mipi® alliance

IF IT'S NOT MIPI, IT'S NOT MOBILE

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

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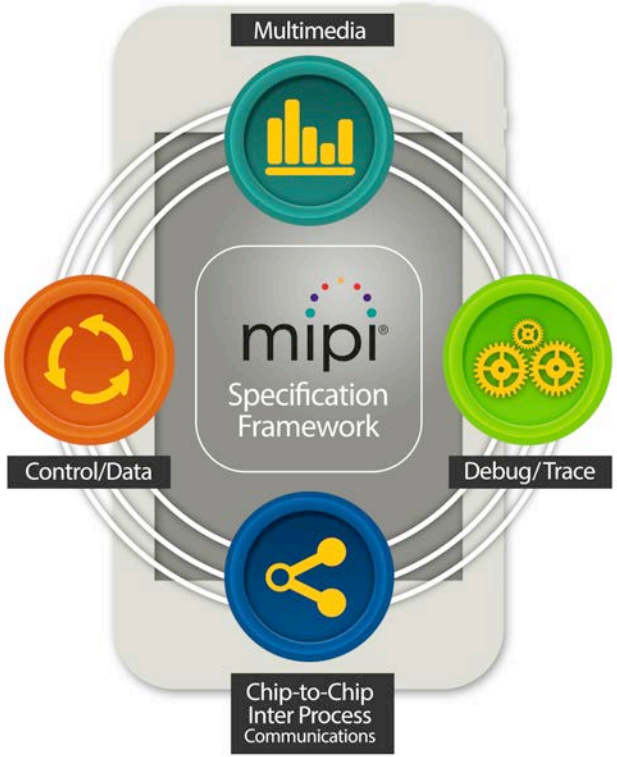
About MIPI Alliance

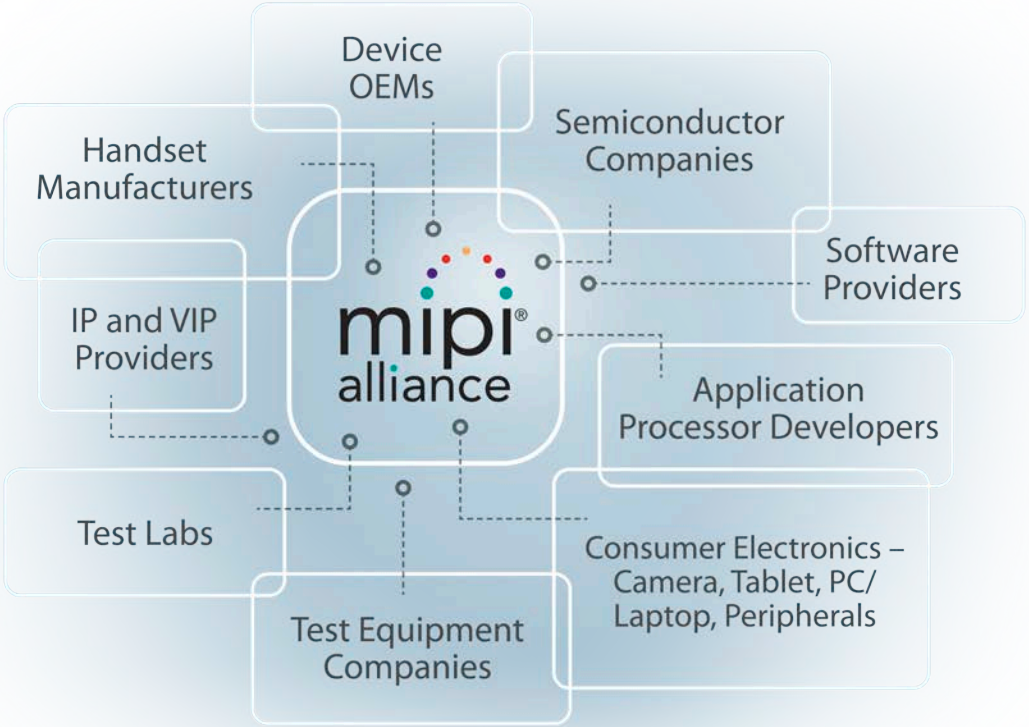
MIPI is a global, collaborative organization founded in 2003 that comprises 300+ member companies spanning the mobile and mobile-influenced ecosystems.

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



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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

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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:

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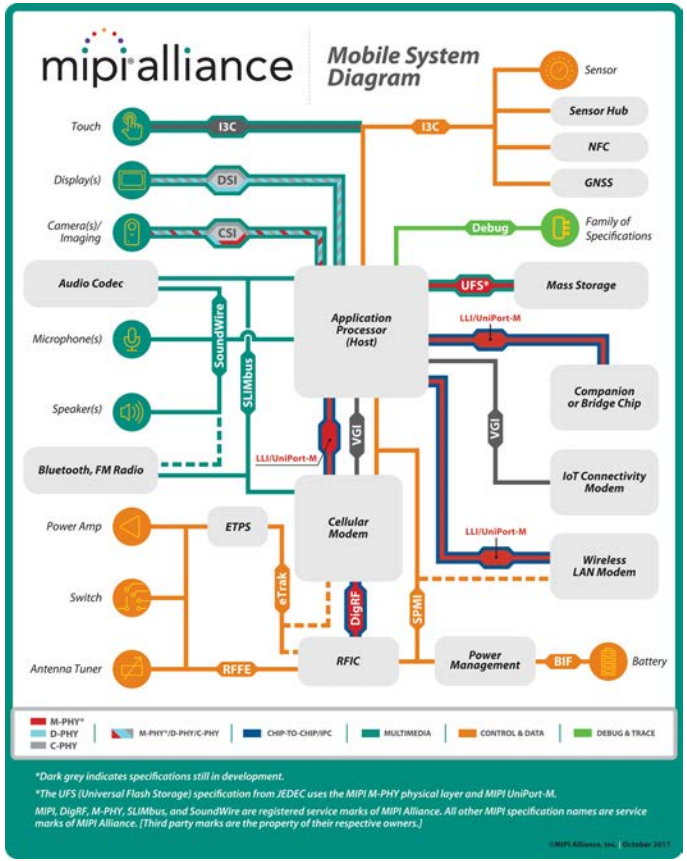
A System of Mobile Interfaces

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

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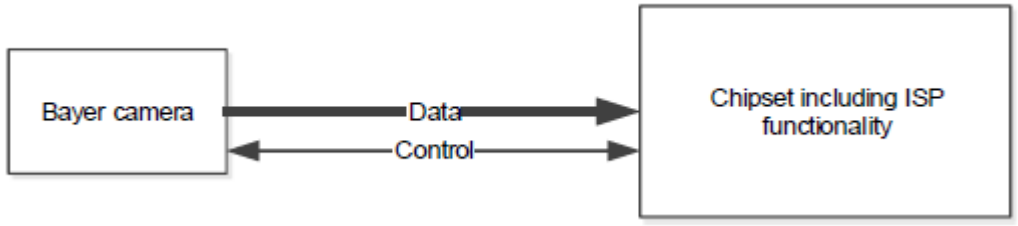
MIPI CCS in one slide

- 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



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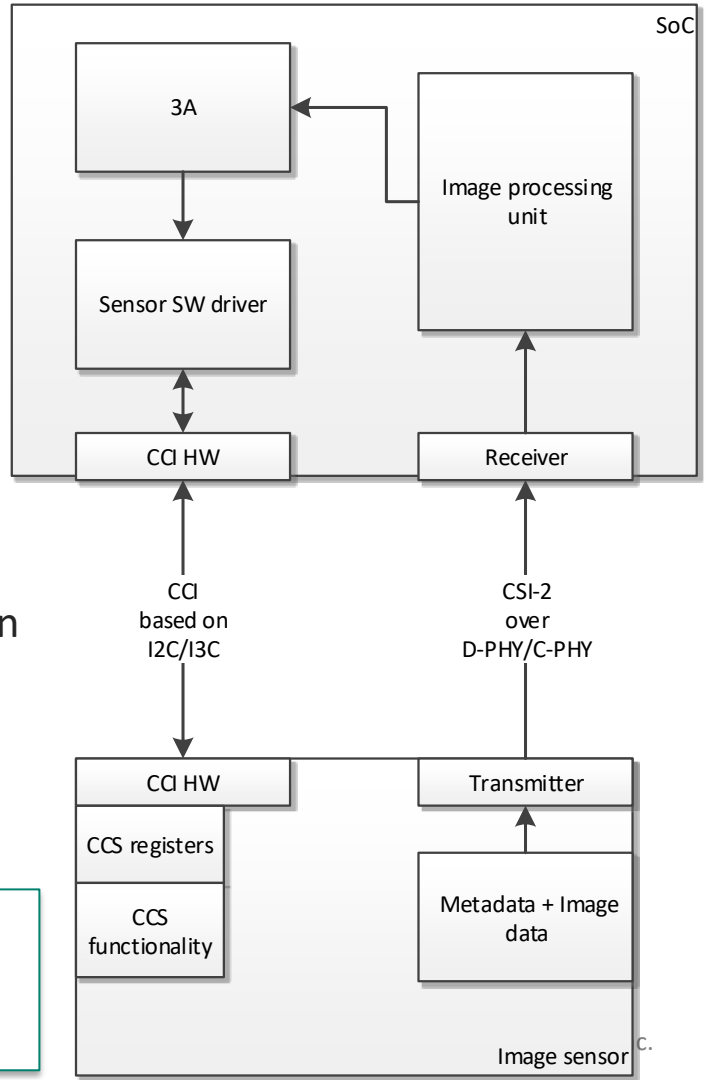
Typical camera system with CCS

- 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

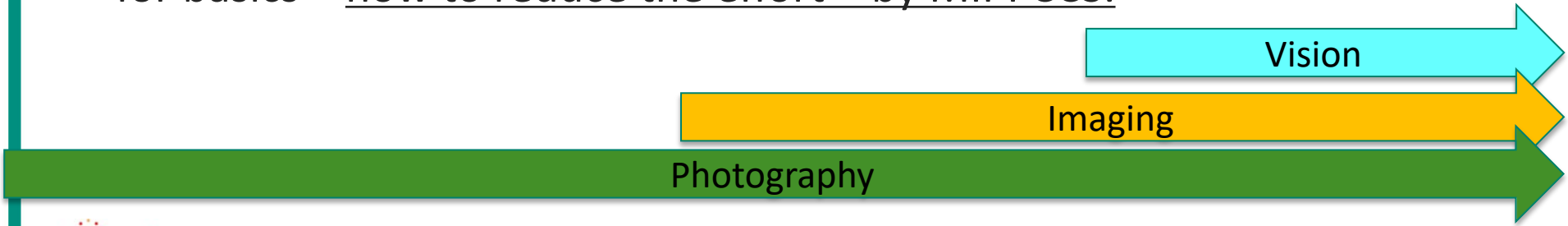
Complexity

Variety

Expansion

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

Time



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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

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MIPI CCS details

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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

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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/

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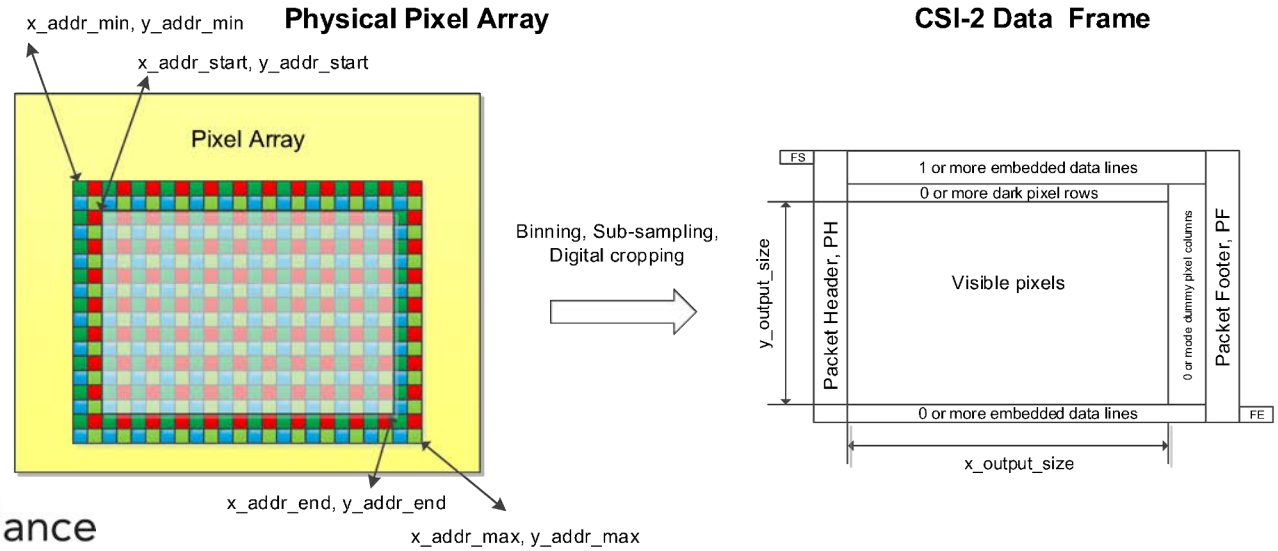
Example – data formats, link and MIPI

- 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

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Example – exposure parameters

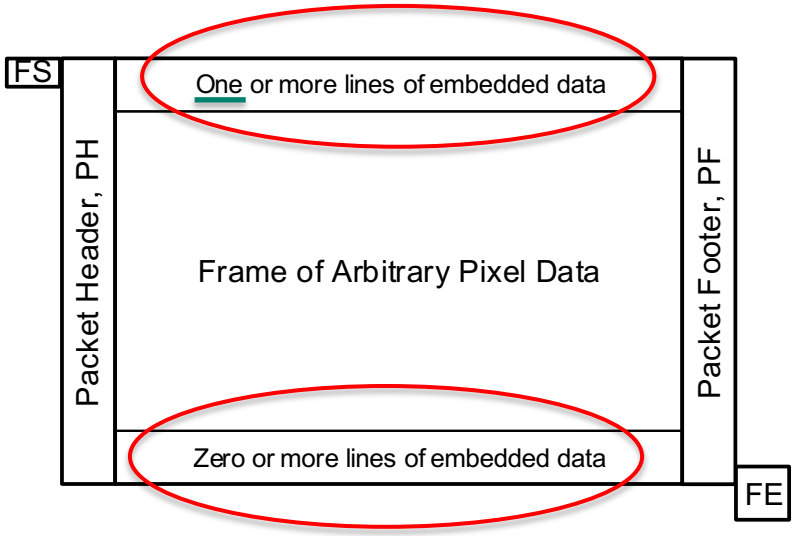
- Basics (mandatory)
  - Exposure time control
  - Analog gain control
- Basic (optional)
  - Global digital gain control
- Advanced (optional)
  - Single frame HDR with timing and synthesis modes
  - Fast bracketing
  - …
- Possibility for manufacturer specific customization/innovation via Manufacture Specific Registers (MSRs)
  - For example, HDR details

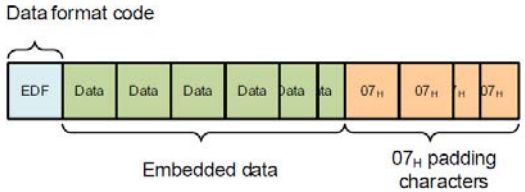
Basic philosophy:
- Basic and mandatory
- Advanced and optional

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)

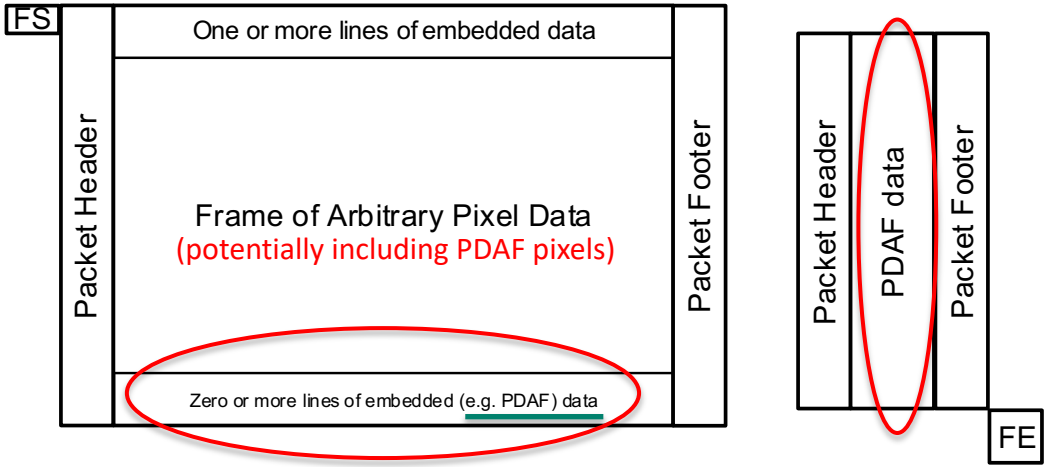




CCS Embedded Data Line Format

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

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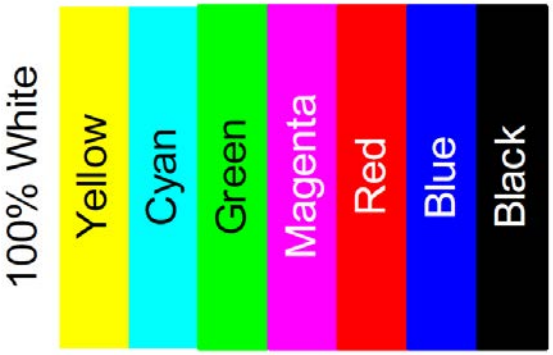
Example – test modes

- 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.



Basic color bar

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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

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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

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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

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Questions ?