HD Digital Video Recorder Using TI DM6467
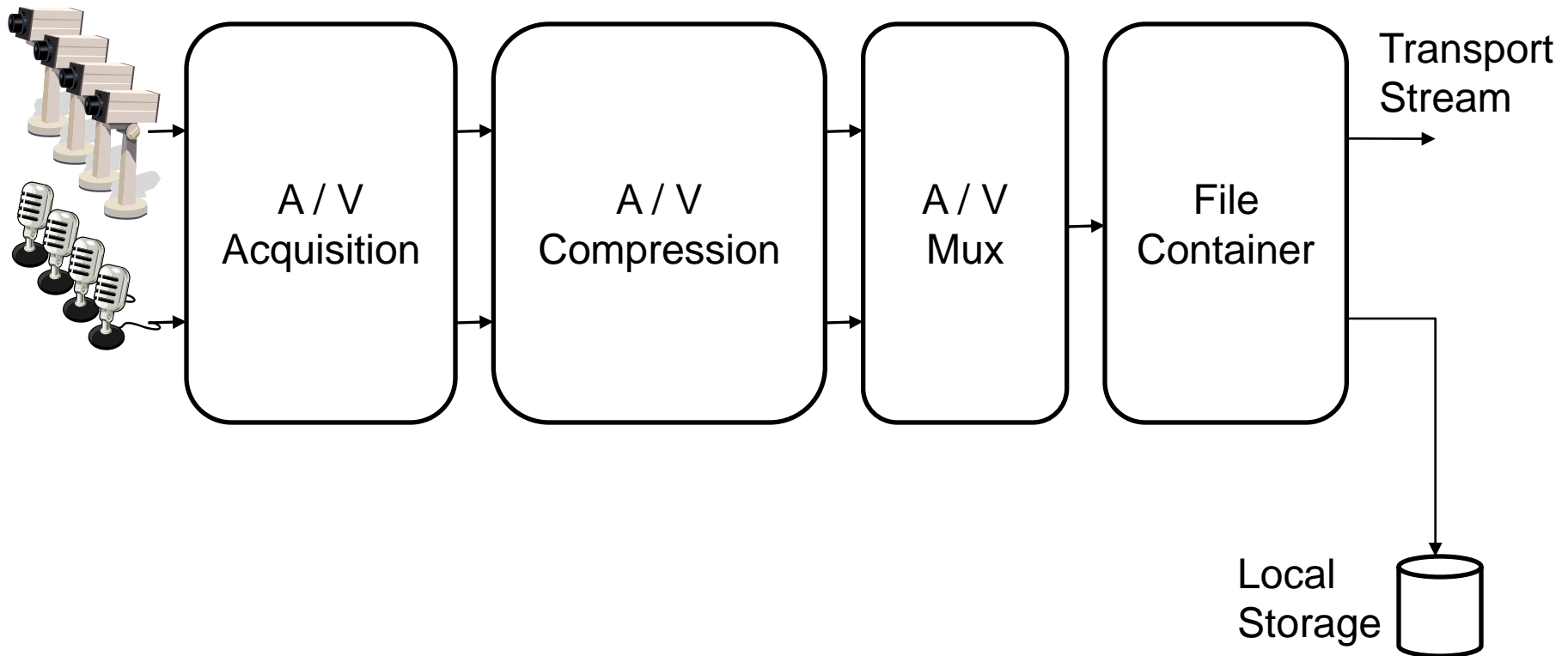
Ingenient Technologies, Inc.

May, 2009

A DM6467-based digital video recorder (DVR) reference design which handles HD encode and decode of the most commonly used video and audio standards is described here. It is designed with an efficient Linux Multimedia Application Framework which includes features crucial to DVR development such as: custom-written kernel routines for maximum performance, trick play and advanced A/V sync support, as well as sophisticated rendering to handle all different types of inputs and outputs. Multiple channel encode and decode with simultaneous encode and decode is also supported.

- A Digital Video Recorder (DVR) records audio and video

- Essential for security and surveillance applications

- Found in various forms:

  - PC-based DVR cards

  - Standalone DVR's

  - Embedded DVR Systems (DVS)

  - Hybrid DVR's

  - Network DVR's and Network Video Recorders (NVR's)

- Hybrid, network, and standalone DVRs are popular products

- The DVR market is booming and technology is evolving quickly

  - Better compression algorithms (MJPEG $\rightarrow$ MPEG-4 $\rightarrow$ H.264)

  - Higher resolutions (CIF $\rightarrow$ D1 $\rightarrow$ HD)

  - Higher channel density (4CH $\rightarrow$ 8CH $\rightarrow$ 16CH $\rightarrow$ 32CH)

A / V Acquisition → A / V Compression → A / V Mux → File Container → Transport Stream

File Container → Local Storage

- Replace tape-based surveillance systems with digital storage

- Embedded DVR's still dominate surveillance storage products today with over 50% of total DVR market share

- The A/V input signals to a DVR are generally analog (camera and microphone)

- Storage devices (requiring hard disk drives) are usually part of the DVR

- Requires support of single and multiple channel view with live playback

- Also used in vehicles (mobile DVR)

- A traditional surveillance system uses analog inputs and outputs

- An IP-camera has a video compression unit built into the camera which transmits the compressed video bitstream

- A Network Video Recorder (NVR) is used with an IP-camera to store compressed video bitstreams streamed over the network

- A complete upgrade of an existing analog surveillance system to a digital system will be *expensive*

Hybrid and Network DVRs

- More and more traditional DVR systems have begun to shift to network-based video recorder systems

- Hybrid DVR's are the result of a gradual transition from existing traditional DVR's to network DVR's

- A hybrid digital video surveillance DVR allows the user to use traditional wired analog video sources as well as IP video sources across LAN, WAN, VPN and over the Internet
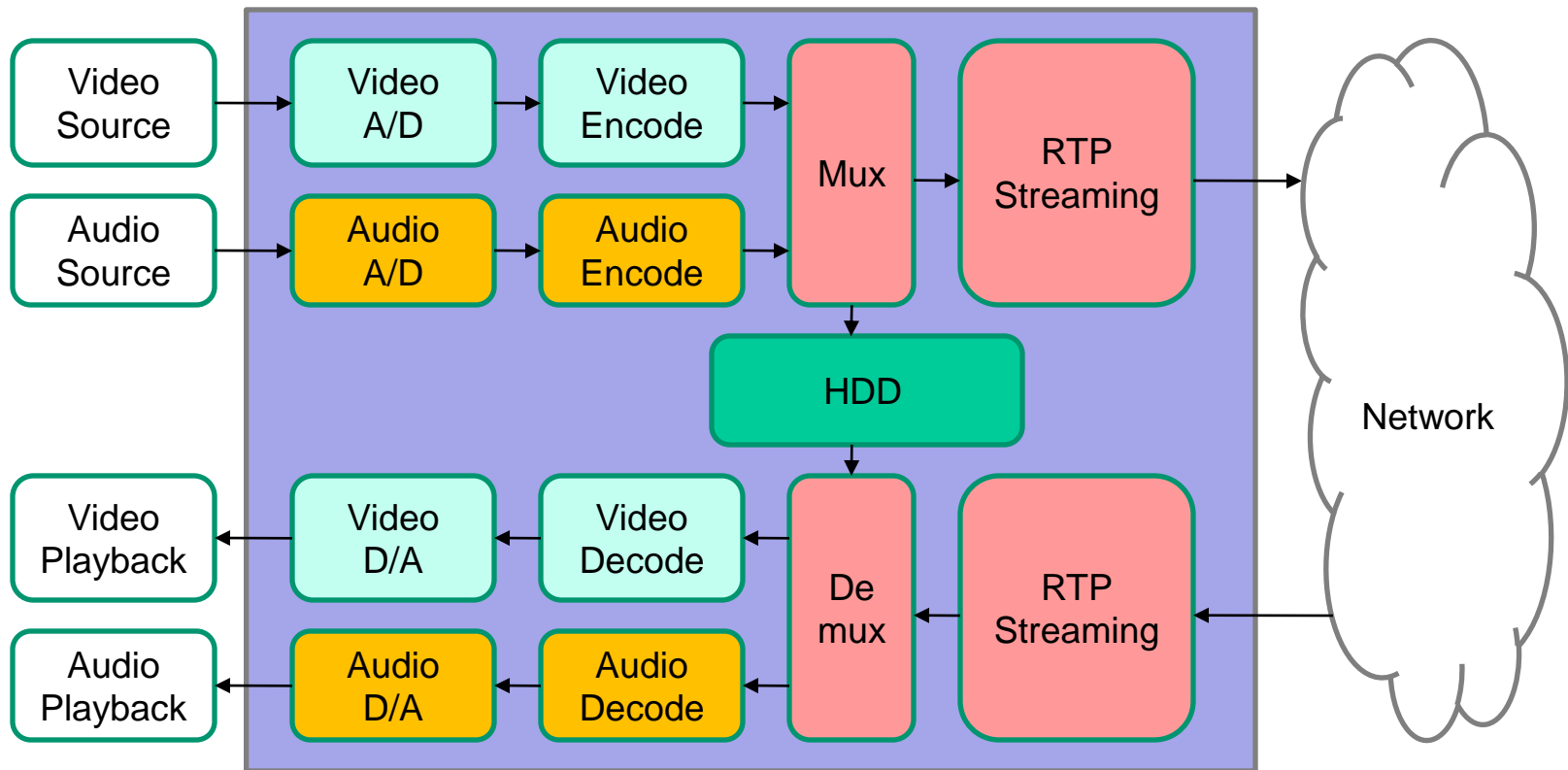
Digital Video Server (DVS)

- For some applications it is desired to send the compressed video bitstream over the network

- DVR's that can stream compressed bitstreams are called DVS devices

- DVS devices can be used to send the compressed video to a larger security network using TCP/IP

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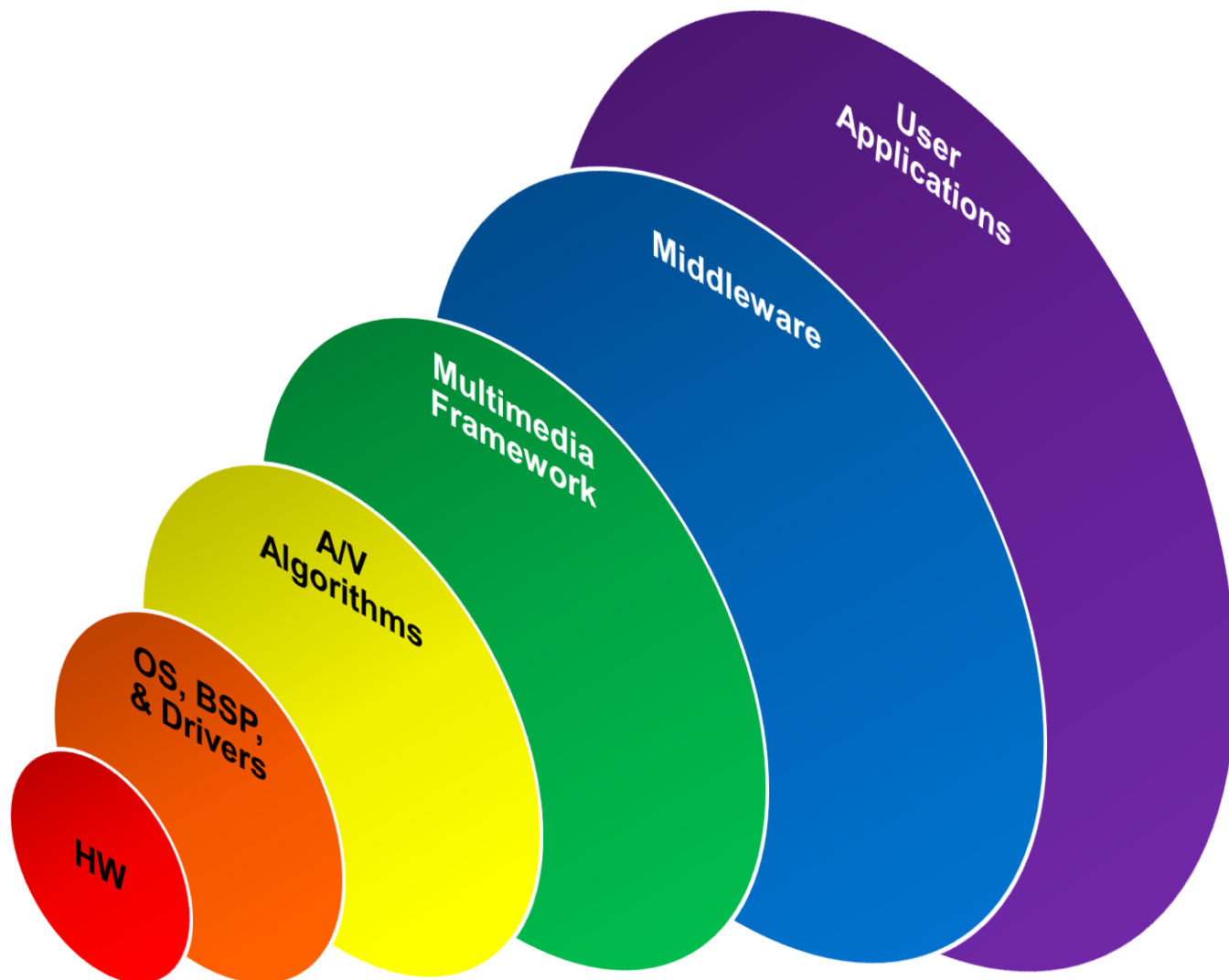
- **Encoder and Decoder**
  - Low delay
  - High picture quality
  - Capable of high frame rate and high resolutions
  - Reentrant for multichannel applications
  - Support multiple industry standards
  - Provide analytics info

- **A comprehensive, effective solution must have …**
  - ➢ **A rich set of audio and video compression algorithms**
    - H.264, MPEG-4, MJPEG (MPEG-2, WMV9 …)
    - AAC-LC, G.7xx, LPCM (MP3, BSAC, SBR …)
    - Transcoding and transrating support

  - ➢ **Optimizations for real-time embedded applications**
    - High video quality
    - Low delay
    - Reentrant (XDM and XDIAS compliant)
    - Motion vector output for motion detection and analytics
    - Ability to tune for specific applications
    - Error resilience

  - ➢ **Ability to upgrade and enhance algorithms**

High Performance H.264 Video Algorithm

	Profile	Performance	Bitrate per Channel
H.264	MP/HP	1920x1080i @ 30fps	5.0 – 12.0 Mbps
H.264	MP/HP	1280x720 @ 30fps	2.5 – 8.0 Mbps
H.264	BP/MP	4-ch 720x480 @ 30fps	1.5 - 4.0 Mbps

- **System Considerations**
  - Support different inputs and outputs (NTSC, PAL, progressive, interlaced, etc.)
  - Support multiple channels and multiple resolutions
  - Support storing and/or streaming of data
  - Support multiple threads and simultaneous encode/decode
  - Support variable or constant bitrate rate control
  - Support camera control
  - Low power consumption
  - Low cost

Facing the Challenges – Reference Hardware Design

- **Audio and video I/O features:**
  - Capable of high definition and high fidelity video capture
  - Capable of multiple-channel standard definition video capture
  - Capable of multiple-channel audio capture
  - Support interlaced and progressive cameras input
  - Audio and video playback capability
  - HDMI input and output

- **Communication connectivity features:**
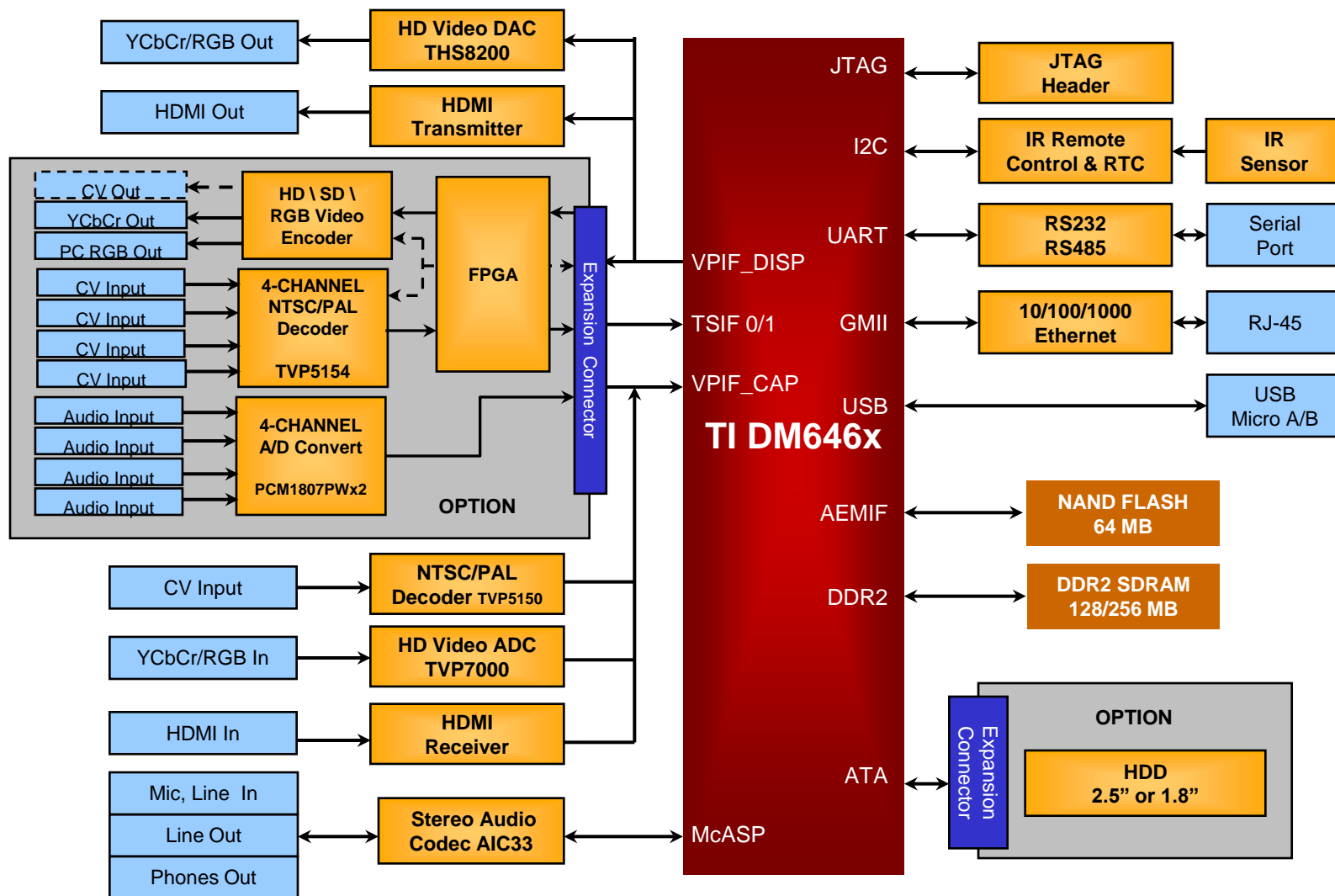 - Local HDD storage devices
  - G-Ethernet network interface
  - UART, SPI, I2S, I2C, etc.

- **Cost and manufacturability:**
  - Low per-channel cost
  - Modularity and expandability
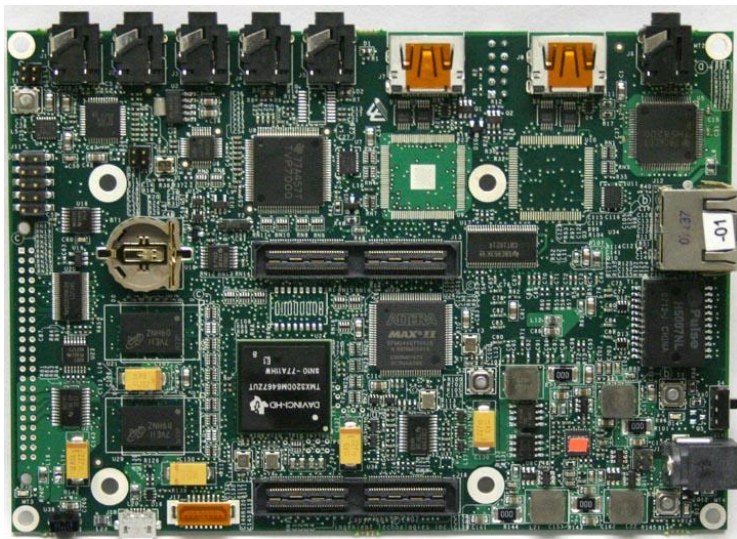 - Simple design and manufacturability

DVR Reference Design - Block Diagram

YCbCr/RGB Out — HD Video DAC THS8200

HDMI Out — HDMI Transmitter

OPTION
- CV Out
- YCbCr Out
- PC RGB Out
- HD \ SD \ RGB Video Encoder
- CV Input (×4) — 4-CHANNEL NTSC/PAL Decoder TVP5154
- Audio Input (×4) — 4-CHANNEL A/D Convert PCM1807PWx2
- FPGA
- Expansion Connector

CV Input — NTSC/PAL Decoder TVP5150

YCbCr/RGB In — HD Video ADC TVP7000

HDMI In — HDMI Receiver

Mic, Line In / Line Out / Phones Out — Stereo Audio Codec AIC33

TI DM646x

- VPIF_DISP
- TSIF 0/1
- VPIF_CAP
- McASP
- JTAG — JTAG Header
- I2C — IR Remote Control & RTC — IR Sensor
- UART — RS232 RS485 — Serial Port
- GMII — 10/100/1000 Ethernet — RJ-45
- USB — USB Micro A/B
- AEMIF — NAND FLASH 64 MB
- DDR2 — DDR2 SDRAM 128/256 MB
- ATA — Expansion Connector — **OPTION** HDD 2.5" or 1.8"

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Communications

- **Ethernet: 10/100/1000 Mbps**
- **High Speed USB: Host or Device**
- **Serial Port: RS232**
- **JTAG**

Storage Devices

- **On-board IDE HDD I/F**
- **External USB Storage Devices**

Expansion I/O Headers

- **Access to Major Interfaces**
  - **VPBE, VPFE, SPI, I2C, ...**
- **Digital Video Interface**
  - **Enables External Video Devices**
  - **BT656 / BT1120 Input, Output**
  - **VGA Display Interface**
  - **CMOS**
- **4-channel D1 (720x480) adapter card**

Video I/O

- **Analog Input**
  - **Composite: 480i, 576i (NTSC / PAL)**
  - **Component: YPbPr (480i, 720p, 1080i)**
- **Analog Output**
  - **Component: YPbPr (480i, 720p, 1080i)**
- **HDMI 1.3 Digital Input**
- **HDMI 1.3 Digital Output**

- **Optimized OS and BSP for embedded A/V applications**
  - Low system overhead
  - Low system latency

- **Expandability to different platforms**
  - ARM or DSP
  - Single core or multi-core

- **Support all peripherals and standard devices**
  - Video port, Memory, PCI, ...
  - Video capture and display, Audio, UART, Ethernet, USB, HDD, ...

- **Extensive support of development kernel options**

- **Control audio and video codec operation**

- **Responsible for system timing and A/V synchronization**

- **Manage the kernel space device drivers**

- **Interface with user space applications**

- **Memory resource management**

- **Frame buffer and video queue management**

- **Application-specific features**
  - Watermarking
  - Embedded text, metadata
  - Analytics (motion detection, tamper detection, etc.)

- **Streaming and communication protocols**
  - Transport Stream
  - RTP/RTSP
  - RFCs (RFC2190, RFC3016, RFC3984 …)

- **File containers**
  - MP4,
  - AVI
  - MPEG-2 PS ...

- **Pre and post processing**
  - Video stabilization
  - Digital zoom
  - Denoising

- **Encryption**

- **Fully featured to support all modes of operation**

- **User friendly, ready to use and easy to modify**

- **Product-proven**

- **Interoperability**

- **Industry standard-driven parameters**
- **Field upgradeable**

Ingenient Advantages

- **One stop shop for multimedia system design (HW, BSP, codecs)**
- **Supporting video compression on TI DSP's since July 2000**
- **Millions of products shipped with Ingenient technology inside**
- **Experienced engineering team (audio, video, BSP, HW & more)**
- **Algorithms tuned for highest quality and channel density**
- **Production ready system reference designs**
- **Custom codec and system support**
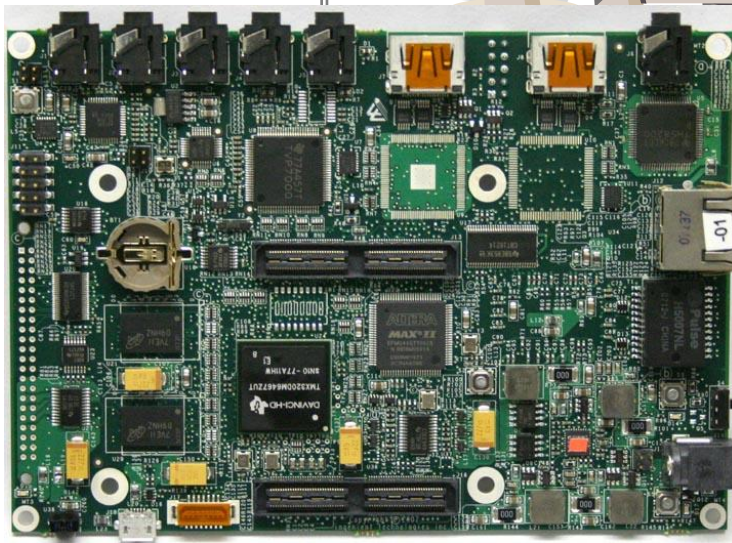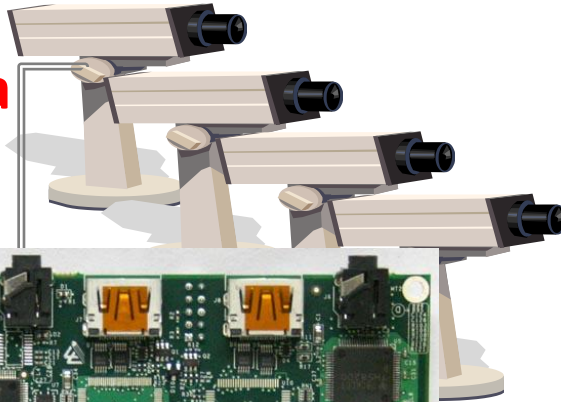- **Clear roadmap for the future**

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DVR Reference Design

Case Study: MP522x-DM6467-10

Camera

MP4900 Reference HW

Ethernet
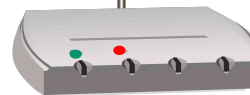
PC Decoder

- 1080i or 720p high definition camera and video input
- 4-channel 720x480 standard definition camera and video input
- 4-channel audio input
- Support multiple video resolutions
- Transcoding and transrating
- High quality H.264 MP video encoder and decoder
- High fidelity AAC-LC audio encoder and decoder
- MPEG-2 video encoder and decoder for backward compatibility
- JPEG and Motion JPEG
- G-Ethernet
- Local hard disk storage
- USB external storage

- Video Decoders and Encoders
  - H.264 BP/MP/HP (1080 / 720p / D1 / CIF @ 30fps, bitrate up to 12Mbps)
  - MPEG-4 SP/ASP (1080 / 720p / D1 / CIF @ 30fps , bitrate up to 16Mbps)
  - MPEG-2 MP@ML/HL (1080 / 720p / D1 @ 30fps , bitrate up to 18Mbps)
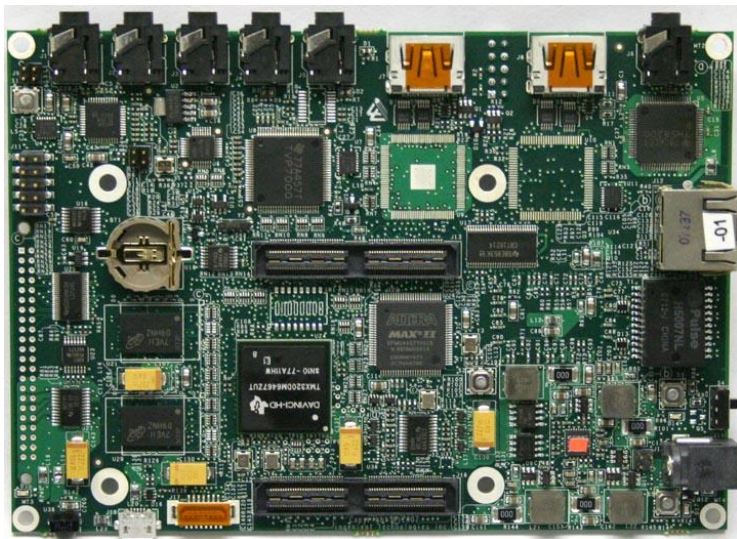 - MJPEG

- Audio Decoders and Encoders
  - MPEG-4 AAC (sampling rate up to 48 kHz, bitrate up to 320 kbps)
  - MPEG-1 Layer 1/2/3 (sampling rate up to 48 kHz, bitrate up to 256 kbps)
  - G.711 and G726 (per ITU specification)
  - Linear PCM

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- HD Video DAC THS8200
- HDMI Out
- HDMI Transmitter

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- PC RGB Out
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- **HDMI 1.3 Digital Input**
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Reference Design - Major Hardware Components

- **Media Processor**
  - TMS320DM6467— Dual-core processor
- **Audio Codec**
  - TLV320AIC33 — support rates 8-96KHz
- **Digital Video Decoder**
  - TVP5150 — support NTSC / PAL or TVP5154 for 4 channel capture
- **HD Digital Video Decoder**
  - TVP7002 — support RGB UXGA and HD 1080
- **Micro Controller**
  - MSP430 — RTC and remote control
- **Memory**
  - 256 MB DDR2 SDRAM + 128 MB NAND Flash
- **HD Video DAC (Option)**
  - THS8200 — support SDTV and HDTV
- **HDMI Receiver (Option)**
  - SiI9013 — support DTV and PC resolutions
- **HDMI Transmitter (Option)**
  - SiI9034 — support 24-bit color depth HD out

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High Definition and Multi-channel DVR

Content Mgmt

File Construction & Parsing

Streaming Transport Protocols

DVR Application User Interface

DVR Configuration Status Information

Multimedia System Management

Multimedia Application Framework

Host / DSP Interface Bridge

Encoder and Decode

Video Algorithms
H.264 HP
MPEG-2 HP
MPEG-4 ASP
MJPEG and more

Audio Algorithms
MPEG-1 Layer 1/2/3
MPEG-2/4 AAC-LC
G.7xx and more

Linux Operating System

Operating System Kernel

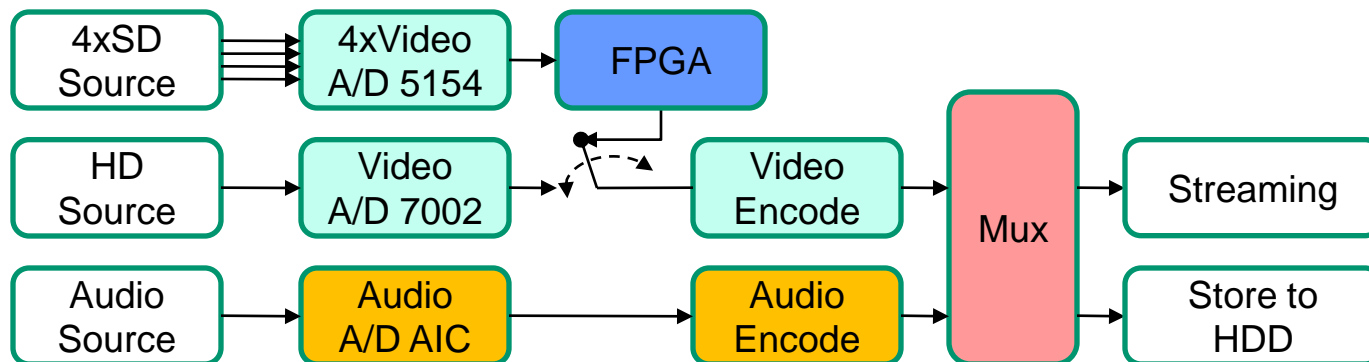Device & Interface Drivers

Network Protocol Stacks

File Management Systems

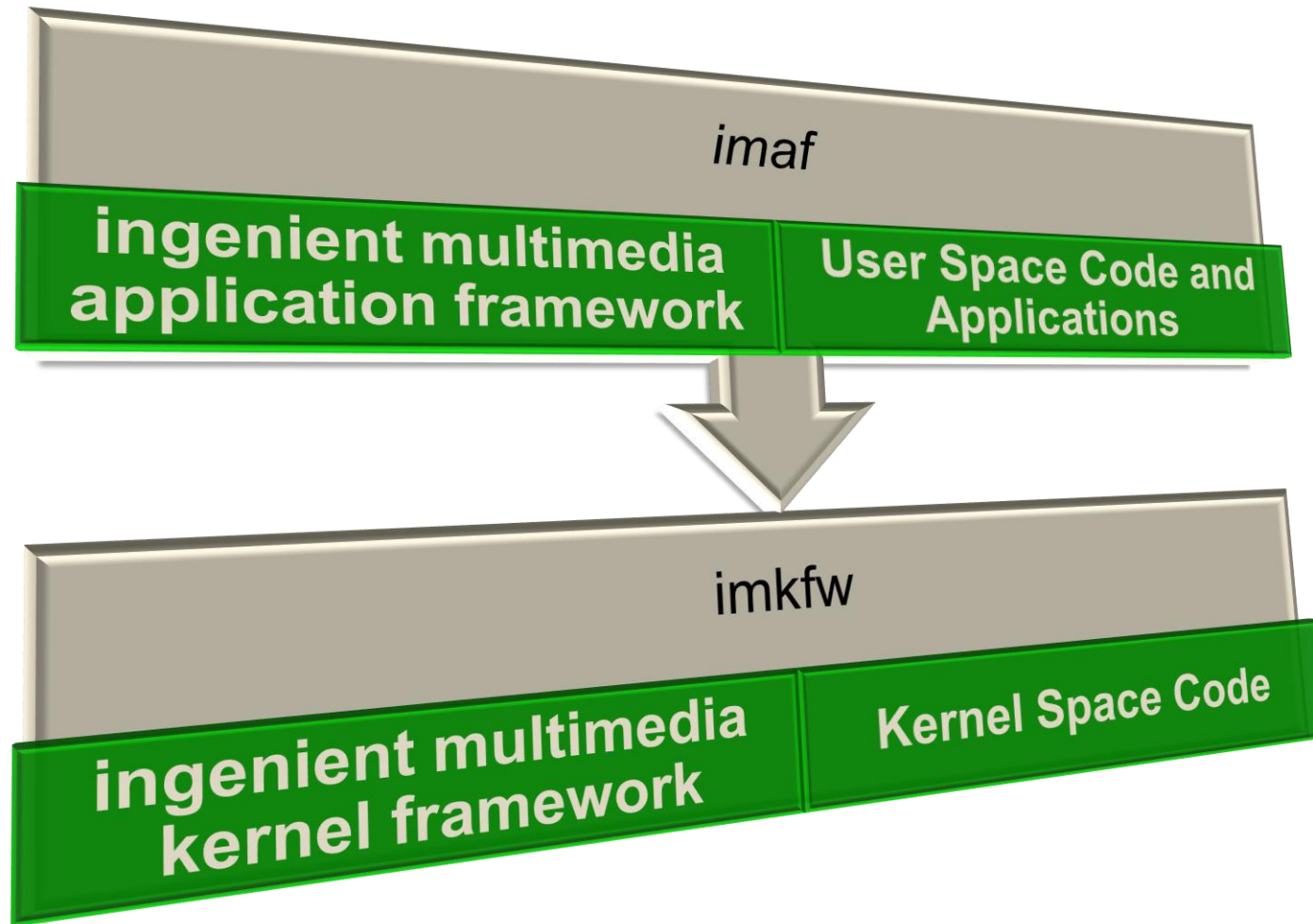## MP4900-BRD-DM6467-10 Hardware Reference Platform

- **Video and Audio Sources**
  - HD or SD (NTSC or PAL) cameras, interlaced or progressive
  - Microphones, wired or wireless mono inputs

- **Video and Audio Signal Acquisition**
  - Video analog to digital conversion, TVP7002, TVP515x
  - FPGA video preprocessing for multi-channel DVR
  - Audio analog to digital conversion, AIC33, PCM1807

- **Video and Audio Compression**
  - Video and audio compression using DM6467
  - A/V sync and mux

```
4xSD Source ──▶ 4xVideo A/D 5154 ──▶ FPGA
HD Source ──▶ Video A/D 7002 ──▶ [switch] ──▶ Video Encode ──▶ Mux ──▶ Streaming
Audio Source ──▶ Audio A/D AIC ──▶ Audio Encode ──▶ Mux ──▶ Store to HDD
```

Additional DVR Features Provided

- Audio and video decoding and composite display
- Trick play
- Video snapshot
- Video transcoding (MPEG-2 $\leftrightarrow$ H.264)
- Video transrating (HD $\rightarrow$ D1, D1 $\rightarrow$ CIF)
- Frame encryption and watermark authentication
- Embedded text and meta data
- Motion detection
- Digital zoom
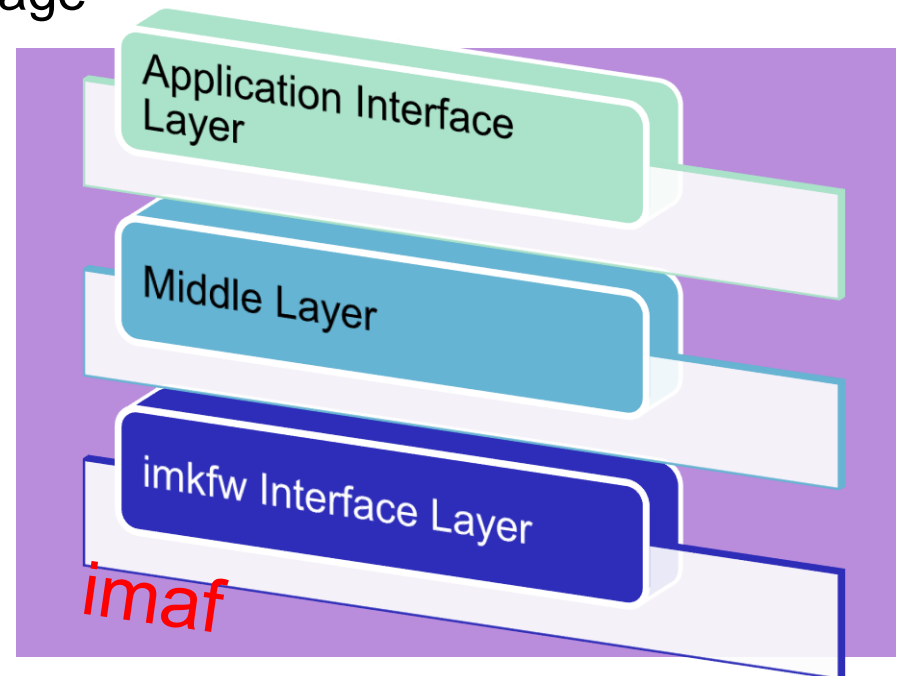- Video Stabilization

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- Ingenient Multimedia Application Framework (imaf)
  Consists of over 60 high level routines in Linux user space
  that are called by the application to support:
  - Encoding and decoding on ARM
  - File parsing and constructing
  - HDD or memory card storage
  - Pre- and post-processing
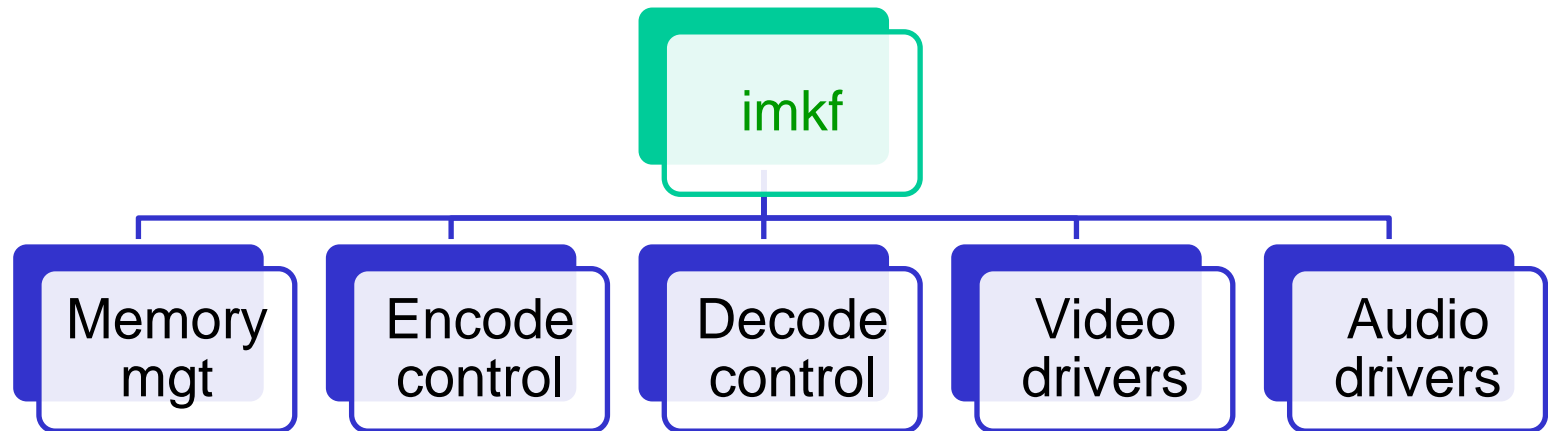 - Network streaming
  - User Interface

Application Interface Layer

Middle Layer

imkfw Interface Layer

imaf

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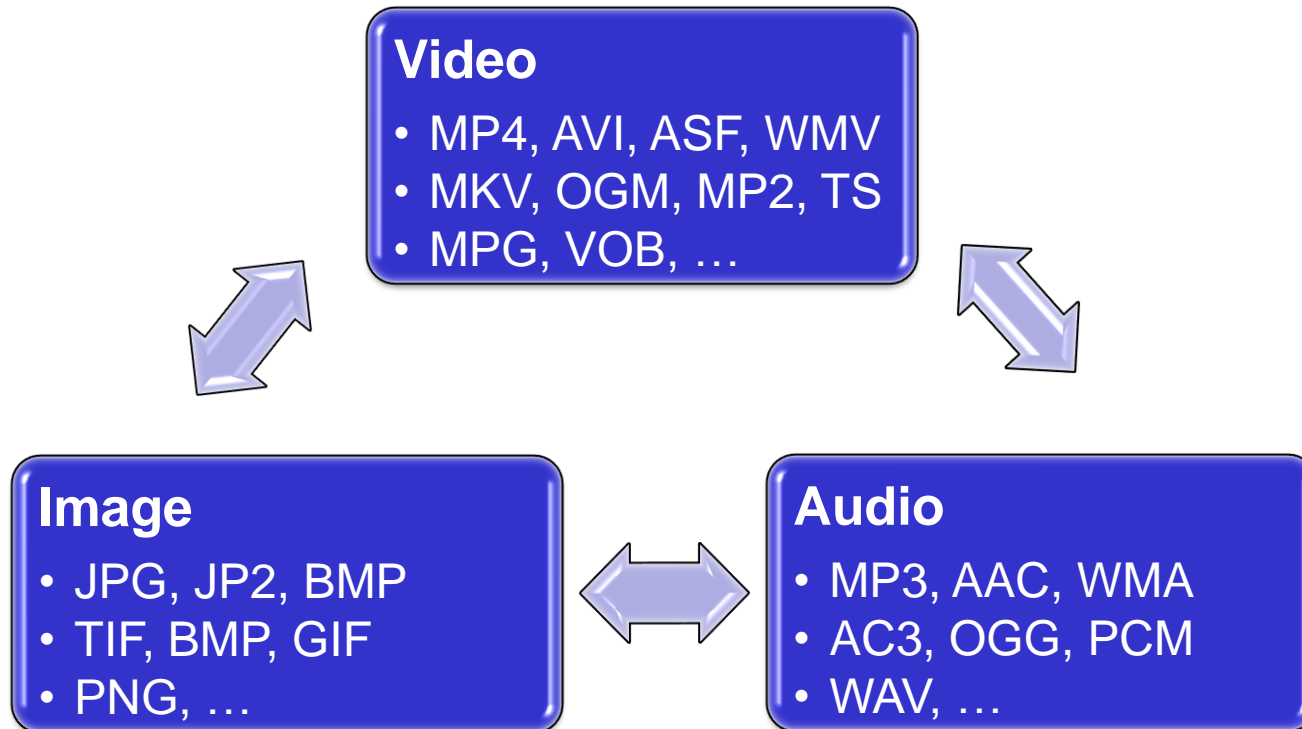- **Ingenient Multimedia kernel Framework (imkf)**

  Consists of routines in Linux kernel space including lower level routines to handle:

  - Video and audio drivers
  - Communication with the DSP
  - System functions that help manage memory allocation
  - Inter-module messaging
  - Queue and buffer management

imkf

| Memory mgt | Encode control | Decode control | Video drivers | Audio drivers |

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Video
- MP4, AVI, ASF, WMV
- MKV, OGM, MP2, TS
- MPG, VOB, …

Image
- JPG, JP2, BMP
- TIF, BMP, GIF
- PNG, …

Audio
- MP3, AAC, WMA
- AC3, OGG, PCM
- WAV, …

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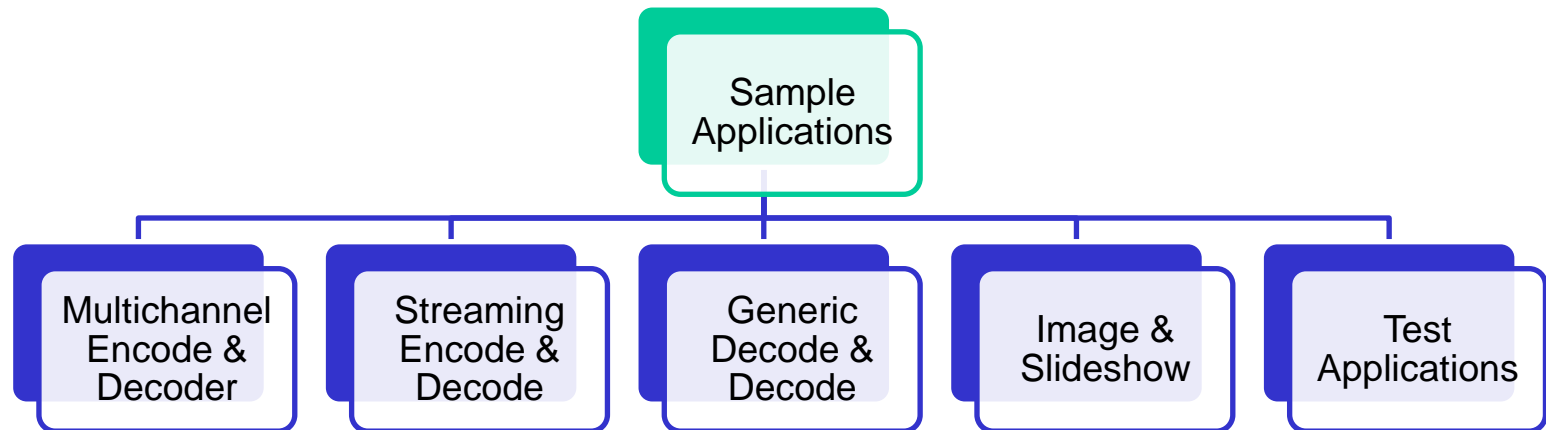|			
RTP [RFC 3550]	RTP [RFC 3984]	RTP [RFC 2190]	RTP Sender I/F
RTP Receiver I/F	RTSP [RFC 2326]	RTSP Server I/F	RTSP Client I/F
RTSP Utilities	RTCP [RFC 3550]	RTCP Test App	ITTS ARIB
LANC Control I/F			

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                    ┌──────────────────┐
                    │ Sample           │
                    │ Applications     │
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        ┌───────┬───────┼───────┬───────┐
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 │Multichannel││Streaming││Generic  ││Image &   ││Test      │
 │Encode &   ││Encode & ││Decode & ││Slideshow ││Applications│
 │Decoder    ││Decode   ││Decode   ││          ││          │
 └──────────┘└──────────┘└──────────┘└──────────┘└──────────┘
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