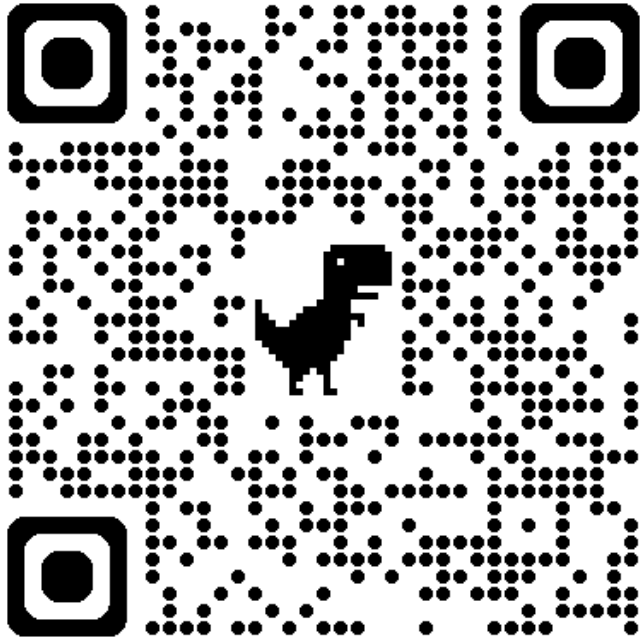


Real-Time Open Source Video Processing and Communications



Christopher Lozinski

May 8, 2026

[@PythonLinks@Mastodon.Social](#)

[lozinski@PythonLinks.info](#)

[Wiki.PythonLinks.info](#)

[Discord Channel](#)

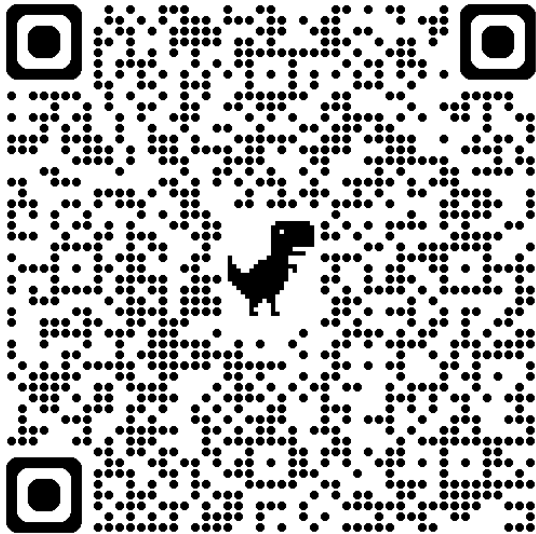
Article

Diese Website ist eine Installation von Qucosa - Quality Content of Saxony!



Publikationsserver

der Hochschule für Technik und Wirtschaft Dresden



Volltext (PDF)

Nutzungshinweise für die digitalen Objekte in Qucosa

Wiki.PythonLinks.info



Open Source Video Processing Wiki

This is a wiki about processing video in real time using microcontrollers, ASICs and FPGAs.

Feedback on the Wiki



venkat_tv 09/11/2025, 21:31

Thats a lot of work condensed into the wiki! Good work

@Christopher Lozinski !



josuah 09/11/2025, 21:03

It looks nice! Organized a bit like a series of chests in a gold mine

btw @Christopher Lozinski I've been reading through your pythonlinks site
it's fascinating

Hermine Exceptionelle 21/02/2026, 10:02

Oh nice project it's a goldmine of
information 🤯

Topics

- Applications
- Cameras
- Image Processes
- FPGAs
- Communications
- Recommendations

Not covering desktop or cell phones



Not a class on FPGA
development



Politechnika
Śląska



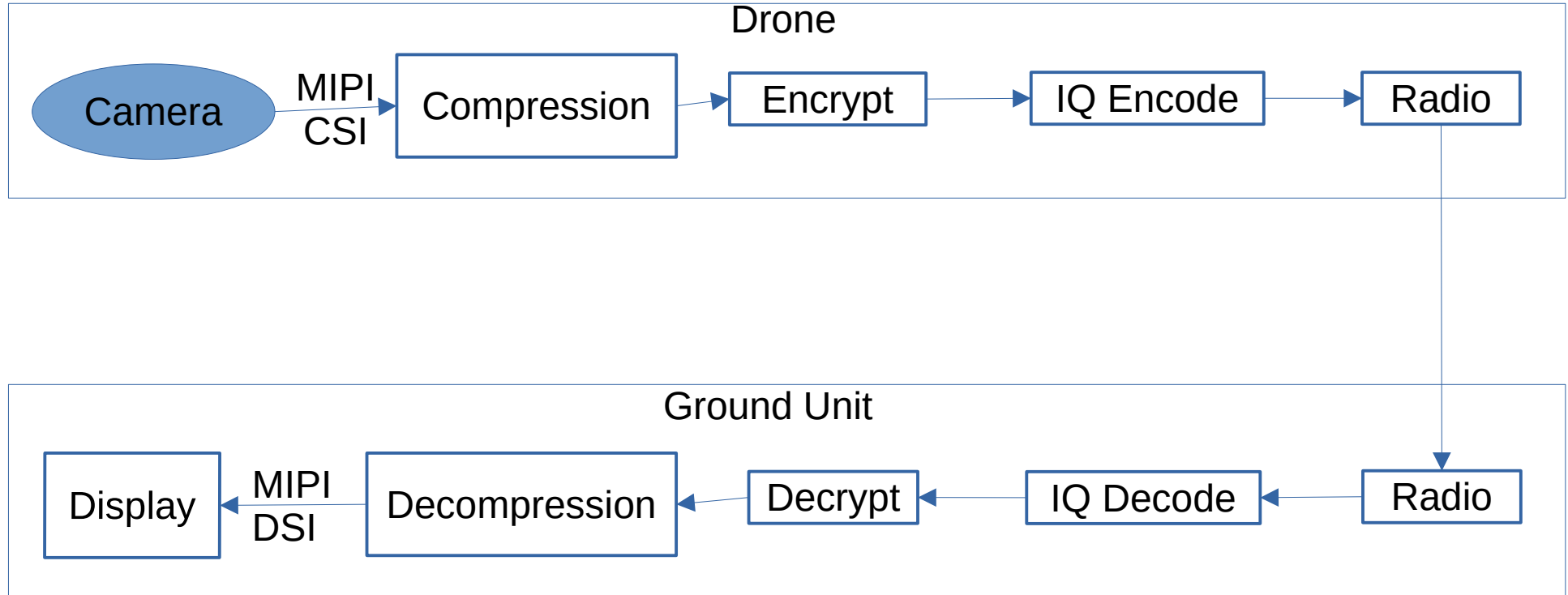
Wydział Automatyki, Elektroniki i Informatyki

Mikroinformatyka systemów cyfrowych, studia magisterskie (stacjonarne)

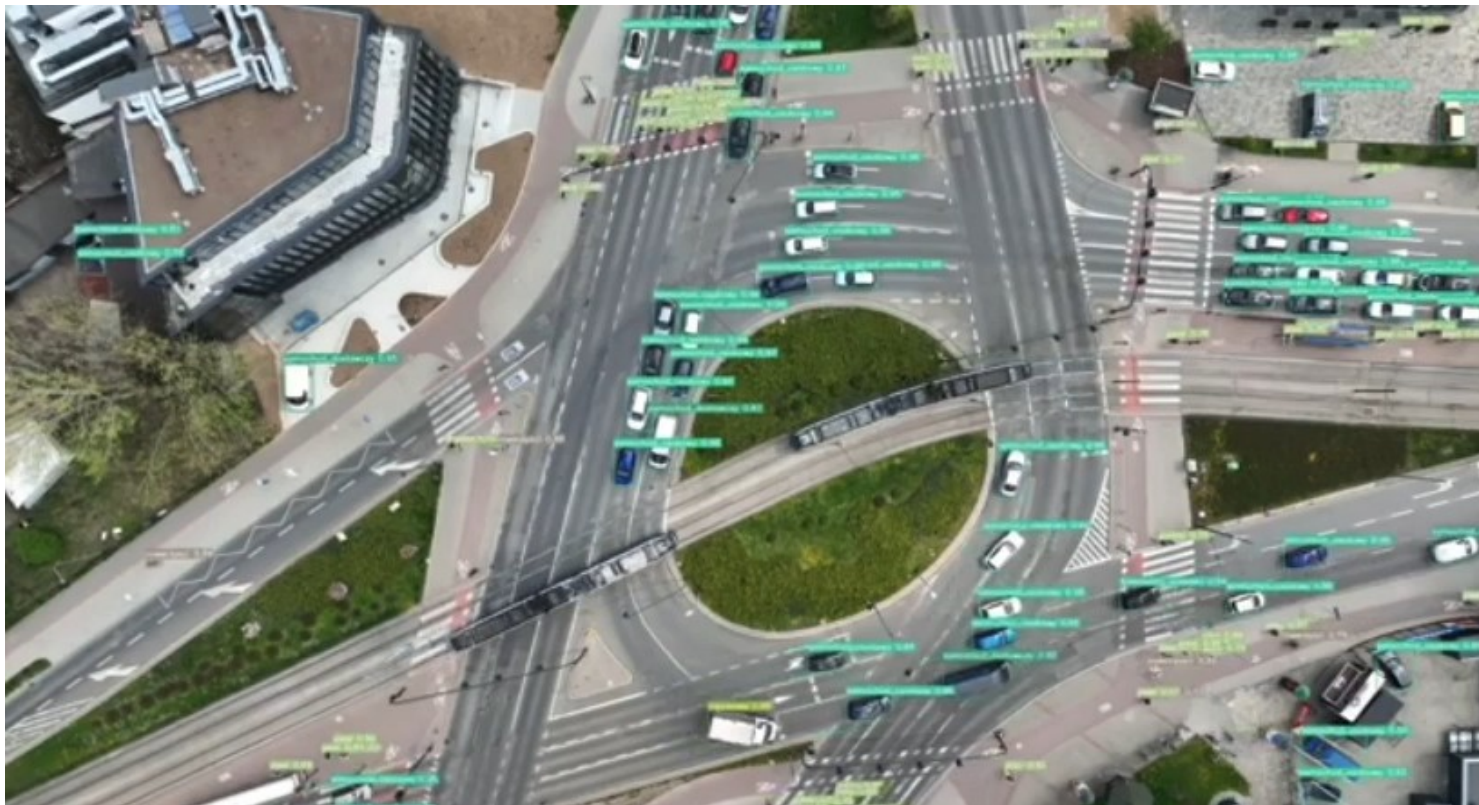
FishEye Dewarping



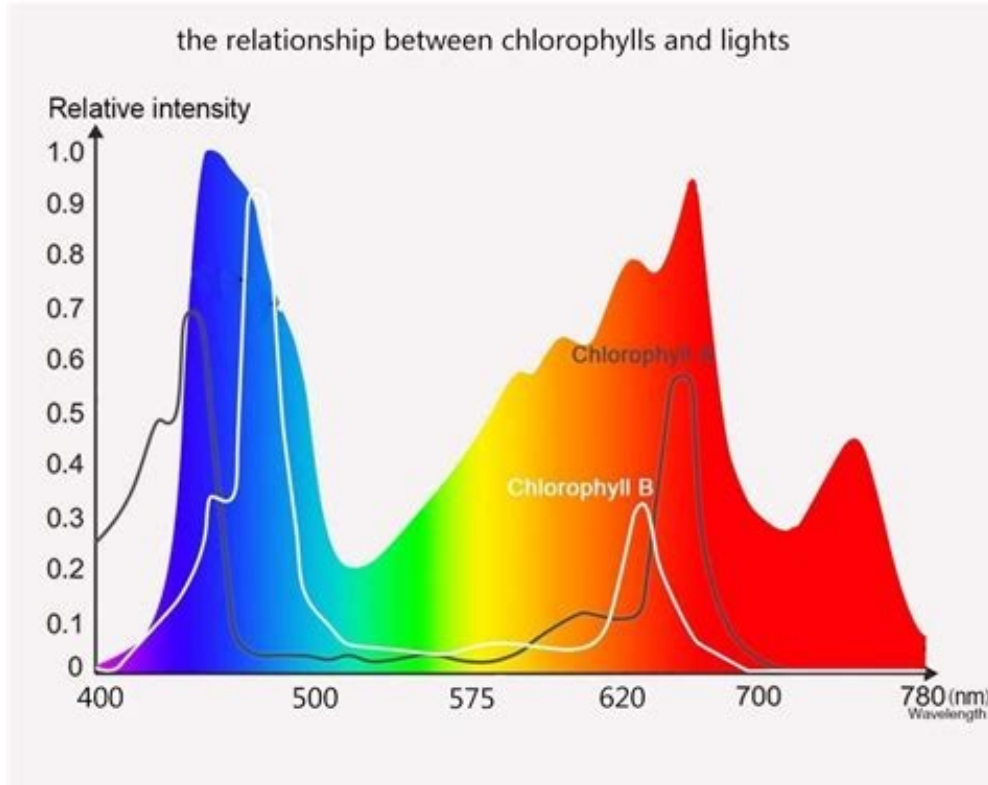
Drone Video Pipeline



Vehicle Detection



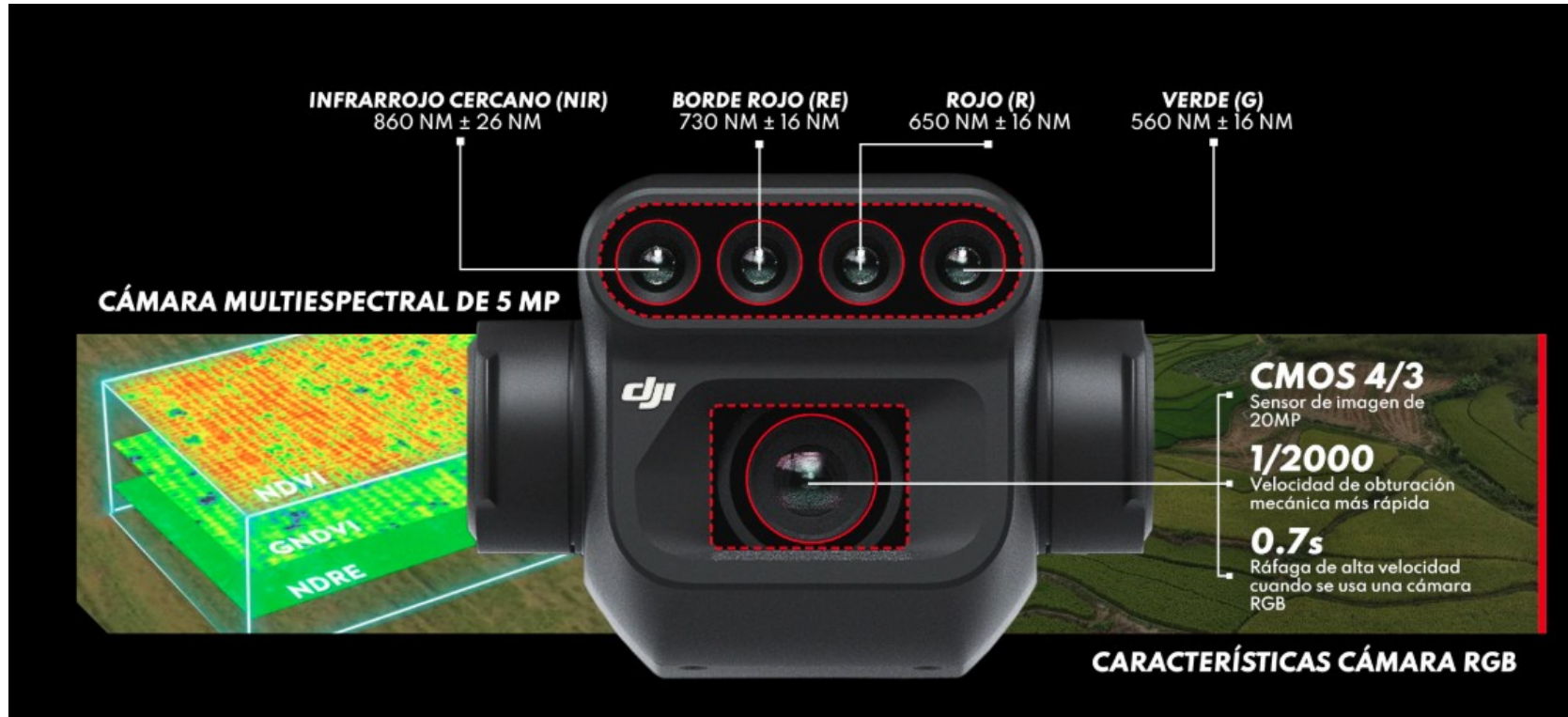
PhotoSynthesis Spectrum



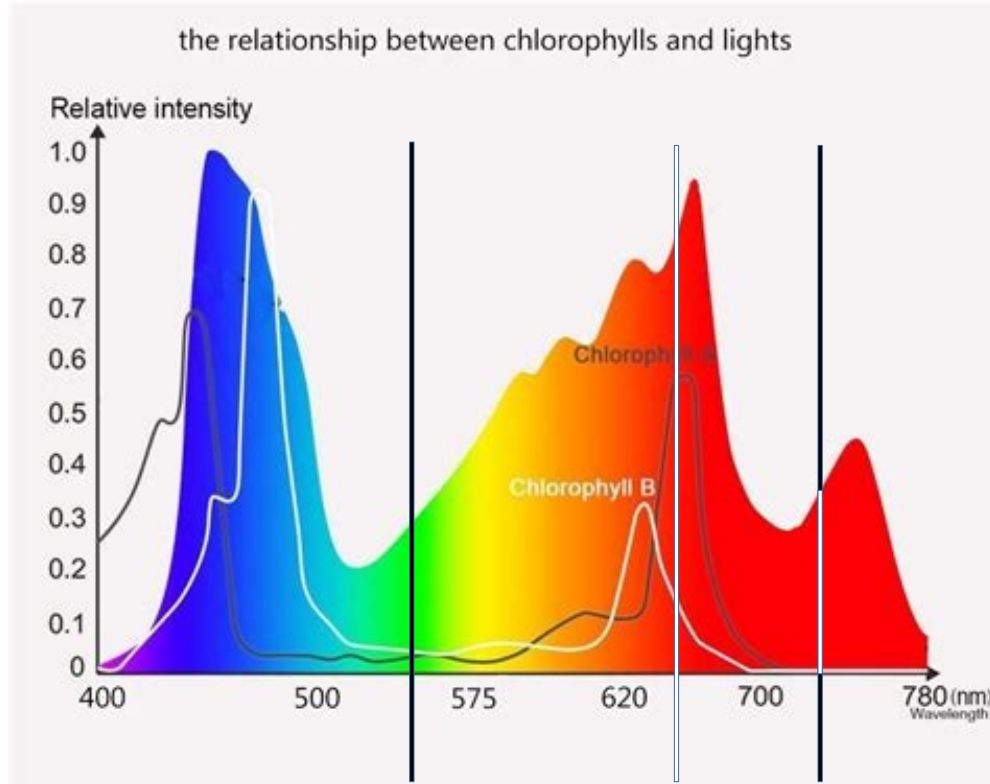
DJI Cameras
operate at
860nm
730nm
650nm
560m,

560 nm 650nm 730nm 860nm

DJI Multispectral Cameras



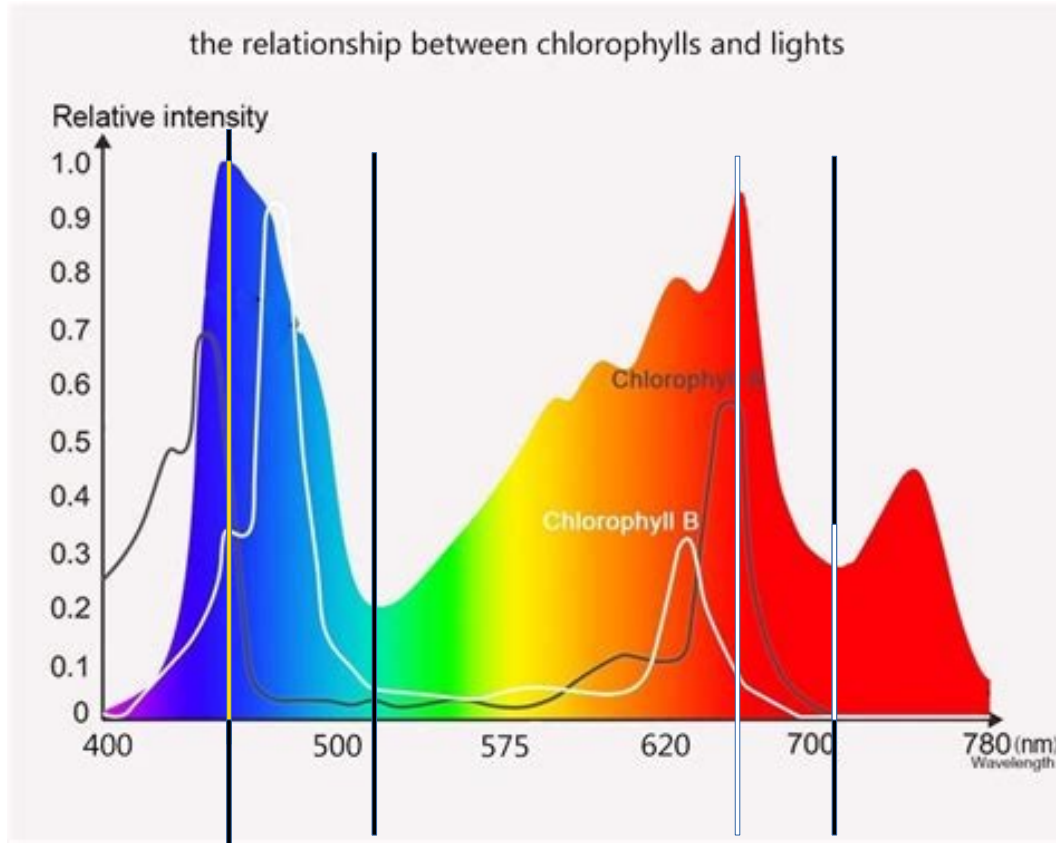
DJI MultiSpectral Camera Frequencies



DJI Cameras
operate at
860nm
730nm
650nm
560m,

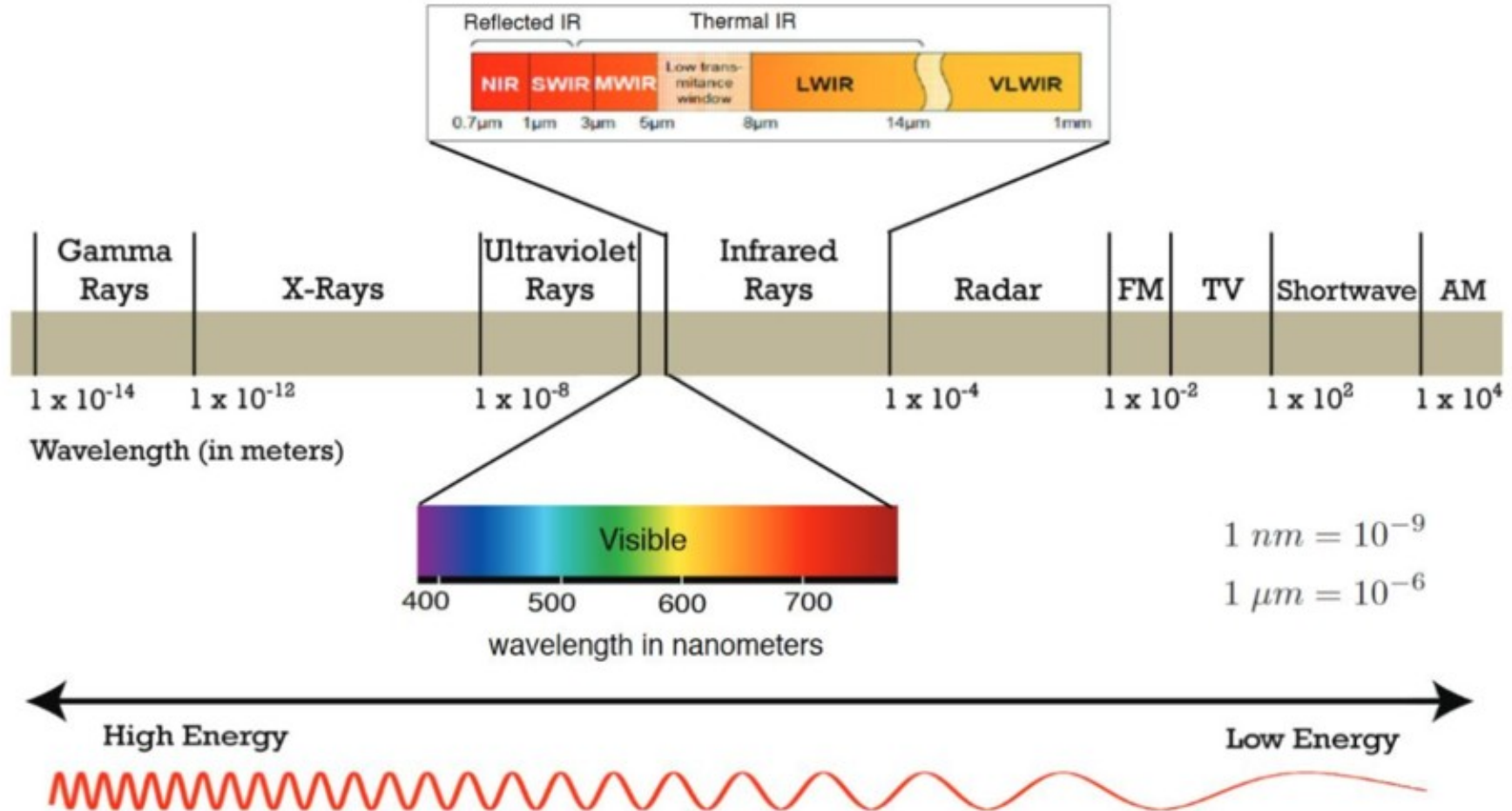
560 nm 650nm 730nm 860nm

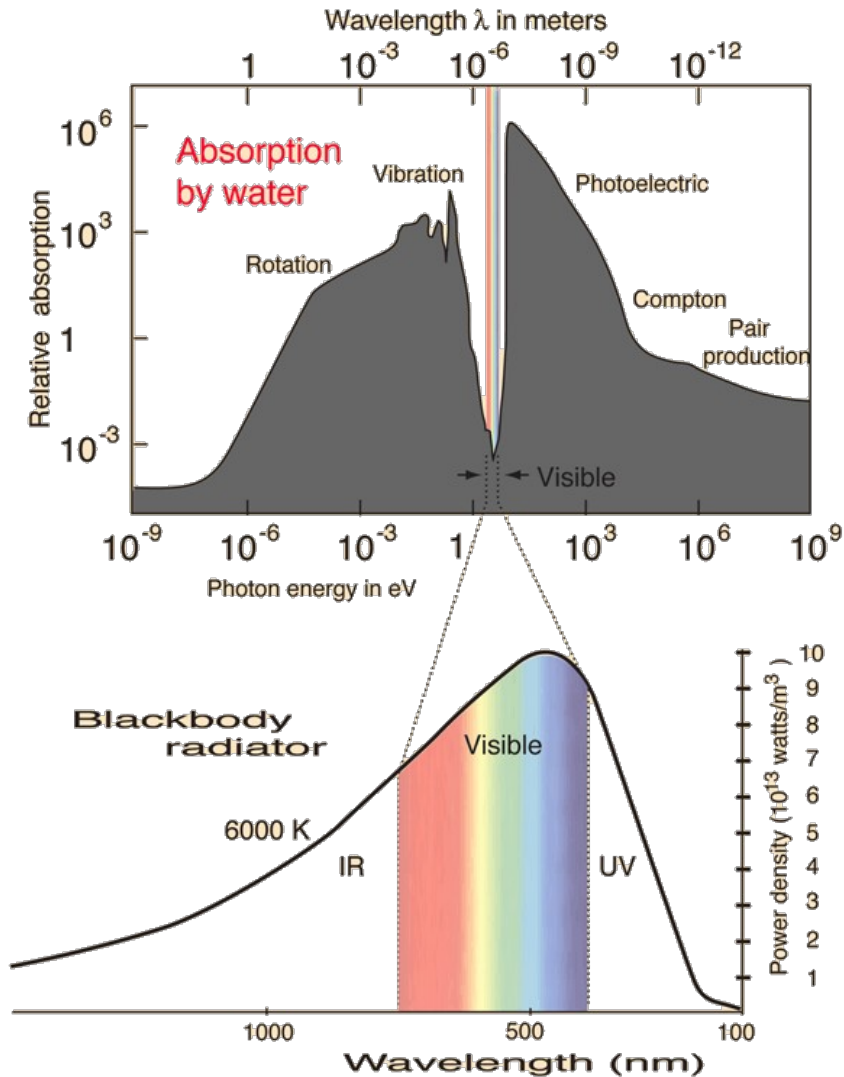
PhotoSynthesis Spectrum



DJI Cameras
operate at
860nm
730nm
650nm
560m,

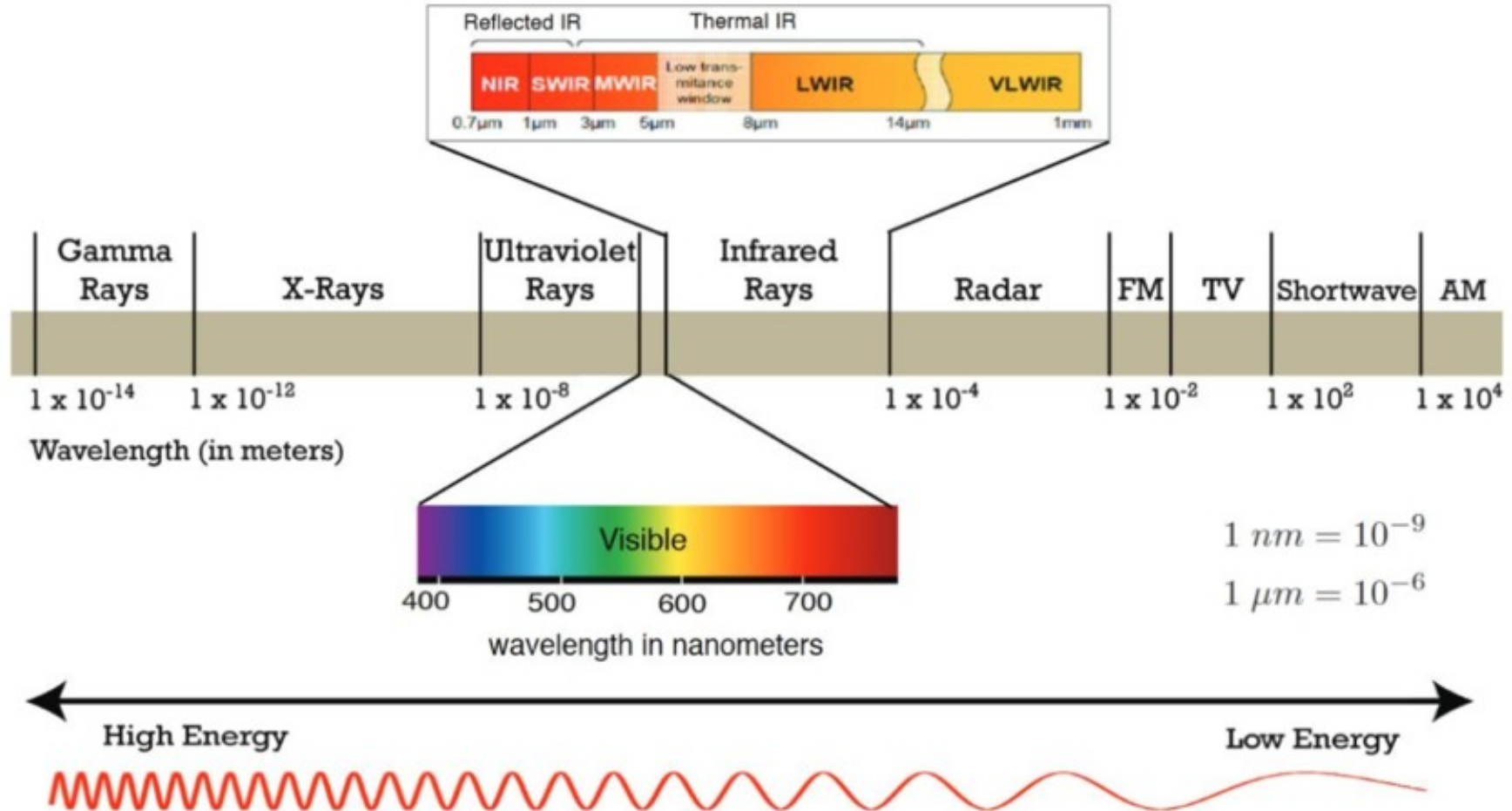
Spectrum





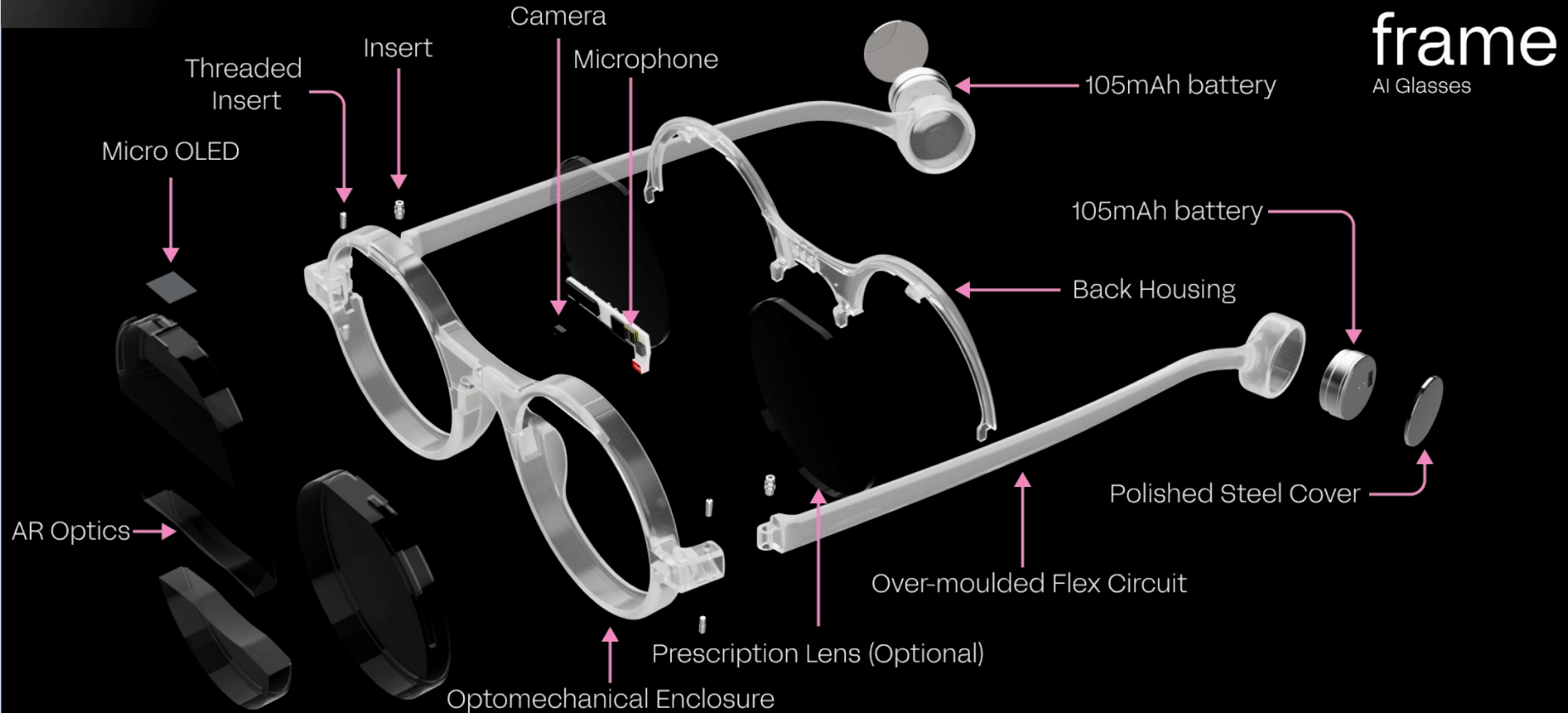
Water Absorption Spectrum

Spectrum

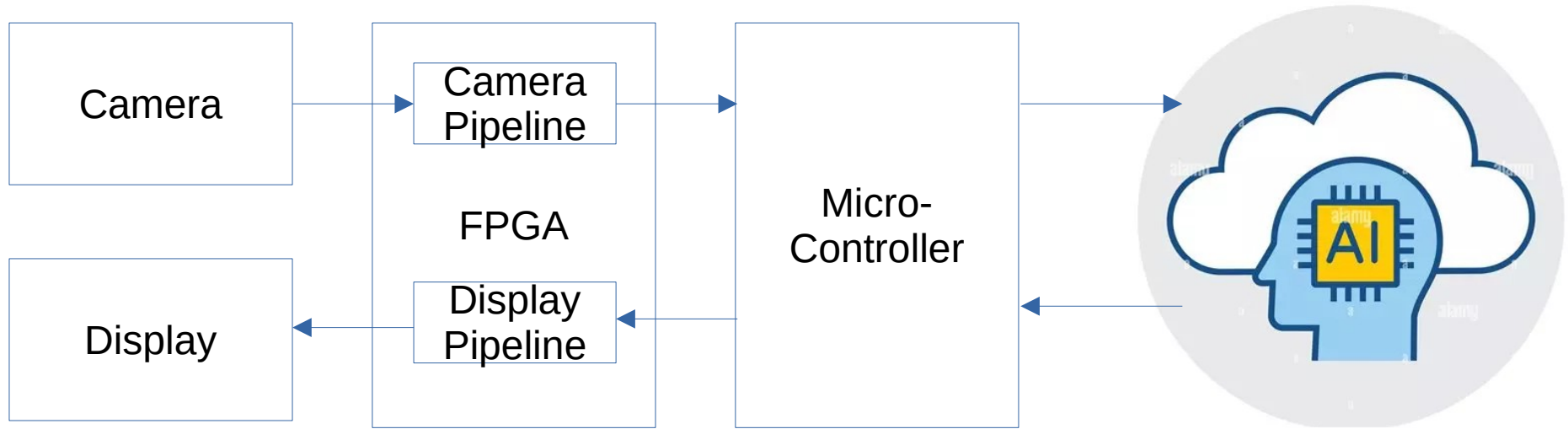




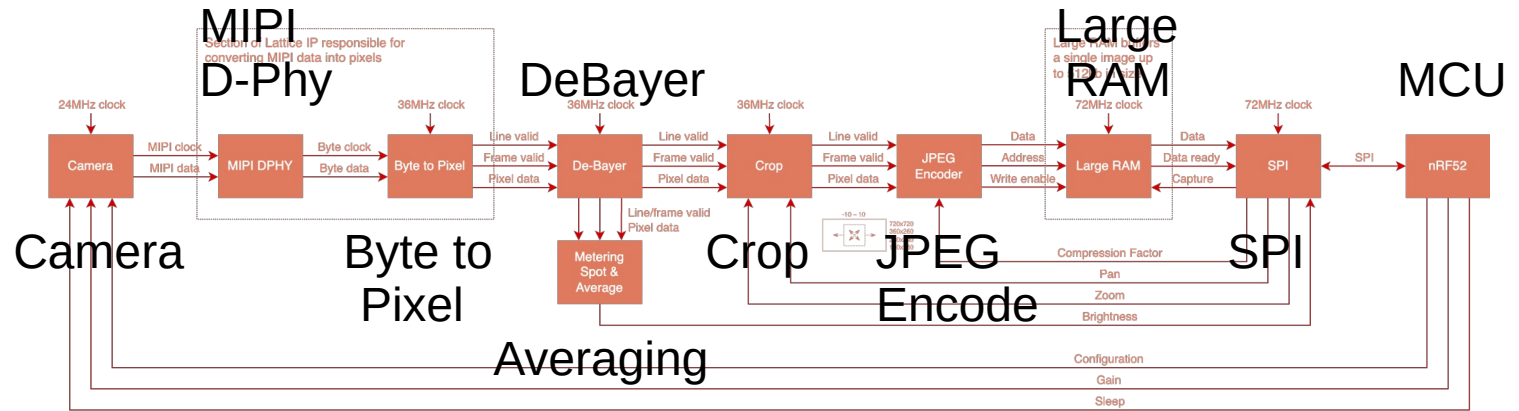
Frame Glasses



Frame Pipeline



Frame Camera Pipeline



Cameras



Raspberry Pi Camera



An engineer thinks of a camera as a sensor with some wires.

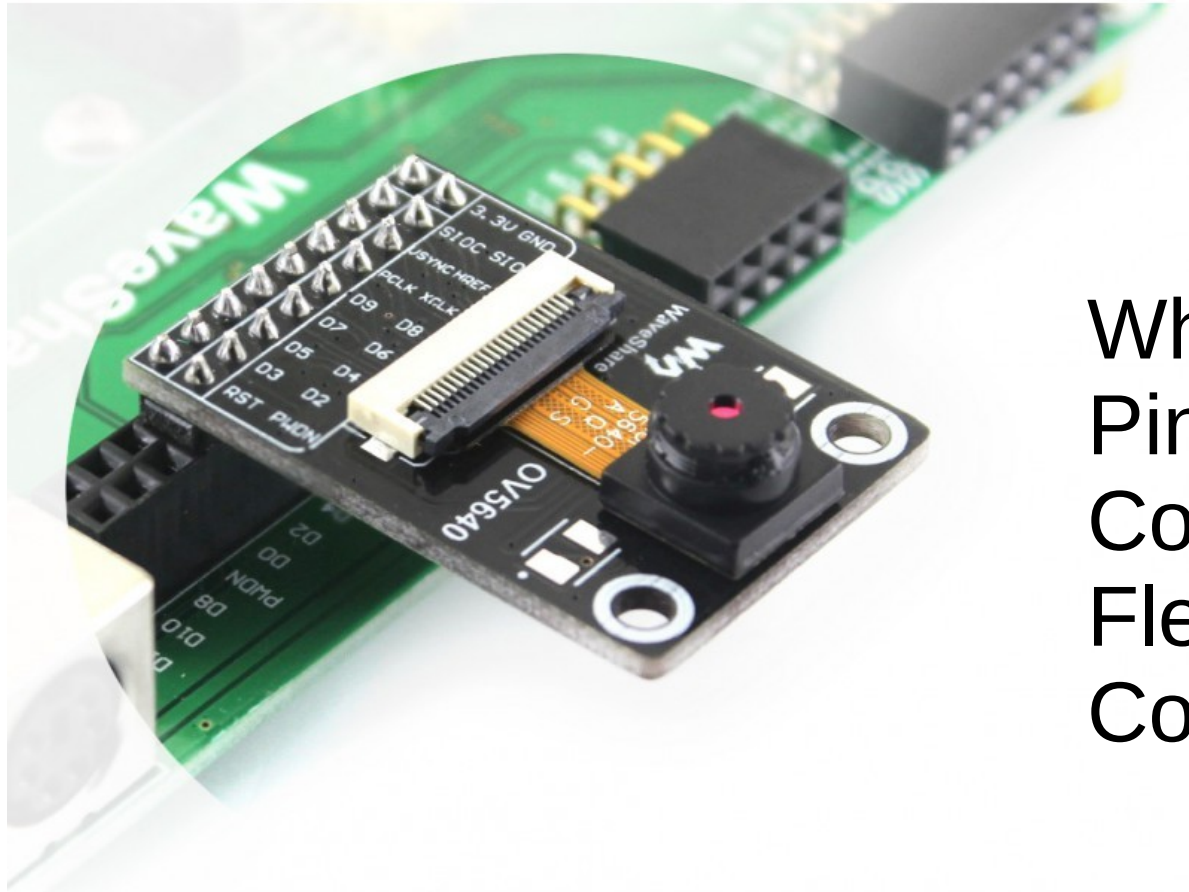
\$17 WaveShare OV5640



Fisheye \$16.60

Rectilinear Lens +
AutoFocus + Flash \$26.00

Zoomed In View



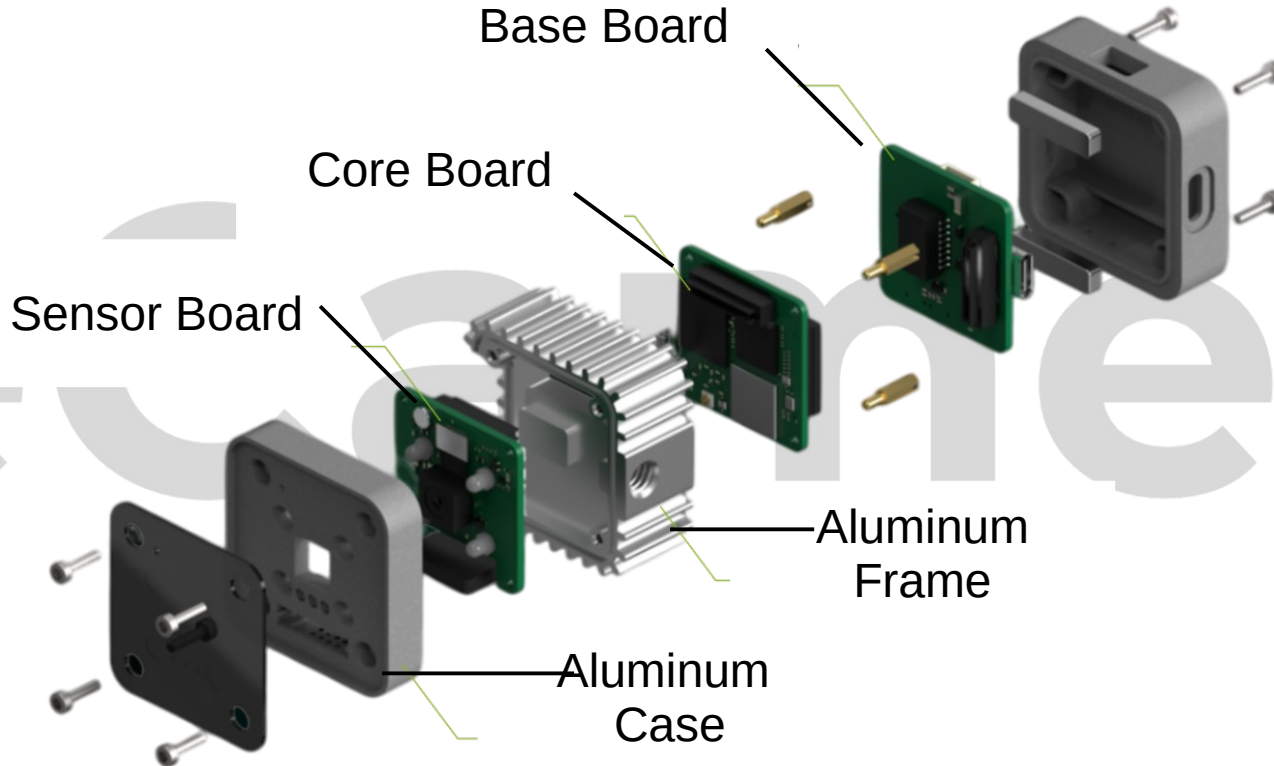
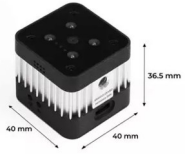
White strip is a 38 Pin Flexible Flat Connector (FFC) or Flexible Printed Connector (FPC)

Arducam USB Shield



Arducam Parallel
Camera Adapter Board

ReCamera



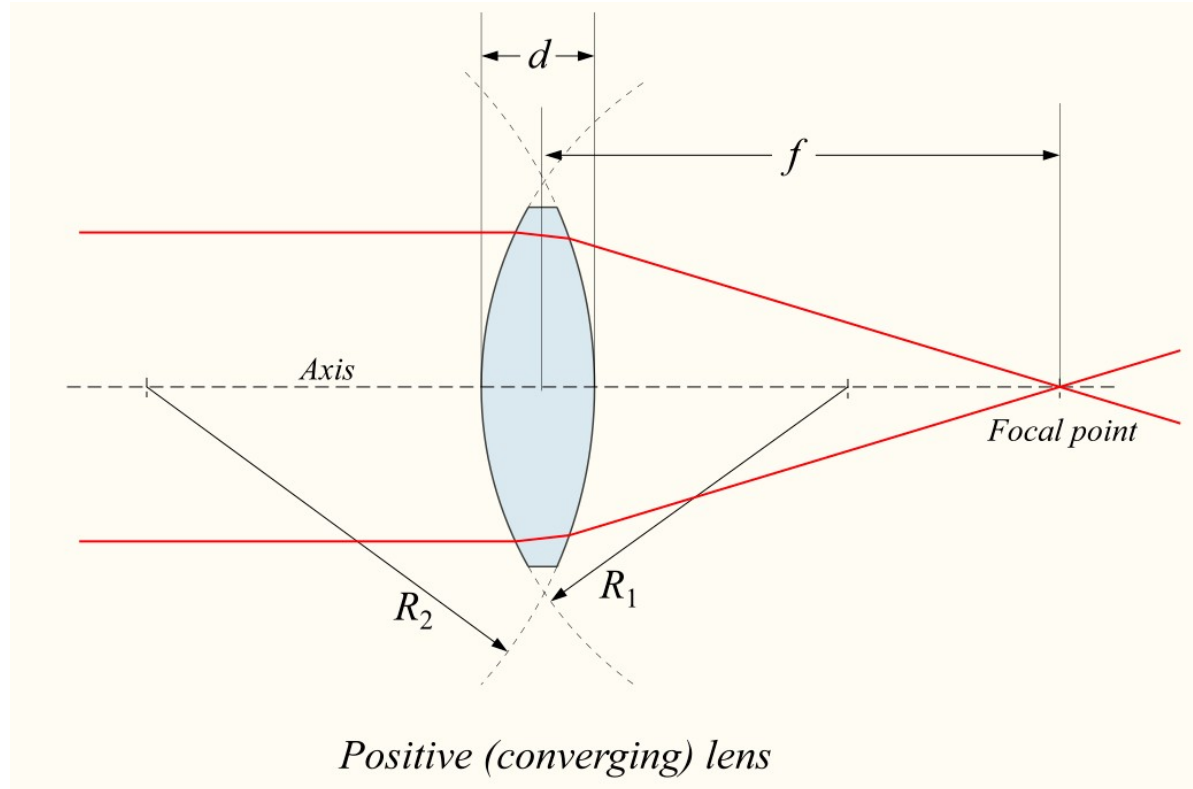
10 minutes



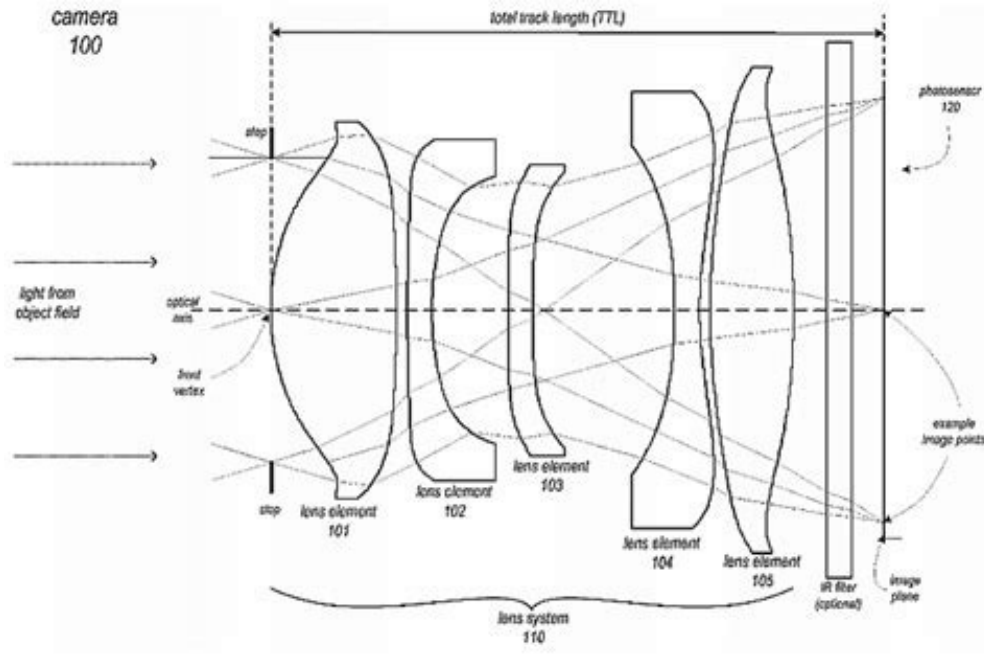
An open source
camera stack from
Seeed studios.
Apache-2 license.

Basic Lens

We think of lenses as being quite simple.



2016 iPhone Lens Patent



Like everything else, lenses are getting more and more complex.

874 Image Sensors

onsemi

OMNIVISION

SONY

GALAXYCORE

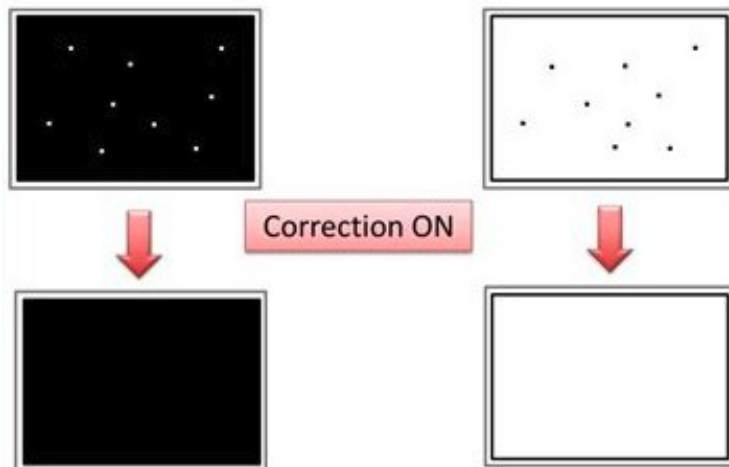
Himax

SMARTSENS

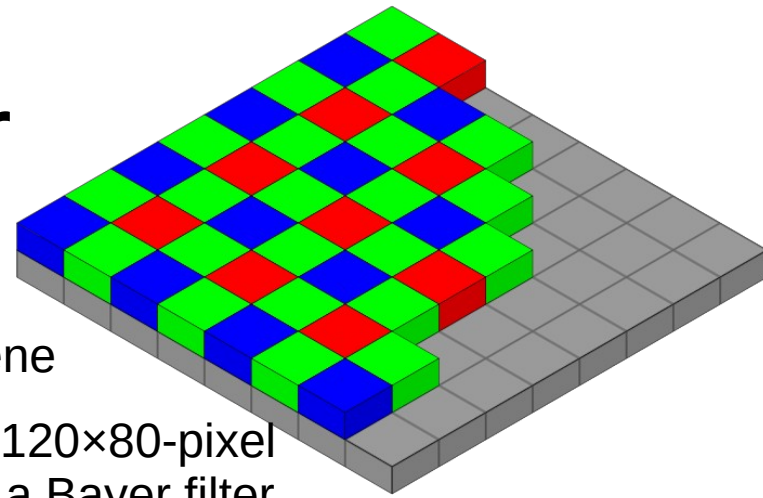
☐	Brigates	RV400	0,25	2.8	BSI
☐	Brigates	BG0851	2,35	13	FSI
☐	Brigates	BG0808	2.1	3	BSI
☐	Brigates	BG0836	2.1	3	FSI
☐	BYD	BF2K21	50	0.72	BSI
☐	BYD	BF2D31	13	1,12	BSI

Camemaker.com is a database of 874 image sensors from 12 vendors. Does not even include AMS OSRAM, Gpixel, Nuvoton, Renesas, Samsung, STMicroelectronics, Teledyne and Tepeddyne Flir.

Defective Pixel Correction

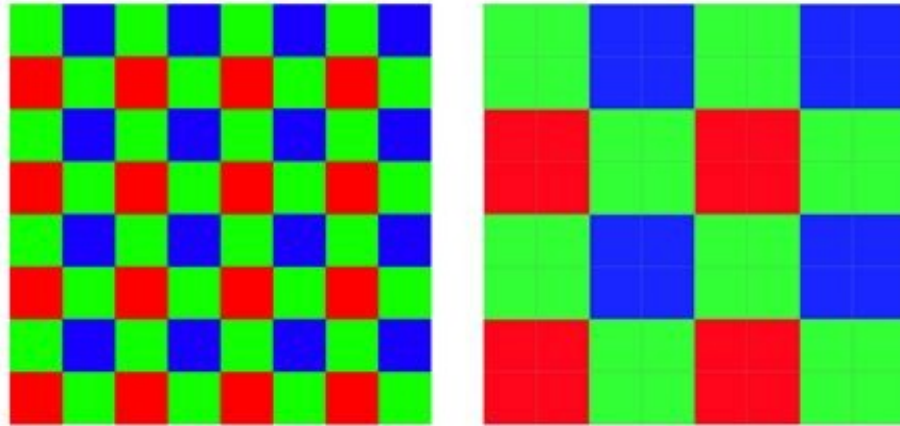


Bayer Filter



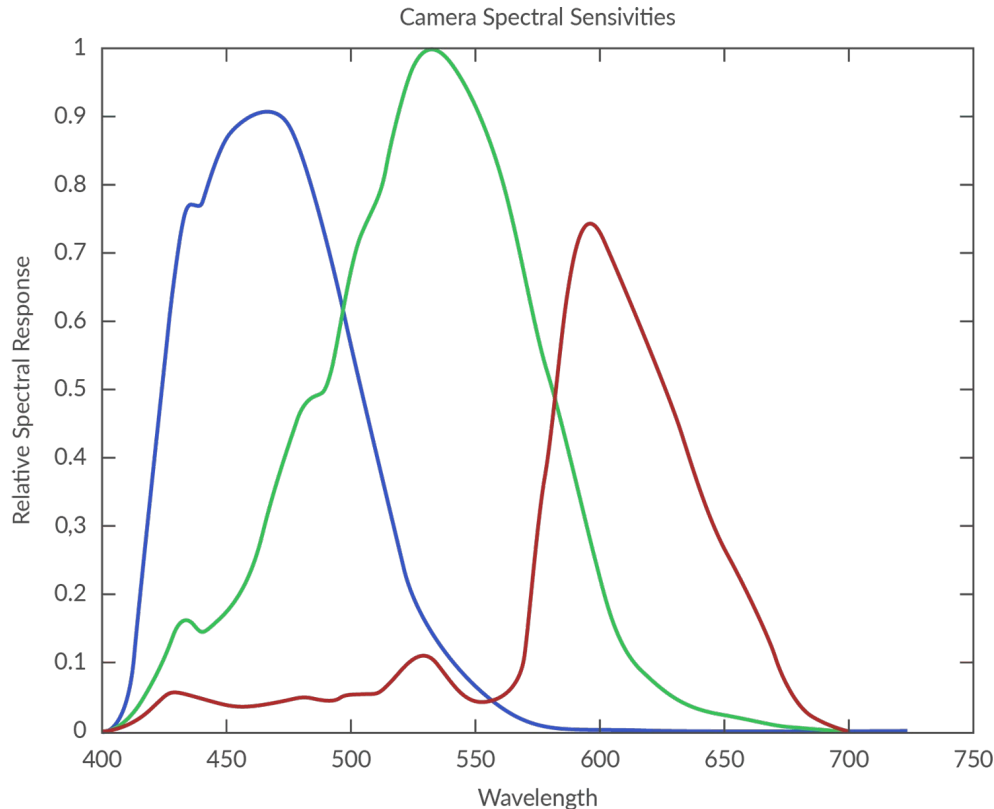
- 1) Original scene
- 2) Output of a 120×80-pixel sensor with a Bayer filter
- 3) Output color-coded with Bayer filter colors
- 4) Reconstructed image after interpolating missing color information
- 5) Full RGB version at 120×80-pixels for comparison (e.g. as a film scan, [Foveon](#) or [pixel shift](#) image might appear)

Pixel Binning



- Pixel Binning averages together multiple measurements.

Camera Spectral Response



Sensors, displays
and human eyes
have different
spectral
responses.

Color Balance

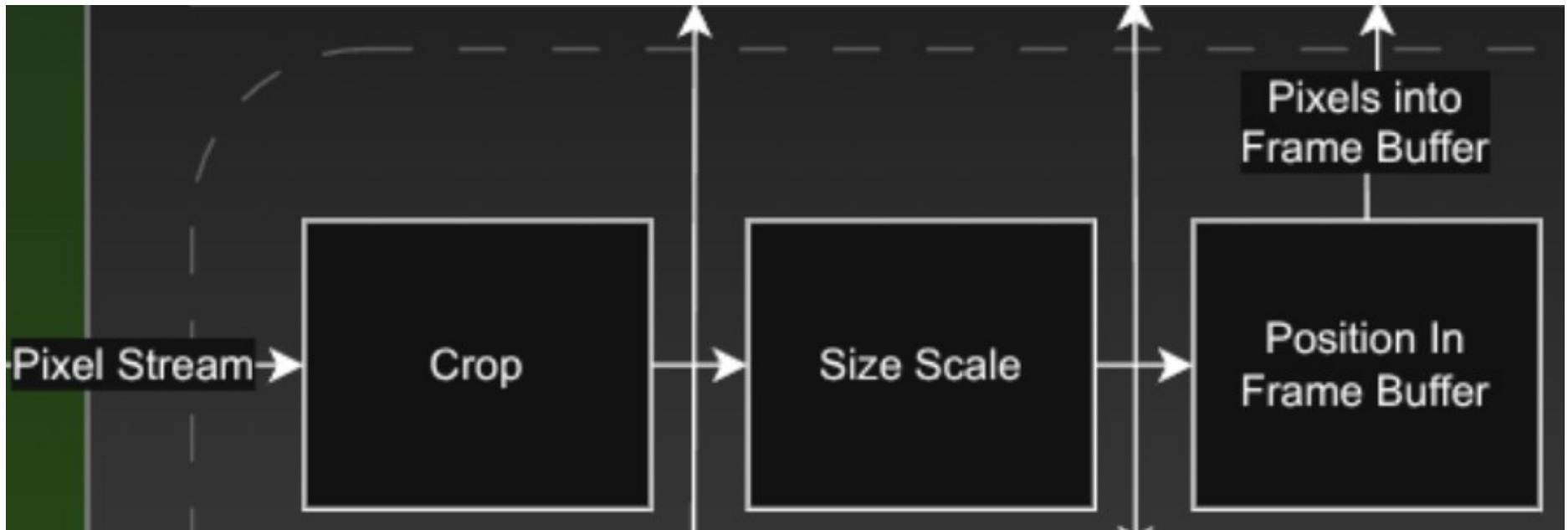


Video Cropping or Digital Zoom

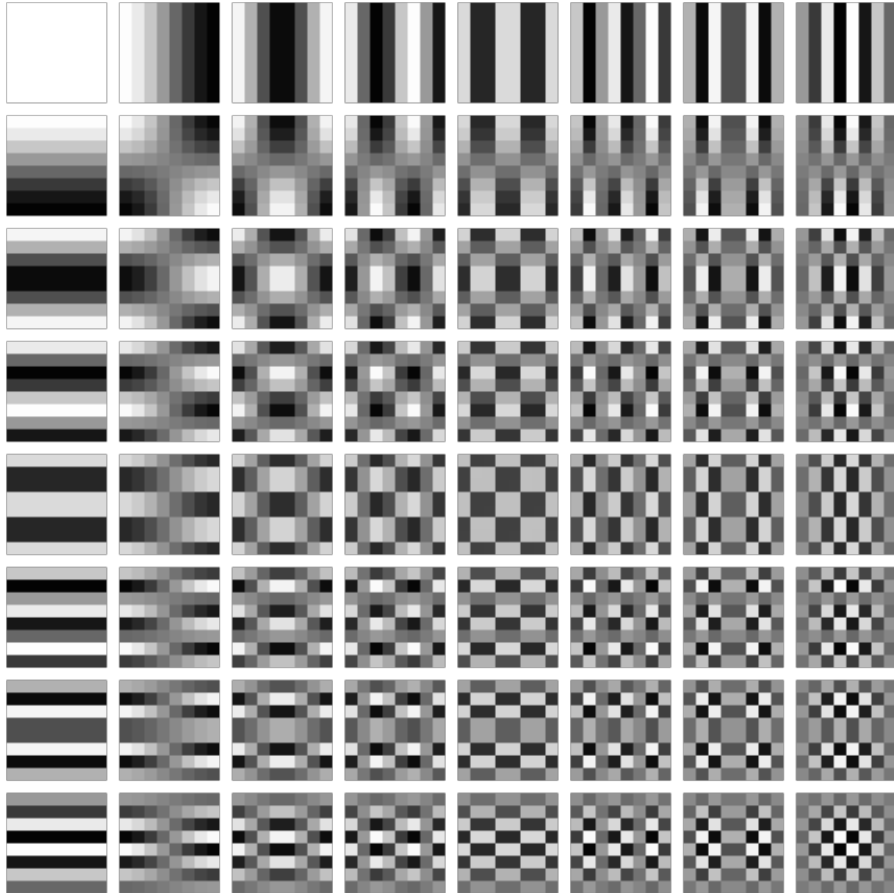


More complex than photo cropping because suddenly you have different size frames in the pipeline.

Video Cropping in PipelineC

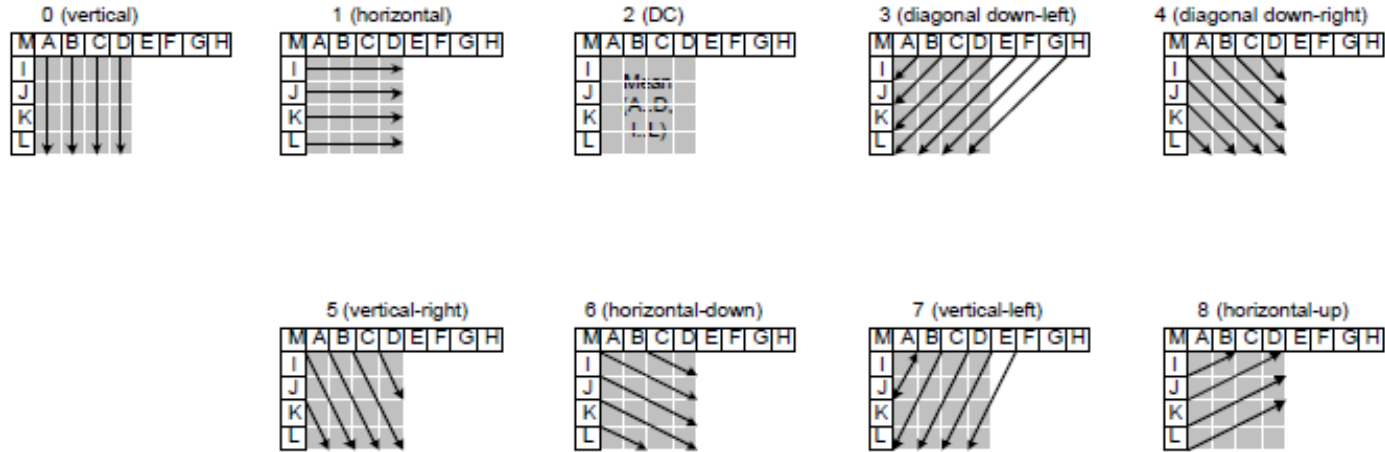


JPEG Compression



JPEG Compression represents one color in an array of 8x8 pixels using just a few of the cosign transforms shown on the left.

H264/H265 Compression



Compensates for motion.

RGB to Gray Scale

$$Y_{\text{linear}} = 0.2126R_{\text{linear}} + 0.7152G_{\text{linear}} + 0.0722B_{\text{linear}}.$$

Note that green is more heavily weighted. For evolutionary reasons our eyes are more sensitive to green.

Sobel Edge Detection

$$\mathbf{G}_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * \mathbf{A}$$

$$\mathbf{G}_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * \mathbf{A}$$

1968 Paper

Well Known

Too much math

Edges can be different widths

Edges are smaller in dark regions

Canny Edge Detector

$$H_{ij} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(i - (k + 1))^2 + (j - (k + 1))^2}{2\sigma^2}\right); 1 \leq i, j \leq (2k + 1)$$

$$\mathbf{B} = \frac{1}{159} \begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} * \mathbf{A}.$$

A good academic concept
But not that practical on
FPGAs.

Step 1 is a gaussian filter.
How do you divide by 159
on an FPGA?

20 Minutes

Canny Edge Detector

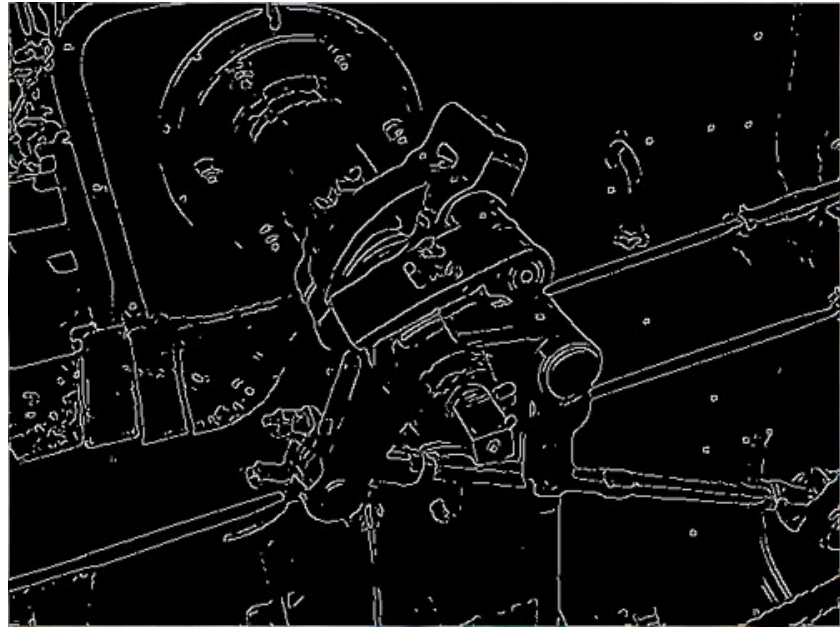
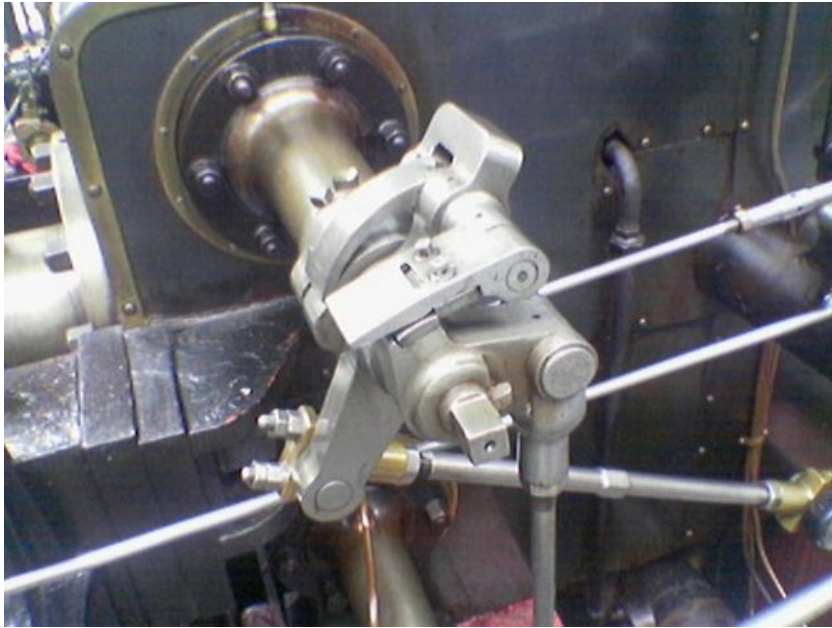
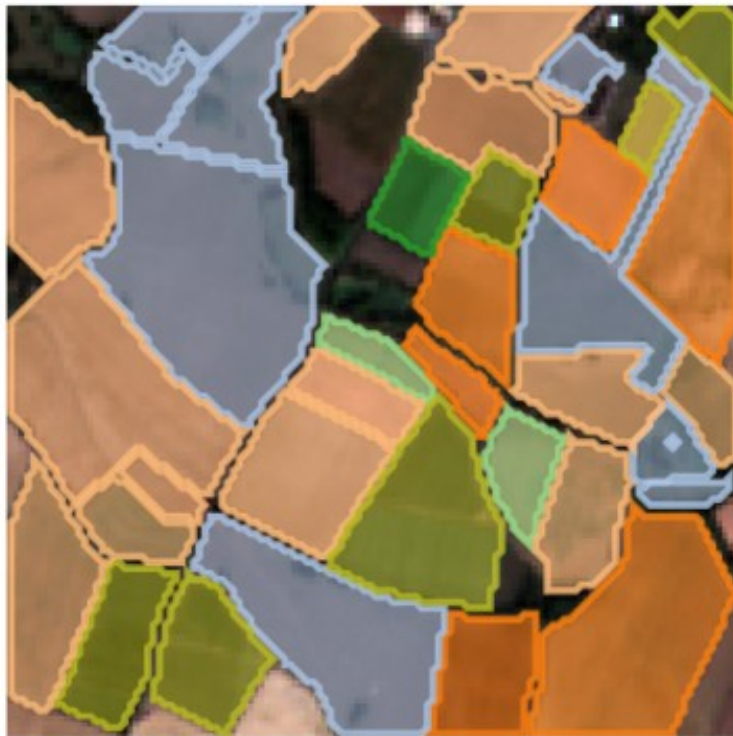


Image Segmentation



Agricultural SegmentationData Set



RGB to YUV

YUV 4:4:4, YUV 4:2:2, YUV 4:2:0, and YUV 4:1:1

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix},$$



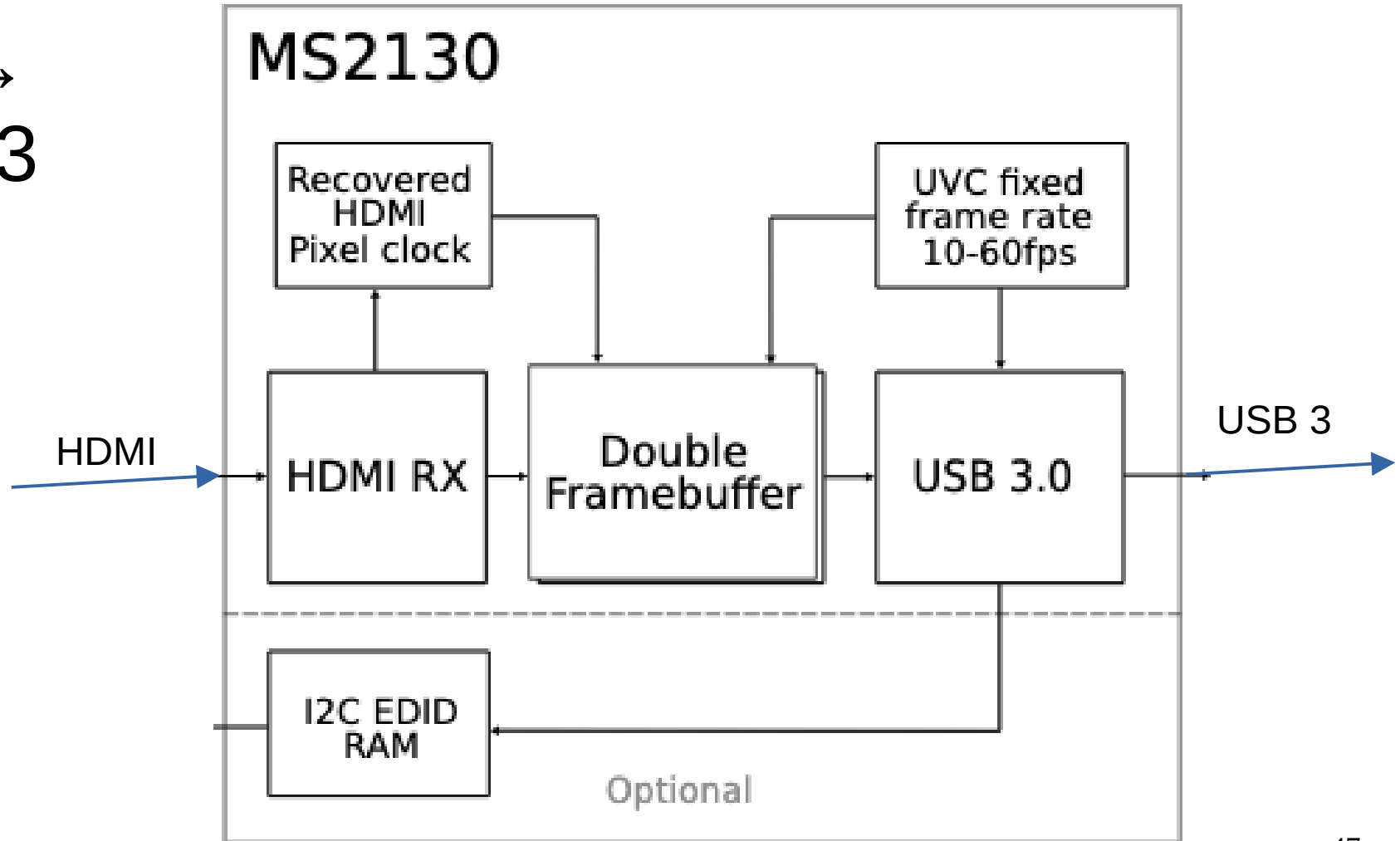
DVI TO USB-3 Dongles



USB-3 Runs at 5 Gbits/s

< \$10 Devices

DVI →
USB 3



Libmpix on Zephyr OS



Libmpix supports auto exposure, black level correction, white balance, debayer, color calibration, gamma correction, gaussian blur, median denoise, sharpen, sobel edge detection, resizing, image statistics, sampling, and JPEG compression. SIMD coming soon.

ALTERA®

XILINX®



Efinix = Pango



Yosys Open SYnthesis Suite (Yosys)

A framework for RTL synthesis



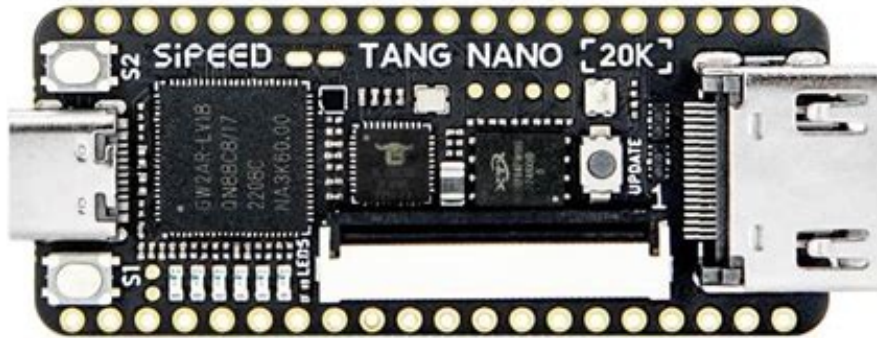
Currently Yosys and Nextpnr support:

- Lattice iCE40 devices supported by [Project IceStorm](#)
- Lattice ECP5 devices supported by [Project Trellis](#)
- Lattice Nexus devices supported by [Project Oxide](#)
- Gowin LittleBee devices supported by [Project Apicula](#)
- NanoXplore NG-Ultra devices supported by [Project Beyond](#)
- Cologne Chip GateMate devices supported by [Project Peppercorn](#)
- A few experimental platforms.

Gowin + Tang Nano 20K

PLN 66.00 = EUR 15.43

- 20K Luts
- DVI/HDMI
- 64Mbits SDRAM
- MIPI DPI





- Ice40, Underpowered compared to RP2350
- ECP5, great ecosystem, supports 1920p DVI/HDMI
- CrossLink NX 17/33/40 MIPI enabled.

Open Source FPGA Vendors with MIPI



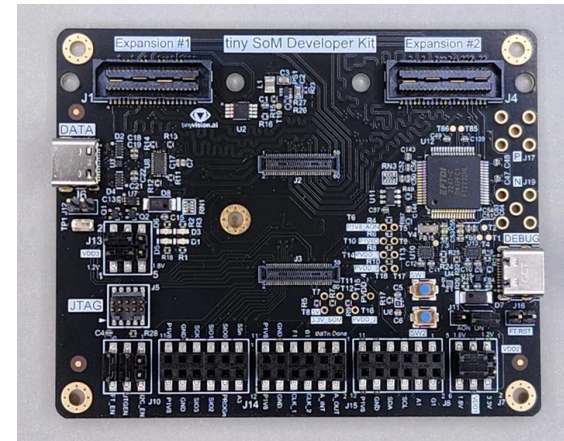
Lattice NX 17/33/40 MIPI Blocs

- Two MIPI Hard Cores.
- 2.5 Gbits/s
- Can be configured to support either Camera Serial Interface (CSI-2) or Display Serial Interface (DSI) applications as either transmitter or receiver.

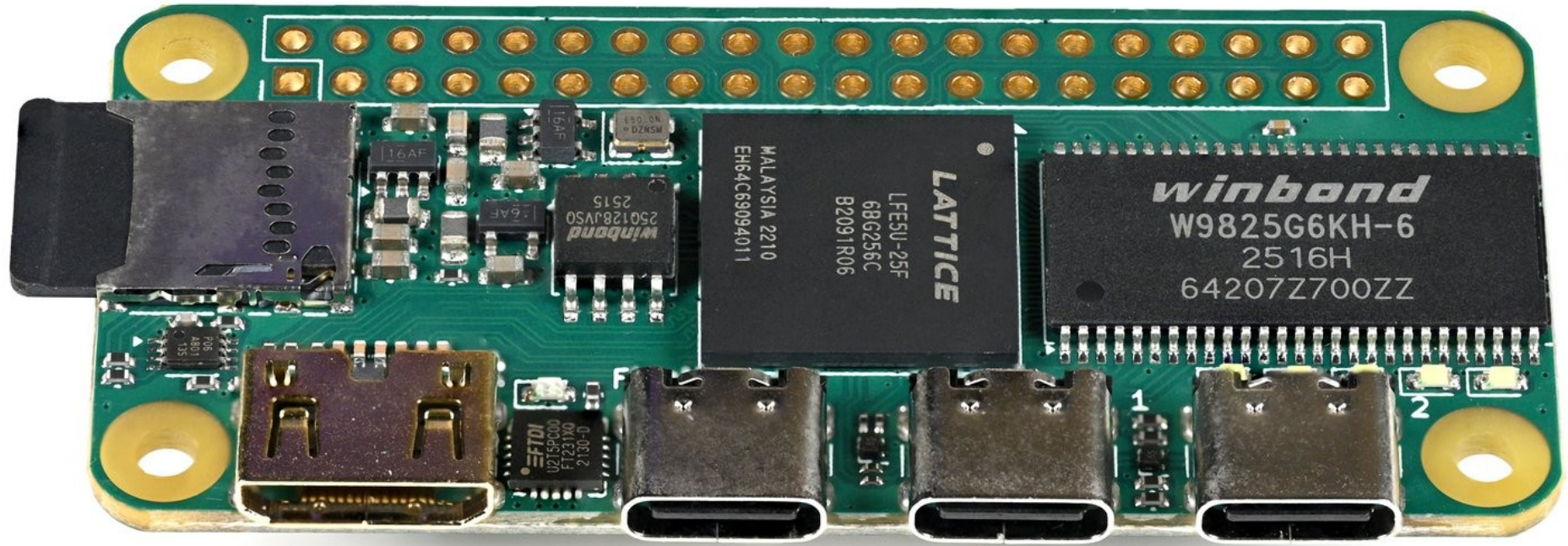
**TinyVision.ai CLUNX33
Developer Kit**

MIPI to USB

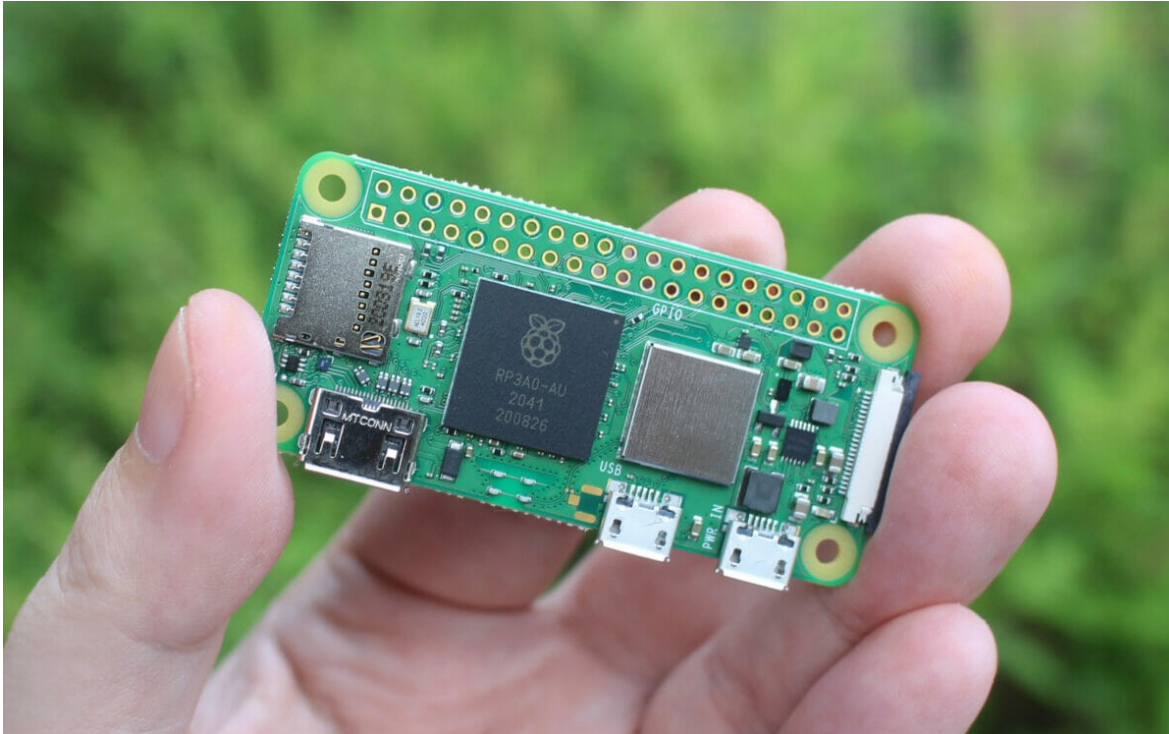
**PLN 923.00 = EUR 217
+ Taxes**



\$79 IcePi Zero



Raspberry Pi Zero Mipi Bridge



RPI Zero \$10

RPI Zero 2W \$15

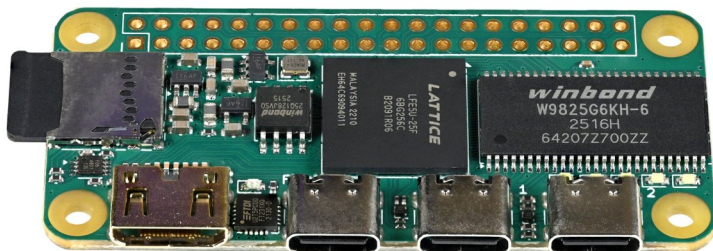
MIPI-CSI

USB-2

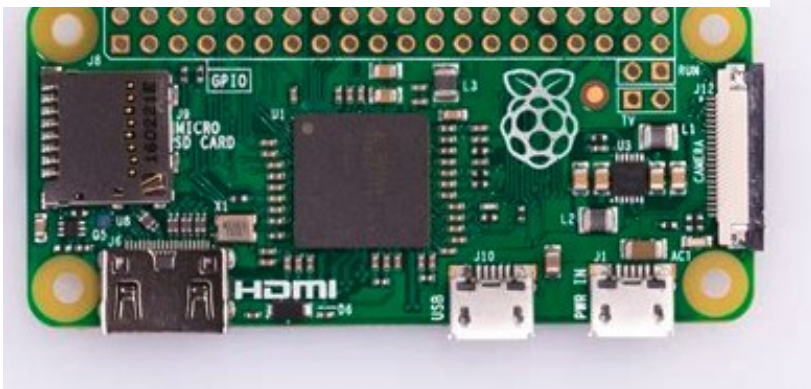
DVI

DPI

\$79 Ice Pi Zero + \$15 Raspberry Pi Zero

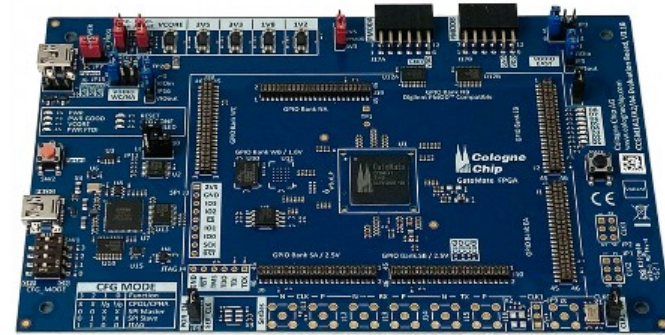


In January the \$79 IcePi Zero will ship. Pin compatible With the Raspberry Pi Zero. Just click them together. MIPI Camera port, And DVI out!

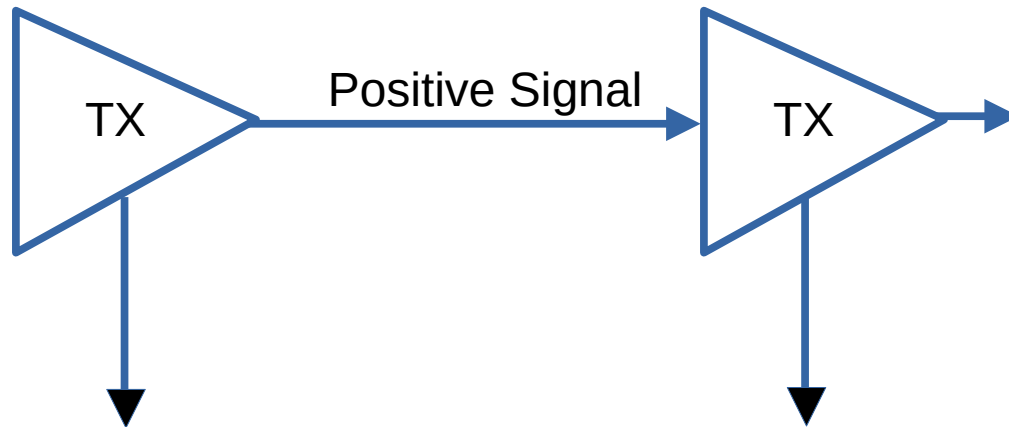


2.7Gbits/s

European Cologne Chips GateMate Evaluation Board 209 € = 885 ZI



Single Ended Signal

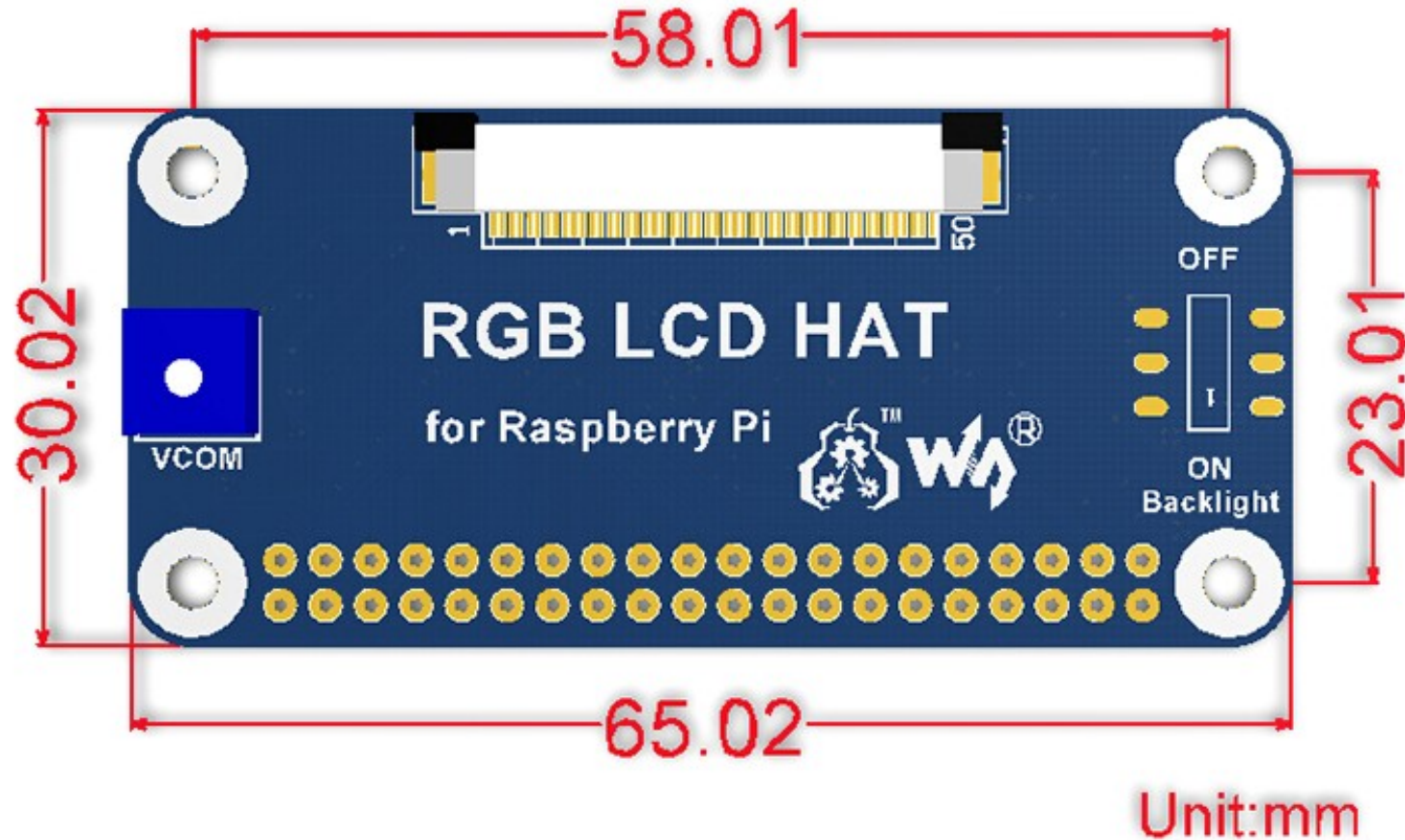


Camera to Processor
Digital Video Port(DVP)

Processor to Display
Digital Parallel Interface
(DPI) or RGB.

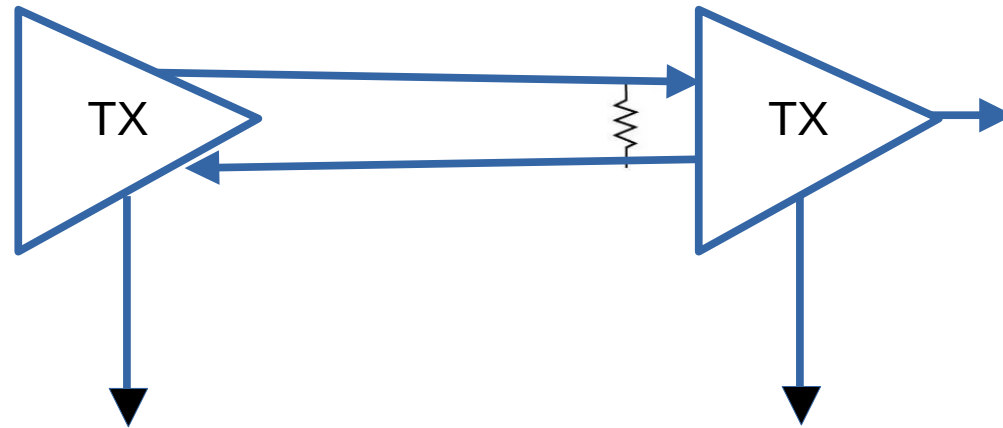
30 Minutes

Parallel RGB or DPI



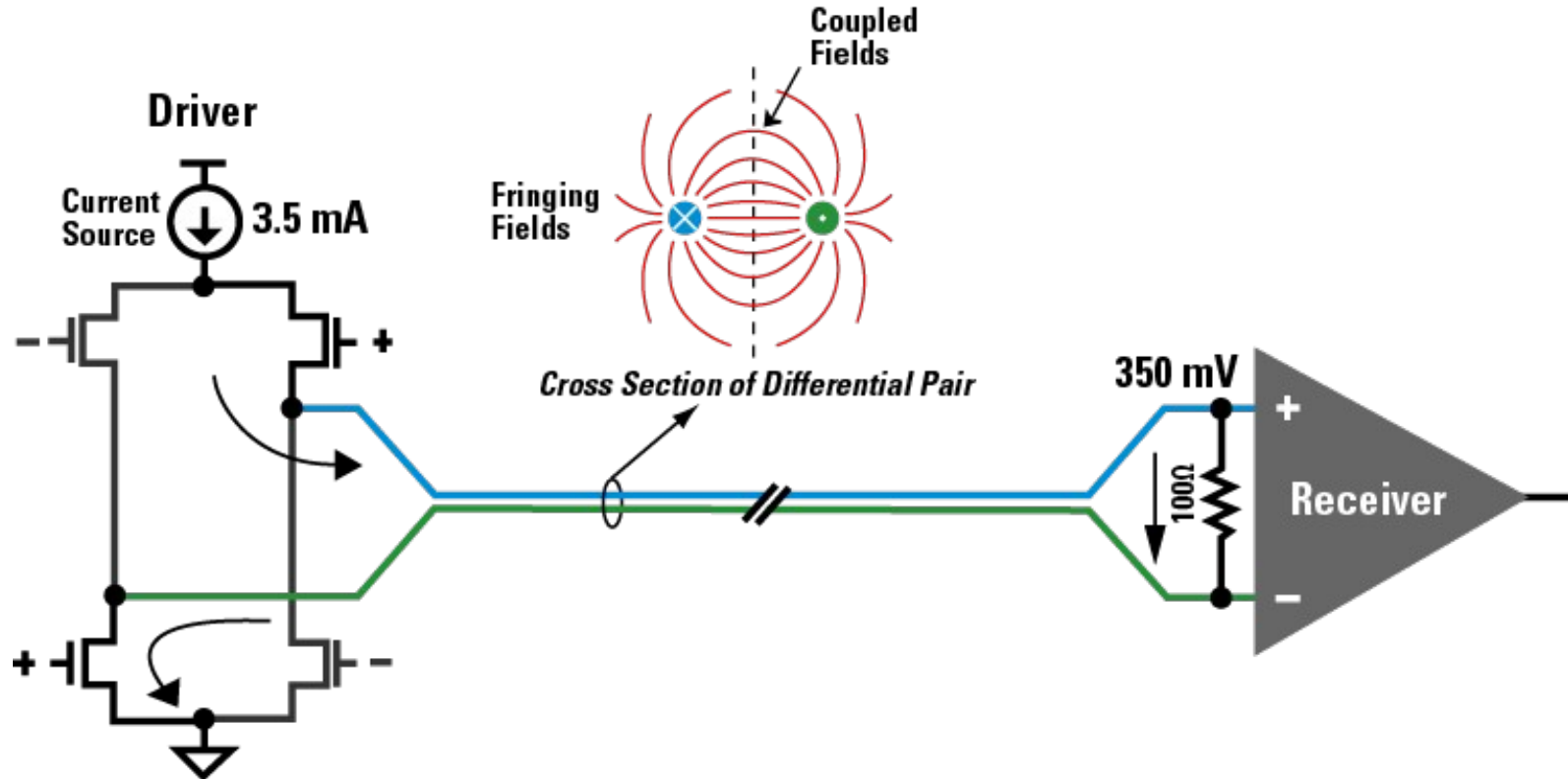
Differential Signaling

DVI, HDMI, USB, MIPI, DisplayPort, PCIe, DDR SDRAM, Ethernet, LVDS, SubLVDS, SLVS-EC, CameraLink,

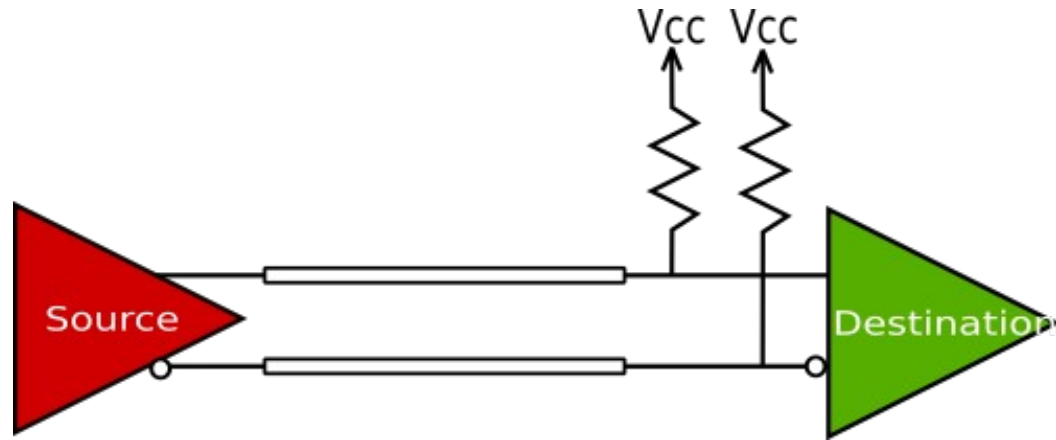


LVDS

MIPI, USB, DisplayPort, PCIe, DDR SDRAM, Ethernet, LVDS, SubLVDS, SLVS-EC, CameraLink



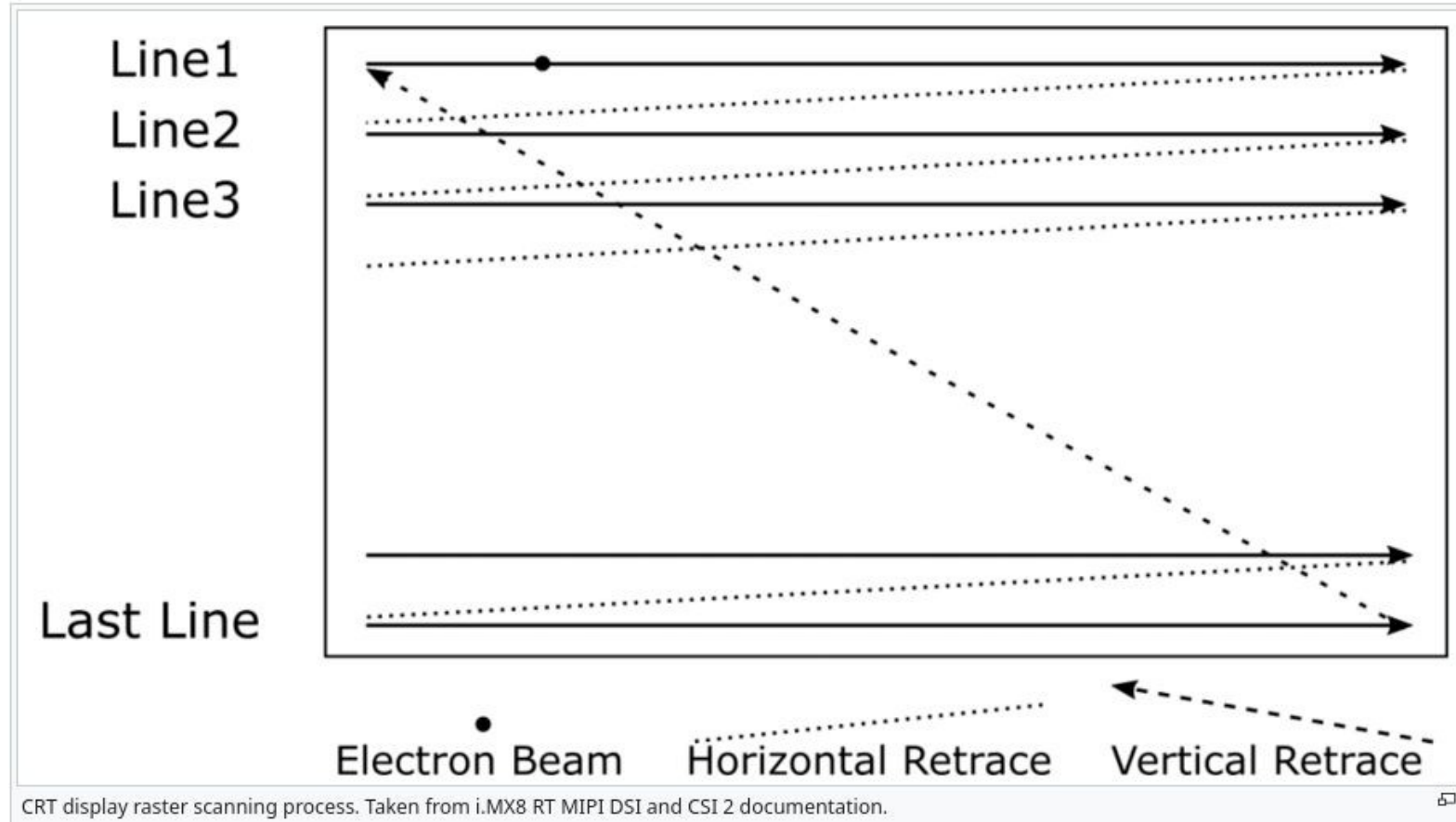
DVI/HDMI over Current Mode Logic (CML)



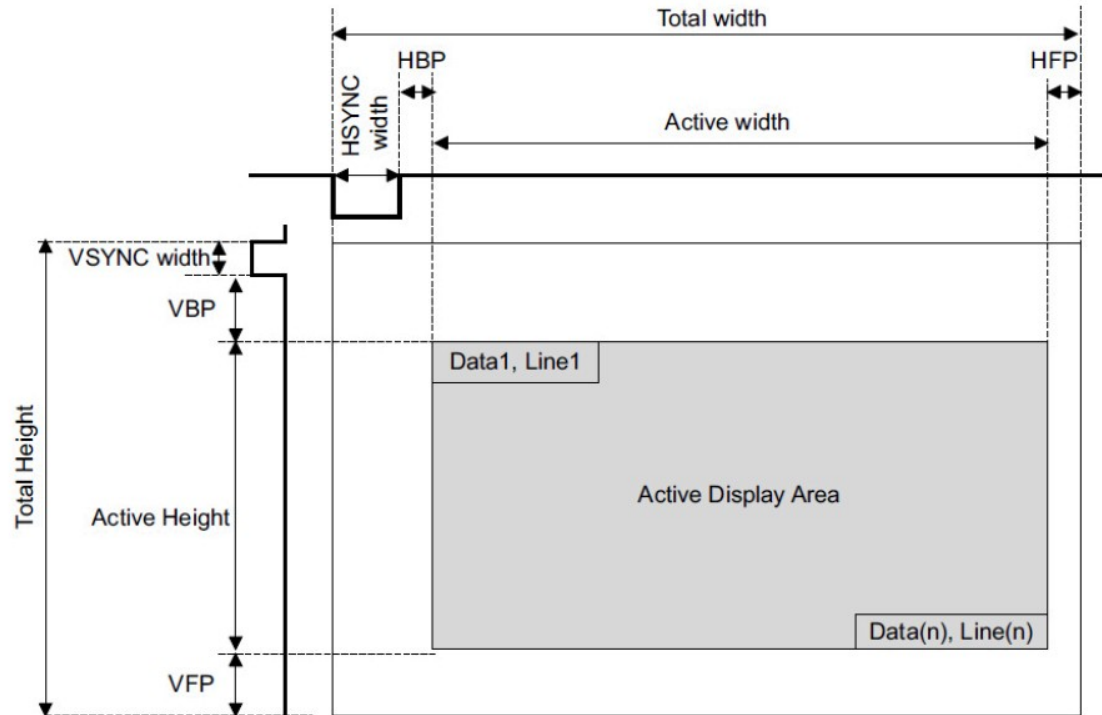
Display Interfaces



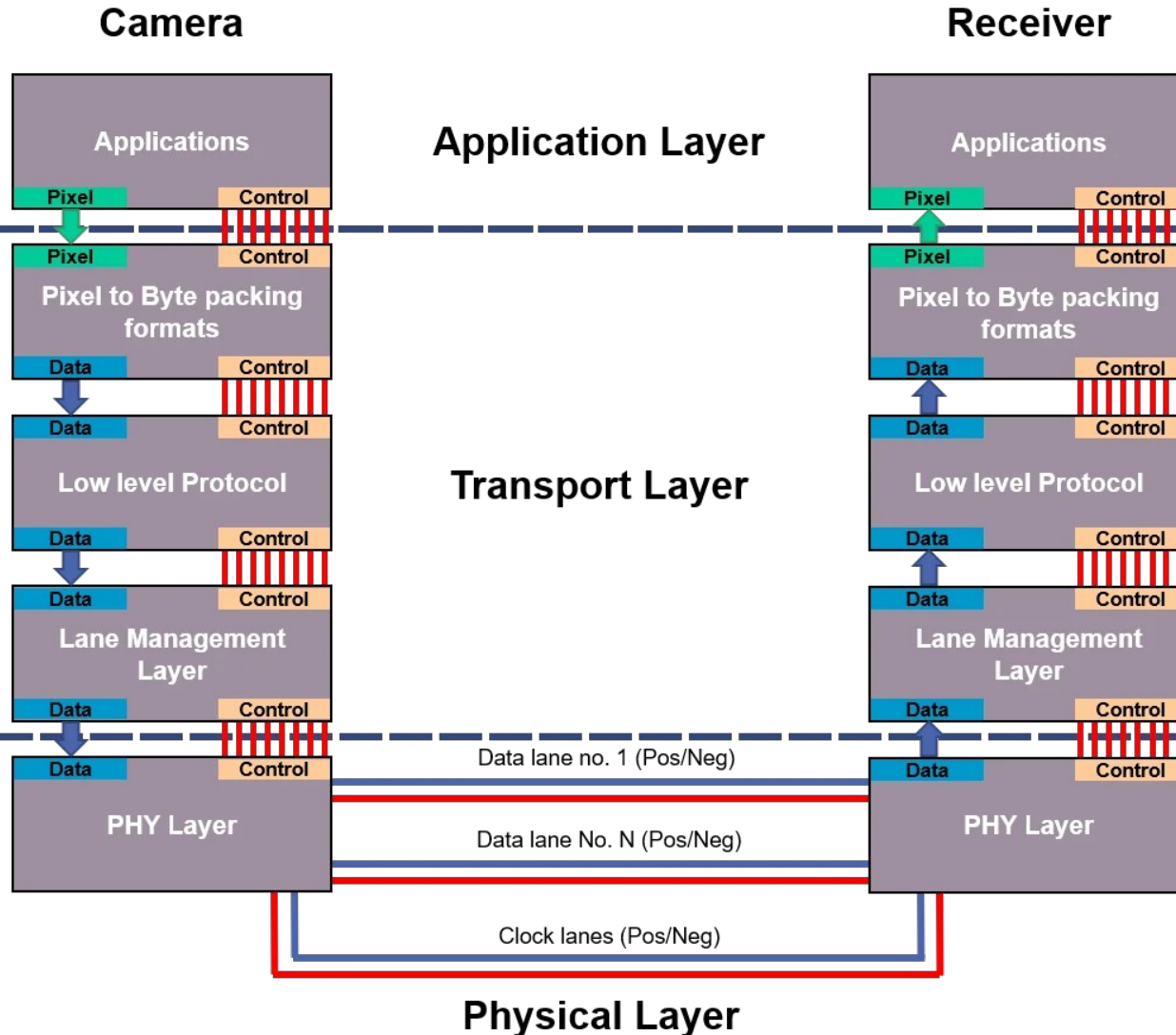
VGA Display Technologies



Front and Back Porch



MIPI CSI-2



SLVS-EC IP Vendors



USB and Ethernet

- USB 2. 5 Meters, 480 Mbits/sec 320Mbs Useable
- USB 3. 3 Meters 5Gbs
- USB 4. Up to 40 Gbs
- Gigabit Ethernet Up to 1 Gbps
- 10G Ethernet

For Cables up to 15 Meters Long



- MIPI C-phy
- ASA Motion Link
- MIPI A-Phy
- Gigabit Multimedia Serial Link (GMSL)

[Video Processing Wiki](#)

[Open Source Video Processing Wiki](#)

[Hardware](#)

[Communication Circuit Boards](#)

[RunCam WifiLink V2](#)

RunCam WifiLink V2



RunCam receives DVI video input and transmits it wireless.
Completely open source hardware and software.

Maia SDR



- Adam Pluto Device
- Zynq FPGA + ARM SoC
- Amaranth HDL
- Python Language

[Video Processing Wiki](#)

[Open Source Video Processing Wiki](#)

[Hardware](#)

[Communication Circuit Boards](#)

[Blade RF](#)



Blade RF

BladeRF is a Software Defined Radio (SDR) platform designed to enable a community of hobbyists, and professionals to explore and experiment with the multidisciplinary facets of RF communication.



Blade RF

Recommendations

Camera Chip or ASIC with the needed functionality.

Cheapest Libmpix on Zephyr OS on a Microcontroller

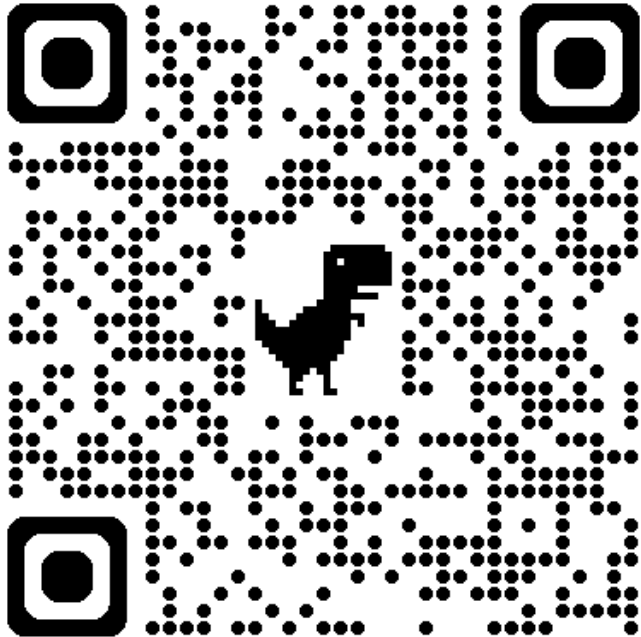
Raspberry Pi MIPI-CSI to DVP to any FPGA. (1.5 Gbps DVP)

Lattice NX 17/33/40 with MIPI-CSI and DSI. (2.5 Gbs MIPI)

Use a closed source FPGA for higher bandwidth. (> 2.5 Gbps)

For a European made FPGA choose GateMate.

Questions?



Christopher Lozinski

May 8, 2026

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[lozinski@PythonLinks.info](#)

[Wiki.PythonLinks.info](#)

[Discord Channel](#)

OpenSourceEcology.com

