- 16K UHDTV has been demonstrated in 2018, targeting applications such as Virtual Reality with true immersion. Its resolution is 15,360 × 8,640 for a total of 132.7 megapixels.

Table 5.5: A Summary of UHDTV

Type of UHDTV	Resolution	Bit Depth	Aspect Ratio	Frame Rate
4K UHD (2160P)	3840 x 2160	10 or 12 bits	16:9	Up to 120P
8K UHD (4320P)	7680 x 4320	10 or 12 bits	16:9	Up to 120P
16K UHD (8640P)	15360 x 8640	10 or 12 bits	16:9	Up to 240P

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5.3 Video Display Interfaces

5.3.1 Analog Display Interfaces

Analog video signals are often transmitted in one of three different interfaces: *Component video*, *Composite video*, and *S-video*. Figure 5.7 shows the typical connectors for them.

Fig. 5.7: Connectors for typical analog display interfaces. From left to right: Component video, Composite video, S-video, and VGA.

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Component video

- **Component video**: Higher-end video systems make use of three separate video signals for the red, green, and blue image planes. Each color channel is sent as a separate video signal.

   a) Most computer systems use Component Video, with separate signals for R, G, and B signals.

   b) For any color separation scheme, Component Video gives the best color reproduction since there is no "crosstalk" between the three channels.

   c) This is not the case for S-Video or Composite Video, discussed next. Component video, however, requires more bandwidth and good synchronization of the three components.

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Composite Video

- **Composite video**: color ("chrominance") and intensity ("luminance") signals are mixed into a *single* carrier wave.

  a) Chrominance is a composition of two color components (I and Q, or U and V).

  b) In NTSC TV, e.g., I and Q are combined into a chroma signal, and a color subcarrier is then employed to put the chroma signal at the high-frequency end of the signal shared with the luminance signal.

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a) The chrominance and luminance components can be separated at the receiver end and then the two color components can be further recovered.

b) When connecting to TVs or VCRs, Composite Video uses only one wire and video color signals are mixed, not sent separately. The audio and *sync* signals are additions to this one signal.

- Since color and intensity are wrapped into the same signal, some interference between the luminance and chrominance signals is inevitable.

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S-Video

- **S-Video**: as a compromise, (separated video, or Super-video, e.g., in S-VHS) uses two wires, one for luminance and another for a composite chrominance signal.
- Less crosstalk between the color information and the crucial gray-scale information.
- The reason for placing luminance into its own part of the signal is that black-and-white information is most crucial for visual perception.
  - Humans are able to differentiate spatial resolution in grayscale images with a much higher acuity than for the color part of color images.
  - As a result, we can send less accurate color information than must be sent for intensity information — we can only see fairly large blobs of color, so it makes sense to send less color detail.

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5.3.2 Digital Display Interfaces

Digital interfaces emerged in 1980s (e.g., Color Graphics Adapter (CGA)), and evolved rapidly. Today, the most widely used digital video interfaces include Digital Visual Interface (DVI), High-Definition Multimedia Interface (HDMI), and DisplayPort.

Fig. 5.8: Connectors of different digital display interfaces. From left to right: DVI, HDMI, DisplayPort.

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High-Definition Multimedia Interface (HDMI)

- HDMI is a newer digital audio/video interface developed to be backward compatible with DVI.
  1. HDMI doesn't carry analog signal and hence is not compatible with VGA.
  2. HDMI supports both RGB and YCbCr 4:4:4 or 4:2:2. [DVI is limited to the RGB color range (0-255).]
  3. HDMI supports digital audio, in addition to digital video.
- The maximum pixel clock rate for HDMI 1.0 is 165 MHz, which is sufficient to support 1080P (1,920 × 1,200) at 60 Hz.
- HDMI 2.0 was released in 2013, which supports 4K resolution at 60 frames per second.

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Exercise 2: Chroma Subsampling Calculation

Task: For a 1920x1080 frame, calculate the total number of samples for Y, Cb, and Cr in each format:

4:4:4

4:2:2

4:2:0

Link chroma subsampling to file size and image quality in compression.

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Exercise 2: Chroma Subsampling Calculation

- **4:4:4**:
  - Y = 1920×1080 = 2,073,600
  - Cb = 1920×1080
  - Cr = 1920×1080
  - **Total = 6,220,800 samples**
- **4:2:2**:
  - Y = 1920×1080 = 2,073,600
  - Cb = 960×1080 = 1,036,800
  - Cr = 960×1080
  - **Total = 4,147,200 samples**
- **4:2:0**:
  - Y = 1920×1080 = 2,073,600
  - Cb = 960×540 = 518,400
  - Cr = 960×540
  - **Total = 3,110,400 samples**

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