IC control using same interface across different buses.
- Separates generic bus behaviour and platform-specific implementation details.
- Supports call forwarding if a bus driver exists in the system.
- Acts as a separate driver (.dll).

Control Framework



What does the Control Framework do?

```
PVOID CF2WireBus::Init(PVOID pData)
{
   CFInitContext *pInitContext = 0;
   CFHWContext *hwctx;

   // Initializing the error code
   DoSetLastError(CFS_SUCCESS);

   hwctx = ControlFramework::GetInstance().GetHWContext();
   if (!hwctx) { ... }

   pInitContext = (CFInitContext *)LocalAlloc(LPTR,
        sizeof(CFInitContext));
   if (!pInitContext)    { ... }

   InitializeCriticalSection(&(pInitContext->critSec));
   if (!hwctx->Init(pInitContext)) { ... }

#if CF_2WIRE_INTR_ENABLE
   g_CF2WireBus_hEvent = CreateEvent(0, FALSE, FALSE, 0);
   if (!g_CF2WireBus_hEvent) { ... }

   DWORD irq2Wire = CF_2WIRE_IRQ;
   if (!KernelIoControl(...)  { ... }

   if (!InterruptInitialize(g_CF2WireBus_sysIntr, ...) { ... }

   g_CF2WireBus_ISTRunning = TRUE;
   g_CF2WireBus_hThread = CreateThread( ... );
   if (!g_CF2WireBus_hThread) { ... }

   HKEY hKey = OpenDeviceKey(pContext);
   if (!hKey) { ... }

   if (RegQueryValueEx(hKey, L"ThreadPriority", ...)  { ... }

   if (!CeSetThreadPriority(g_hTransferThread, threadPriority)) { ... }
   RegCloseKey(hKey);

#endif CF_2WIRE_INTR_ENABLE
   return pInitContext;
}

static DWORD WINAPI g_CF2WireBUS_IST(LPVOID lpParameter)
{
   CFHWContext *hwctx;
   hwctx = ControlFramework::GetInstance().GetHWContext();

   while (g_CF2WireBus_ISTRunning)
   {
      WaitForSingleObject(g_CF2WireBus_hEvent, INFINITE);
      if (!g_CF2WireBus_ISTRunning) { ... }
      if (hwctx)
      {
         hwctx->IST(lpParameter);
      }
      else  { ... }
      InterruptDone(g_CF2WireBus_sysIntr);
   }
   return CFS_SUCCESS;
}
```

What does the hardware context do?

```
CF_STATUS CFMainstoneII2WireHWContext::Read(PVOID pOpenContext,
      CFIo *in,
      BOOL isEndOfTransmission, DWORD *bytesRead)
{
   DWORD numberOfWriteTries = 5;
   DWORD numberOfReadTries = 5;
   CFOpenContext *pContext = (CFOpenContext *)pOpenContext;
   CF_STATUS retVal = CFS_SUCCESS;
   XLLP_UINT32_T reg;

   twowire_regs->ICR = XLLP_ICR_UIE | XLLP_ICR_SCLEA;
RepeatedWrite:
   twowire_regs->IDBR = (in->GetSlaveAddress() << 1) | XLLP_IDBR_MODE;
   // Initiate the write
   reg = twowire_regs->ICR;
   reg &= ~(XLLP_ICR_ALDIE | XLLP_ICR_STOP);
   reg |= (XLLP_ICR_START | XLLP_ICR_TB);
   twowire_regs->ICR = reg;

   if (!WriteFinished(twowire_regs, WRITE_TIMEOUT)) {
      numberOfWriteTries--;
      if (numberOfWriteTries > 0) goto RepeatedWrite;
      // Send STOP condition
      twowire_regs->ICR &= ~XLLP_ICR_START;
      twowire_regs->ICR |= XLLP_ICR_STOP;
      retVal = CFS_DATA_TIMED_OUT;
      goto StopCondition;
   }

   for (DWORD i = 0; i < in->GetCount(); i++)
   {
RepeatedRead:
      // Initiate the read
      reg = twowire_regs->ICR;
      reg &= ~(XLLP_ICR_START | XLLP_ICR_STOP);
      reg |= XLLP_ICR_ALDIE | XLLP_ICR_TB;

      if ((in->GetCount() - 1) != i) { ... }
      else // Last byte { ... }
      twowire_regs->ICR = reg;

      // Wait for transmission
      if (!ReadFinished(twowire_regs, READ_TIMEOUT)) { ... }

      // Save the data
      (in->GetInData())[i] = (UCHAR)(twowire_regs->IDBR & 0xFF);

      if (bytesRead)
      {
         ++*bytesRead;
      }
   }

StopCondition:
   // Signal stop
   twowire_regs->ICR &= ~(XLLP_ICR_STOP | XLLP_ICR_ACKNACK);
   twowire_regs->ICR &= ~(XLLP_ICR_UIE | XLLP_ICR_SCLEA);

   return retVal;
}
```

What does the driver adapter do?

```
DWORD CFSMRP6400I2CBus::Read(PVOID hOpenContext,
      LPVOID pBuffer, DWORD count)
{
   CFOpenContext *pOpenContext =
     (CFOpenContext *)hOpenContext;
   CFIo *ioData = (CFIo*)pBuffer;
   DWORD retVal = 0;

   // Initializing the error code
   DoSetLastError(CFS_SUCCESS);

   if (!pBuffer || sizeof(CFIo) != count ||
      !ioData->GetCount() ||
      !ioData->GetInData() ||
      !ioData->GetOutData())
   {
      SetLastError(ERROR_INVALID_PARAMETER);
      ...
   }

   IIC_IO_DESC IIC_Data_In;
   IIC_Data_In.SlaveAddress =
     (ioData->GetSlaveAddress() << 1) + 1;
   IIC_Data_In.Data = ioData->GetInData();
   IIC_Data_In.Count = ioData->GetCount();

   IIC_IO_DESC IIC_Data_Out;
   IIC_Data_Out.SlaveAddress =
     (ioData->GetSlaveAddress() << 1) + 1;
   IIC_Data_Out.Data = ioData->GetOutData();
   IIC_Data_Out.Count = ioData->GetRegisterWidth();

   if (!DeviceIoControl(pOpenContext->hDriverHandle,
                IOCTL_IIC_READ,
                &IIC_Data_Out, sizeof(IIC_IO_DESC),
                &IIC_Data_In, sizeof(IIC_IO_DESC),
                &retVal, NULL))
   {...}

   return retVal;
}
```

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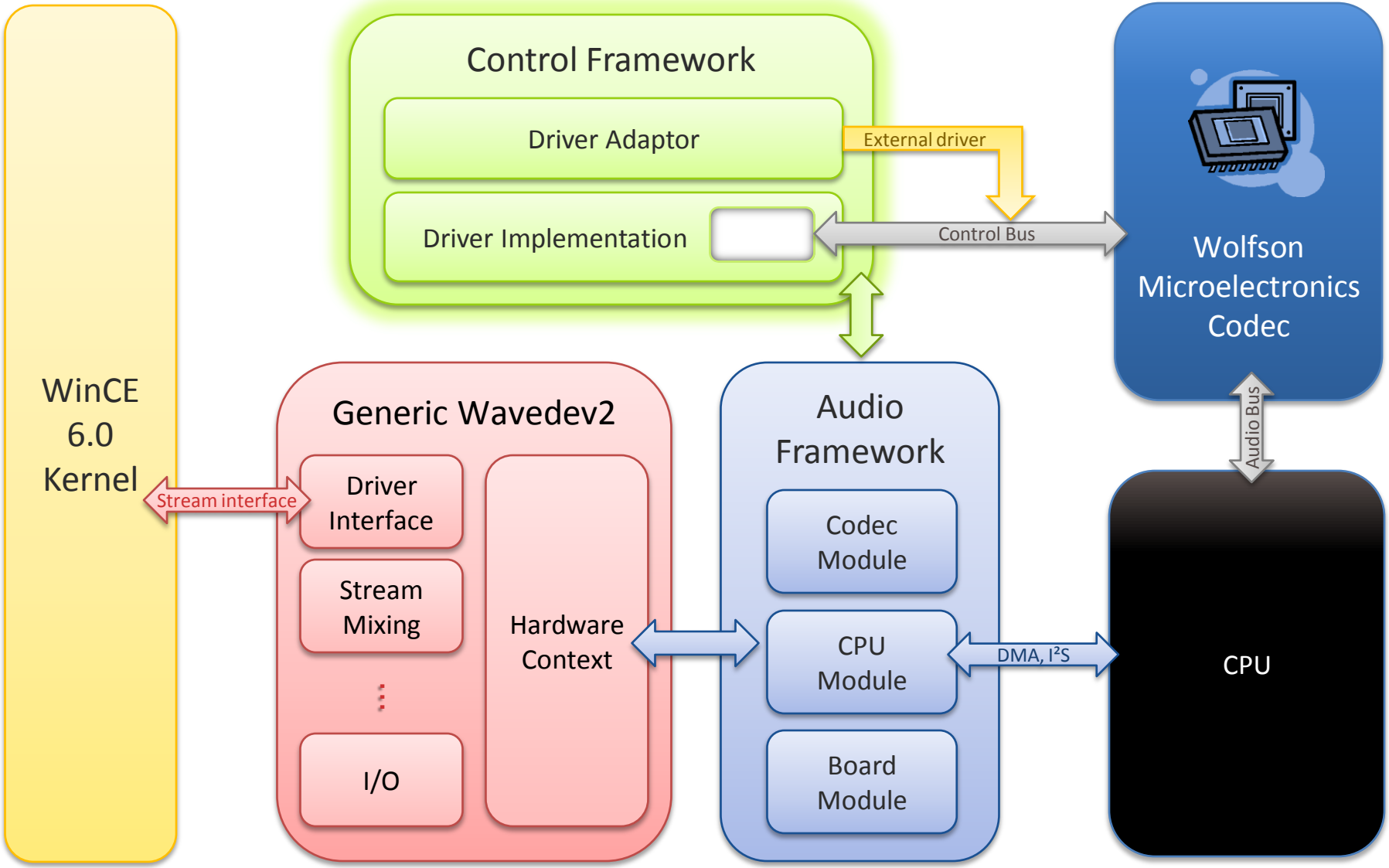

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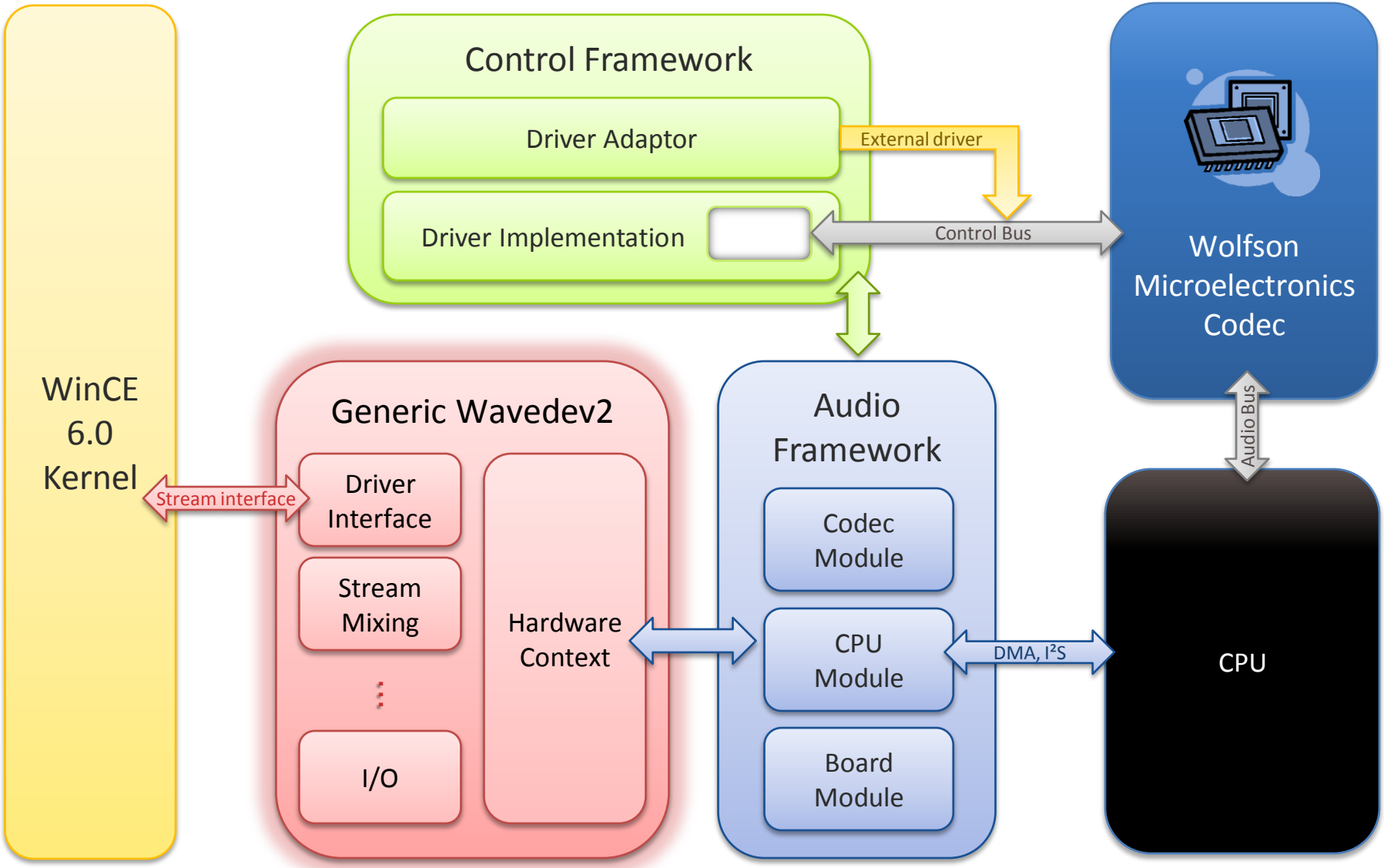

Wavedev2

- Standardized Windows CE approach to audio drivers.
- Multiple-stream input/output support, built-in mixing, volume control, format/sample-rate conversion.

Structure	
devctxt.cpp	Implementation of device context class
input.cpp	Implementation of audio input streams
midistrm.cpp	Implementation of MIDI stream and MIDI parser
mixerdrv.cpp	Implementation of Mixer API classes
output.cpp	Implementation of audio output streams
strmctxt.cpp	Implementation of base audio stream class
wavemain.cpp	Device driver interface
hwctxt.cpp	Implementation of hardware context class

Problem

- Different (and incompatible) Wavedev2 drivers in every BSP.
- Insufficiently abstracted from hardware – portability, code re-use and support issues.
- Not flexible enough – many input/output formats not supported by the driver, e.g. stereo playback on mono output.

Solution

- Different Wavedev2 drivers analysed (Microsoft/Ensoniq, WM's WDCL, others) best ideas used when writing a Generic Wavedev2 driver.
- Extended stream and mixing support.
- Hardware specific behaviour migrated into the hardware context (hwctxt.cpp).
- The latter formed the basis for the Audio Framework: further hardware separation into codec, board and CPU.

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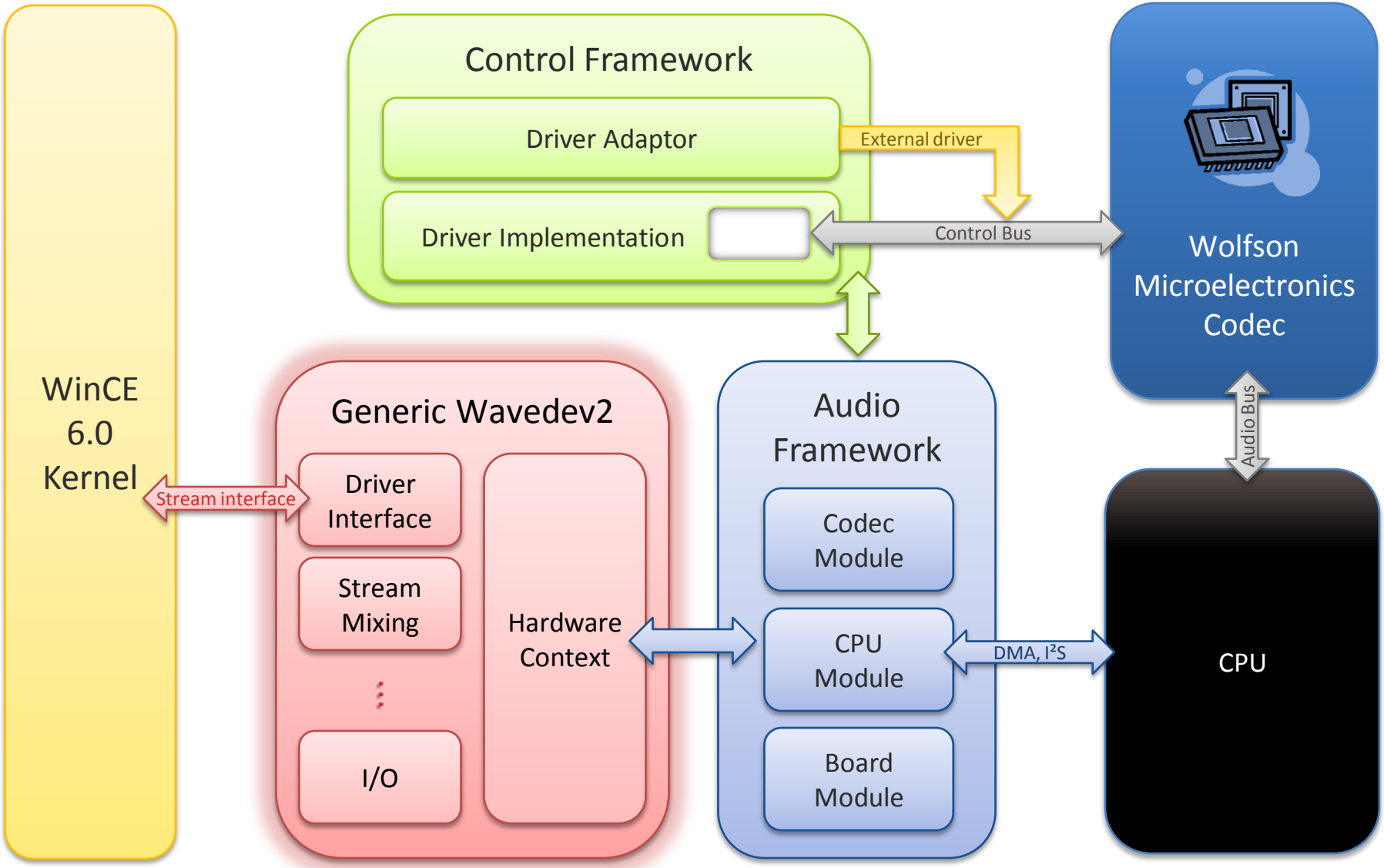

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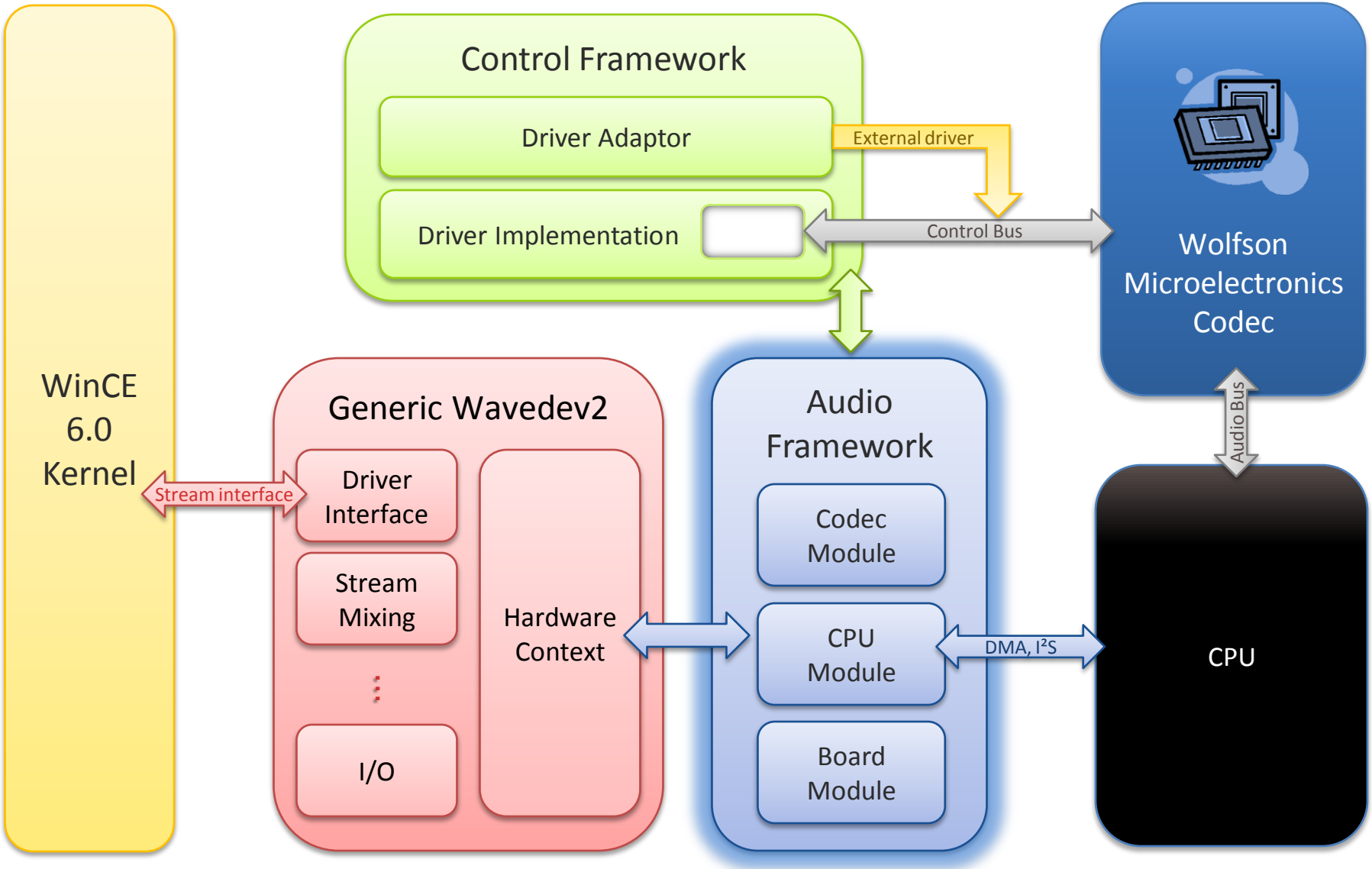
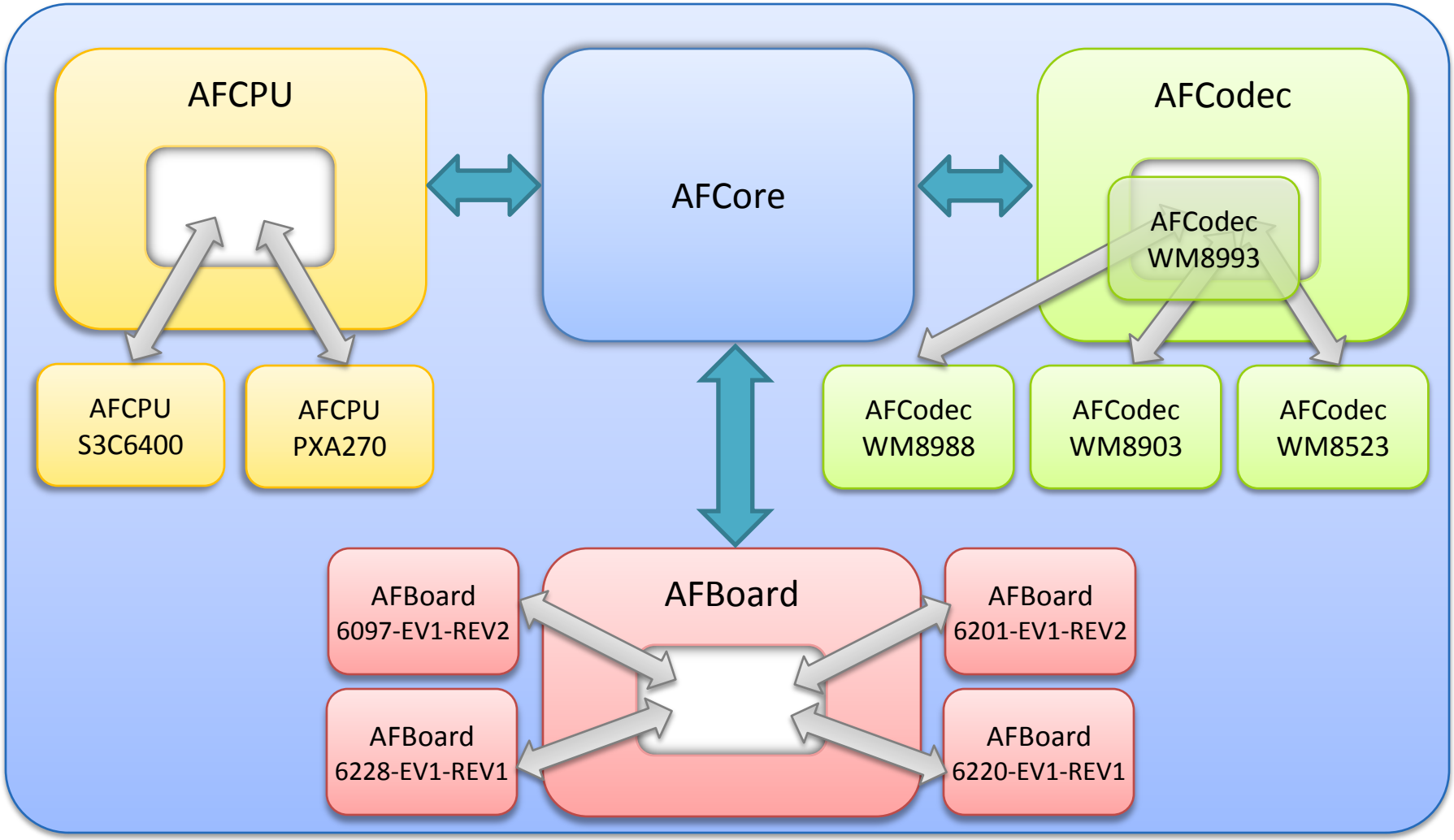


Audio Framework

- The Audio Framework is an abstraction layer that allows audio codec drivers to integrate with multiple target platforms.
- Separates CPU, board and codec implementation details.
- Provides auto-configuration facilities such as clocking, capabilities matching and path management.
- Features a flexible and extensible API. Future extensions might include advanced power management and dynamic routing.

Overall design:



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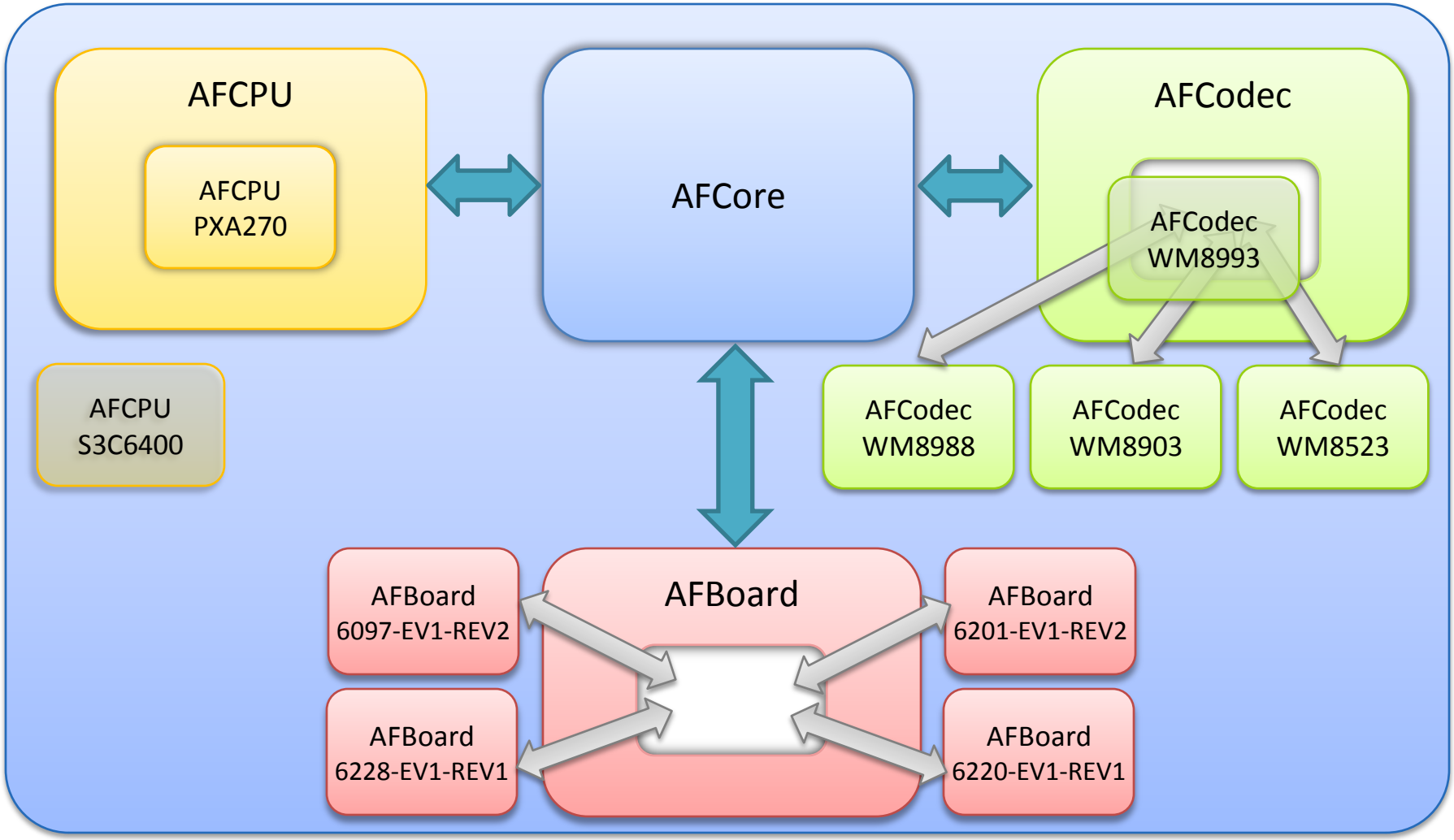

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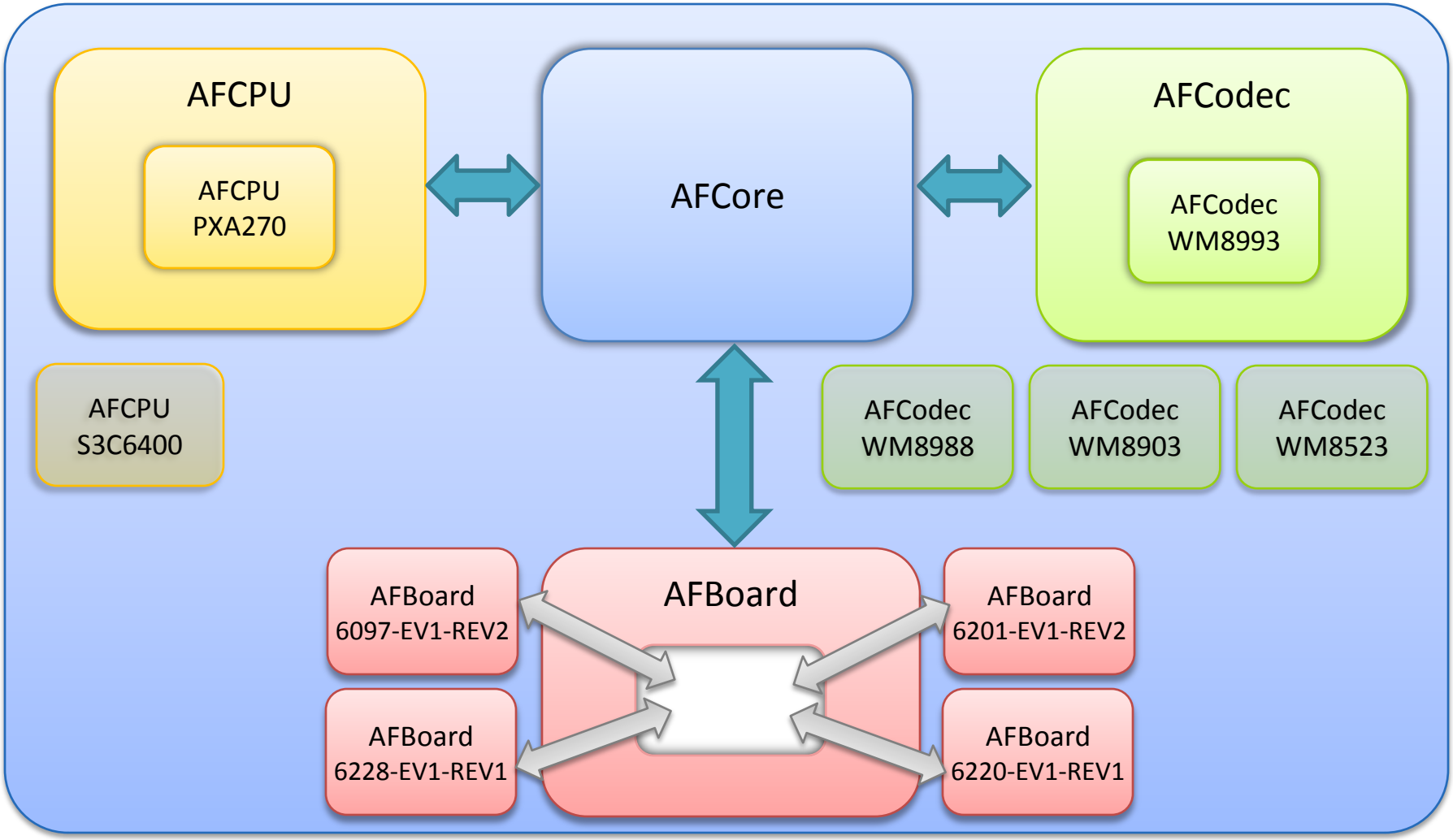

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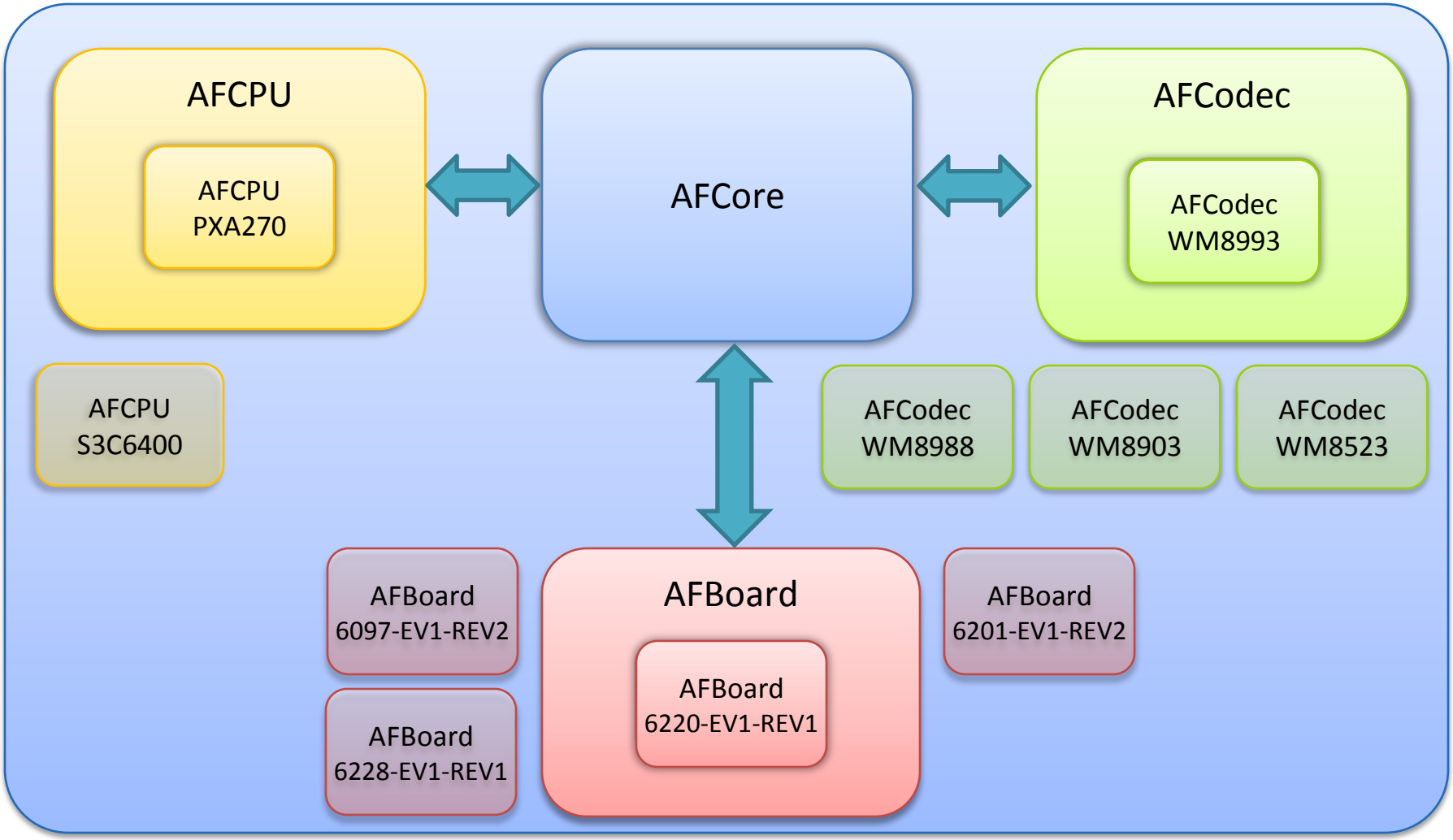


Supported platforms:

- MainstoneIII (I^2C, I^2S, DMA)
- Samsung SMRP6400 (I^2C, I^2S, DMA)

Supported codecs:

- WM8993 (master/slave, playback/recording, multiple formats)
- WM8903 (slave, playback/recording, multiple formats)
- WM8523 (slave, playback, multiple formats)
- WM8988 (slave, playback/recording, multiple formats, basic power management)

Supported boards:

- 6201-EV1-REV2
- 6220-EV1-REV1
- 6228-EV1-REV1
- 6097-EV1-REV2

Adding Codec Support to Audio Framework

To support a new codec you need to:

- Fill in the codec capabilities so it can be picked up by the Audio Framework when doing automatic configuration.
- Implement *AFCodec::Init* to initialize the codec given the currently used path.
- Implement *AFCodec::InitI2SBus* to support all the featured capabilities of the codec such as different sample rates, master/slave playback and recording.
- Implement *AFCodec::Deinit* for shutting down the codec **(optional)**.
- Implement other codec specific functionality like muting/unmuting, actions on power-up/power-down and so on. **(optional)**.

Sample codec implementation

```
AF_STATUS AFCodecHardware::InitI2SBus(AFI2SBusCap *cap)
{
    ...
   if (MASTER == cap->mode)
   {
      USHORT LRCLK_DIV = 2 * cap->bitLength;
      // Master LRCLK
      WRITE_CODEC(WM8993_AUDIO_INTERFACE_4,       LRCLK_DIV);
      FLOAT BCLK_DIV =
        (FLOAT)((USHORT)((core->GetBoard()->GetSysClk() /
        (FLOAT)cap->samplingFreq) + 0.5f)) / (FLOAT)LRCLK_DIV;
      UINT16 i, BCLK_DIV_count = sizeof(BCLK_DIV_valid) /
        sizeof(FLOAT);
      for (i = 0; i < BCLK_DIV_count; ++i)
      {
         if (BCLK_DIV_valid[i] == BCLK_DIV)
         {
            WRITE_CODEC(WM8993_CLOCKING_1,   (i << 1));
            break;
         }
      }
      if (BCLK_DIV_count == i) { ... }
      WRITE_CODEC(WM8993_AUDIO_INTERFACE_3,    0x8000);
   }
   ...
   UINT32 sysRates[] =  { FS_64, FS_128, FS_192, FS_256, FS_384, ... };
   UINT32 sampleFreqs[] = { HZ_8000, HZ_11025, HZ_16000, ... };
   for (int i = 0; i < LEN(sysRates); ++i)
      {
         if (cap->sampleRate == sysRates[i])
         {
            val |= ((i & 0xf) << 1);
            break;
         }
      }

      for (int i = 0; i < LEN(sampleFreqs); ++i)
      {
         if (cap->samplingFreq == sampleFreqs[i])
         {
            val |= ((i & 0xf) << 7);
            break;
         }
      }

      WRITE_CODEC(WM8993_CLOCKING_3,              val   );
      WRITE_CODEC(WM8993_WRITE_SEQ_3,             0x0108);

      return AFS_SUCCESS;
   }
```

Adding CPU Support to Audio Framework

To support a new CPU you need to:

- Fill in the CPU capabilities so it can be picked up by the Audio Framework when doing automatic configuration.
- Map /unmap the registers to memory for configuring the controllers.
- Initialize I2S (either directly or via another driver or library).
- Initialize and prepare DMA (either directly or via another driver or library).
- Create an IST to trigger input/output events in case the CPU does not have distinct IRQs for input/output.
- Implement power up/down functionality.
- Implement other CPU specific functionality **(optional)**.

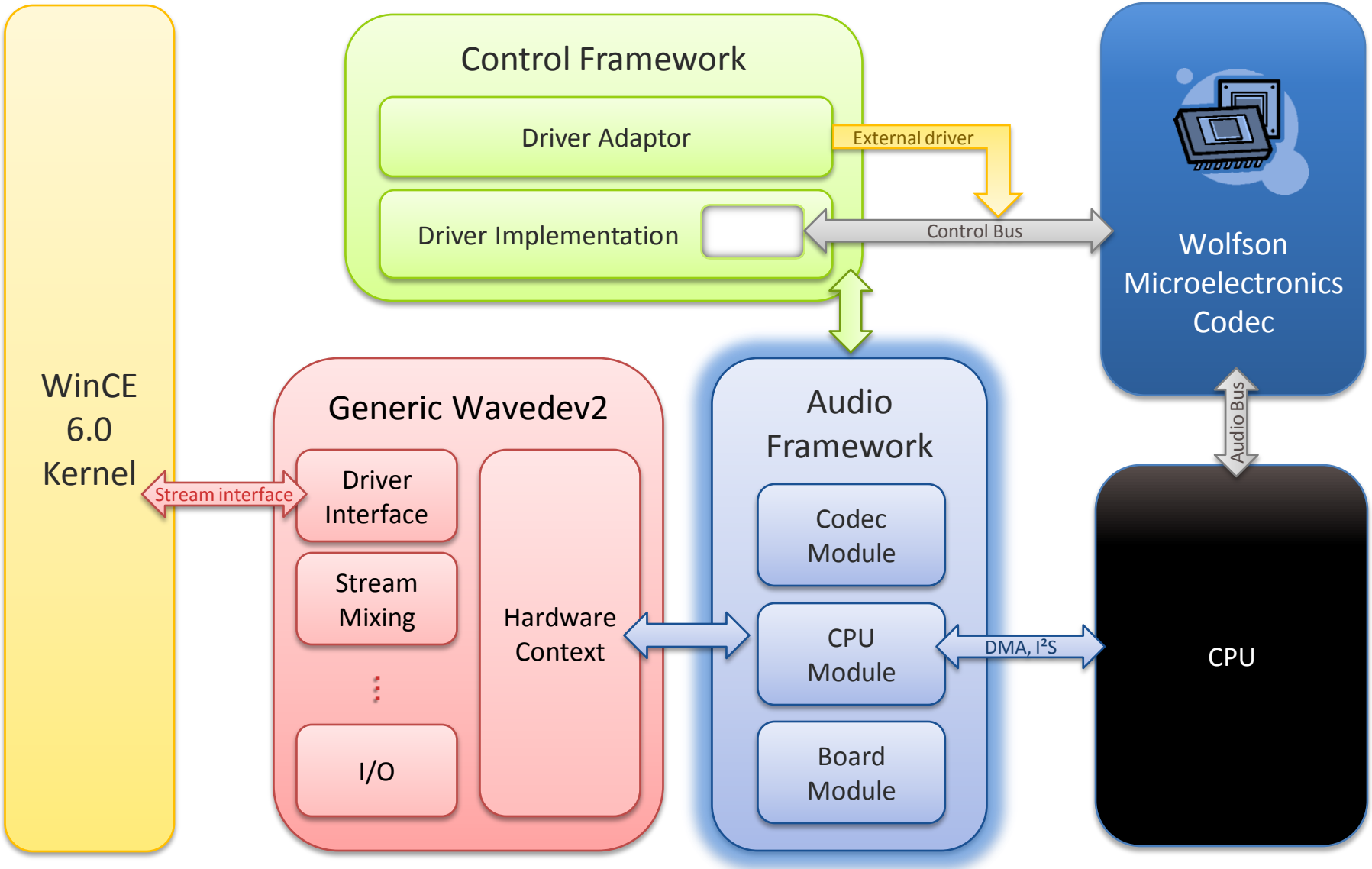
Sample CPU implementation

```
AF_STATUS AFCPUHardware::InitI2SBus(AFI2SBusCap *cap)
{
   ...
   pSysConReg->CLK_SRC = (pSysConReg->CLK_SRC & ~(0x7<<7)) | 0x4;
   pSysConReg->CLK_DIV2 = (pSysConReg->CLK_DIV2 & ~(0xF<<8));
   ...
   IIS_set_active_off();
   IIS_port_initialize(IIS_CH_0);
   ...
   switch (cap->mode)
   {
      case MASTER:
      {
         IIS_set_interface_master_slave_mode(IIS_MASTER_BYPASS_MODE);
      }
      break;
      case SLAVE: { ... }
      break;
      default: { ... }
   }
   sysClk = 16933333.33f;
   switch (cap->samplingFreq)
   {
      case HZ_44100:
      {
         ...
         IIS_set_interface_bit_clock_frequency(IIS_BIT_CLOCK_32FS);
      }
      break;
      case HZ_32000: { ... }
      default: { ... }
   }

   switch (cap->bitLength)
   {
      case BIT_16:
      {
         IIS_set_interface_bit_length(IIS_BIT_LENGTH_16BIT);
      }
      ...
   }

   switch (cap->dataAlign)
   {
      case I2S:
      {
         IIS_set_interface_tranmit_receive_mode(IIS_TRANSFER_BOTH);
         ...
      }
      ...
   }
   ...
   return AFS_SUCCESS;
}
```

Overall Design



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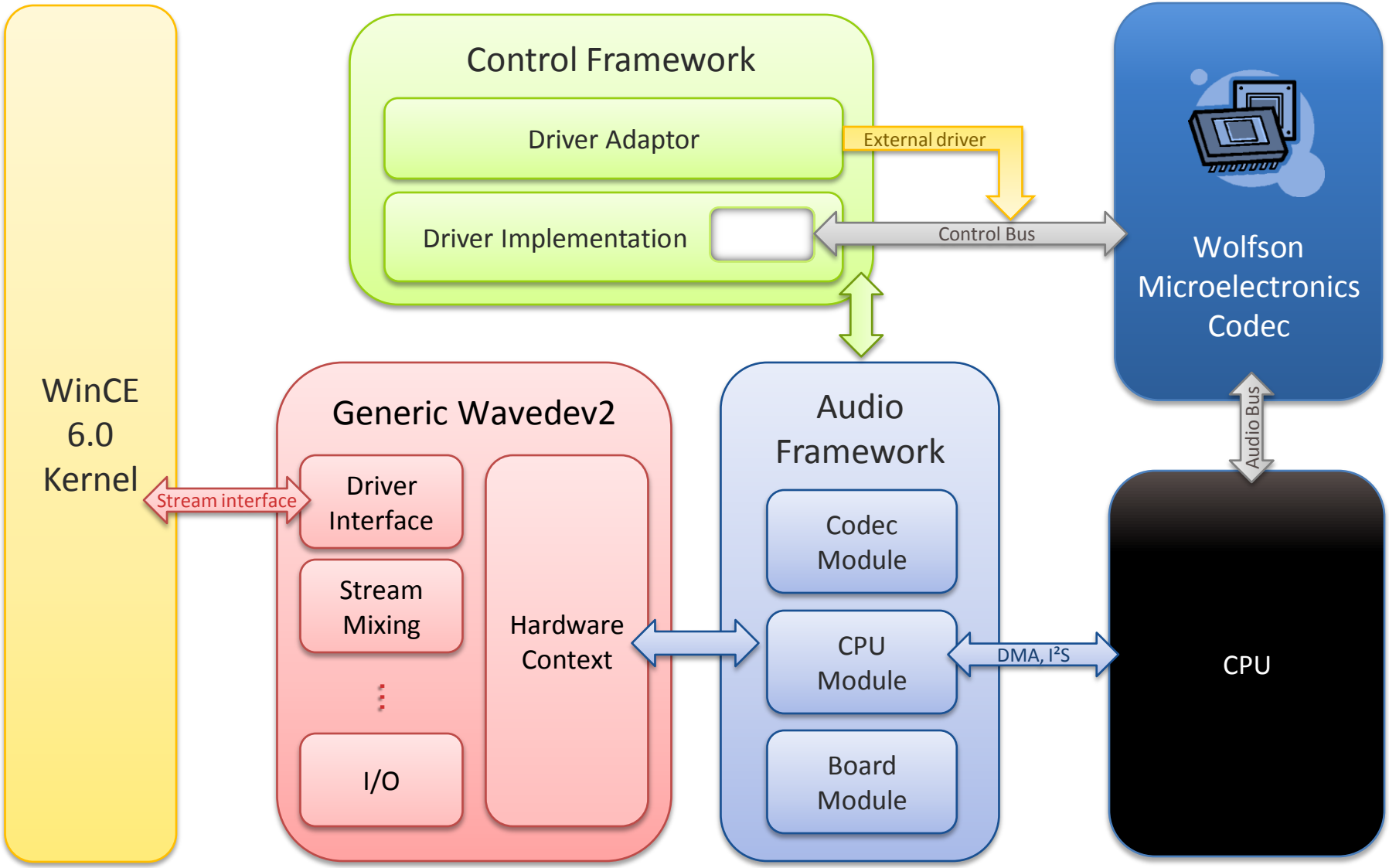

Questions?