Introduction to MIPI Camera
Command Set v1.0
Mikko Muukki
Huawei | MIPI CCS Project lead
Topics

• Introduction to MIPI Alliance – Peter Lefkin, Managing Director

• MIPI CCS v1.0 Introduction – Mikko Muukki, MIPI CCS Project Lead
  – What is MIPI CCS
  – Why MIPI CCS
  – MIPI CCS details
  – Summary
  – Questions
Introduction to MIPI Alliance

Peter Lefkin
MIPI Alliance Managing Director
About MIPI Alliance

MIPI is a global, collaborative organization founded in 2003 that comprises 300+ member companies spanning the mobile and mobile-influenced ecosystems.

MIPI’s mission:
To provide the hardware and software interface specifications device vendors need to create state-of-the-art, innovative mobile-connected devices while accelerating time-to-market and reducing costs.
Who Our Members Are

- Device OEMs
- Semiconductor Companies
- Software Providers
- Application Processor Developers
- Consumer Electronics – Camera, Tablet, PC/Laptop, Peripherals
- Test Equipment Companies
- Test Labs
- IP and VIP Providers
- Handset Manufacturers
What Does MIPI Alliance Do?

- **Define and promote specifications** focusing on the mobile interface but applicable to IoT, Auto, wearables, etc.
- **Complement existing standards bodies** through collaboration
- **Provide members with access to licenses** as needed to implement and market specified technologies
- **Promote member companies’ brands** through promotion, public relations, tradeshows, events and speaking opportunities
Mobile & Mobile-Influenced Markets

MIPI’s focus has always been on mobile. In fact, every smartphone on the market today has at least one MIPI specification.

With the development of new mobile-influenced markets, you can now find MIPI specifications in a variety of products:
A System of Mobile Interfaces

To date, MIPI has developed more than 45 specifications. Our leading specifications:

- CSI, CCS
- RFFE
- DSI
- I3C
- SoundWire
- UniPro

Physical layers:

- C-PHY
- D-PHY
- M-PHY

This diagram is represents a potential system – MIPI Alliance does not define or recommend a particular architecture.
What is MIPI CCS

Mikko Muukki

Huawei | MIPI CCS Project lead
MIPI CCS in one slide

• MIPI CCS is a **Camera Command Set**, specifying **image sensor functionality** in register level.

• MIPI CCS is **independent from OS and host system features**, thus it can be used in many systems.

• MIPI CCS does not specify any system partitioning for host, used SW drivers and only minimally specifies link related items ensuring **modular design** principles.

Example
Typical camera system with CCS

• Datalink
  – Using **MIPI CSI-2** over **MIPI D-PHY** or **MIPI C-PHY**
  – Carrying data formats defined in **MIPI CSI-2**
  – Carrying metadata defined in **MIPI CCS**

• Control link
  – Using CCI defined in **MIPI CSI-2** specification, based on **I2C** or **MIPI I3C**
  – Carrying payload defined in **MIPI CCS**

• Functionality and registers in image sensor
  – Defined in **MIPI CCS**

cci=Camera Control Interface
3A=Automatic white balance, focus and exposure control
Why MIPI CCS
Expanding use of image sensors

• Exponential growth of image sensor started by smartphones.
  – PCs, tablets, connected cars, the Internet of Things, AR/VR and other areas are expanding the usage to new device categories.

• Small companies, medium size companies and large companies all use cameras
  – in specialized and
  – mass-market products.
Changed usage of image sensors

- From one image sensor to multiple image sensors in device
- From simple sensors to sensors with advanced features
- From photography to imaging and vision
- From few companies to thousands of companies

- More and more time is used in image sensor integration, even for basics – how to reduce the effort – by MIPI CCS.
MIPI CCS benefits

• Rapid integration of basic camera functionalities in plug-and-play fashion
  – For improved time-to-market of products
  – For greater adoption of image sensors
  – For increased stability and quality

• Supporting also advanced camera and imaging systems with innovative designs targeting various industries/areas
  – By having possibility for crafting standard SW driver
  – And having flexibility to customization
MIPI CCS details
Key concepts for efficient MIPI CCS usage

• Mandatory controls for all relevant basic functions

• Identification

• Capability information to detect supported features and limits (for system parametrization)

• Embedded data for synchronization of sensor and host (e.g. 3A)

• Parameter retiming rules for robust operation

• Standard register map
Example - start-up and identification

- Standard power-up sequence
  - From SW point of view, standard timing sequence can be used when powering up and identifying camera module.
  - Electrically there are more possibilities (e.g. in case of shared power supplies)

- Identification
  - Module and sensor level ID and version control information for SW parametrization

- Capability information
  - Binary capability info and also limit values for SW parametrization

Manufacturer ID request via MIPI also for non-members
http://mid.mipi.org/
Example – data formats, link and MIPI

• Supports all MIPI RAW and DPCM data formats (e.g. RAW10, DPCM10-8), defined in MIPI CSI-2 specification.
  – MIPI CCS does not define the formats, but defines controls how to select them.

• Supports MIPI CSI-2 over D-PHY and C-PHY.
  – PHY selection, lane configurations, PHY related controls
  – Supports all MIPI CSI-2 v2.0 features and also older MIPI CSI-2 and PHY versions

• CCI as control interface
  – I2C or MIPI I3C based, defined in MIPI CSI-2
  – To access standardized CCS registers and additional Manufacturer Specific Registers
Example – resolution

- ROI, binning, subsampling
  - Way to control cropping (analog, digital, output) and readout mode (full, subsampling, binning)

ROI = Region of Interest, i.e. cropping

FS=Frame Start
FE=Frame End
Example – exposure parameters

• Basics (mandatory)
  – Exposure time control
  – Analog gain control

• Basic (optional)
  – Global digital gain control

• Advanced (optional)
  – Single frame HDR with timing and synthesis modes
  – Fast bracketing
  – ...

• Possibility for manufacturer specific customization/innovation via Manufacture Specific Registers (MSRs)
  – For example, HDR details

Basic philosophy:
• Basic and mandatory
• Advanced and optional

CCS Exposure controls are for rolling shutter. MSRs can be used for global shutter.
Example – embedded data

- Embedded data can be used to synchronize host and sensor.
- MIPI CSI-2 defines what is meant by embedded data i.e. top or bottom embedded data
  - both optional in CSI-2, but top is mandatory in CCS.
- CCS defines:
  - that the embedded data content must be valid for the particular frame
  - layered format for the embedded data lines
  - what register information must be transferred in top embedded data using specific format (i.e. certain CCS registers in green area in certain format)
- CCS allows:
  - using the specific format for manufacturer specific registers and other CCS registers in top embedded data
  - using additional Embedded data formats for additional data (in other embedded data lines)
Example - PDAF

- Supports variety of sensors
  - Sensors having only PDAF pixels
  - Sensors being able to separate PDAF pixels to different CSI-2 logical channel (Virtual Channel or DataType interleaving) from visible pixels
  - Sensors with or without PDAF data processing

PDAF = Phase Difference Auto Focus

FS=Frame Start
FE=Frame End
Example – test modes

• A set of mandatory or optional test modes have been specified, for example:
  – Programmable data
  – Basic color bar
  – Advanced color bars
  – PN9

• To use different known test patterns to verify various items in the system.
Was that all?

- No, MIPI CCS has comprehensive list of features
  - Mandatory or
  - Optional

- Covering also
  - Frame timings and clocking, meaning e.g. frame rate and frequencies
  - Timers for additional usages
  - Interface for sensor internal NVM
  - Controls for image corrections
  - And many more

NVM = Non-Volatile-Memory e.g. for calibration usage
Who should read the CCS Specification?

• CCS Specification is beneficial to many people
  – Image sensor designers
  – SW developers
  – Camera engineers
  – Someone who defines how to use image sensor or what image sensor needs to support
  – For all, who work with image sensor control or need to know how to use image sensor or need to know how image sensor behaves

• Access to Specification, also for non-members
  – https://mipi.org/specifications/camera-command-set
Summary of MIPI CCS

• A camera command specification that streamlines configuration of image sensors in mobile devices by:
  – standardizing mandatory basic features and optional advanced features.

• Developed in MIPI Camera Working Group
  – https://mipi.org/groups/camera

• Accessible by non-members also
  – https://mipi.org/specifications/camera-command-set
Questions ?