Cheap Complex Cameras

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About me

Kernel hacker

Decided to want up-to-date kernel on cellphone

...and that’s N900

Wanted flash LED control

Hardware is cheap and complex

flash

voice coil support for focus

two sensors

- back camera - et8ek8
- front camera - smiapp

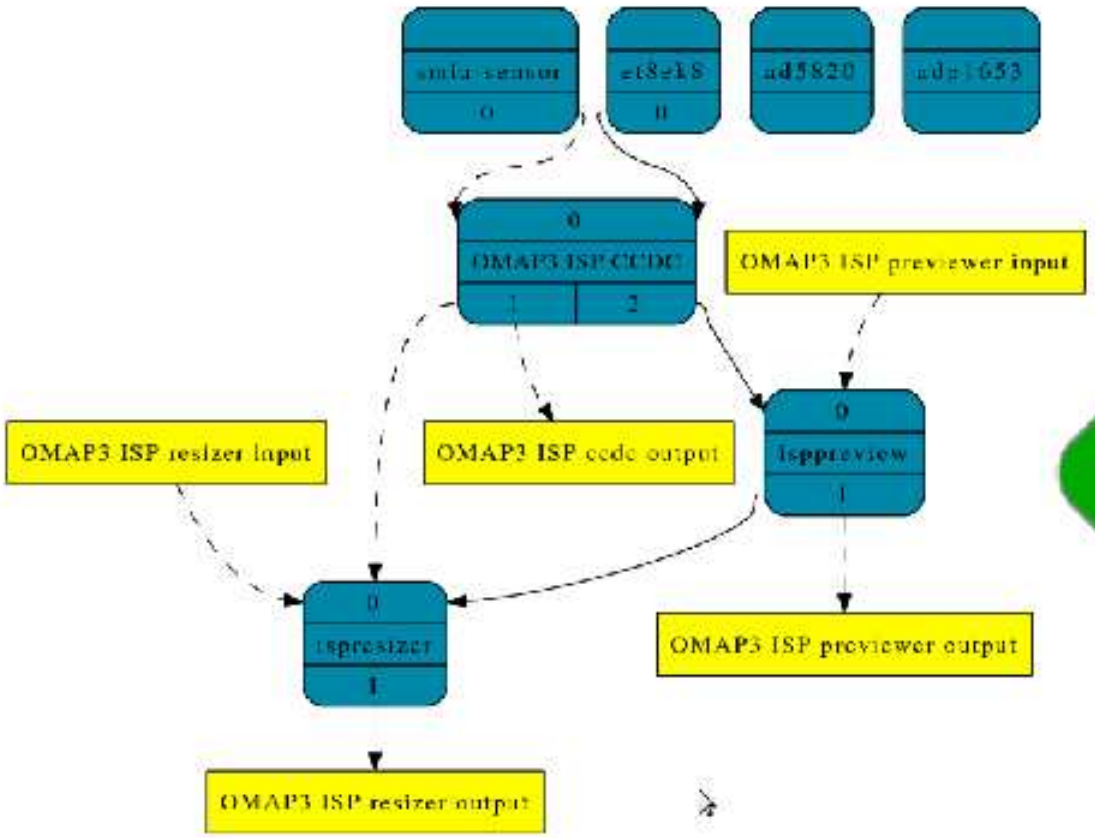
GPIO controlled switch

front end

preview module

resizer

statistics collection


0
OMAP3 ISP CCDC
1
2
OMAP3 ISP previewer input
OMAP3 ISP resizer input
OMAP3 ISP ccdc output
0
ispreview
1
0
ispresizer
1
OMAP3 ISP previewer output
OMAP3 ISP resizer output

Nokia N900

12.4.3.2 CSI2 Receiver Block Diagram

Figure 12-62 is the block diagram of the CSI2 receiver connected to the com

Figure 12-62. CSI2 Receiver Block Diagram

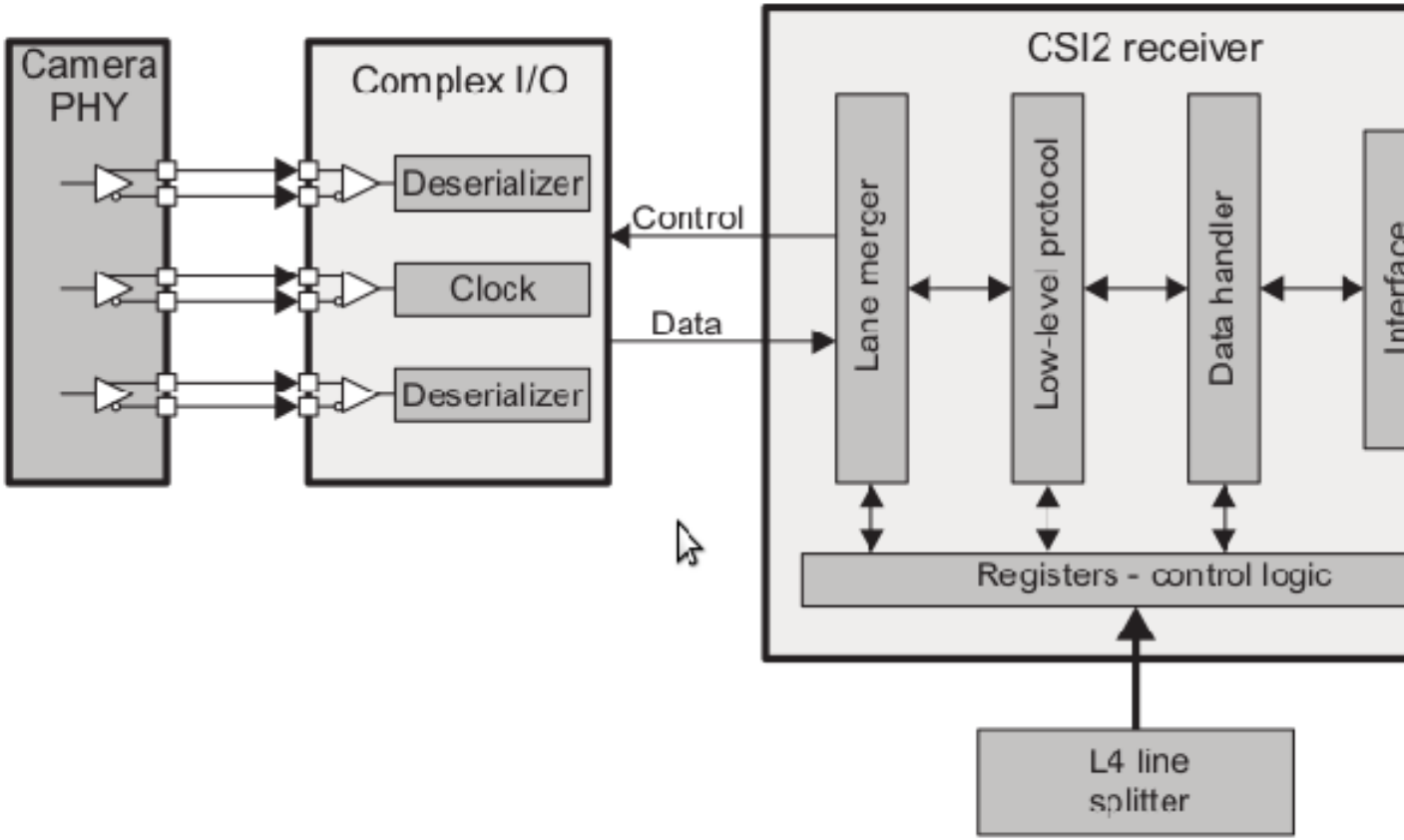


Figure 12-72. CCDC Block Diagram

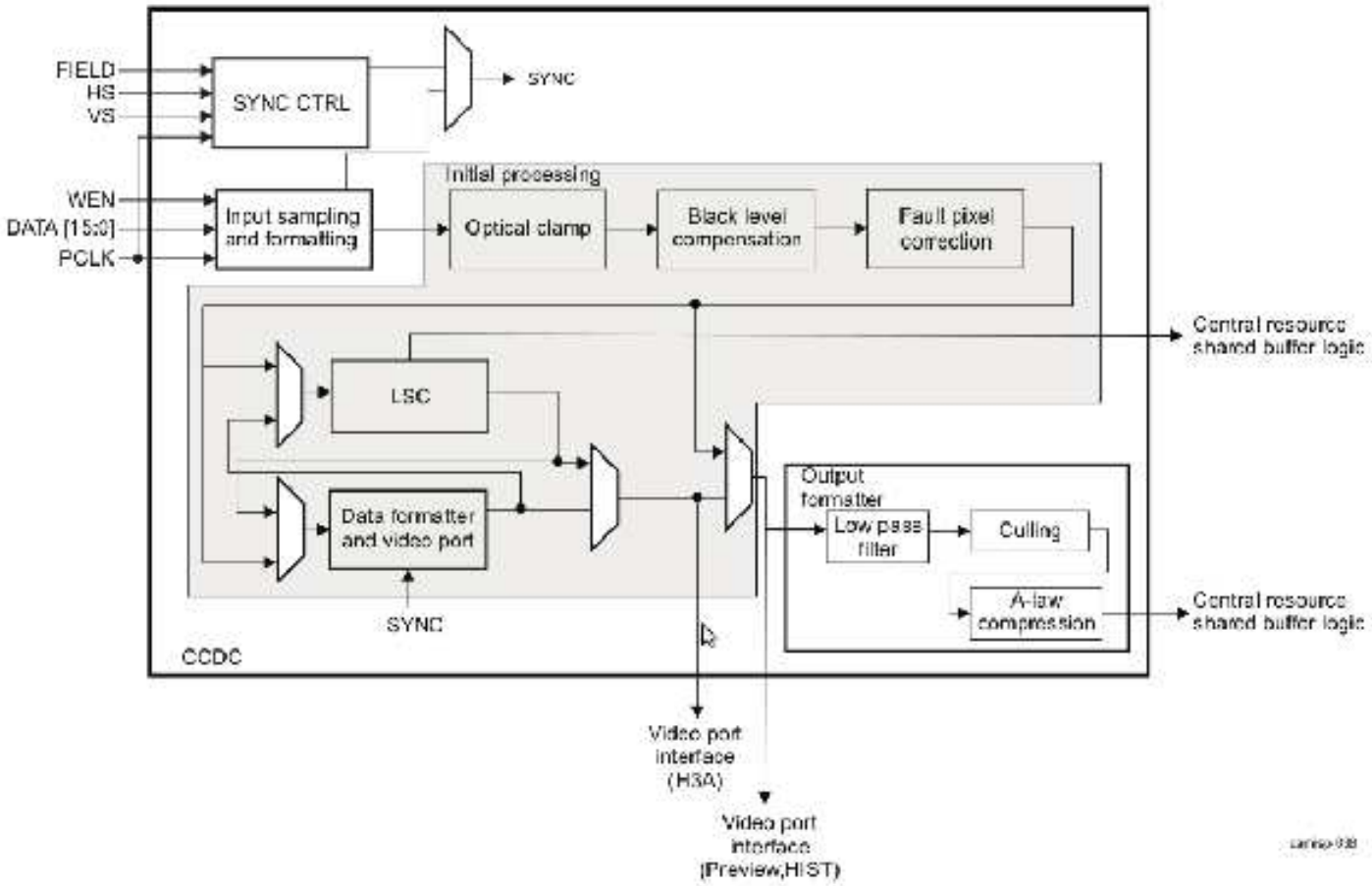


Table 12-28 summarizes allowed data flows through the CCDC.

Table 12-28. Allowed Data Flows Through the CCDC

Figure 12-53. Camera ISP Block Diagram

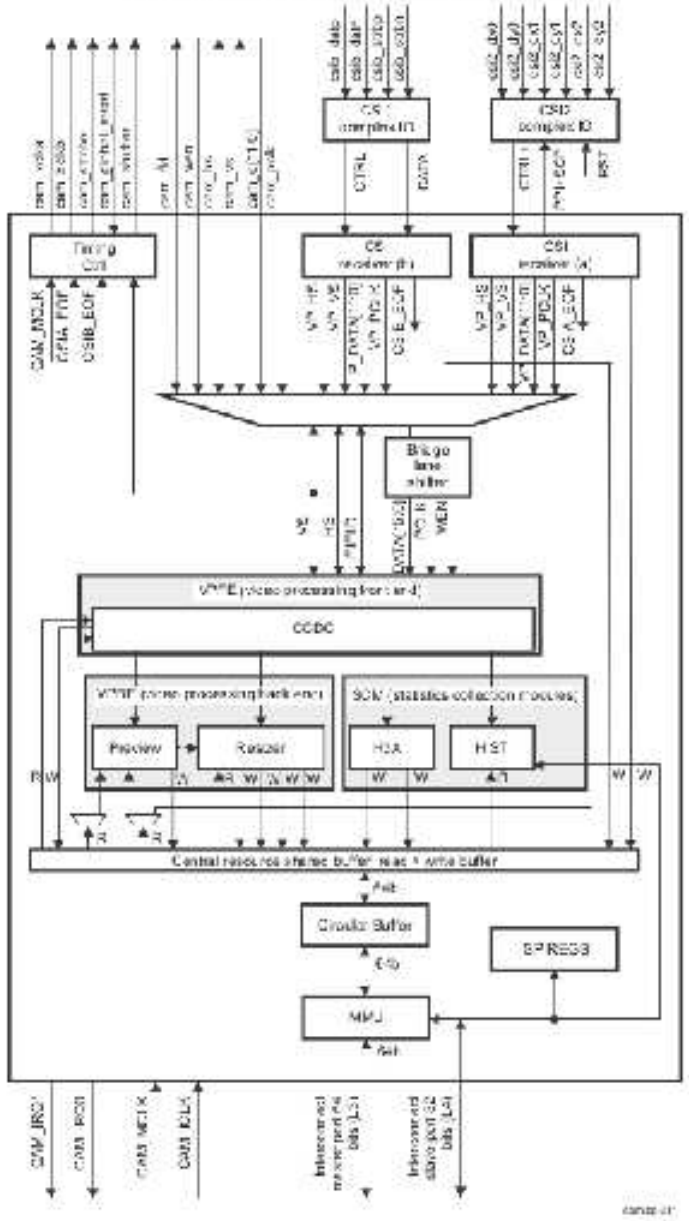
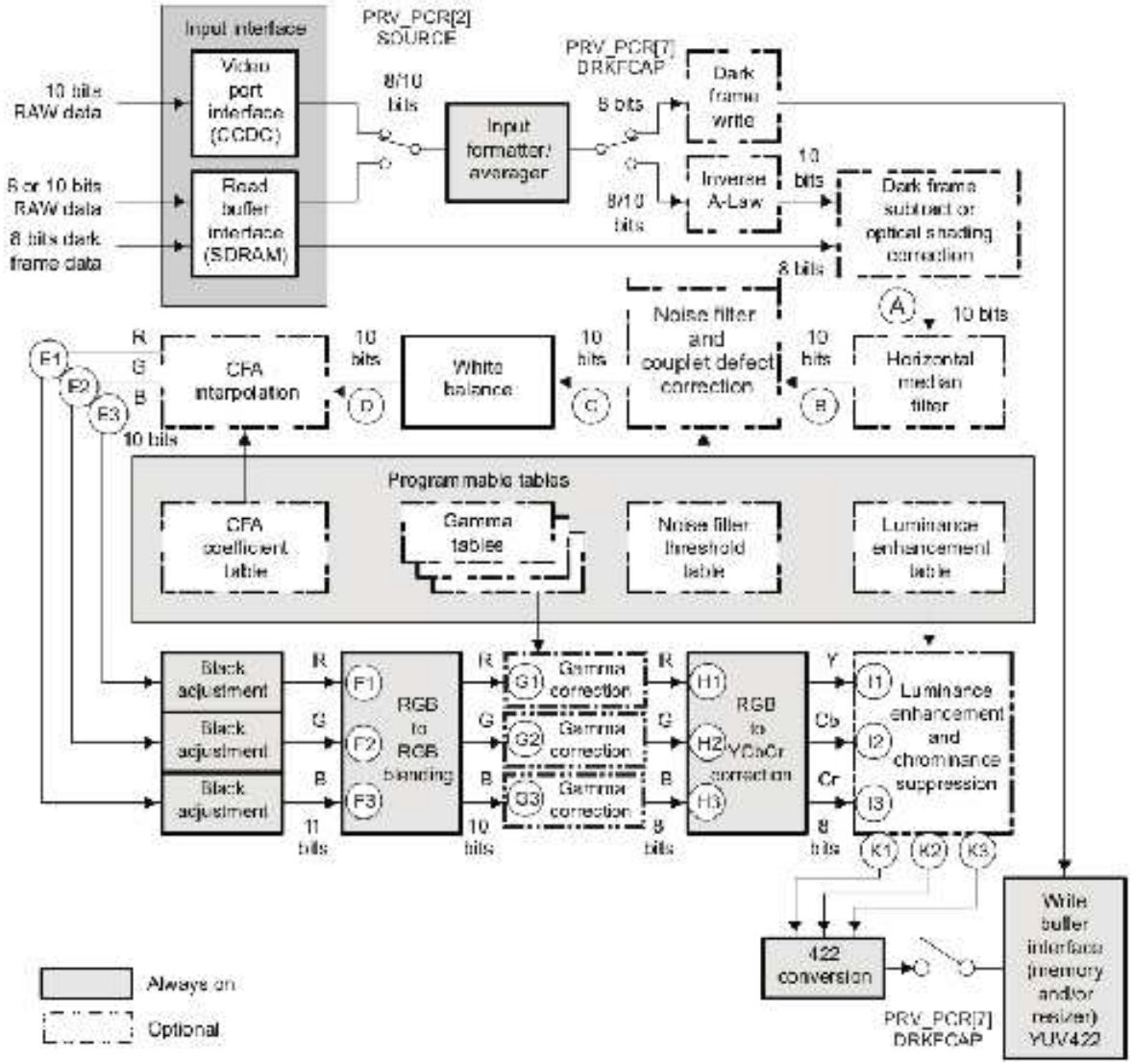
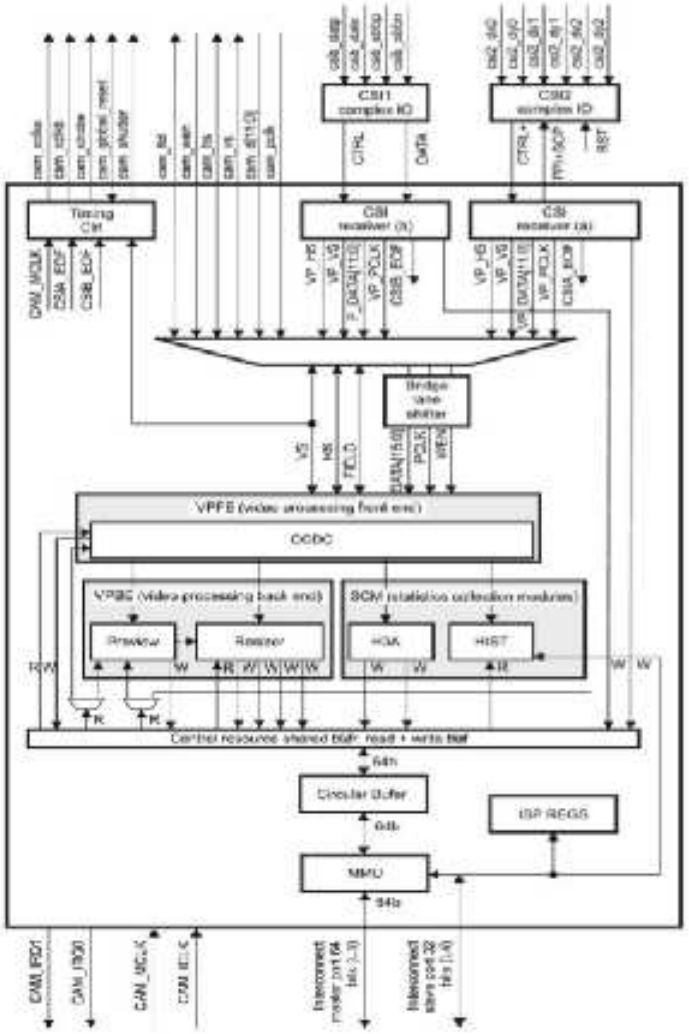


Figure 12-78. Preview Engine Block Diagram



Embedded mess



OMAP3430 ISP

- Reconfigurable pipeline
- Parallel processing
- Memory-to-memory paths
- Fine-grain parameters

How do we handle the zillion configuration options through a single video device ?

Drawing is © Texas Instrument

V4L2 makes world simple

TV card: /dev/video0

- enum format: 1024x768, RGB24
- capture

simple, right?

Media-control API

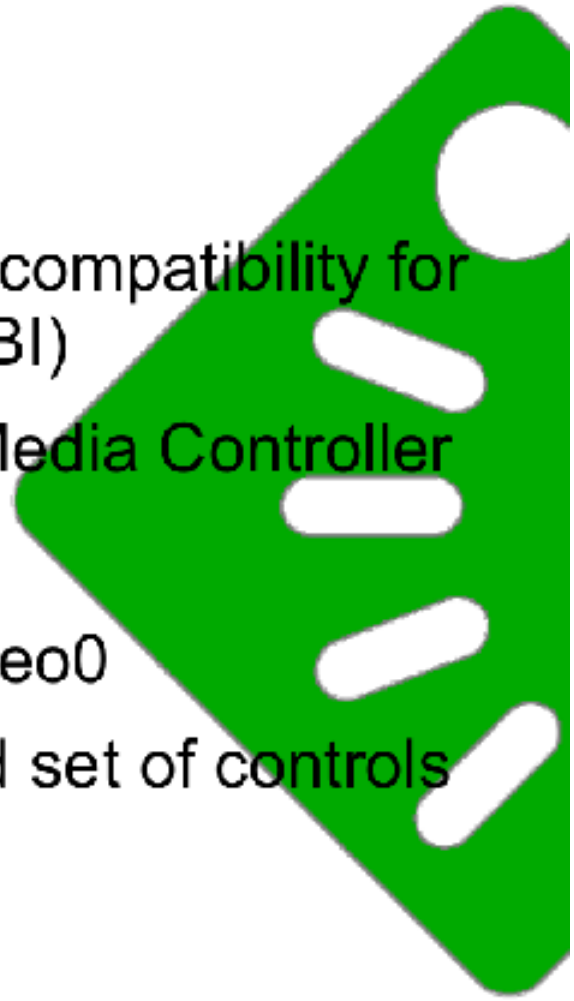
video0 OMAP3 ISP CCP2 input
video1 OMAP3 ISP CSI2a output
video2 OMAP3 ISP CCDC output
video3 OMAP3 ISP preview input
video4 OMAP3 ISP preview output
video5 OMAP3 ISP resizer input
video6 OMAP3 ISP resizer output
v4l-subdev0 OMAP3 ISP CCP2
v4l-subdev1 OMAP3 ISP CSI2a
v4l-subdev2 OMAP3 ISP CCDC
v4l-subdev3 OMAP3 ISP preview
v4l-subdev4 OMAP3 ISP resizer
v4l-subdev5 OMAP3 ISP AEWB
v4l-subdev6 OMAP3 ISP AF
v4l-subdev7 OMAP3 ISP histogram
v4l-subdev8 ad5820 focus

Is this V4L3 ?

- No, V4L2 is still alive and well
- Best effort to provide V4L2-only compatibility for existing applications (API and ABI)
- Advanced features will require Media Controller

OMAP3430 ISP

- Default pipeline through /dev/video0
- Limited set of resolutions, limited set of controls



V4L2 plain API

2010: Media-control API is not V4L3

It really is V4L3

Nothing works before pipeline is setup

Mostly nothing works after that

Not even format enumeration works

Kernel progress

N9 sensor: in 4.13

N900 sensor: merged in 4.14-rc4, 1.3MPix only

AF coil support: being reviewed

flash support: being reviewed for N9

v4l-utils

- Oct 2017 version

Alive and well

C

No media-control support

- thus no resolution change

(Poor) auto-gain

No auto-focus

(Unsuitable) auto-whitebalance

8-bit only

Programming interface limited by kernel interface

- no easy way to add detailed autofocus/autogain control
- no way to convert existing data

FCam-dev

Full featured camera application
10-bit support
Including autofocus, autogain, raw+jpeg, HDR
Ability to change resolutions
Accelerated preview
Nice programming interface (university project)

C++
Threads
Custom kernel interface
Dead project
Gets us photos, but not application support

Goals

Real

- LED light
- Kernel testing

Bonus

- Basic camera application
- Auto-gain
- Preview
- Some way to get photos
- Quick shutter speed
- Run over ssh

Future goals

Hard

- Accelerated preview
- High-quality jpeg

Very hard

- Video capture
- Concurent access to camera from multiple applications

Performance research, on 1MPix data

GRBG10 -> RGB24 conversion is too slow

Displaying select pixels is not

- small window, reduced framerate

Sampling 1 in 361 pixels for autogain is not

Sampling three thirds of line for autofocus is not

sdlcam project

Available at git@gitlab.com:tui/v4l-utils.git

Reasonable branch is my-1.13

Bad news

- Hard-coded pipeline parameters
- Simple ioctl propagation
- Hard-coded picture parameters
- Simple ui in SDL
- Capture into RAW
  - .dng is too complex
  - .pgm is suitable
- 8-bit internally
- Capture into JPEG is missing stuff
  - white balance
  - dead pixel processing
  - lens shading


NA VÝHĽ

Good news

- Auto-gain works
- Auto-focus mostly works
- Fast shutter speed
  - negative shutter delay possible
- RAW capture
- Good enough for testing kernels

Auto-gain

old: Average is target

new: Get enough bright pixels

- but not too many

Auto-focus

Single-shot focus

- sweep whole range
- small steps around best focus

Continuous focus

- constantly moves lens around
- to see if it improves on either side

Wishlist for kernel

Default pipeline config

Format enumeration for media-ctl

Absolute units for controls

Provide capture settings for each frame

V4L2 is too asynchronous

Current interface

- select resolution
- start capture
- frame comes
- select gain
- frame comes (what gain was used?)
- frame comes (what gain was used?)
- frame comes (what gain was used?)
- set focus
- frame comes (what focus was used?)

Wishlist for v4l-utils

- Media-ctl support
  - resolution changing
- libv4lconvert
  - API not modelled after kernel one
  - usable without /dev/videoX devices
- 16-bit support
- Ability to get pixel color for single pixel

Questions?

Hardware is complex

CSI1 / MIPI CSI2 / parallel interface

front end

- optical clamping
- black-level compensation
- faulty pixel correction
- lens-shading compensation

Hardware is complex

preview module

- A-law compression
- dark frame substraction
- horizontal median filter
- programmable 3x3 filter
- couplet faulty pixer correction
- digital gain
- white balance
- color filter array interpolation
- black adjustment
- color correction (RGB -> RGB)
- gamma correction

Hardware is complex

preview

- color conversion (RGB->YCbCr 4:4:4)
- color subsampling (YCbCr 4:4:4->4:2:2)
- luminance enhancement

resizer module

- x.25 to x4

statistic collection

- 3A metrics for AWB, AE, AF
- histogram