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
12.4.3.2 CSI2 Receiver Block Diagram

Figure 12-62 is the block diagram of the CSI2 receiver connected to the complex I/O.

Figure 12-62. CSI2 Receiver Block Diagram
Table 12-28 summarizes allowed data flows through the CCDC.

Table 12-28. Allowed Data Flows Through the CCDC
Figure 12-78. Preview Engine Block Diagram

- Input interface
- Video port interface (CCDC)
- Read buffer interface (SDRAM)

- Input formation: averager
- PRV_PCR[2] SOURCE
- PRV_PCR[7] DRKFCAP

- Dark frame write
- 8/10 bits
- Inverse A-Law

- 8 bits
- Dark frame
- Subtract on
- Optical blending
- Correction

- Noise filter
- and couplet defect
- Connection

- Horizontal
- Median filter

- CFA interpolation

- White balance

- Programable tables
  - CFA coefficient tables
  - Gamma table
  - Noise filter threshold tables
  - Luminance enhancement table

- Block adjustment
- RGB to YCbCr

- RGB to YCbCr connection

- RGB to YCbCr correction

- Luminance enhancement and chrominance suppression

- PRV_PCR[7] DRKFCAP
- YUV422

- 10 bits
- 8 bits
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
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

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
- Concurrent 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
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