A Multi-Format HDTV Camera Head
What it’s all about: the third generation of 2/3” HDTV cameras...

Philips LDK6000 System

1080i  720p

Triax-HD
Agenda

• Against all odds
  - History
  - HDTV DPM Imager
  - HDTV ASICs
  - Triax

• Philosophical
  - Aspects of CCDs in Relation to Film Parameters

• Conclusions
History

- LDK9000 with 1” HDTV FT Imager
  - 1920 (H) x 1125 (V)
  - 1080I60, 1035I60, 970I60, 480P60,
  - 1125I50, 575P50
  - 480P 30

- LDK9000-720P with 1” HDTV FT Imager
  - 1280 (H) x 720 (V): 72 Hz, 60 Hz, 24 Hz

- LDK23 with 2/3” DPM FT Imager
  - 485I180
  - 575I150
Multi-Format Camera

- **Imager**
  - Multi-Format Imager
  - 1920 x 1080P
  - 1920 x 1080I
  - 1920 x 720P

- **Digital Signal Processing**
  - ASICs

- **Dockable**
  - Triax (large installed base)
  - Multipurpose adapter (standalone)
  - other
Multi-Format Imager

IMAGE AREA
9.2 Mpixels

STORAGE AREA

HORIZONTAL SHIFT REGISTER
1920 pixels

Column with 4320 pixels

Channel stop

pixel
FT and IT-Imager

FT-Imager

Storage

Image

IT-Imager

Storage

Image

Horizontal Shift Register
FT and IT-Imager

FT-Imager

Image

Storage

Horizontal Shift Register

IT-Imager

Image

Storage

Horizontal Shift Register
The importance of 4320 pixels per column
## Multi-Format Imager

<table>
<thead>
<tr>
<th>Scanning Format</th>
<th>Prime decomposition</th>
<th>Log-prime notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1080P</td>
<td>$2^3 \cdot 3^3 \cdot 5$</td>
<td>[3,3,1,0,0,0]LP6</td>
</tr>
<tr>
<td>1080I</td>
<td>$2^2 \cdot 3^3 \cdot 5$</td>
<td>[2,3,1,0,0,0]LP6</td>
</tr>
<tr>
<td>720P</td>
<td>$2^4 \cdot 3^2 \cdot 5$</td>
<td>[4,2,1,0,0,0]LP6</td>
</tr>
<tr>
<td>480P</td>
<td>$2^5 \cdot 3^1 \cdot 5$</td>
<td>[5,1,1,0,0,0]LP6</td>
</tr>
<tr>
<td>480I</td>
<td>$2^4 \cdot 3^1 \cdot 5$</td>
<td>[4,1,1,0,0,0]LP6</td>
</tr>
</tbody>
</table>

Least Common Multiple: 4320
Multi-Format Imager

- 1920 (H) x 4320 (V)

- Adding pixels enables the scanning formats
  - 4320 = 1080 x 4 1080P
  - 4320 = 720 x 6 720P
  - 4320 = 540 x 8 1080I
  - 4320 = 480 x 9 480P
  - 4320 = 240 x 18 480I

- Minimal number of interconnections
  - 8 = 2 x 4, 9 = 3 x 3, 18 = 3 x 6
  - with 12 = 3 x 4 = 4 x 3 = 2 x 6 one can do it all
Multi-Format Imager

Channel stop

Pixel

3 phase: 1440P
4 phase: 1080P
6 phase: 720P
Multi-Format Imager

Pixel: one light sensitive element
Super Pixel: addition of pixels
Image Cell: equals one scanning line

2*4 phase: 1080I
3*3 phase: 480P
3*6 phase: 480I
Multi-Format Imager

• what can one do with a 12-phase system and 4320 pixels per column
  - 1440P (Image area only)
  - 1080P 1080I
  - 720P
  - 480P 480I

• and with a DPM cut
  - 1080P in 2.37:1 too
  - 720P in 2.67:1 too
Multi-Format Imager

9.2 Million pixel CCD

Combining vertical pixels for 720 lines

Combining vertical pixels for 1080 lines

Let's make things better.
Multi-Format Imager
1920x1080 with 2.37:1 aspect ratio

1440 (V) 1920 pixels (H) 1080 (V)

2.37
HDTV DPM Imager
Vertical Filtering to reduce aliasing
Vertical Filtering

- One needs optical filtering to reduce aliasing
  - Maximum reduction is obtained when the optical MTF has zero transfer at the sample frequency
  - The zero transfer can be made through the aid of an optical low pass filter (glass)
  - Or through the addition of pixels
Vertical Filtering

• Adding 2 pixels
  - The simplest optical filtering that exists in a CCD-imager is adding two pixels together
  - Its effect is to shape the optical MTF of one pixel with a cosine; like in interlaced mode!
  - Adding more pixels together makes an even more ingenious and complex shaping of the MTF curve possible
  - And complex it is when one has to shift the notch depending on scanning format
Vertical Filtering

Vertical MTF

vertical frequency [lp/mm]

1080I
720P
1080P

Let's make things better

Peter Centen
Camera chain
### HDTV ASICs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ASIC-B</th>
<th>ASIC-A</th>
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<tbody>
<tr>
<td>Process</td>
<td>0.35 um</td>
<td>0.35 um</td>
</tr>
<tr>
<td>Gate count</td>
<td>185455</td>
<td>425000</td>
</tr>
<tr>
<td>Die-size</td>
<td>59 mm$^2$</td>
<td>74 mm$^2$</td>
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<tr>
<td>RAMs</td>
<td>540 kbit (delaylines + control)</td>
<td>132 kbit</td>
</tr>
<tr>
<td>Input word length</td>
<td>12 bit</td>
<td>14 bit</td>
</tr>
<tr>
<td>Internal representation</td>
<td>20 bit</td>
<td>20 bit</td>
</tr>
<tr>
<td>Package</td>
<td>QFP160</td>
<td>QFP208</td>
</tr>
</tbody>
</table>
HD-Triax

- Y-signal: 30MHz BW
- Cr and Cb 15 MHz, Quadrature modulated
- Triax-HD: 3000 ft using 14mmØ Triax cable
- High Definition transmission for standard Triax cables
- Triax: Reliable, Robust, and a huge installed base
Philosophical

- Transfer curve
- MTF
- Noise
- Film and CCD-Imager
Transfer curve

![Graph showing transfer curve with labels for electrical density and relative exposure in f-stops.]

Electrical "Density" [A.U] vs. Rel. Exposure [f-stops]
<table>
<thead>
<tr>
<th>Film</th>
<th>Red [lp/mm]</th>
<th>Green [lp/mm]</th>
<th>Blue [lp/mm]</th>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>16mm</td>
<td>30</td>
<td>60</td>
<td>100</td>
<td>671</td>
<td>1343</td>
<td>2238</td>
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<tr>
<td>35mm</td>
<td>30</td>
<td>60</td>
<td>100</td>
<td>1469</td>
<td>2937</td>
<td>4895</td>
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<tr>
<td>65mm</td>
<td>30</td>
<td>60</td>
<td>100</td>
<td>2727</td>
<td>5455</td>
<td>9091</td>
</tr>
<tr>
<td>CCD</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>1920</td>
<td>1920</td>
<td>1920</td>
</tr>
</tbody>
</table>
MTF and Aspect Ratio

1.78:1 and 2.37:1

1920 pixels per line in both aspect ratios

2.37:1  1.78:1

MTF

0 20 40 60 80 100
lp/mm

0 5 10 15 20 25 30 35 40
MHz

0.5 1

MTF

0 200 400 600 800 1000 1200
TVL

0 200 400 600 800 1000 1200
TVL

MTF

0.5

0 20 40 60 80 100
lp/mm

0 5 10 15 20 25 30 35 40
MHz

0.5 1

MTF

0 200 400 600 800 1000 1200
TVL

0 200 400 600 800 1000 1200
TVL

MTF

0.5
3 Noise Regions
- independent of exposure
  - readout noise (temporal) and
  - fixed pattern (spatial)
- proportional with the SQ RT
  - shotnoise (temporal)
- linear with exposure
  - non random uniformity (spatial)
- Noise ‘area’ the same every pixel
Film and CCD-Imager

**FILM (negative)**
- Random sample grid
  - both spatial and temporal
- No visible spatial aliasing
- Photon/Tag (grain) 4
- Exponential response
- Shoulder
- Large latitude
- Different MTF for R,G,B
- Fixed Speed (ASA)

**CCD-Imager**
- Fixed sample grid
  - both spatial and temporal
- Sometimes visible aliasing
- Photon/electron 2-3
- Linear response
- Qmax
- Large dynamic range
- Equal MTF for R,G,B
- Gain switch as a Speed (ASA) control
Conclusion

• A novel way for capturing native 1080P, 1080I and 720P at 16:9 aspect ratio and for 1080P at aspect ratio of 2.37:1 is presented.
• The successful development and design considerations that lead to the Philips LDK6000 multi-format HDTV camera are reported.
• The camera was first demonstrated at the NAB 2000 exhibition.
Thank You!