Embedded Video Systems With Zephyr

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Background

A contractor working essentially with tinyVision.ai


Helion
ENGINEERING VISION
tinyvision.ai

Autoportrait: I am curious about a lot of topics, but only scratch the surface.

You are welcome and invited to dive in depth!

Video Systems

Famous example: home cinema

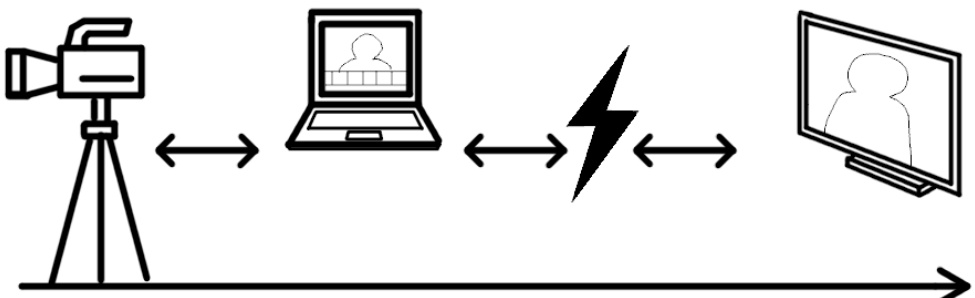

BRAVIA
DONOR
CURRENT WORK UNIT
SONY

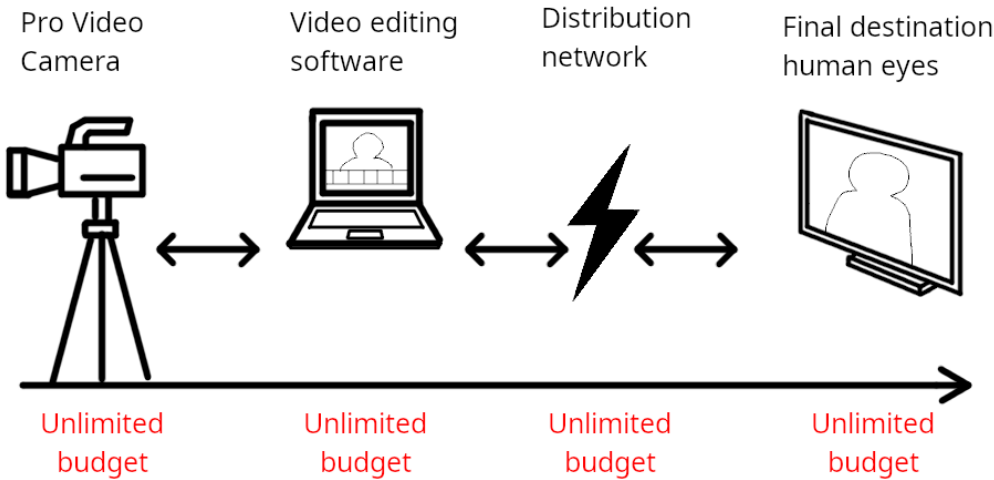
Pro Video Camera

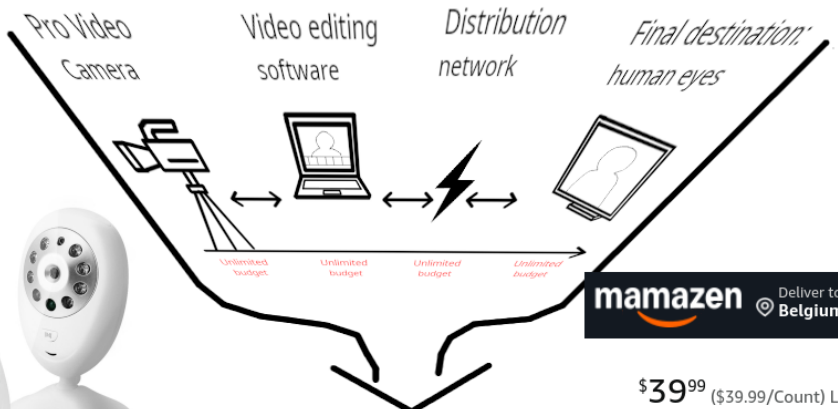
Video editing software

Distribution network

Final destination: human eyes




Pro Video Camera
Video editing software
Distribution network
Final destination: human eyes
Unlimited budget
Unlimited budget
Unlimited budget
Unlimited budget



mamazen Deliver to Belgium All ba

$39.99 ($39.99/Count) List: $49.99

Embedded Video Systems

Constraints:

-> Cost budget

-> Processing budget

-> Time budget (low-latency, real-time)

Can only work at low-resolution...

Embedded Video Systems

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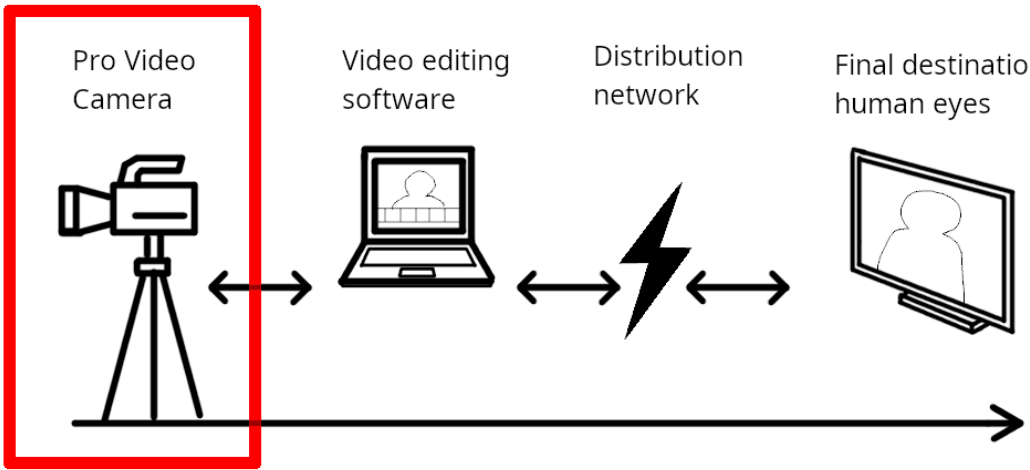
-> Cost budget

-> Processing budget

-> Time budget (low-latency, real-time)

Can only work at low-resolution... <- FALSE!



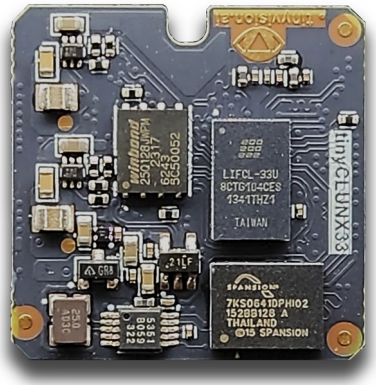
Needs an operating system too!

Embedded is not always low-end.

Embedded Video Systems

"Why not use an USB camera?"

We are now implementing the USB camera *itself*.


winbond
LIFCL-33U
8CTG104CES
1341THZ1
TAIWAN
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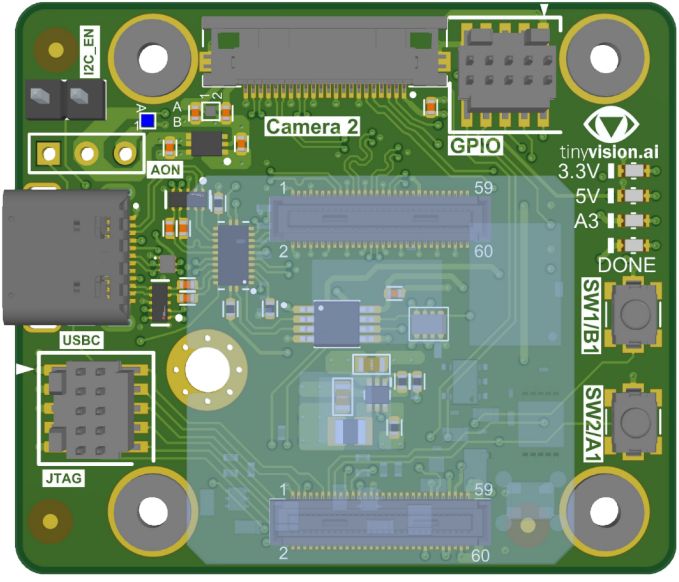
THAILAND
©19 SPANSION
TinyCLUNX33


I2C_EN
A
B
1
2
Camera 2
GPIO
AON
USBC
JTAG
tinyvision.ai
3.3V
5V
A3
DONE
SW1/B1
SW2/A1
1
59
2
60
1
59
2
60

Embedded Video Systems

"Why not just a Raspberry Pi?"

-> Power budget

-> Performance

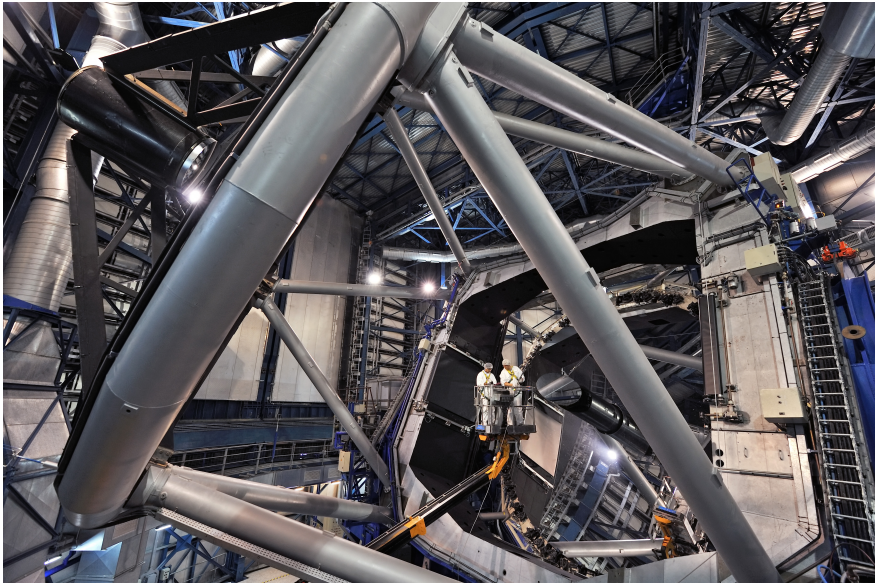
-> Cost

-> Latency

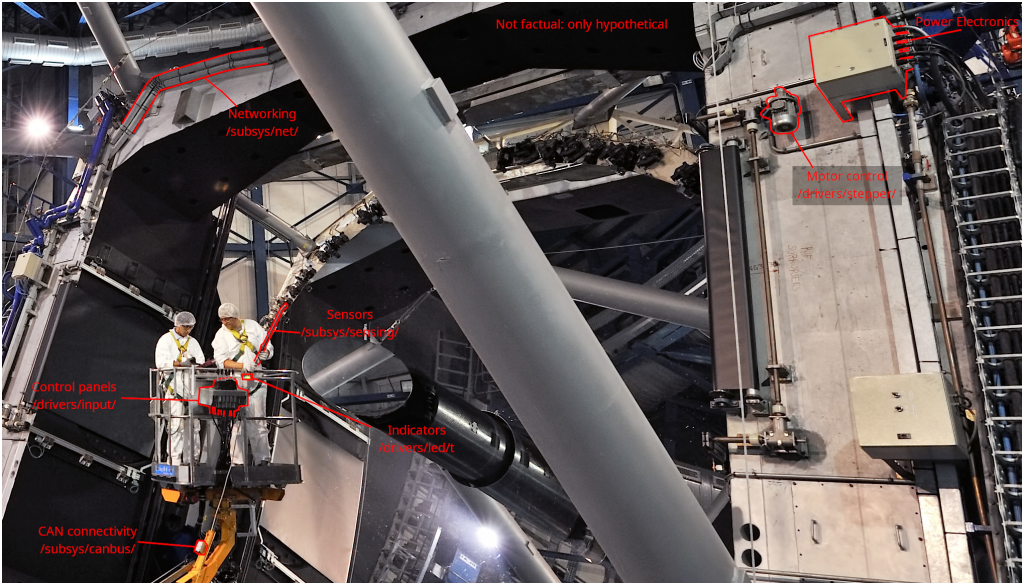

ArduCam

Embedded Video Systems

Can be very large:



We can imagine a lot involved to assist the video function:


Not factual: only hypothetical
Power Electronics
Networking
/subsys/net/
Motor control
/drivers/stepper/
Sensors
/subsys/sensing/
Control panels
/drivers/input/
Indicators
/drivers/led/t
CAN connectivity
/subsys/canbus/

Still there on small embedded systems:

-> Motor for auto-focus ("VCM" motor `#include <zephyr/drivers/video-controls.h>`)

-> I2C communication with other chips (`#include <zephyr/drivers/i2c.h>`)

-> Turning on/off the chip power (Power Management)

Embedded Video Systems

But usually the smaller the better: how to shrink?

Switch from Linux OS -> RTOS like Zephyr

FFmpeg -> ???

Gstreamer -> ???

OpenCV -> ???

PyTorch -> ???

`/dev/video0` -> ???

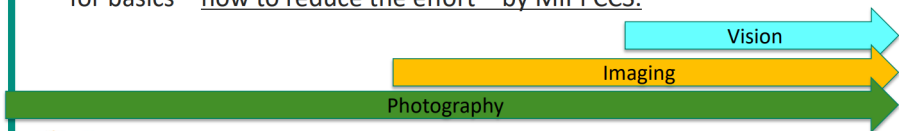
Everything to reinvent! Needs a new ecosystem.

Zephyr Video APIs

Systems doing what?

Changed usage of image sensors

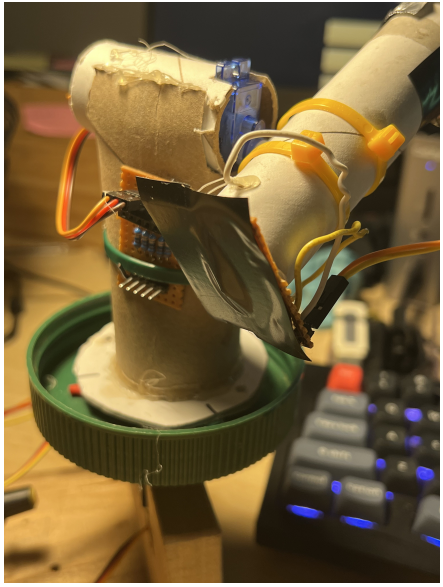
- From one image sensor to multiple image sensors in device **Complexity**
- From simple sensors to sensors with advanced features
- From photography to imaging and vision **Variety**
- From few companies to thousands of companies **Expansion**
- More and more time is used in image sensor integration, even for basics – how to reduce the effort – by MIPI CCS. **Time**

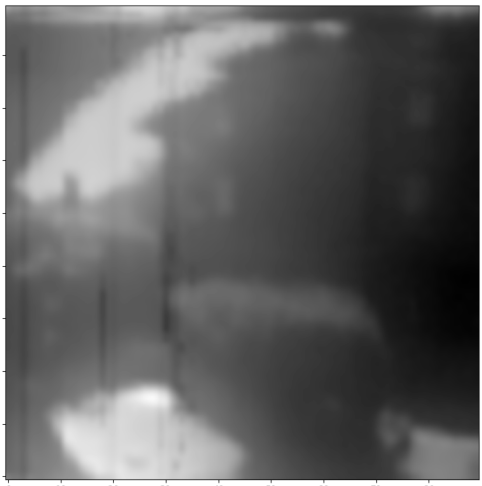


On a journey from Phontons to Video

Photodiode

Phenomenon of semiconductors producing voltage when exposed to the light.




0
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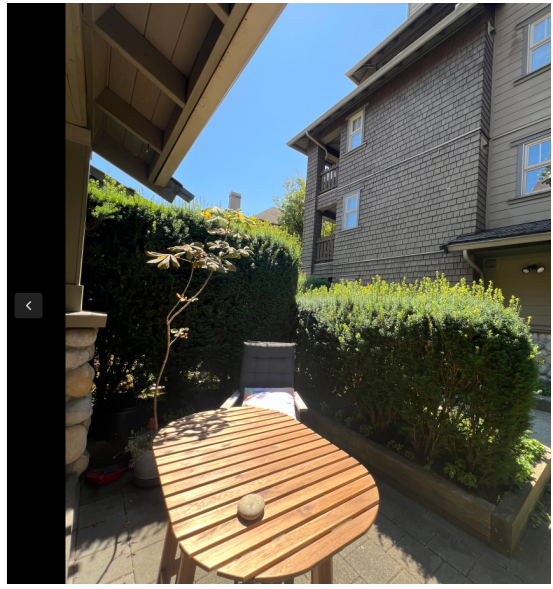


Note: photoresistor instead of photodiode here

```
#include <zephyr/drivers/pwm.h> // if using servomotors
#include <zephyr/drivers/stepper.h> // if using stepper motors
#include <zephyr/drivers/adc.h> // measure the light intensity
```

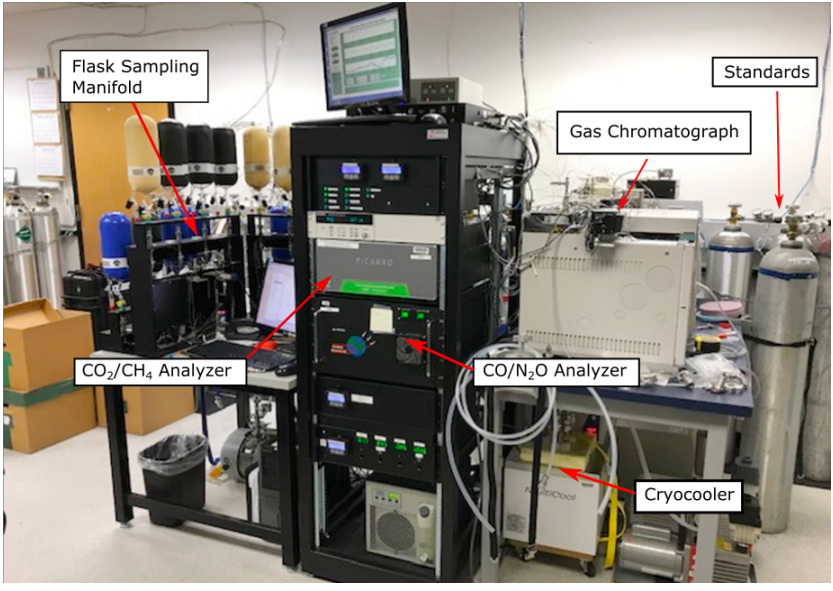
Photons -> Photonics

Much more than just video:

-> Gas detection/characterization, i.e. NDIR CO2 sensors

Industrial, safety, medical use-cases.

Since 1958: measuring Earth atmospheric CO2 with "1-pixel image sensors"


Flask Sampling Manifold
Standards
Gas Chromatograph
CO_2/CH_4 Analyzer
CO/N_2O Analyzer
Cryocooler
PICARRO

-> Biology/medical research, i.e. DNA sequencing

HAMAMATSU
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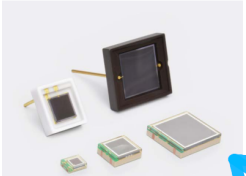
MPPC® (multi-pixel photon counter)

S13360 series



MPPCs for precision measurement

MPPC is a type of device called SiPM (silicon photomultipliers). It is a new type of photon counting device that consists of multiple Geiger mode APD (avalanche photodiode) pixels. It is an opto-semiconductor with outstanding photon counting capability and low operating voltage and is immune to the effects of magnetic fields.
The S13360 series are MPPCs for precision measurement. The MPPCs inherits the superb low afterpulse characteristics of previous products and further provide lower crosstalk and lower dark count. They are suitable for precision measurement, such as flow cytometry, DNA sequencer, laser microscope, and fluorescence measurement, that requires low noise characteristics.

Features

- **Reduced crosstalk and dark count (compared to previous products)**
- **Outstanding photon counting capability (outstanding photon detection efficiency versus numbers of incident photons)**
- **Compact**
- **Operates at room temperature**
- **Low voltage (V_{BR}=53 V typ.) operation**

Applications

- **Fluorescence measurement**
- **Laser microscopes**
- **Flow cytometry**
- **DNA sequencers**
- **Environmental analysis**
- **Various academic research**

Sensing voltage: not a very Linux thing to do...

Multiple sensors on a line

Line sensors: single cameras.

External systems measure responsible the voltage. Sensing one pixel at a time, scanning through them fast.

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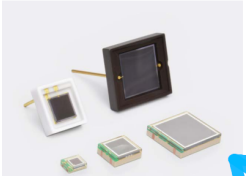

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Requires a fast ADC, i.e. ADI, contributing Zephyr RTOS

Multiple lines

An image sensor, at last!

Line scanning hyperspectral.

Doing imaging but without a machine at the other end: computer vision.

Tools that can be used for building video systems: hardware to access the sensors implement all of that chain

-> Difficulty of embedded video: accessing parallel port or MIPI -> Can use adapter chips like Himax WiseEye2 (Zephyr port might be coming too)

What comes out of an image sensor

Dark (no auto-exposure) Green (no color correction)

Steps of an ISP.

Why an ISP is useful for robotics?

-> Get always values withing same range -> Poor exposure: no data at all -> Defisheye -> Avoid artefacts to trigger a detection on the NPU or other vision algorithm

Conclusion: A lot to handle to get a reasonable image out of a sensor!

Hardware that can help accessing this image.

OpenMV: Python framework that could be useful to put on top