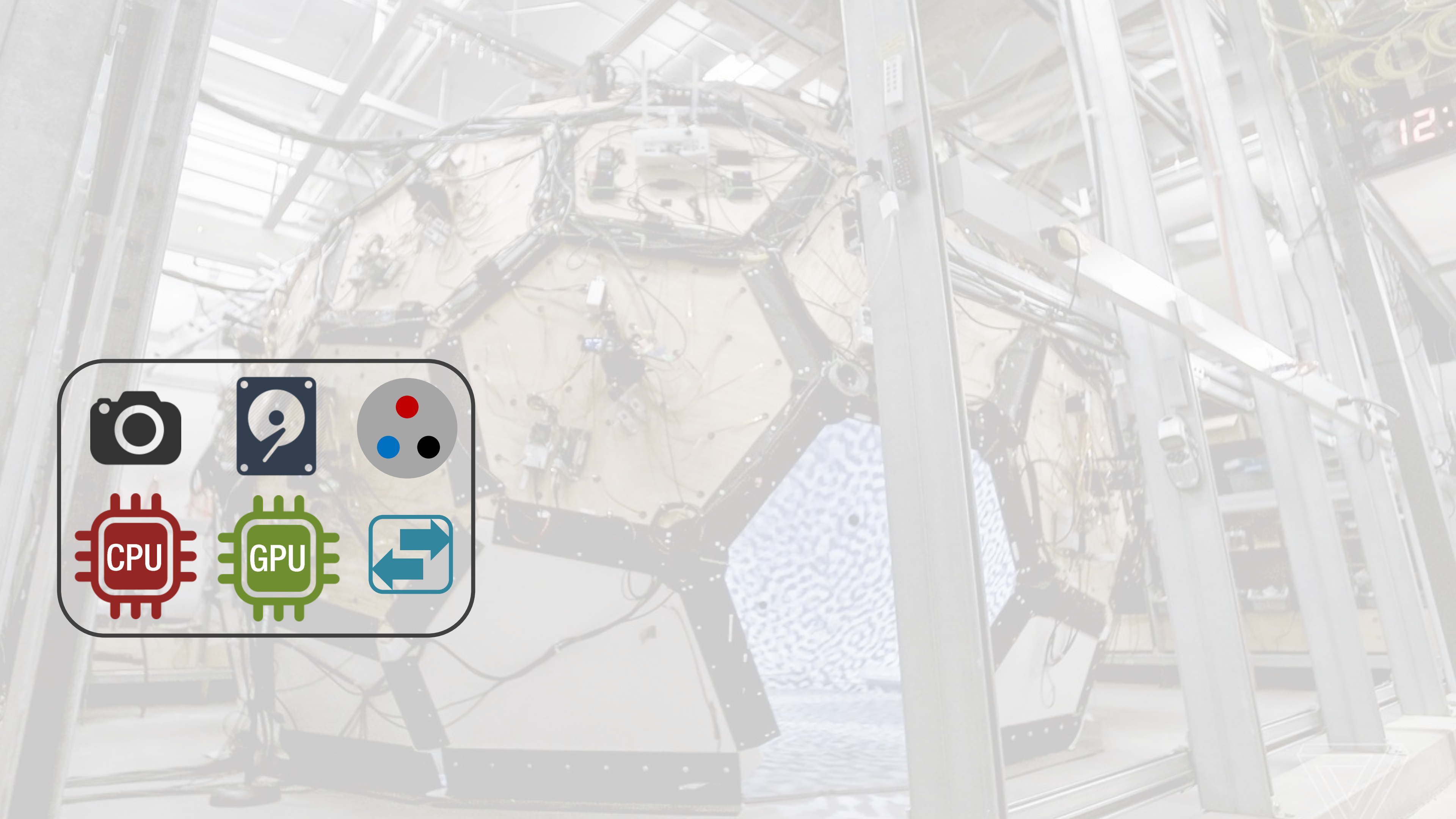
Do It Yourself: Multicamera Engineering

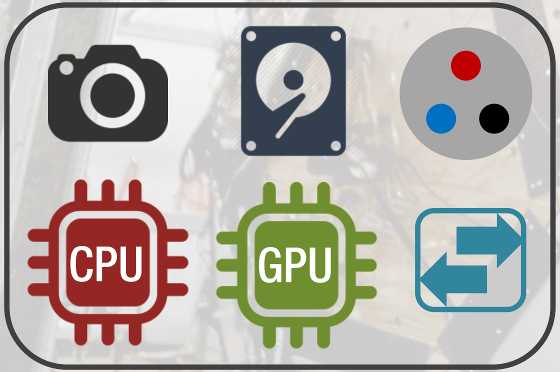
Precision

Diversity

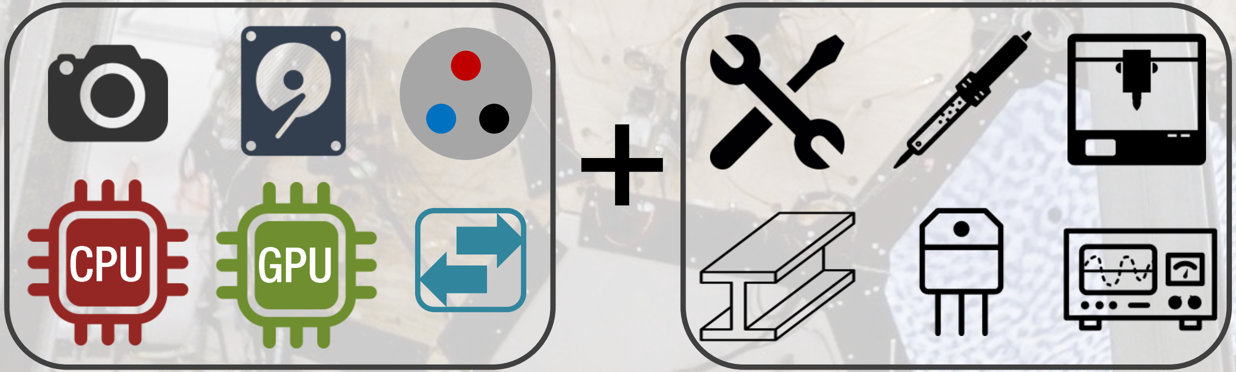
Scalability


CPU
GPU

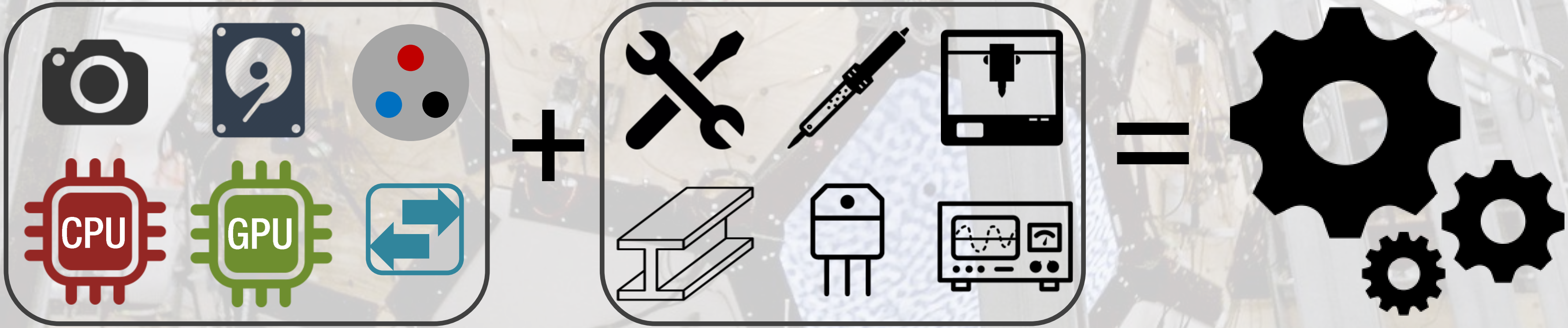
Can you build your own *Panoptic Studio?*



Can you build your own *Panoptic Studio?*



Can you build your own *Panoptic Studio?*



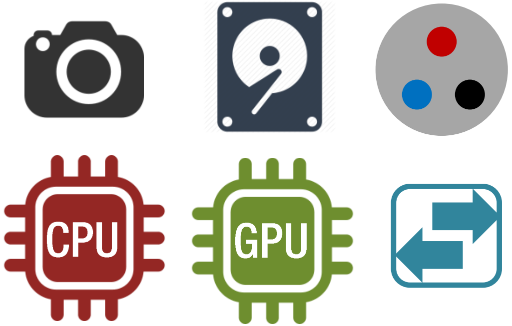
Can you build your own *Panoptic Studio?*

Design optimization with <u>budget</u> and <u>space/time</u> constraints

Budgetary Constraint

Total cost

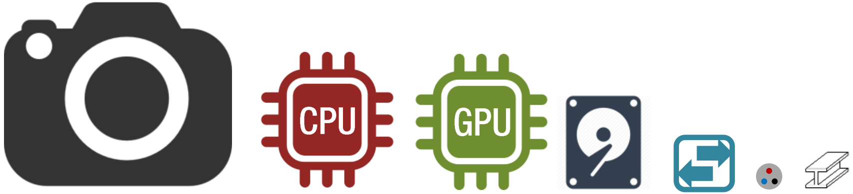
Cf) Vicon/Qualisys~$60K



Budgetary Constraint

Total cost

Cf) Vicon/Qualisys~$60K

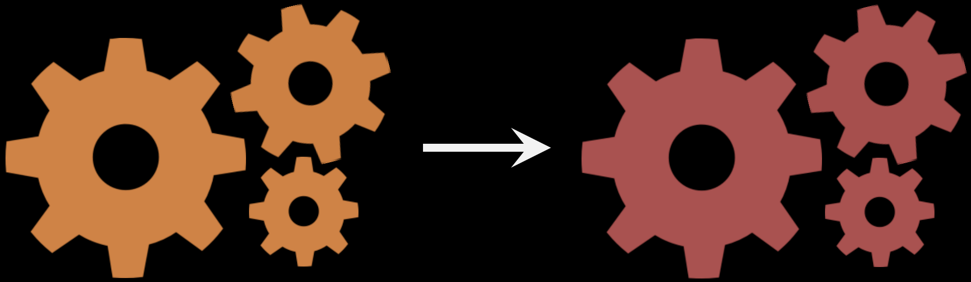


Budget allocation

Space and Time Constraint

Space and Time Constraint

Reproducible



Space and Time Constraint

Reproducible

Modular

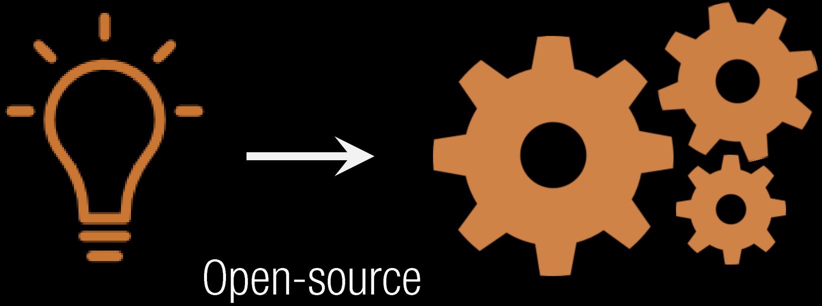
Diversity

Space and Time Constraint

Reproducible

Modular

Fast prototyping



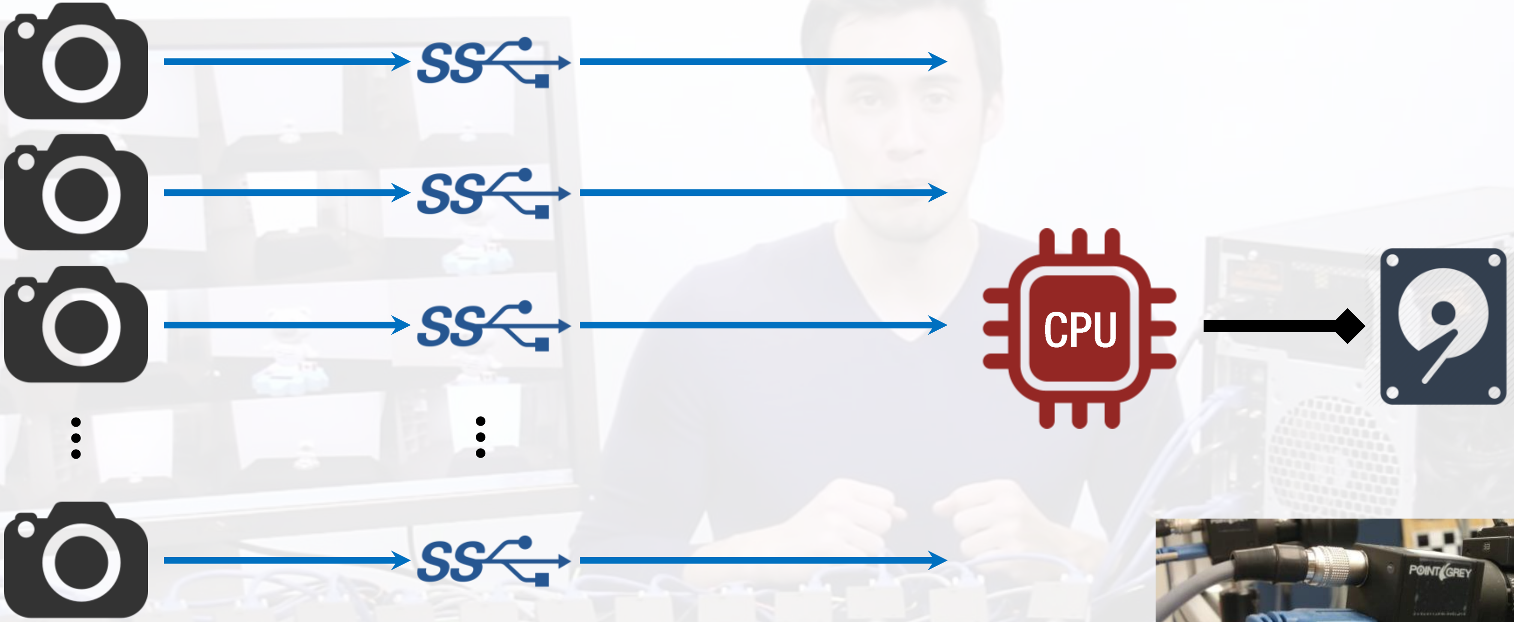
Point Grey/FLIR Multiple Camera System

https://www.youtube.com/watch?v=svY2NOEBEQA

Point Grey/FLIR Multiple Camera System

USB 3.0

Point Grey/FLIR Multiple Camera System



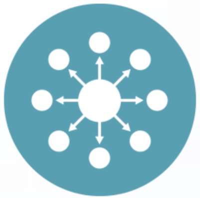
USB 3.0

Point Grey/FLIR Multiple Camera System

GPIO

USB 3.0

Is this suitable?

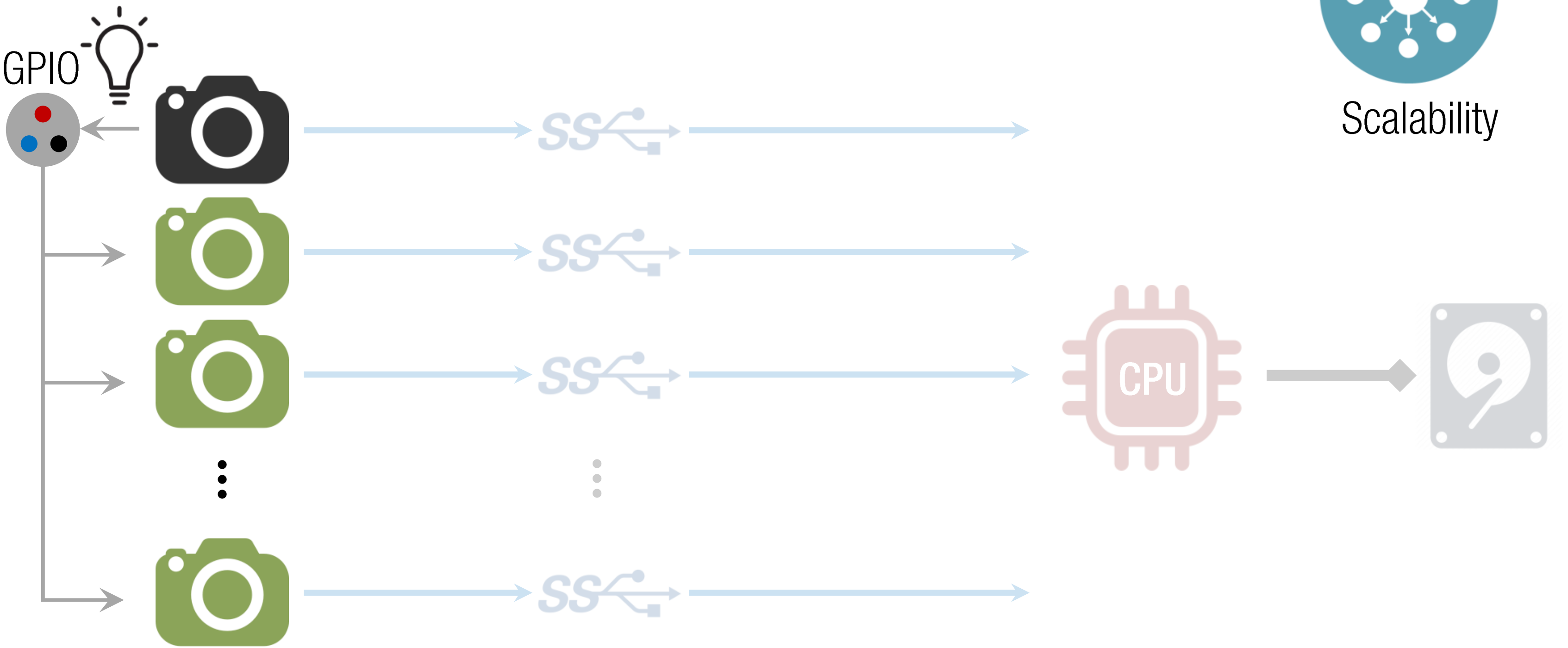


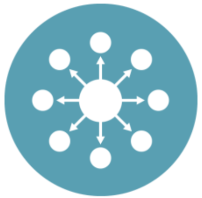
Scalability

GPIO

USB 3.0

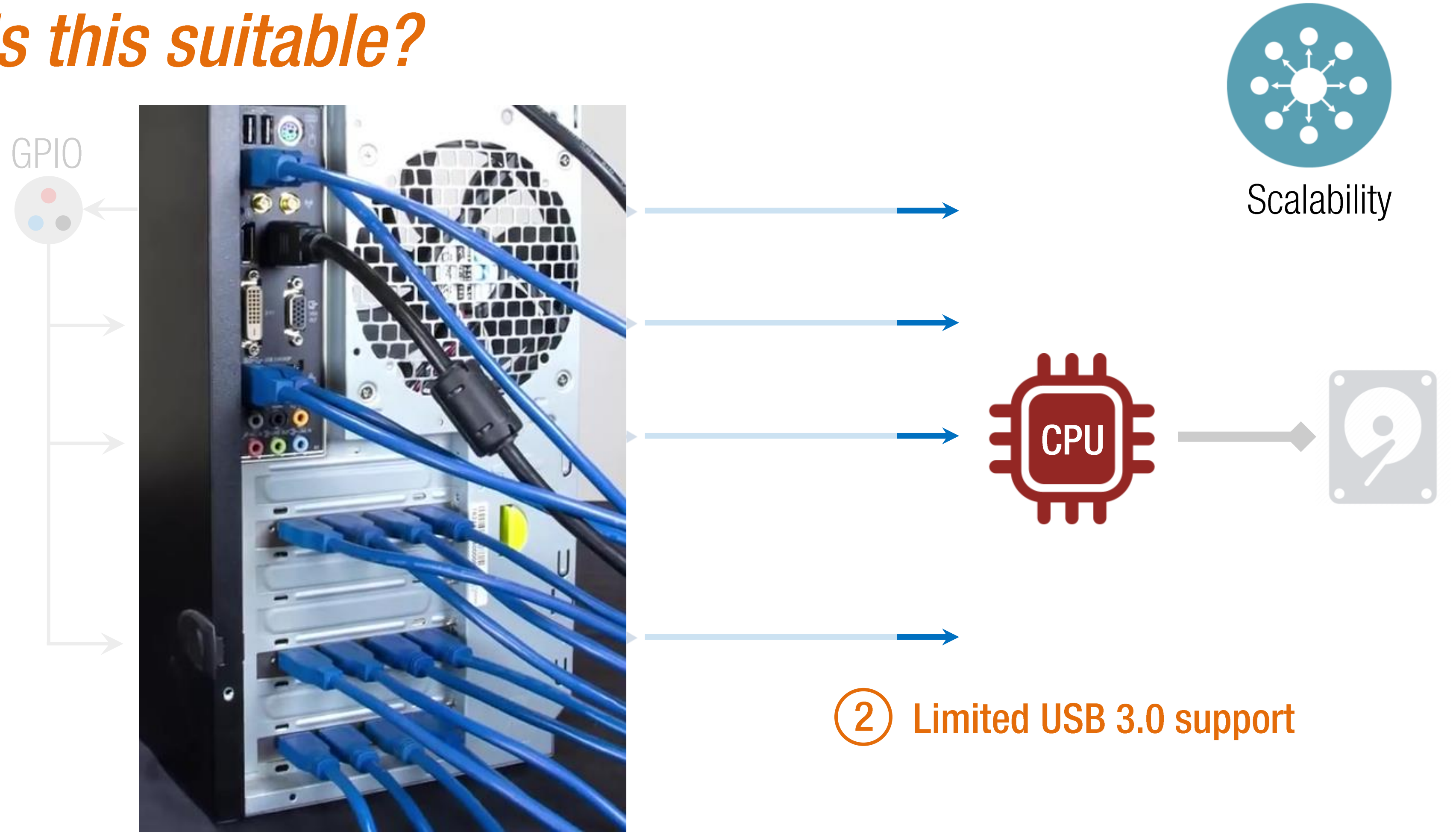
Is this suitable?





① Sync signal attenuation

Is this suitable?



② Limited USB 3.0 support

Is this suitable?

1280x1024 resolution~1.3 MB/image

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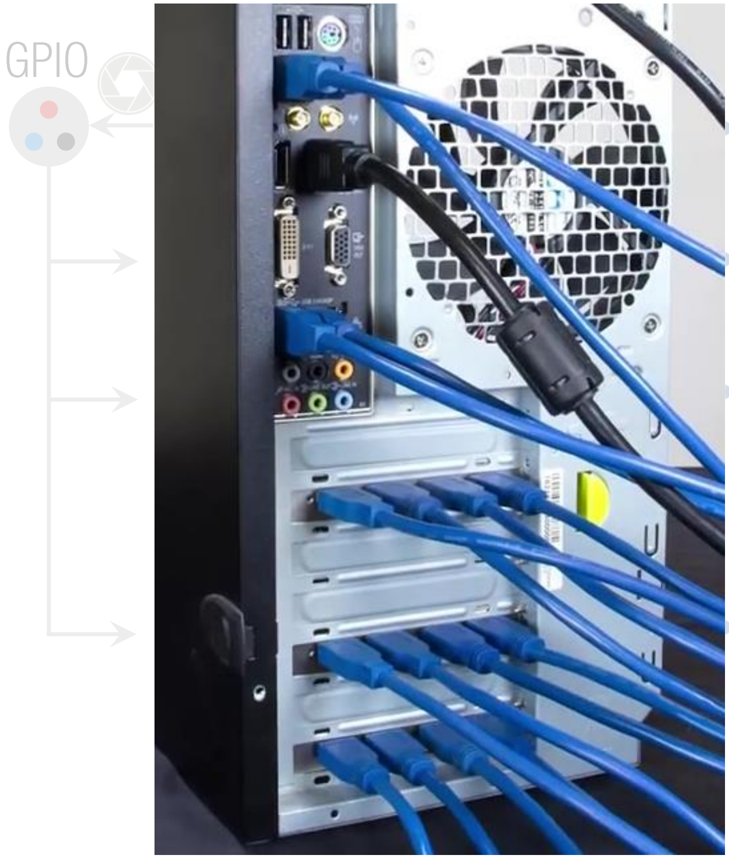
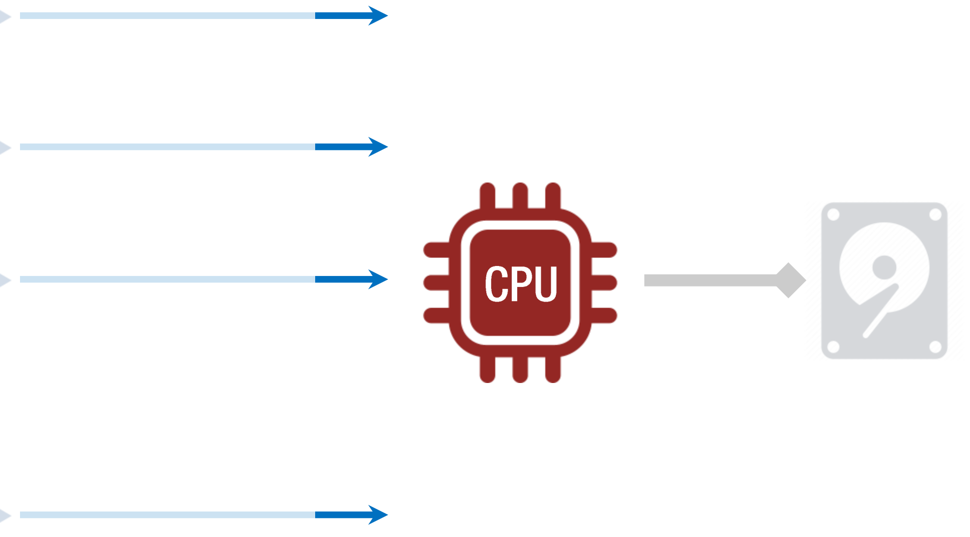
Is this suitable?

1280x1024 resolution~1.3 MB/image
200 fps~260 MB/sec





2 Limited USB 3.0 support

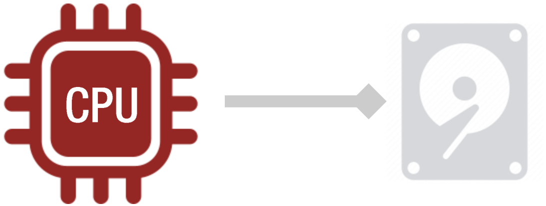
Is this suitable?

1280x1024 resolution~1.3 MB/image

200 fps~260 MB/sec

12 cameras~3.12 GB/sec

SSD writing speed: max 650 MB/sec



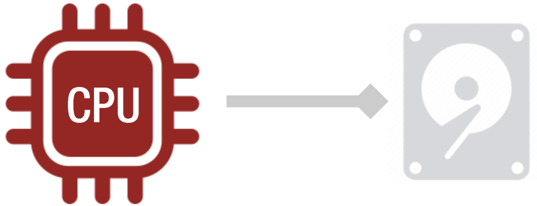
2 Limited USB 3.0 support

Is this suitable?

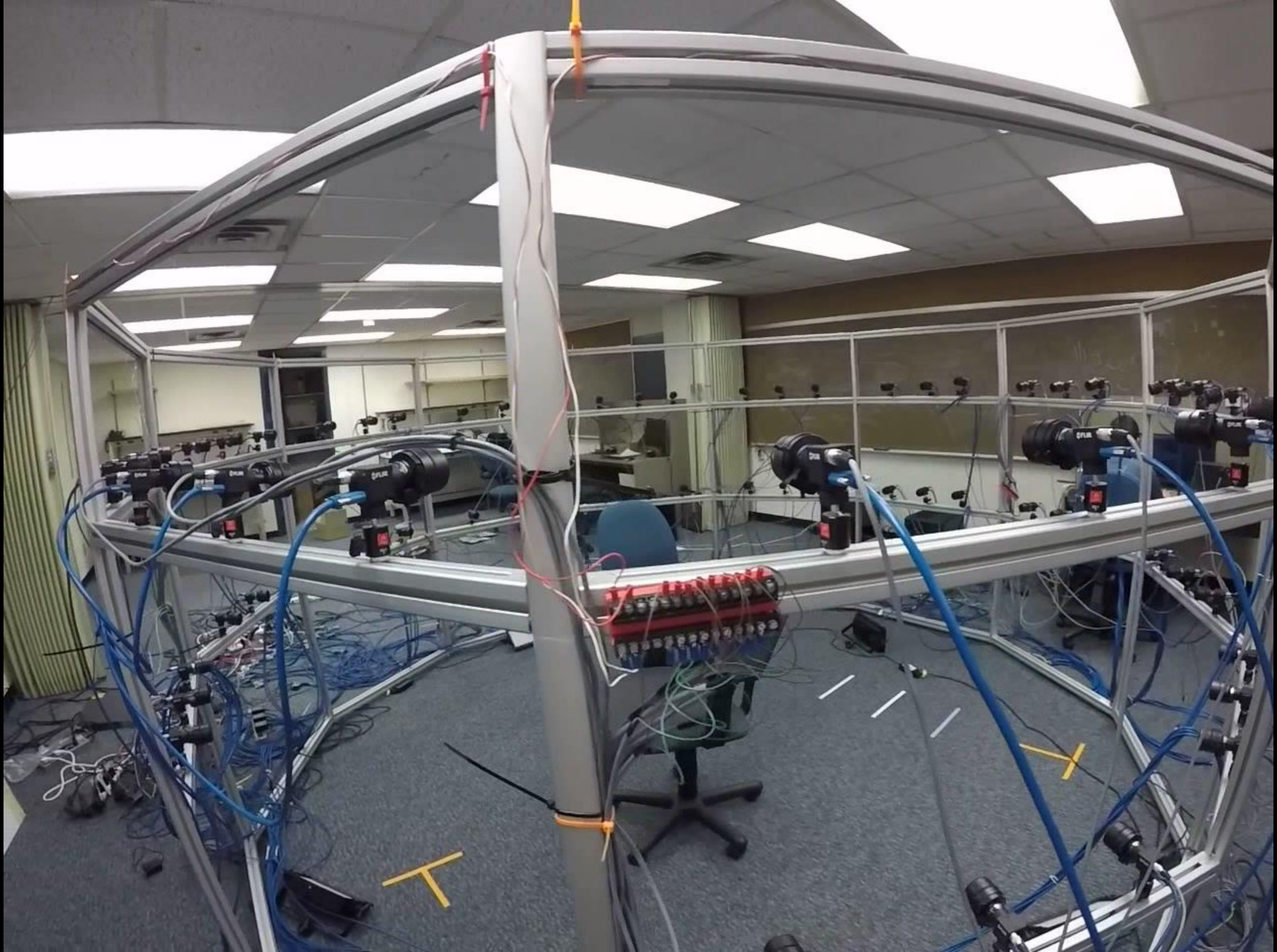
1280x1024 resolution~1.3 MB/image
200 fps~260 MB/sec
12 cameras~3.12 GB/sec

SSD writing speed: max 650 MB/sec
28 camera max w/o SSD

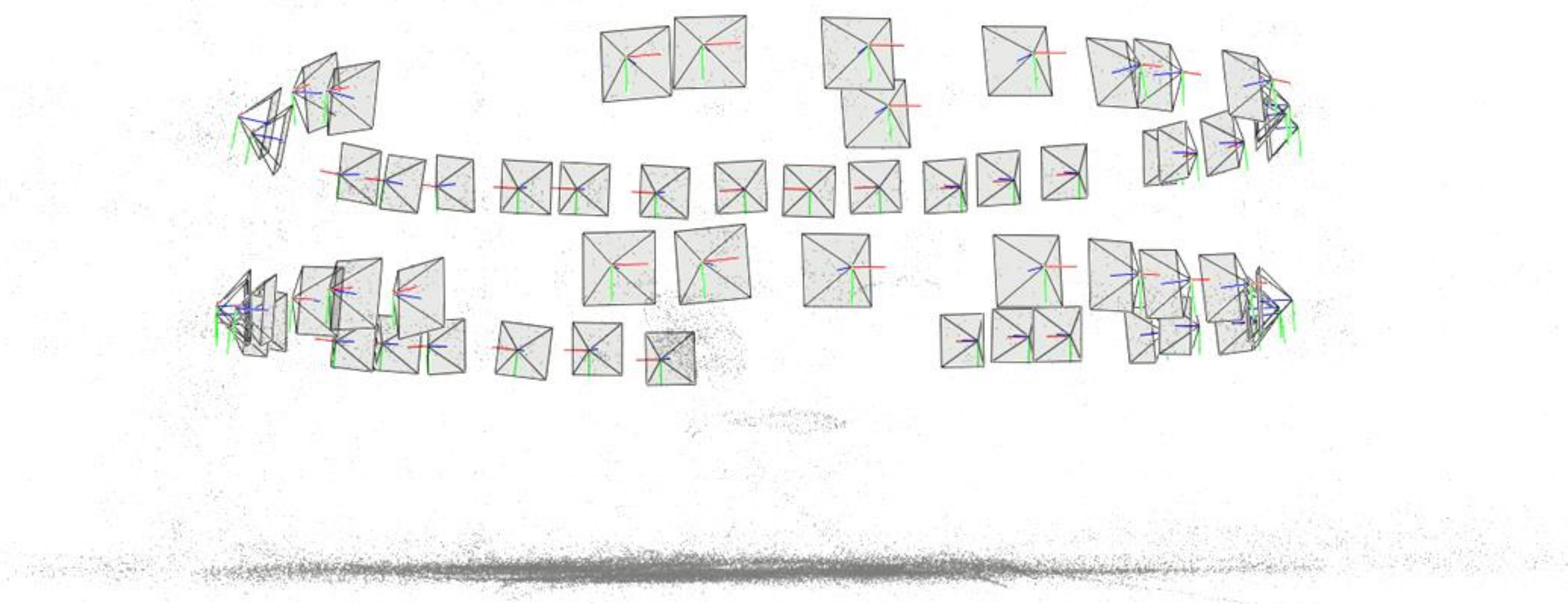
7 PCIe max



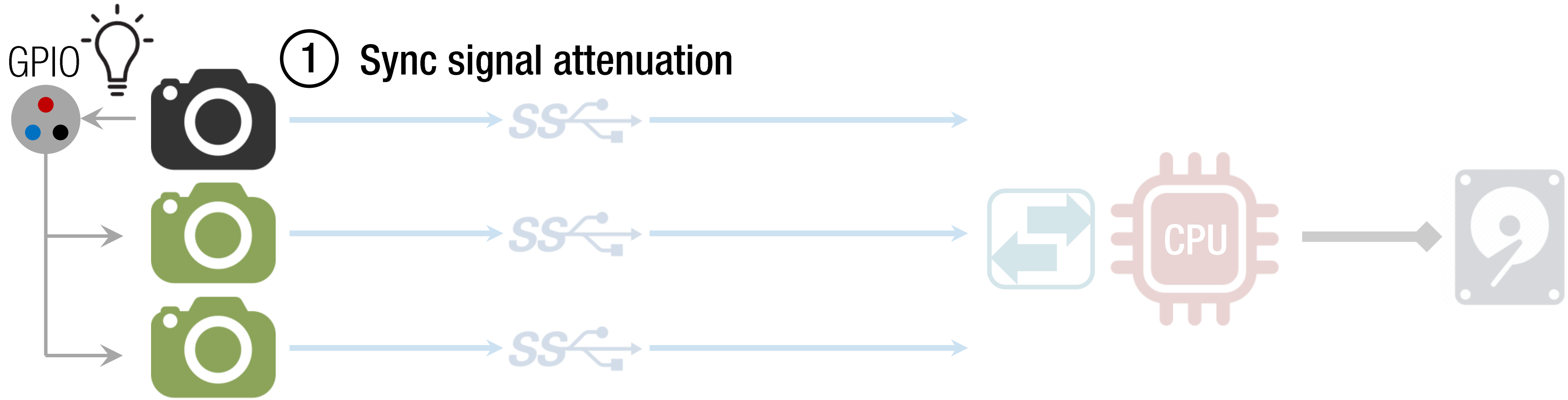
2 Limited USB 3.0 support



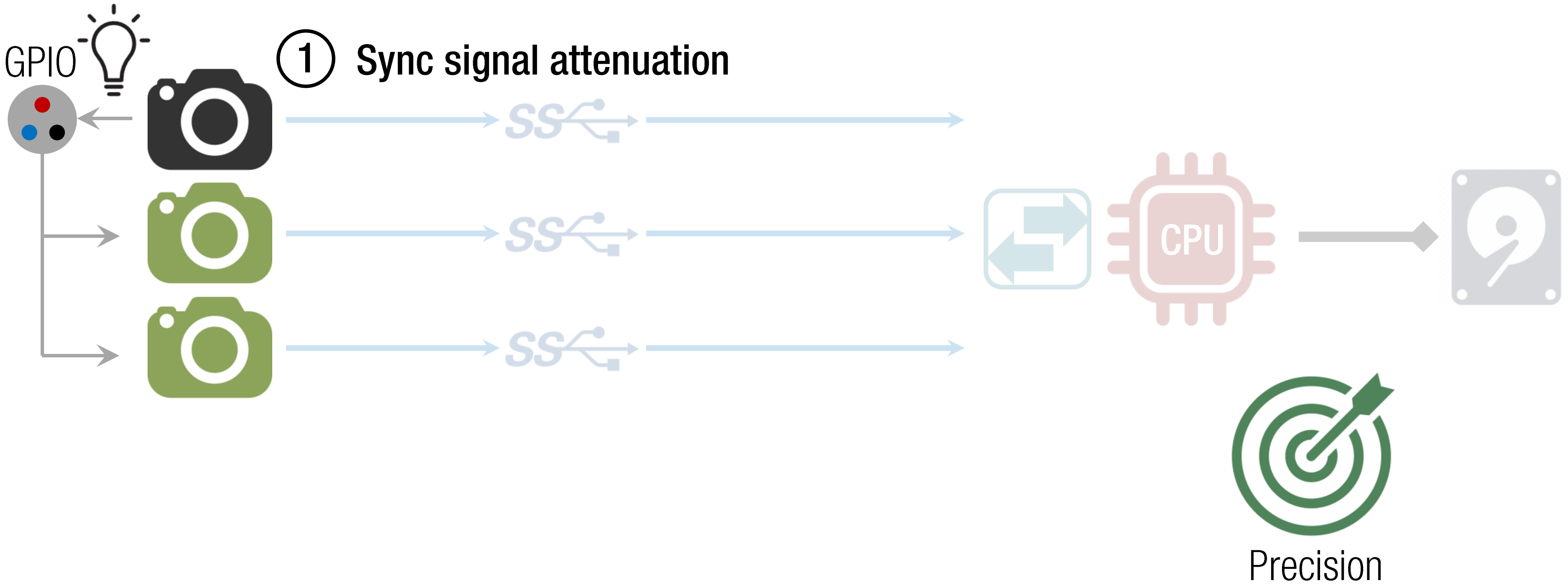
~$60K



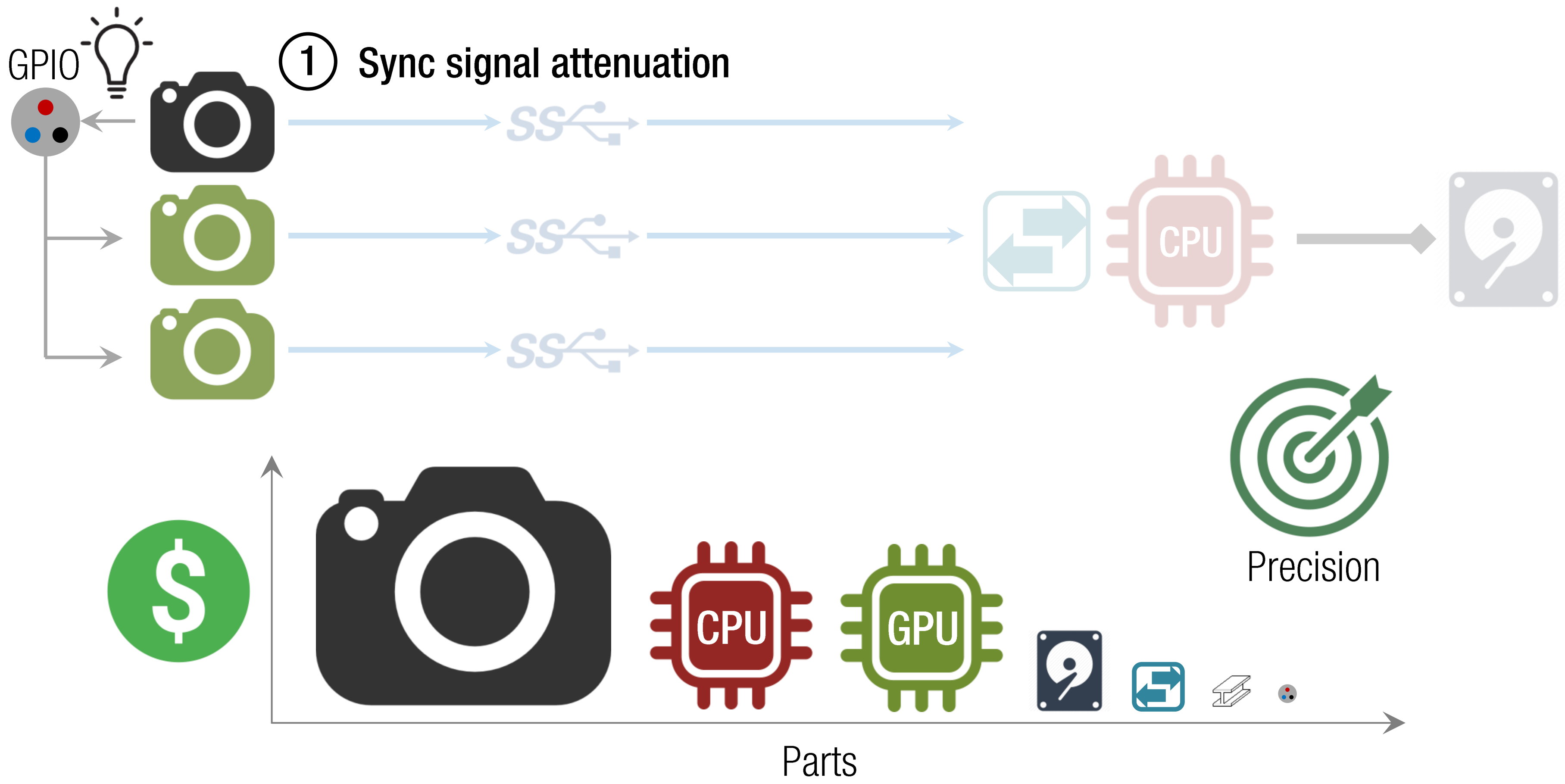
3D camera calibration

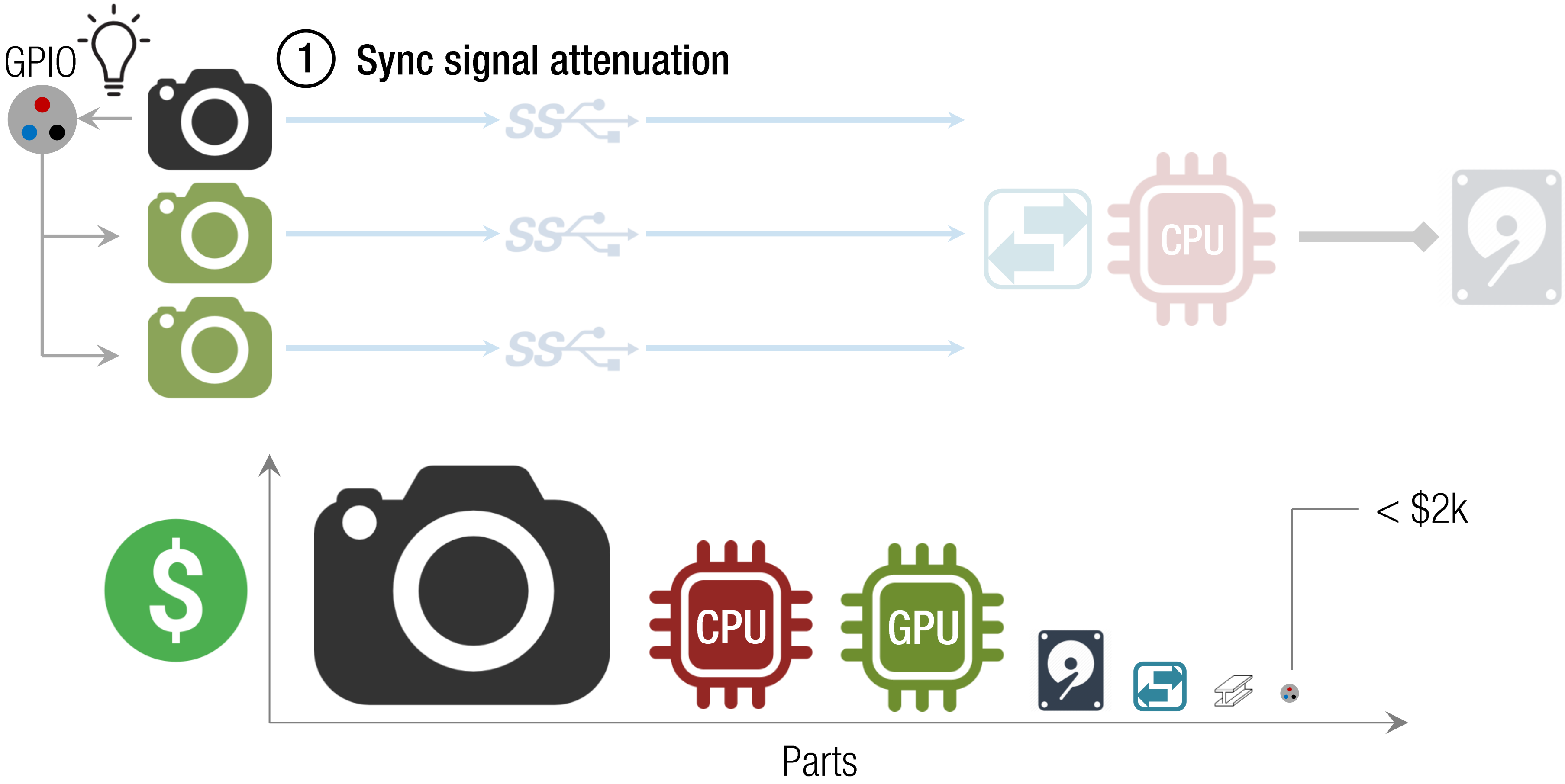


GPIO
1 Sync signal attenuation
CPU

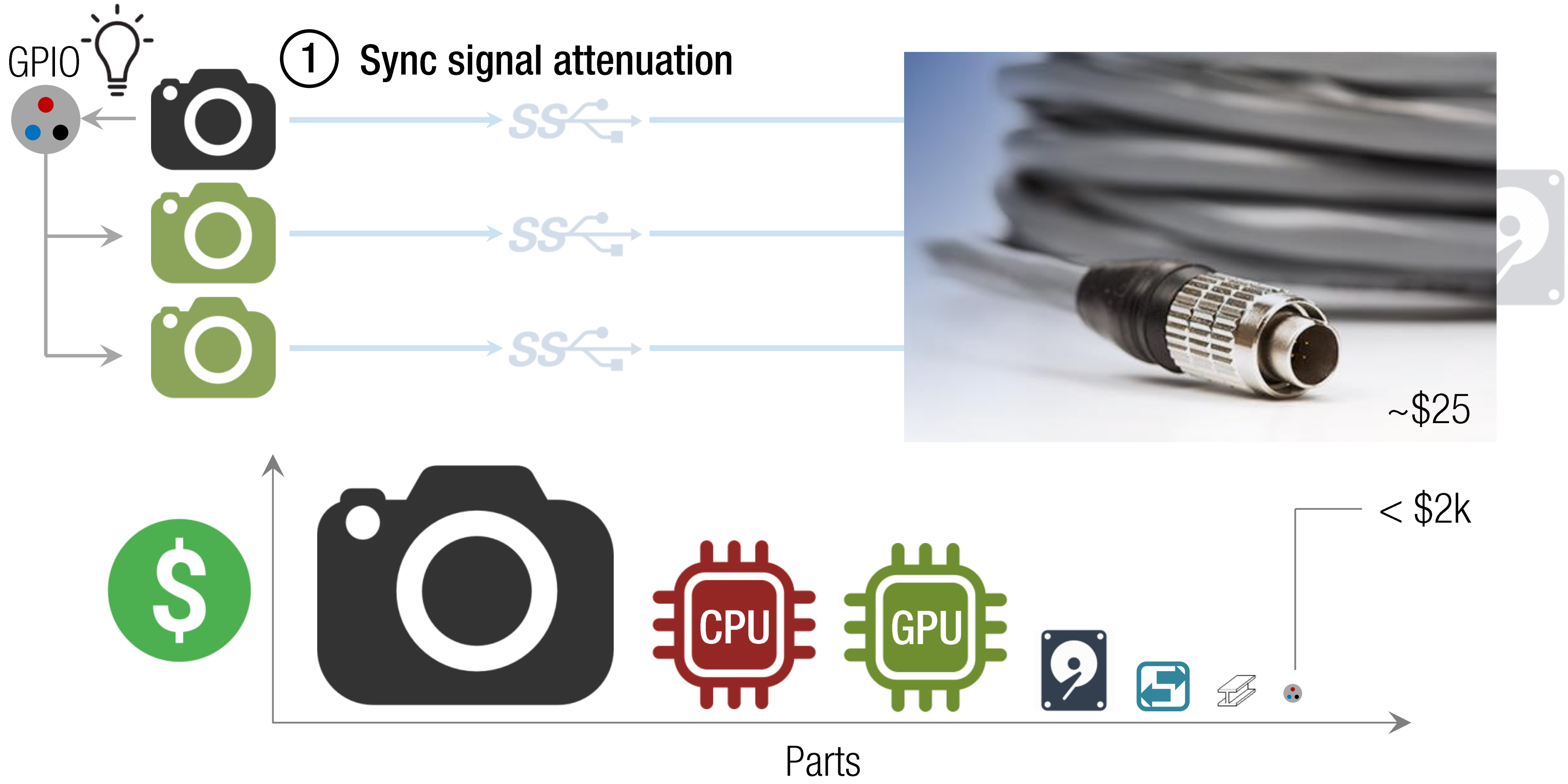


GPIO
1 Sync signal attenuation
CPU
Precision

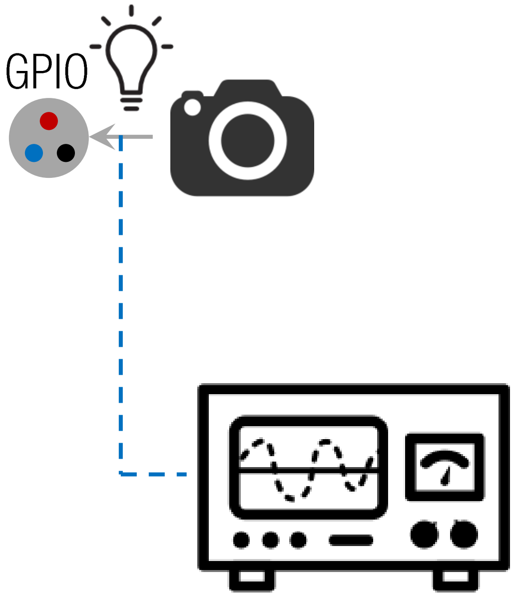

GPIO
1 Sync signal attenuation
SS
SS
SS
CPU
CPU
GPU
Precision
Parts



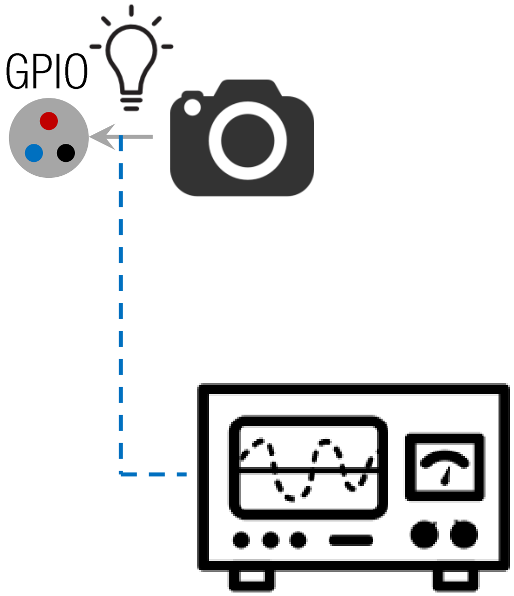
GPIO
① Sync signal attenuation
SS
SS
SS
CPU
CPU
GPU
< $2k
Parts

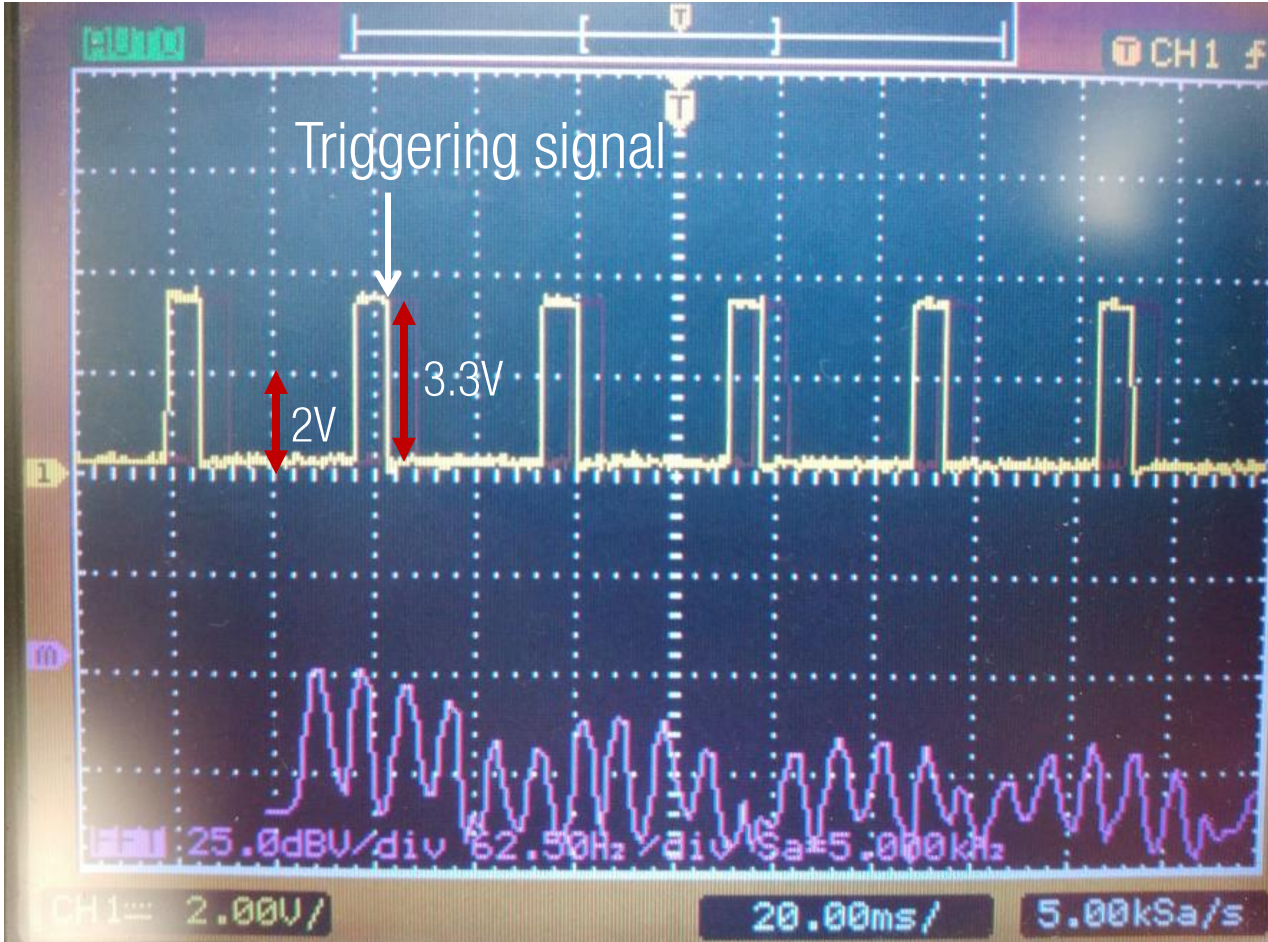

GPIO
1
Sync signal attenuation
~$25
< $2k
CPU
GPU
Parts

DIY: Synchronization Module

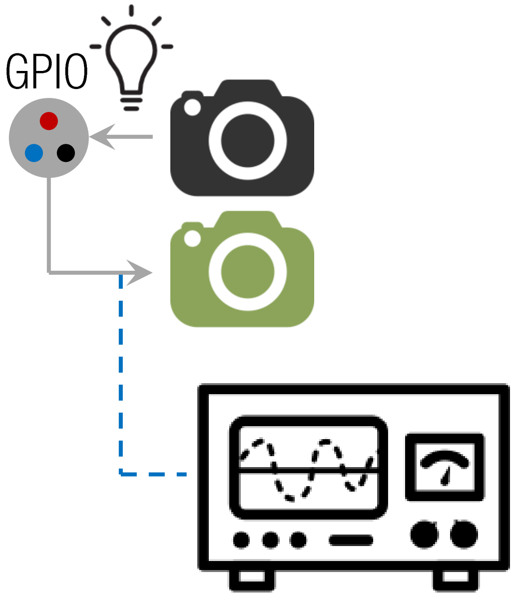


DIY: Synchronization Module

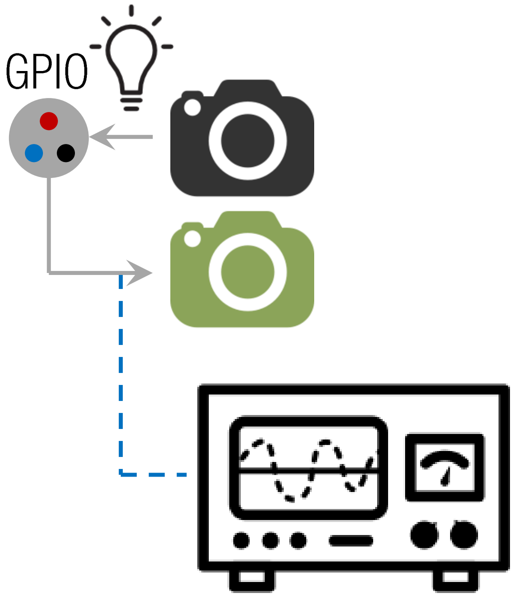


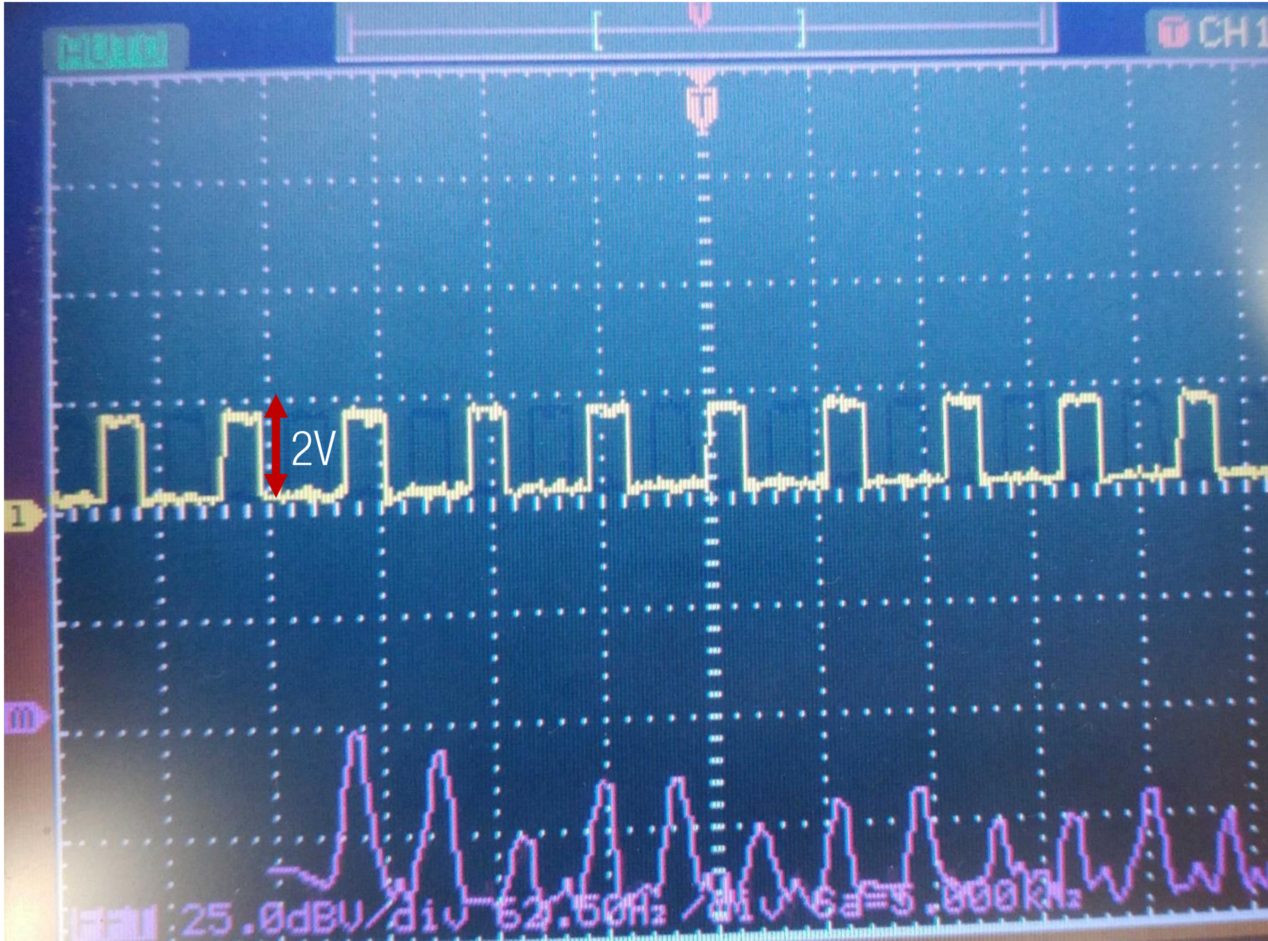


DIY: Synchronization Module

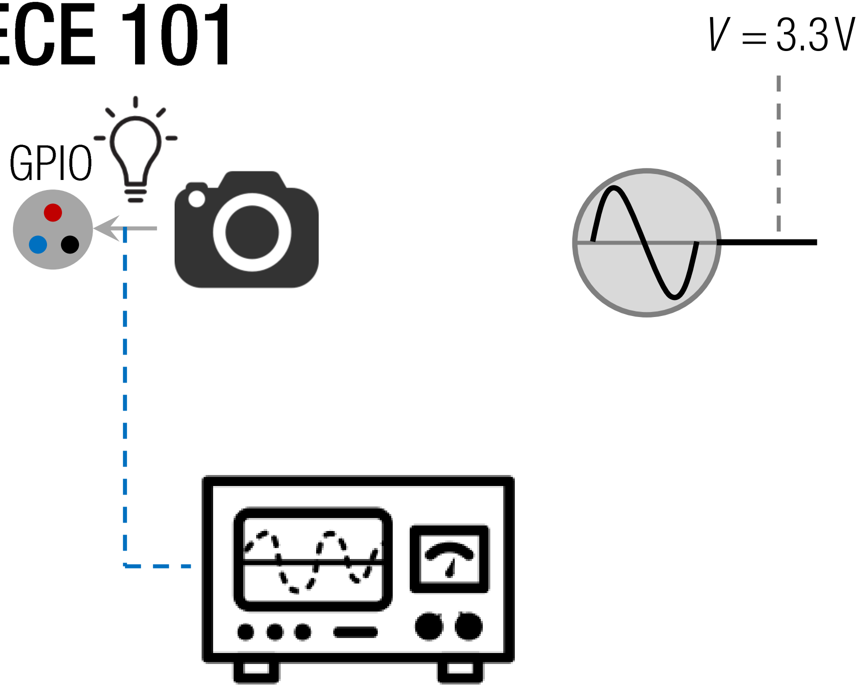


DIY: Synchronization Module

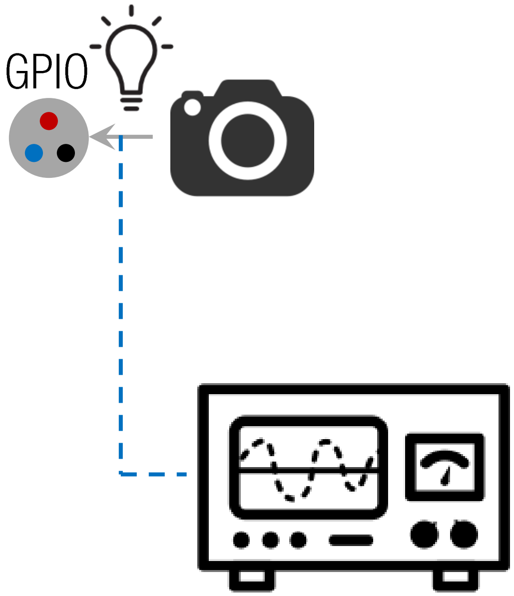




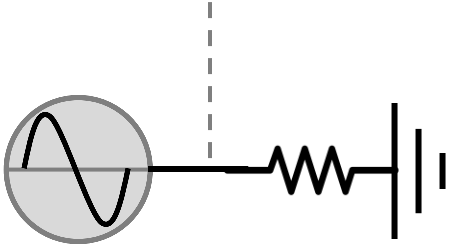
ECE 101



ECE 101



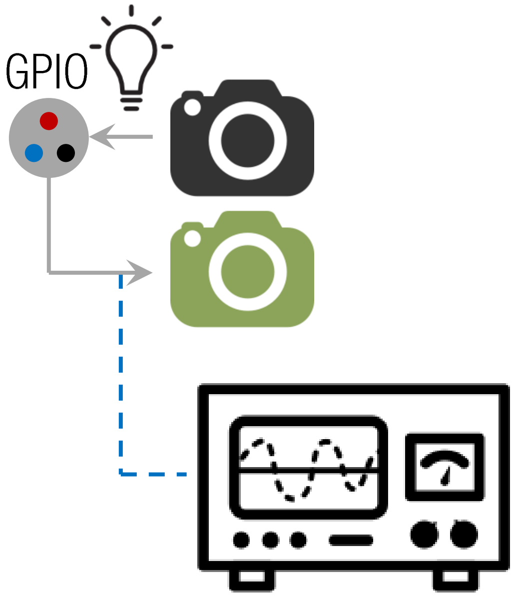
$V = 3.3\,\text{V}$

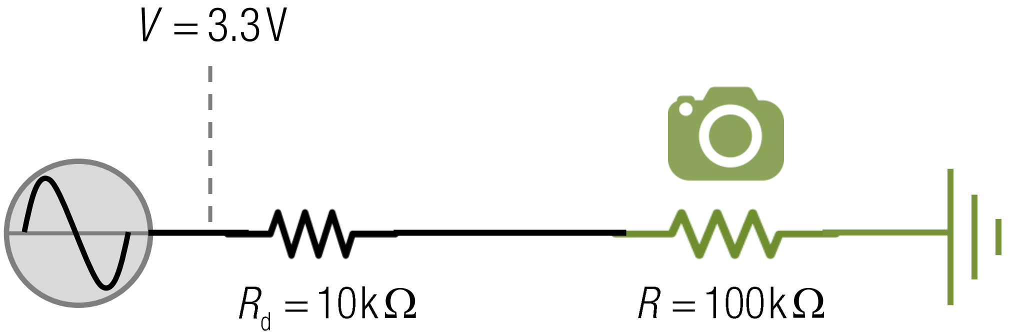


$R_d = 10\,\text{k}\Omega$

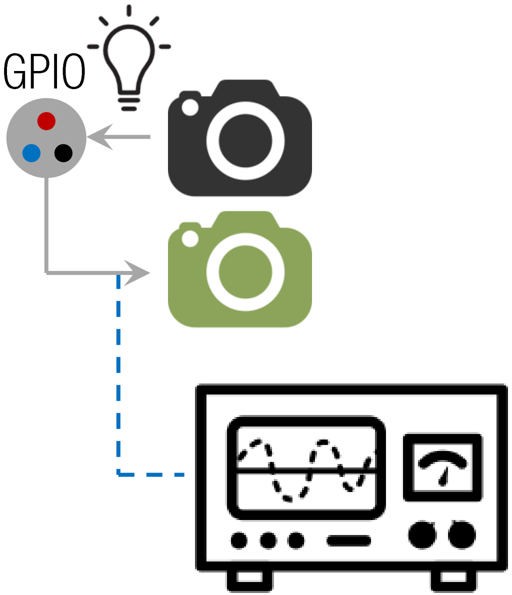
$$I = \frac{V}{R_d} = 0.33\,\text{mA}$$

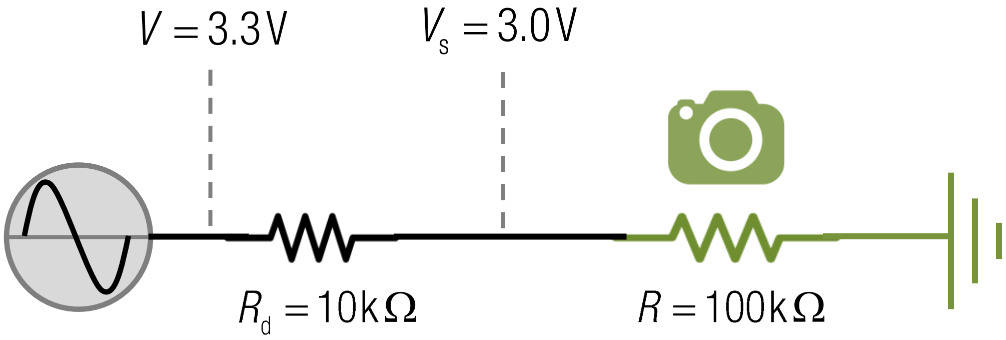
ECE 101





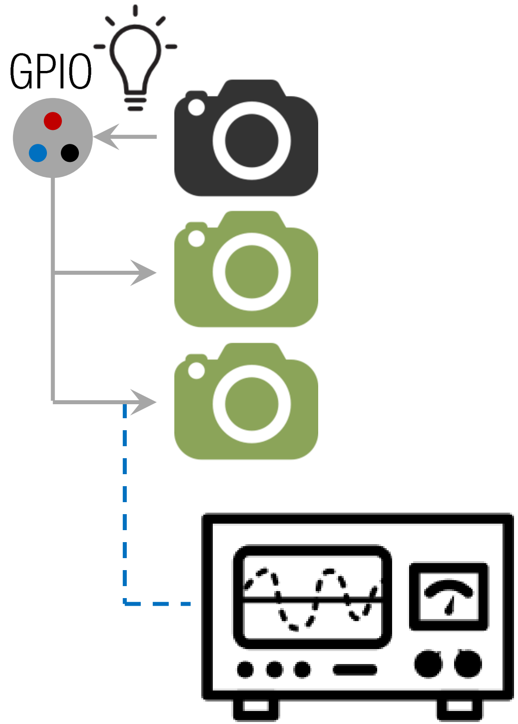
ECE 101

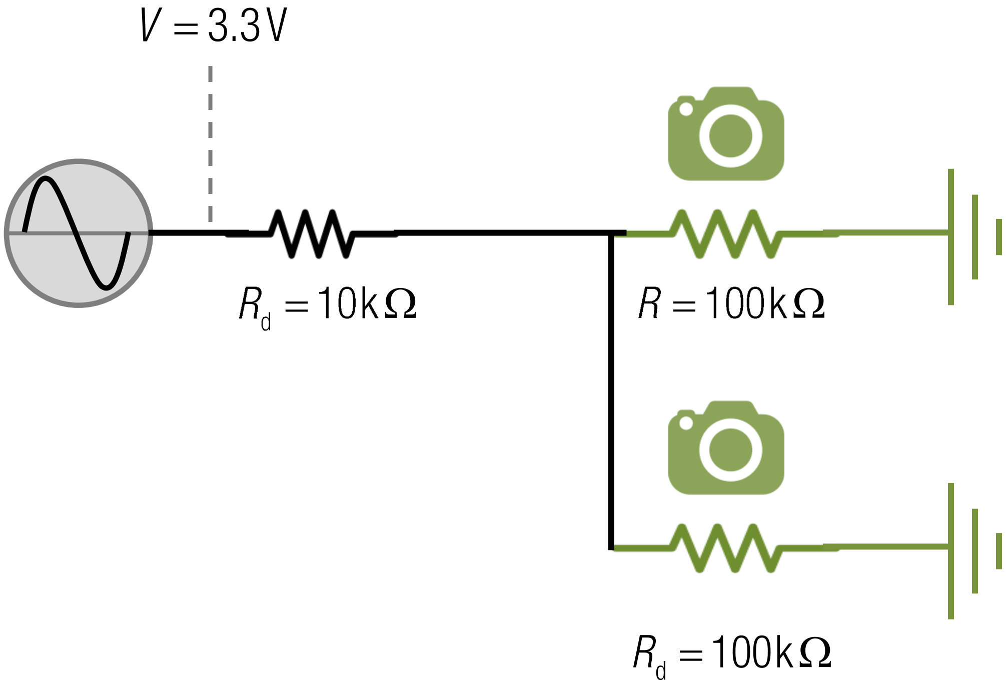




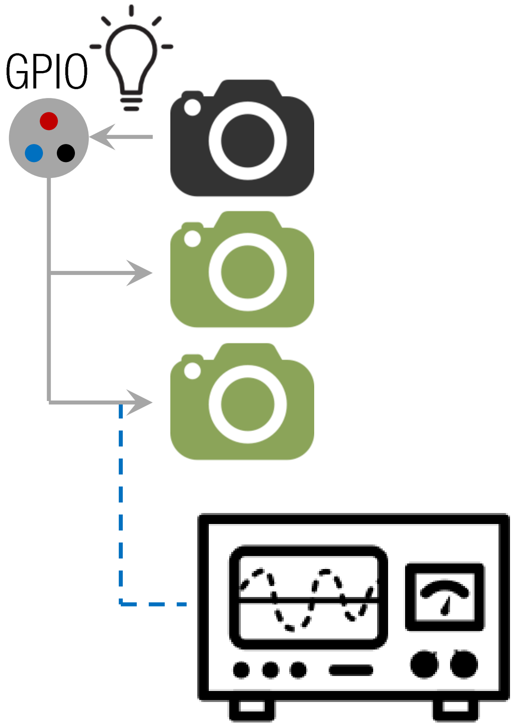
$$\frac{V}{R_d} = \frac{V_s}{R}$$

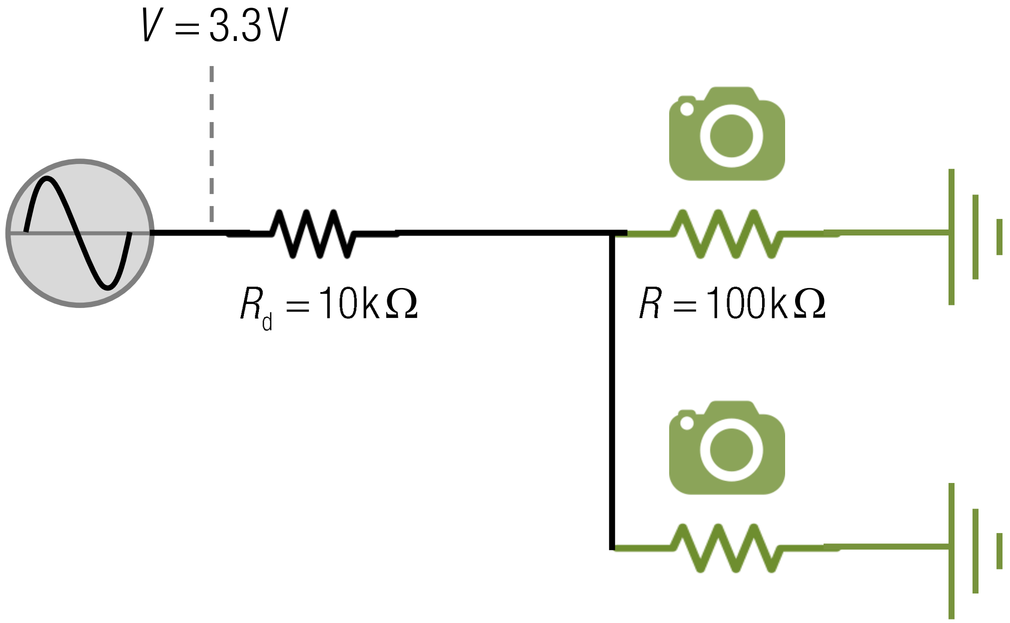
ECE 101


GPIO


$V = 3.3\,\mathrm{V}$
$R_d = 10\,\mathrm{k}\Omega$
$R = 100\,\mathrm{k}\Omega$
$R_d = 100\,\mathrm{k}\Omega$

ECE 101

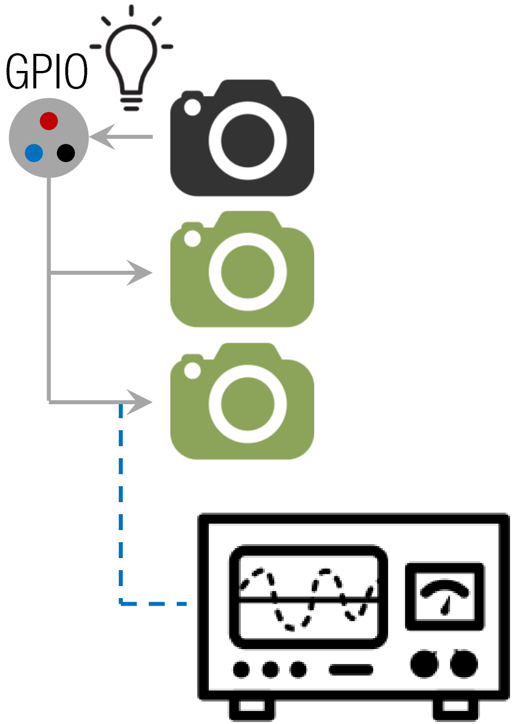


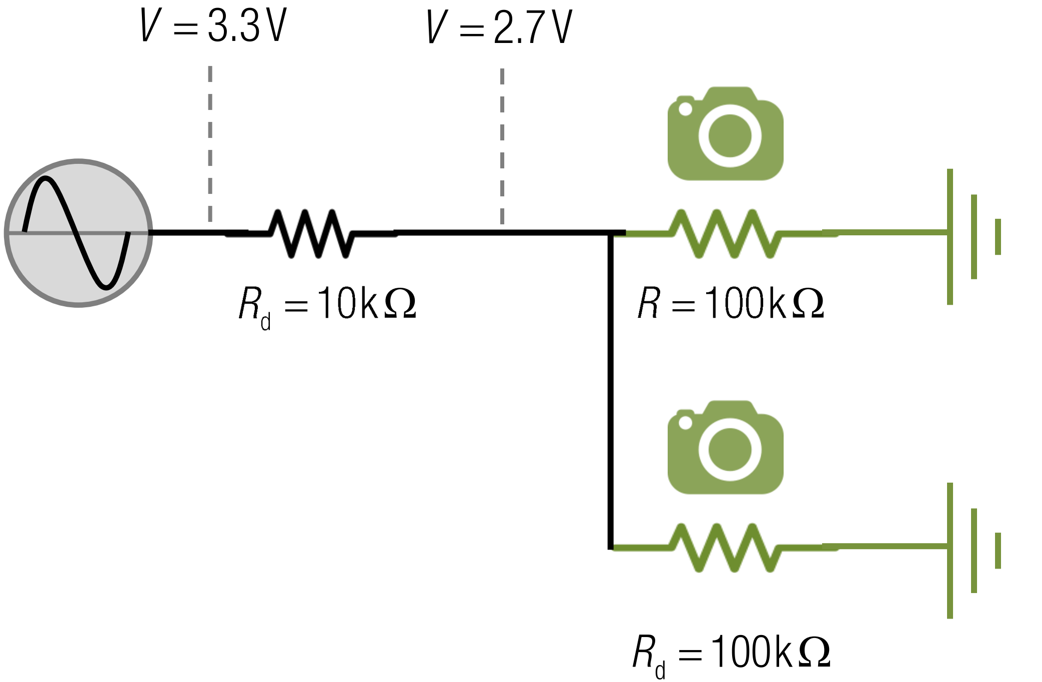


$R_d = 100\text{k}\Omega$

$$R_{net} = \frac{R^2}{R+R} = \frac{R}{2} = 50\text{k}\Omega$$

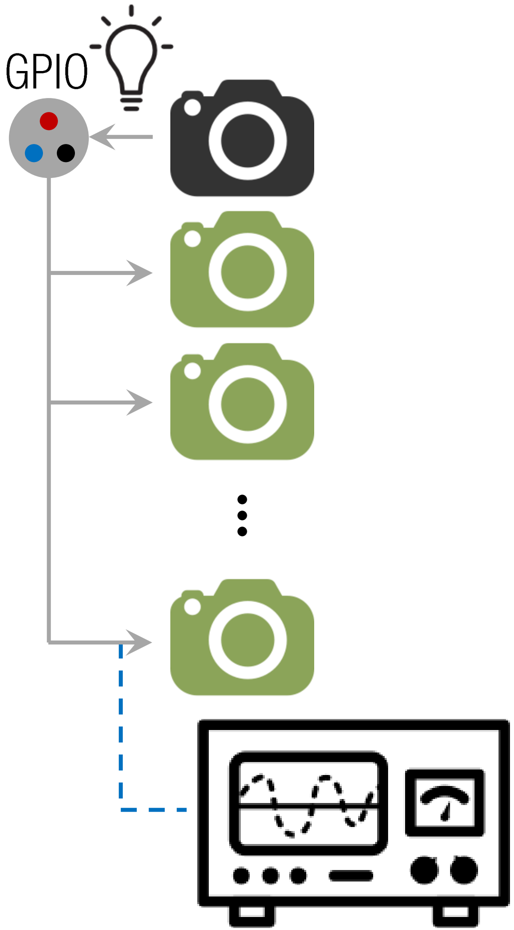
ECE 101

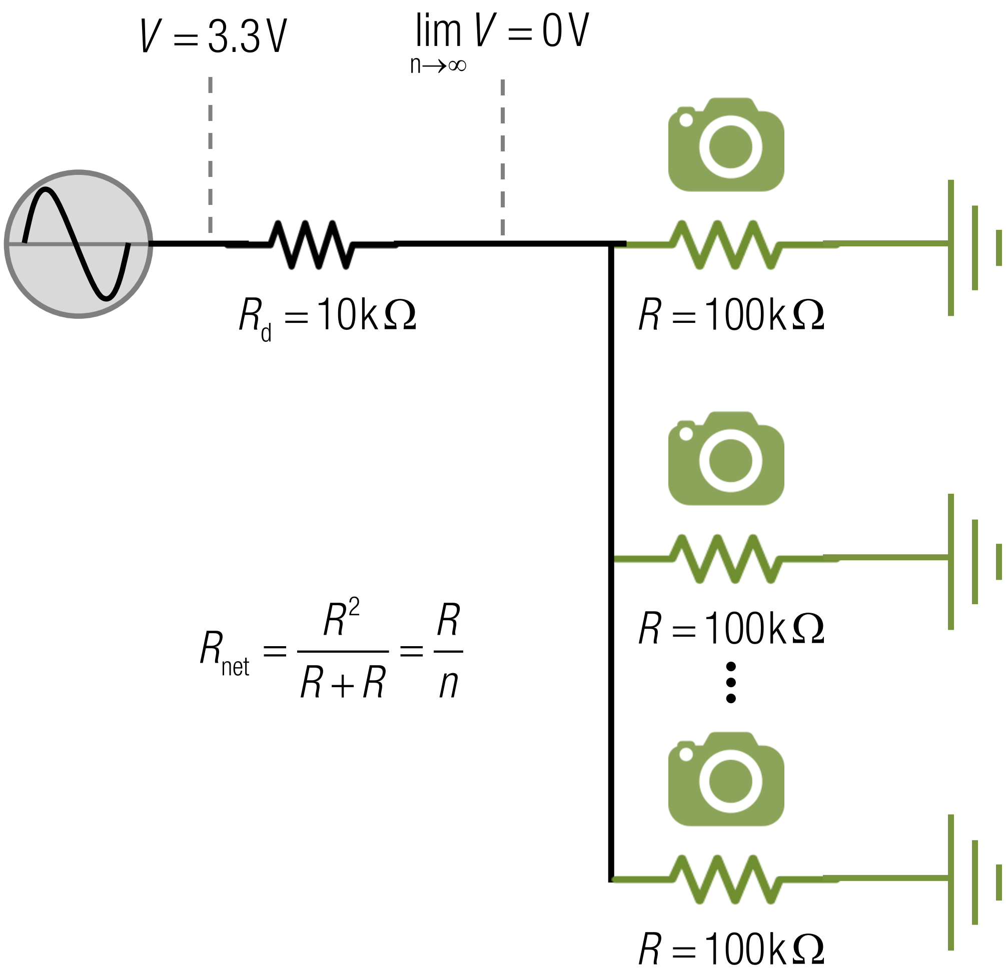




$$R_{net} = \frac{R^2}{R+R} = \frac{R}{2} = 50\,\mathrm{k}\Omega$$

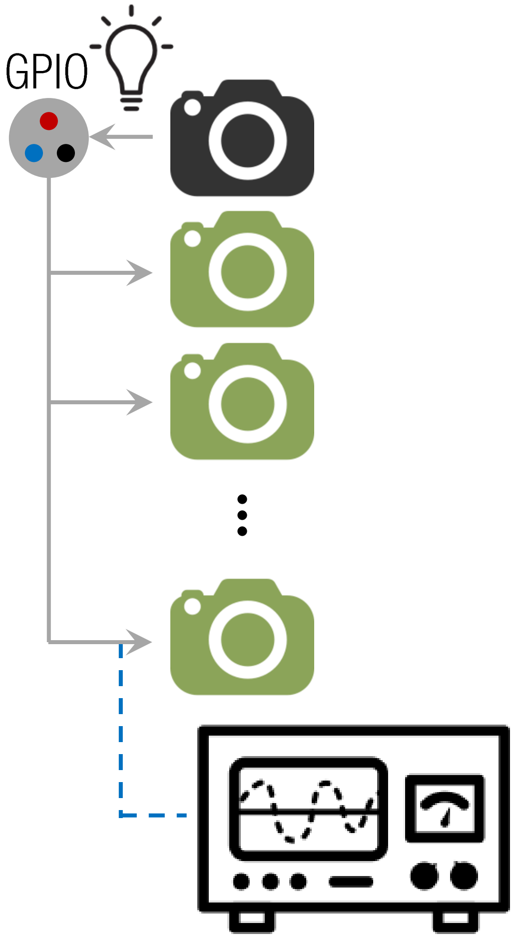
ECE 101

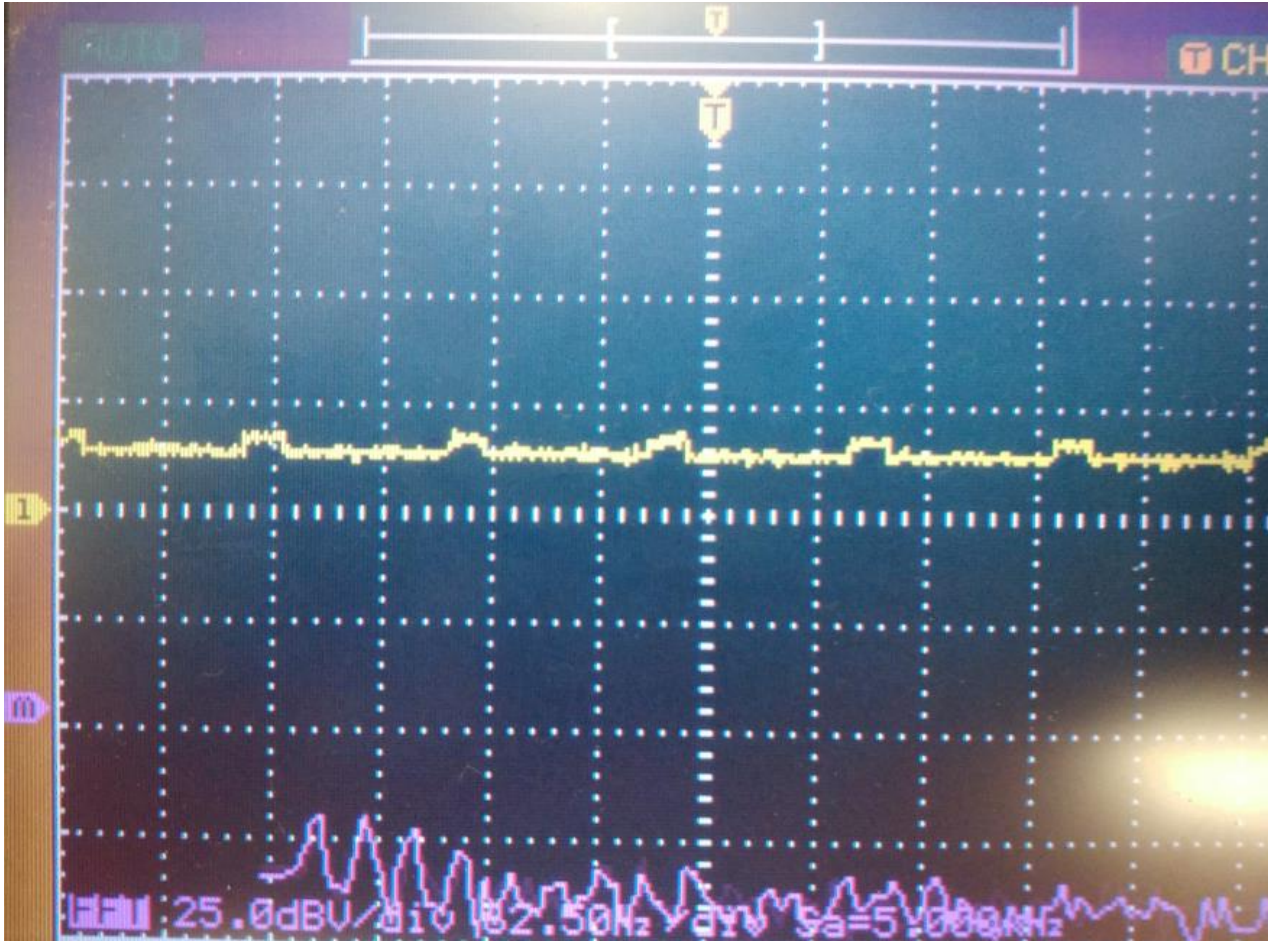




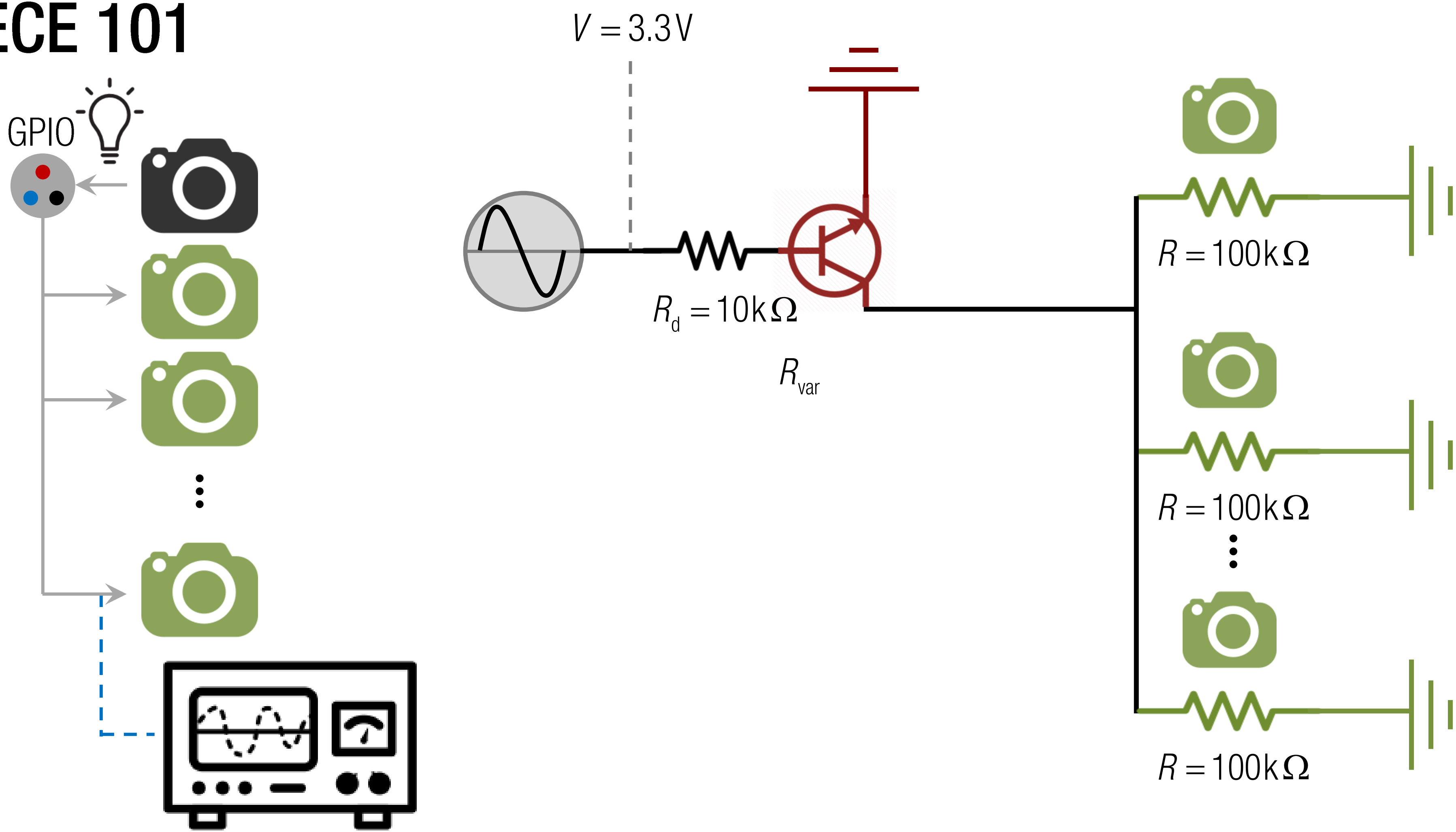
$$R_{net} = \frac{R^2}{R+R} = \frac{R}{n}$$

ECE 101



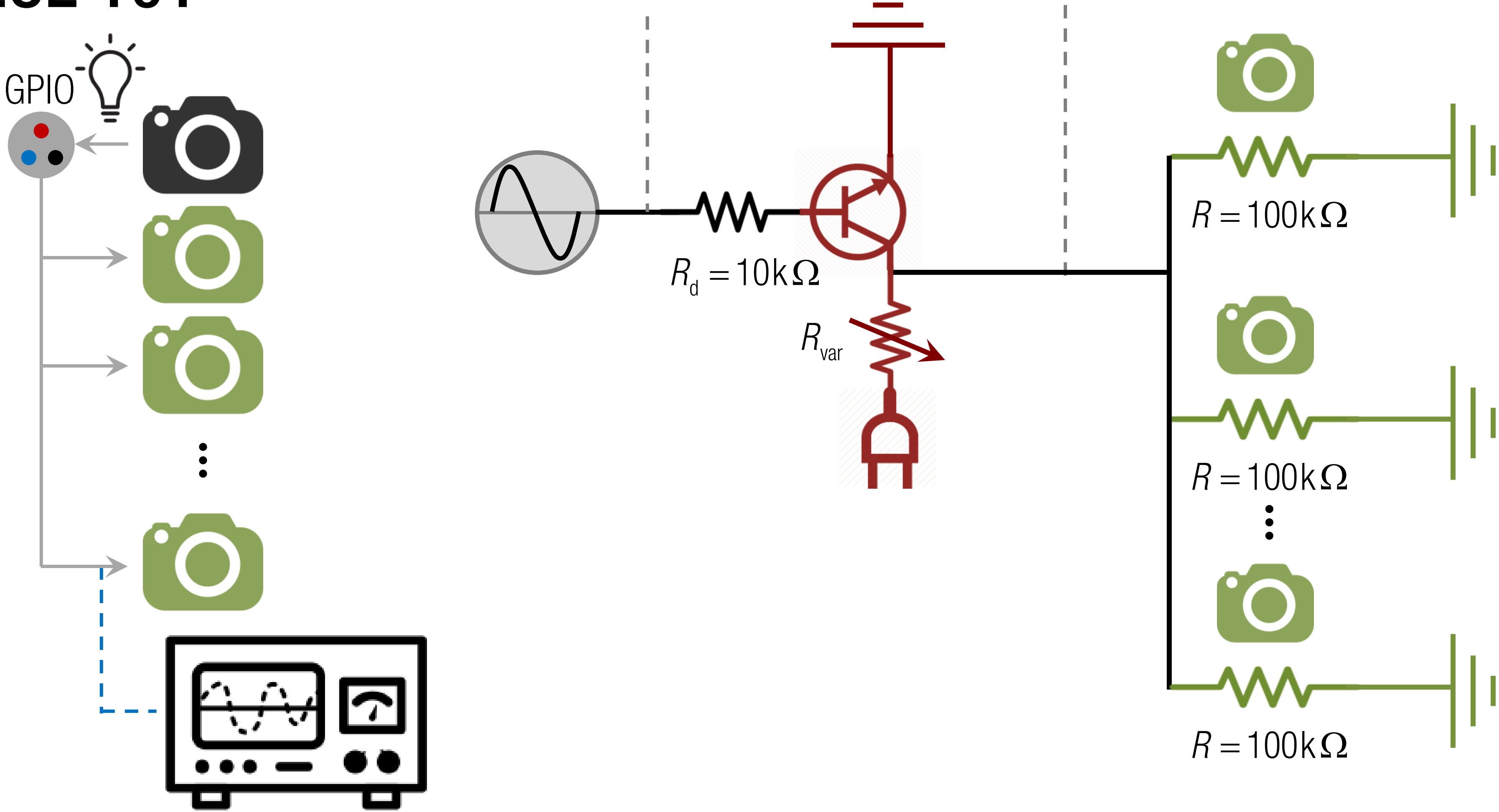


ECE 101



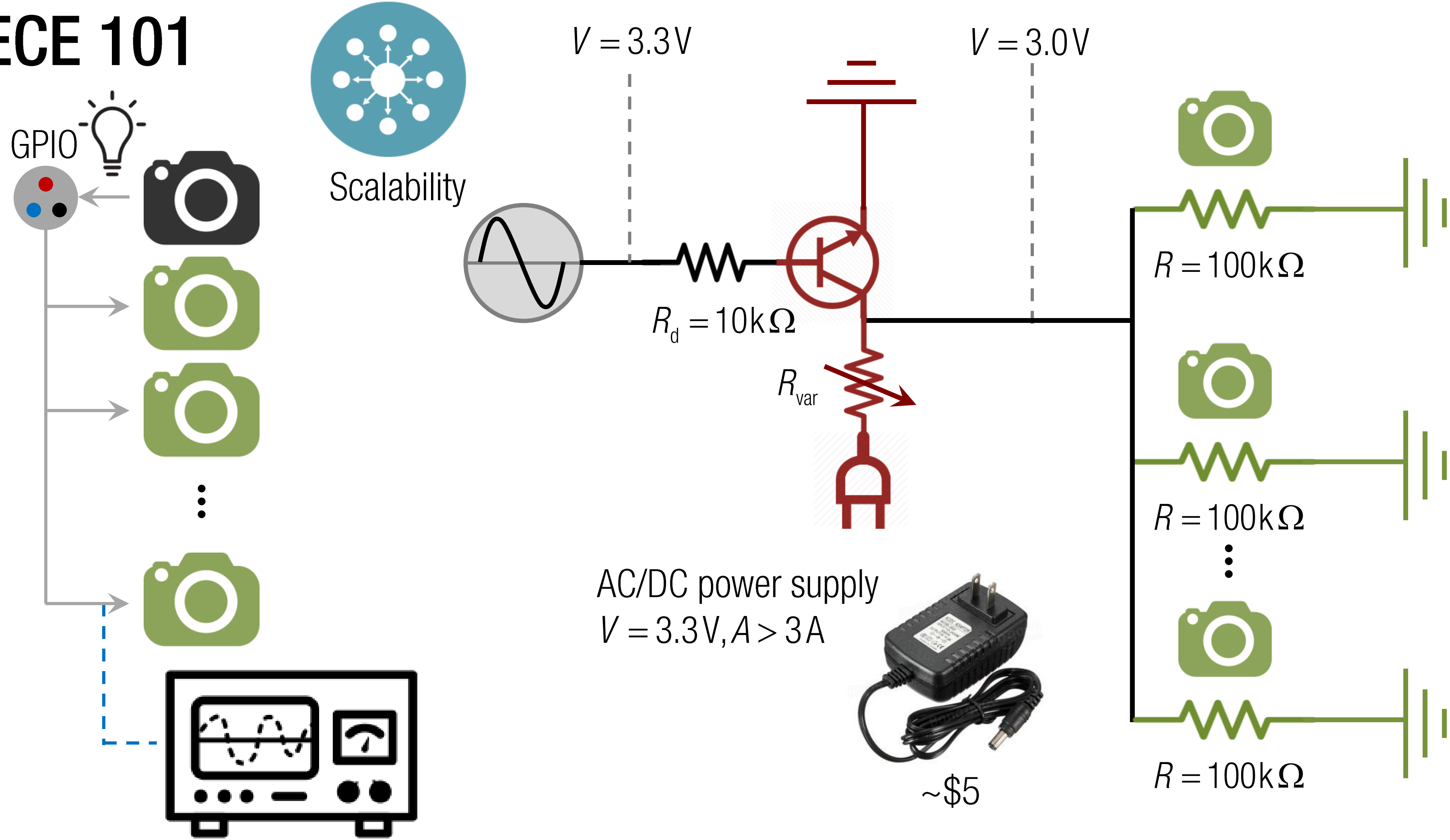
GPIO
$V = 3.3V$
$R_d = 10k\Omega$
R_{var}
$R = 100k\Omega$
$R = 100k\Omega$
$R = 100k\Omega$

ECE 101

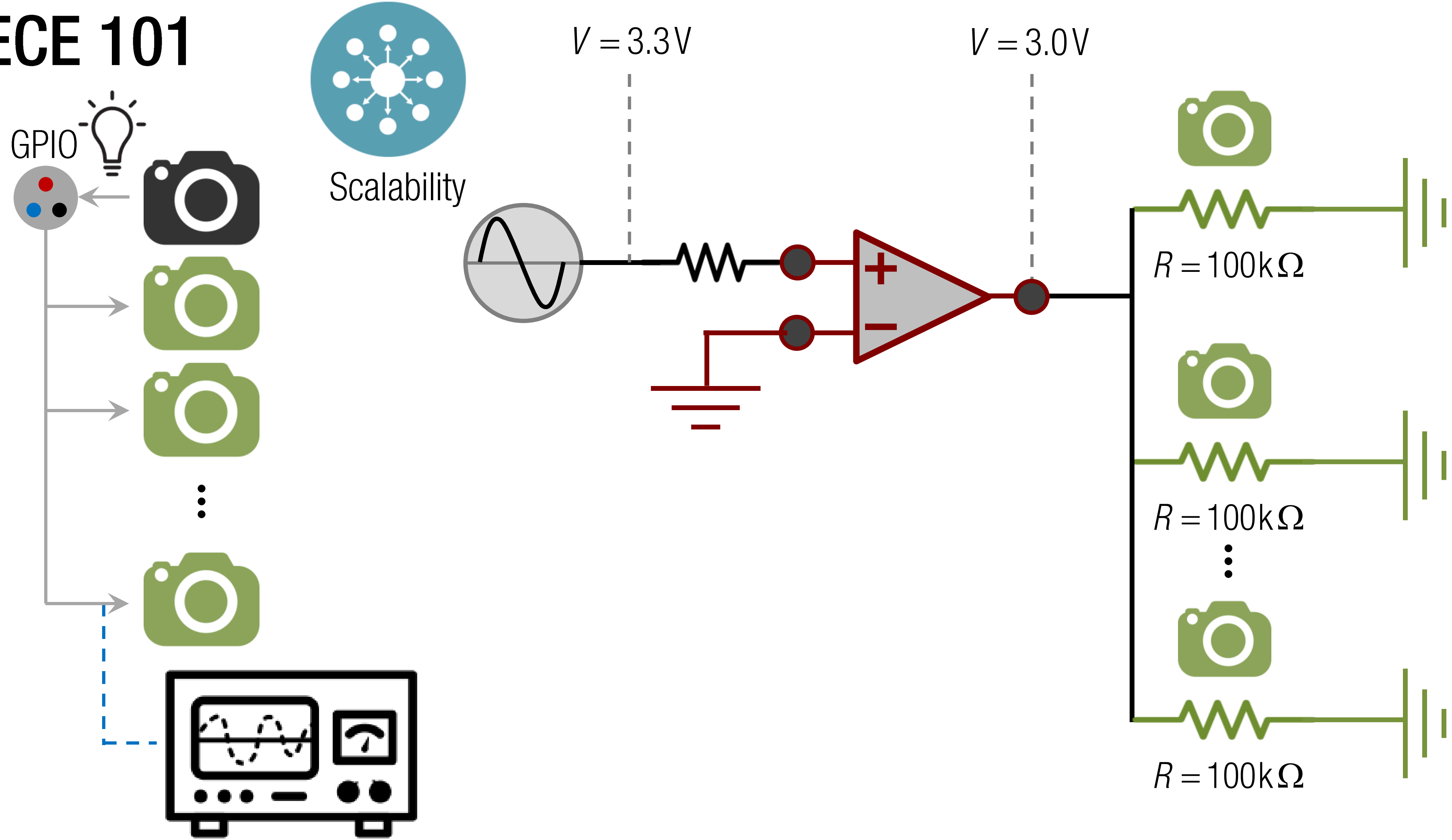


GPIO
$V = 3.3\,\mathrm{V}$
$V = 3.0\,\mathrm{V}$
$R_d = 10\,\mathrm{k\Omega}$
R_{var}
$R = 100\,\mathrm{k\Omega}$
$R = 100\,\mathrm{k\Omega}$
$R = 100\,\mathrm{k\Omega}$

ECE 101

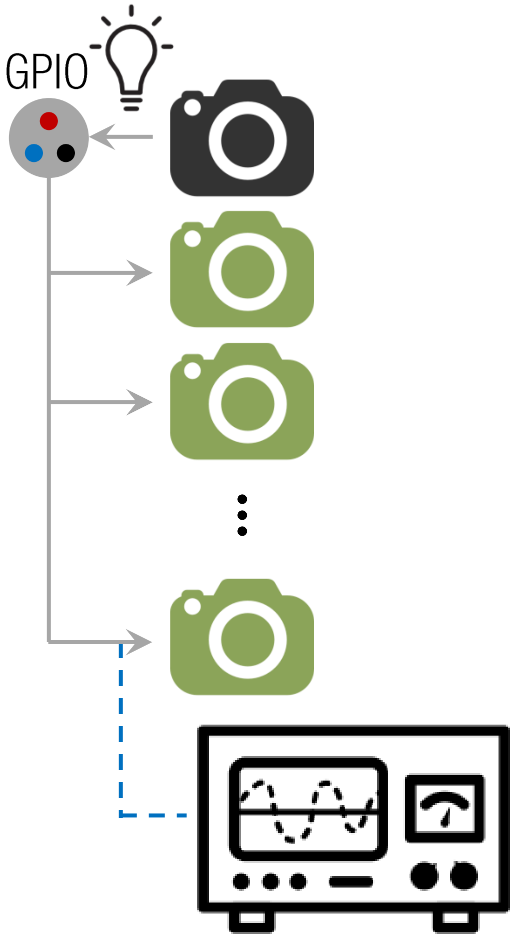

GPIO
Scalability
$V = 3.3\,\mathrm{V}$
$V = 3.0\,\mathrm{V}$
$R_d = 10\,\mathrm{k}\Omega$
R_{var}
$R = 100\,\mathrm{k}\Omega$
$R = 100\,\mathrm{k}\Omega$
$R = 100\,\mathrm{k}\Omega$
AC/DC power supply
$V = 3.3\,\mathrm{V}, A > 3\,\mathrm{A}$
~$5

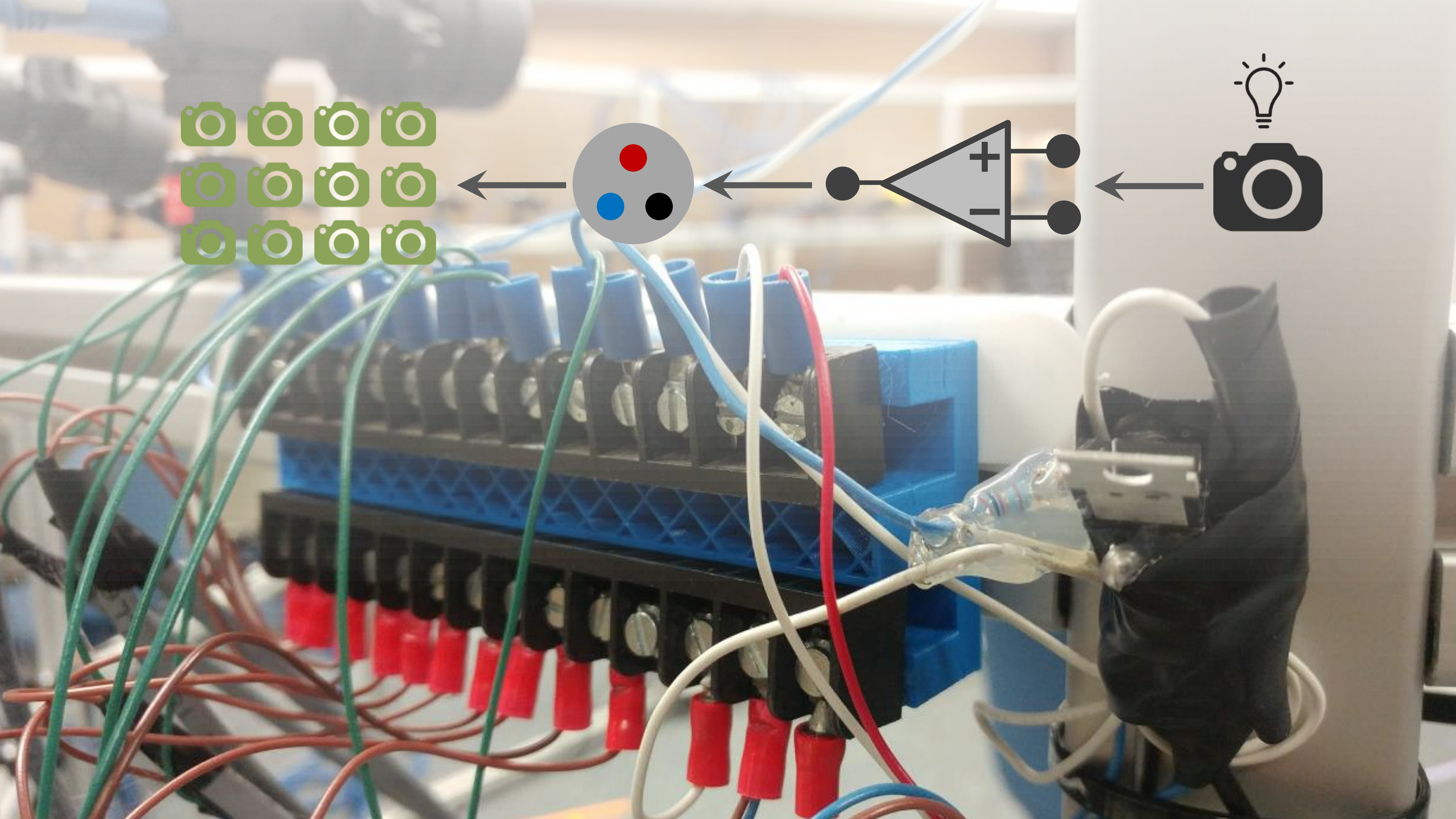
ECE 101

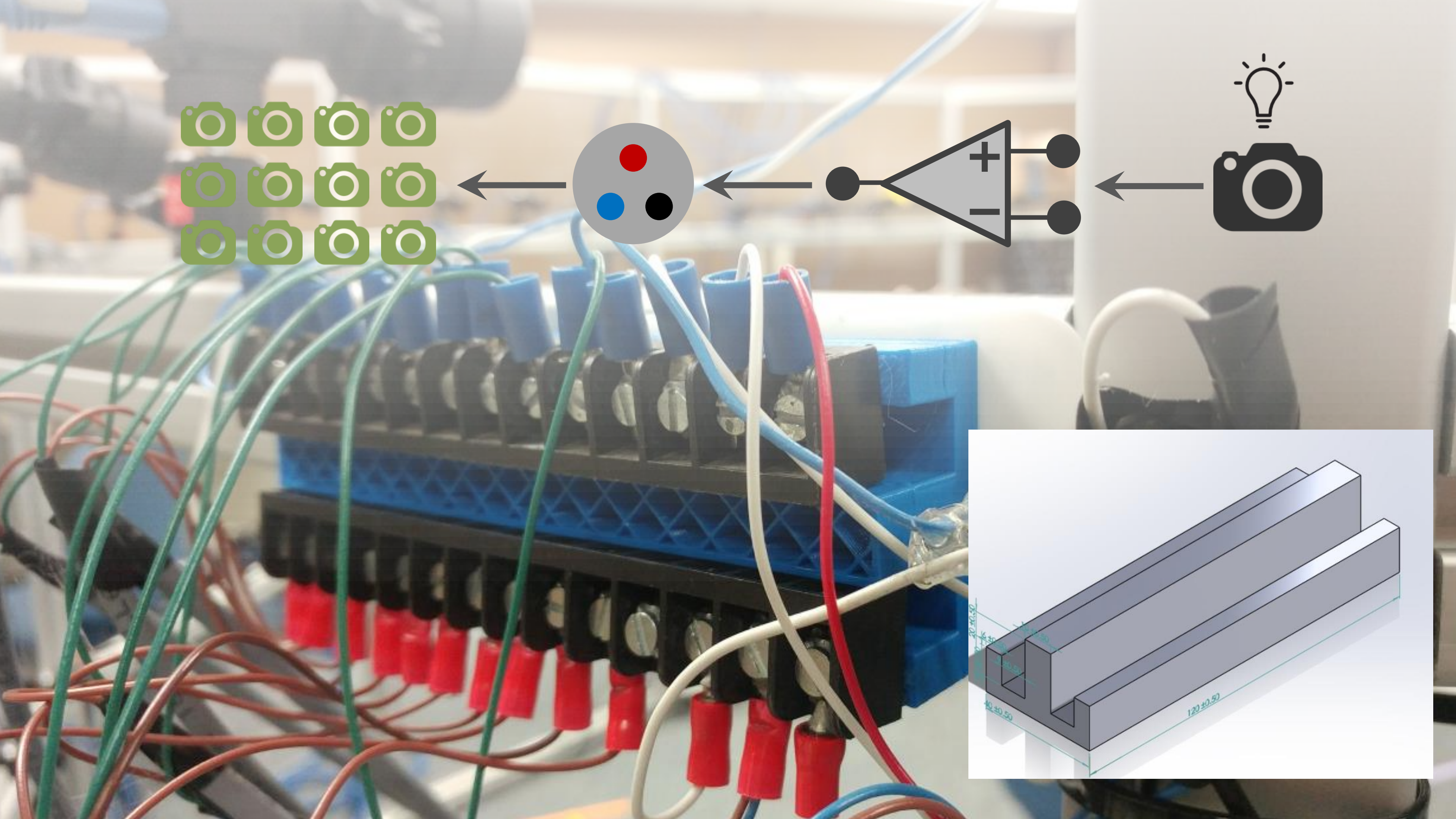


GPIO
Scalability
$V = 3.3\,\mathrm{V}$
$V = 3.0\,\mathrm{V}$
$R = 100\,\mathrm{k}\Omega$
$R = 100\,\mathrm{k}\Omega$
$R = 100\,\mathrm{k}\Omega$

ECE 101

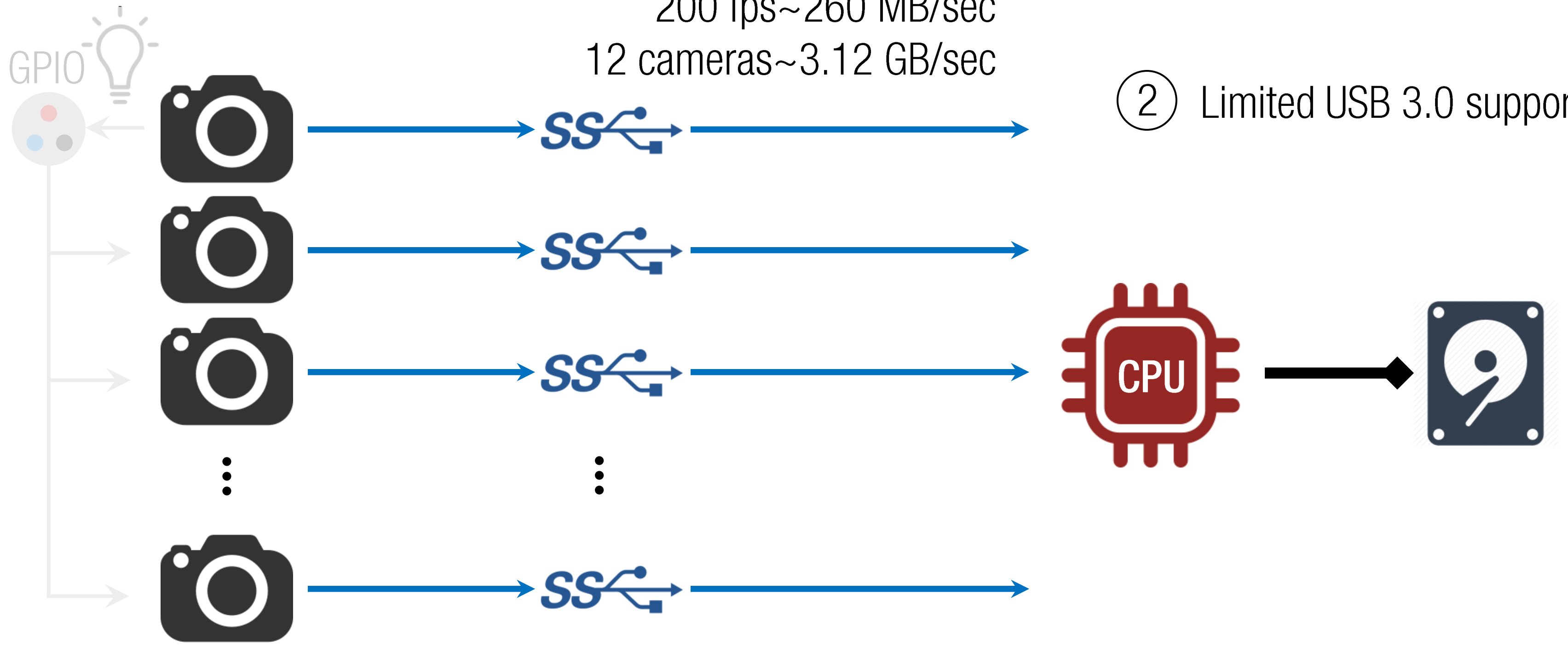


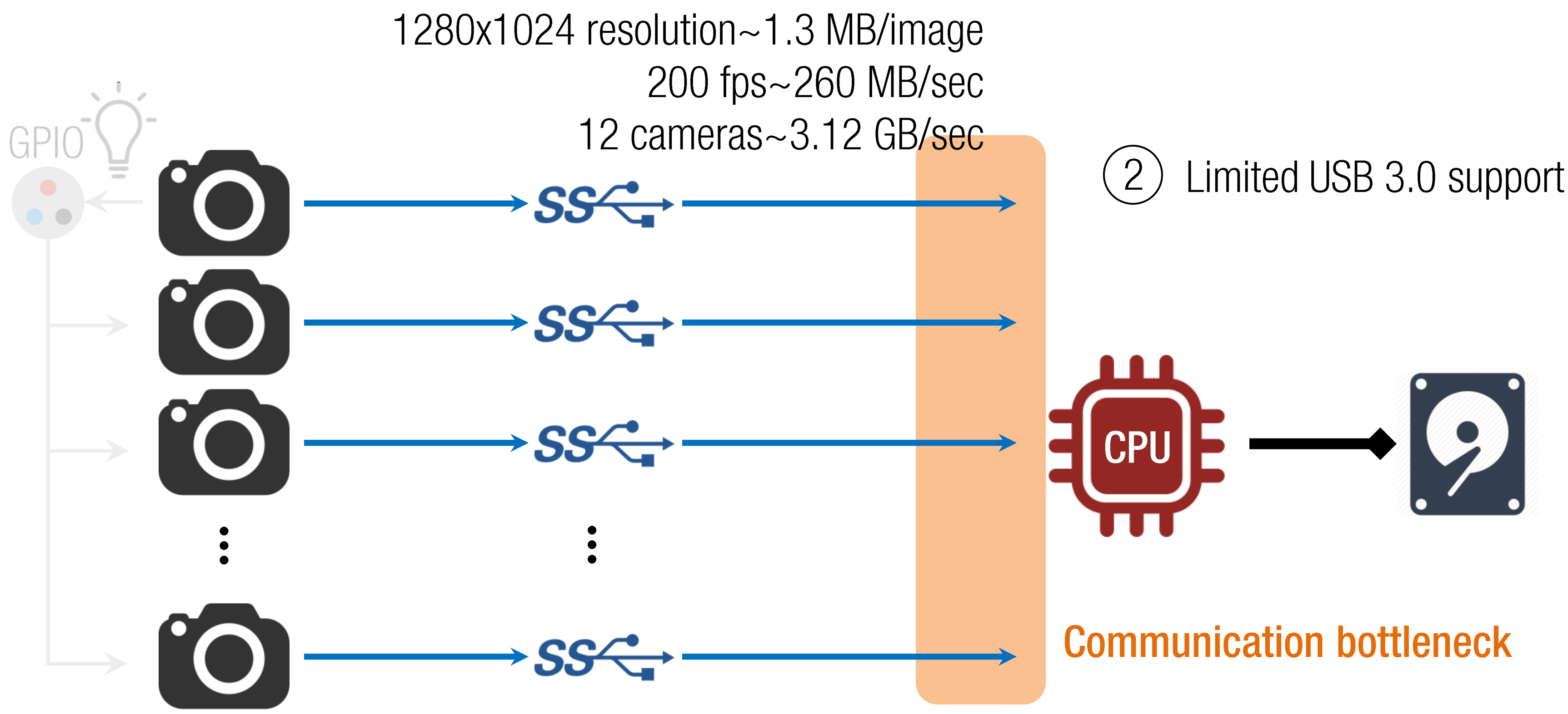



120±0.50
40±0.50

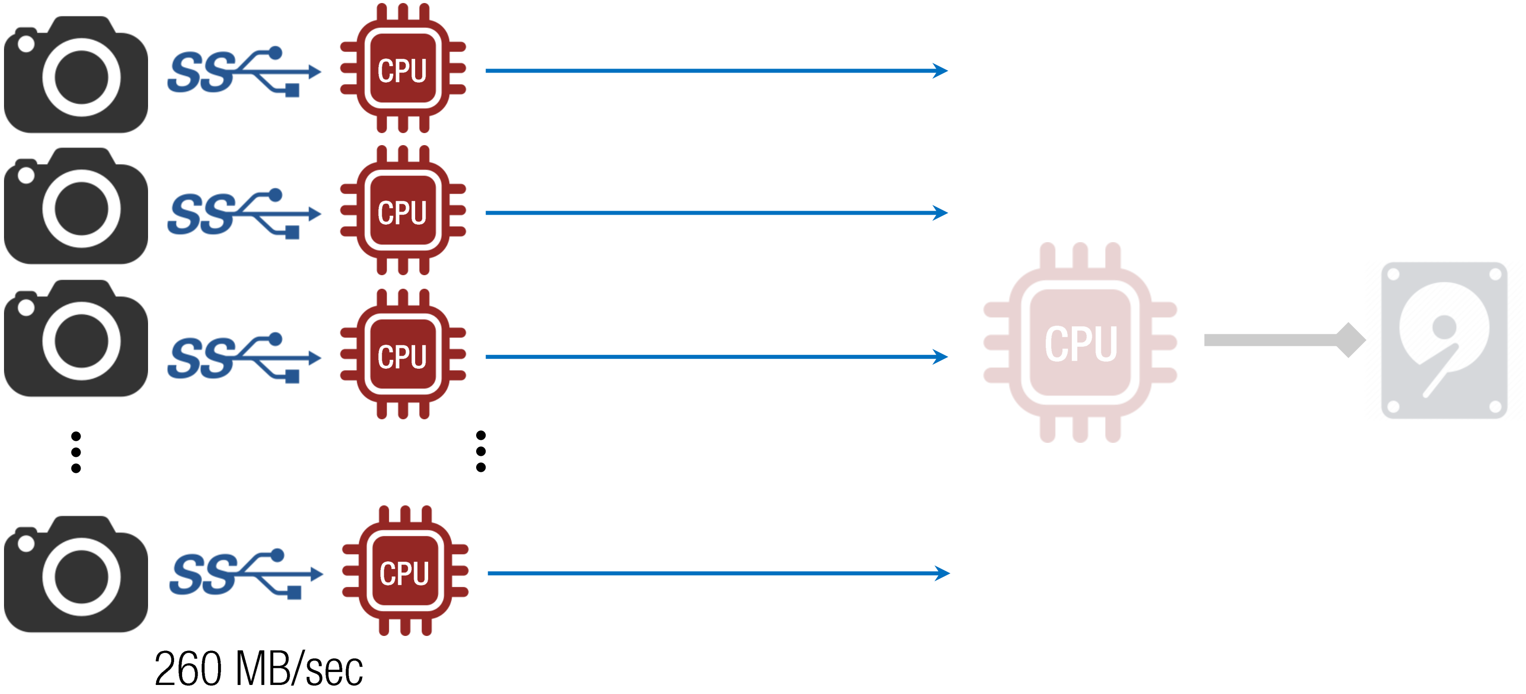
Sync result.

1280x1024 resolution~1.3 MB/image
200 fps~260 MB/sec
12 cameras~3.12 GB/sec

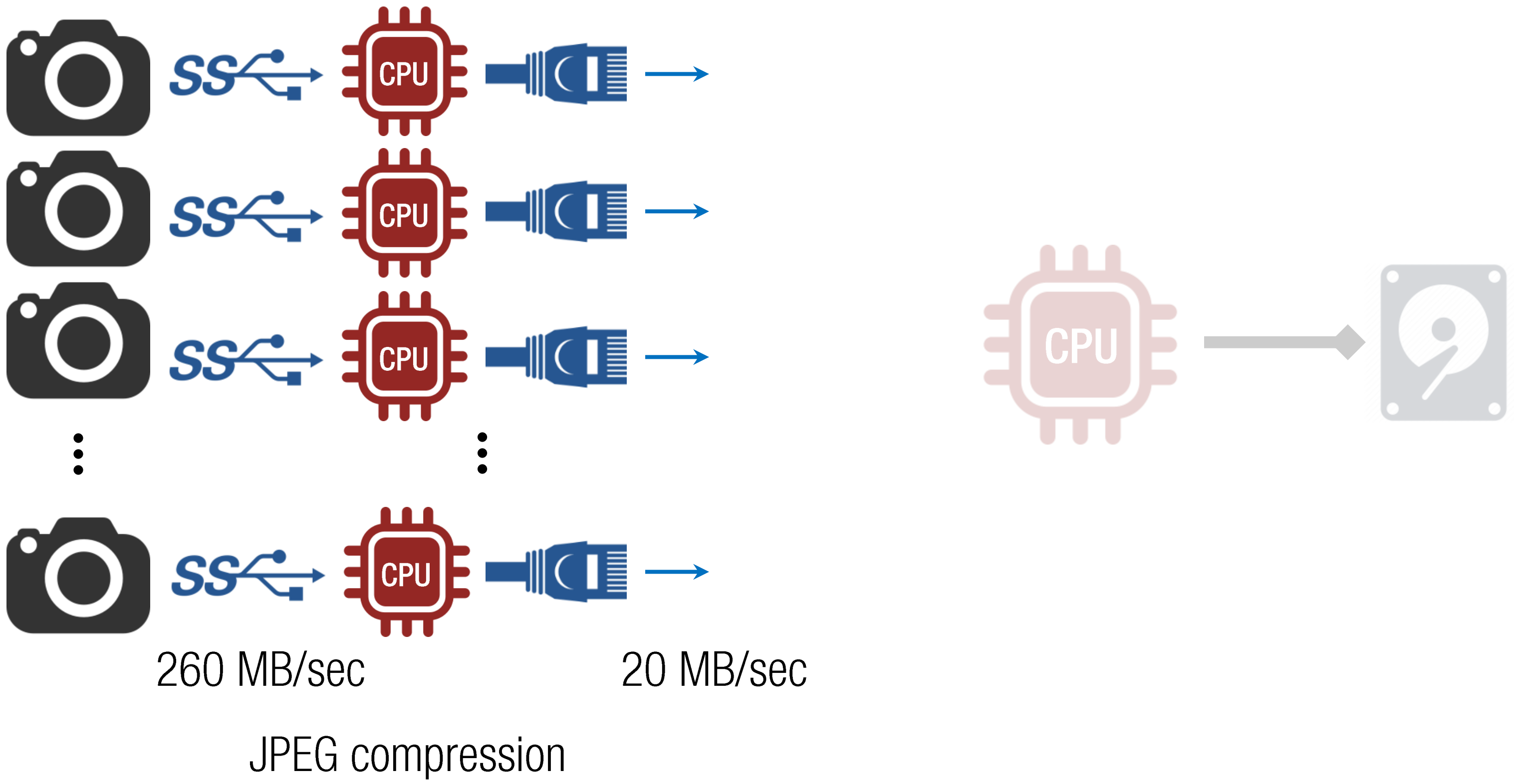



1280x1024 resolution~1.3 MB/image
200 fps~260 MB/sec
12 cameras~3.12 GB/sec
GPIO
2 Limited USB 3.0 support
CPU
Communication bottleneck

DIY: Distributed Computing



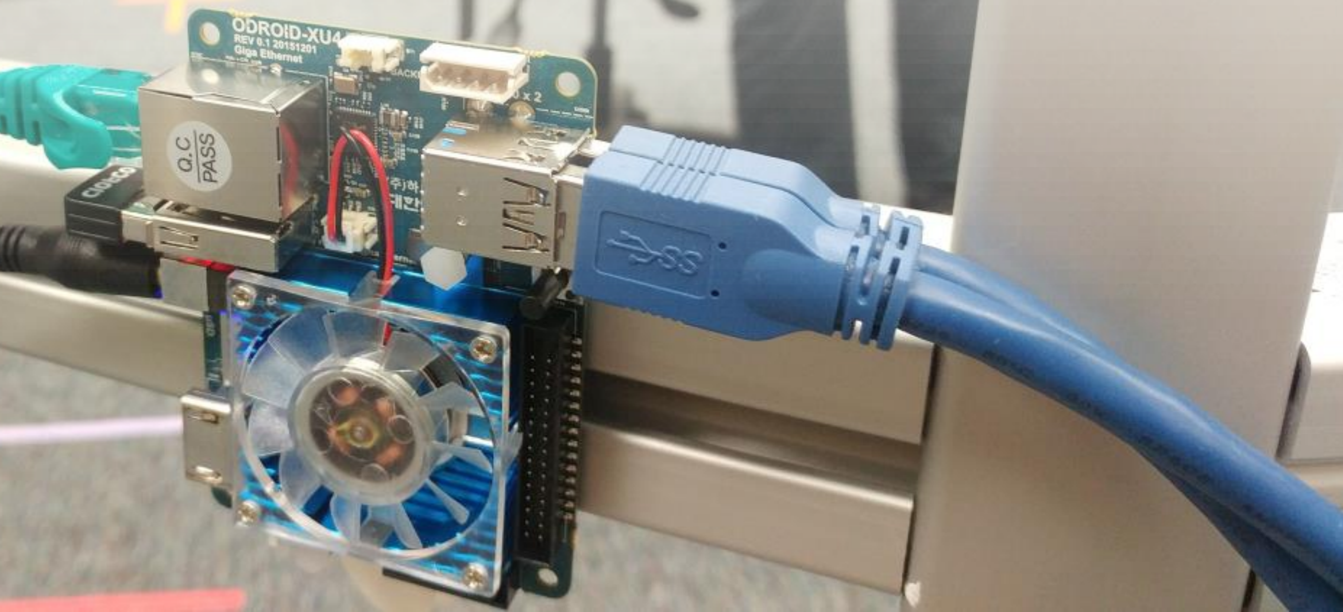
DIY: Distributed Computing



Single Board Computer (SBC)

ODROID XU4

+ ARM based 8 core CPUs
+ 2GB DDR memory
+ 2x USB 3.0 ports
+ Gigabit Ethernet port
+ WIFI module
+ ~$90



Precision

Precision

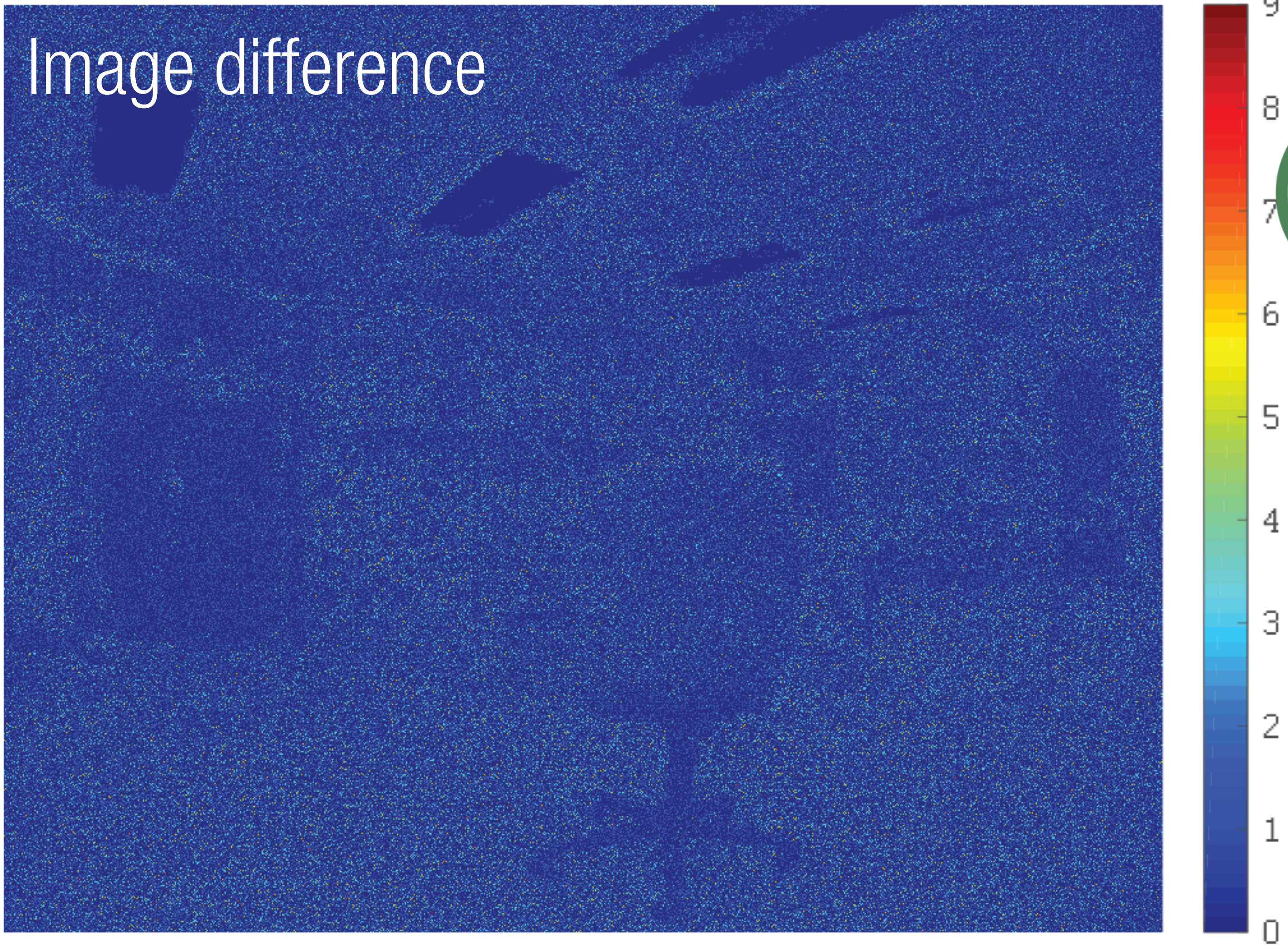
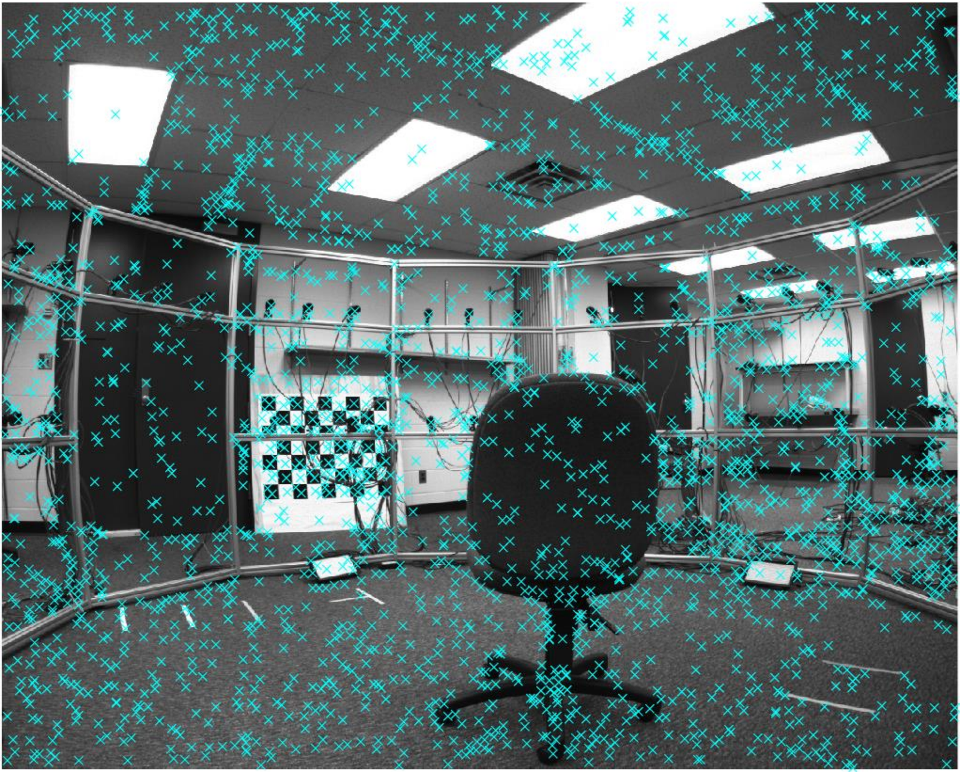
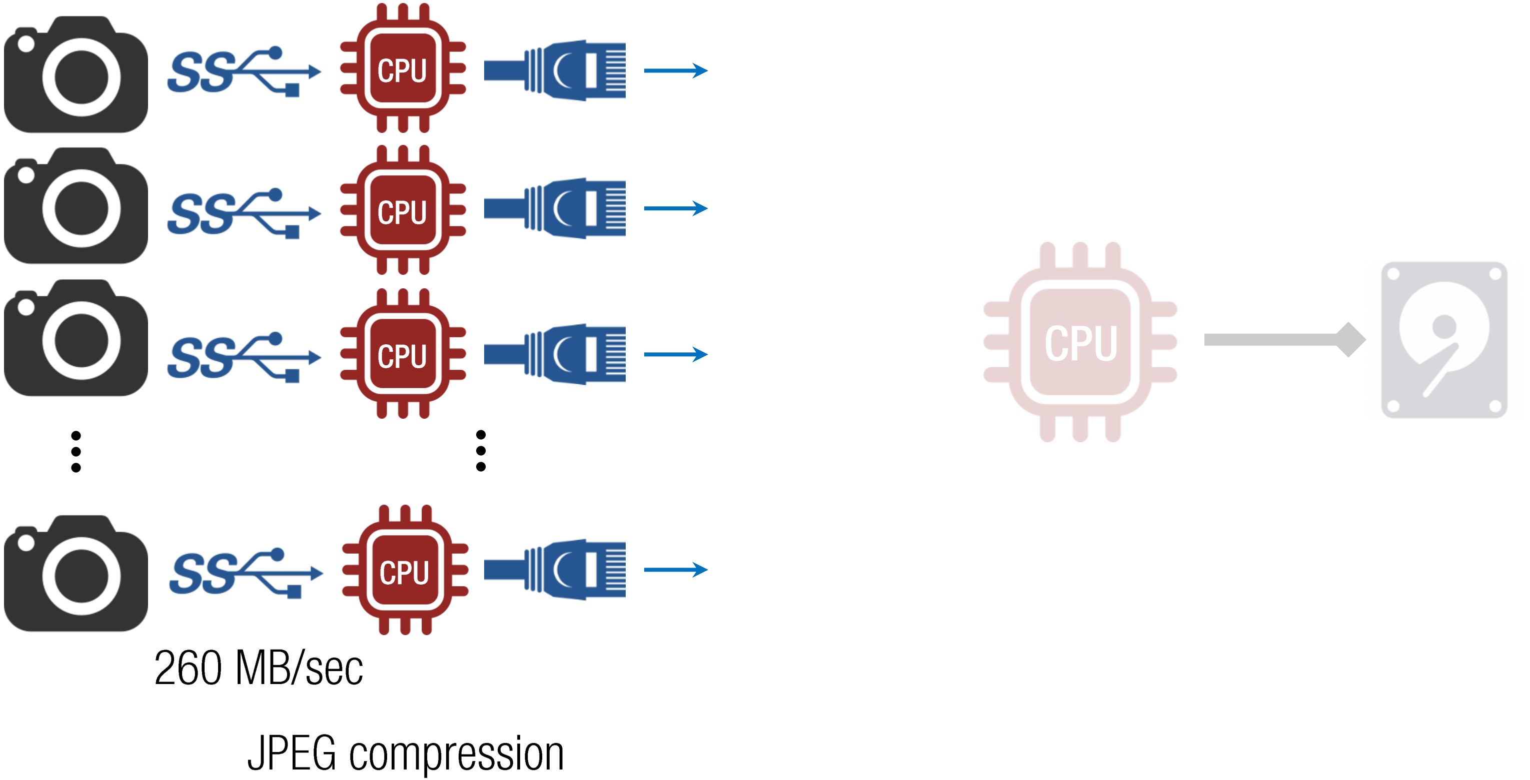


Image difference
9
8
7
6
5
4
3
2
1
0

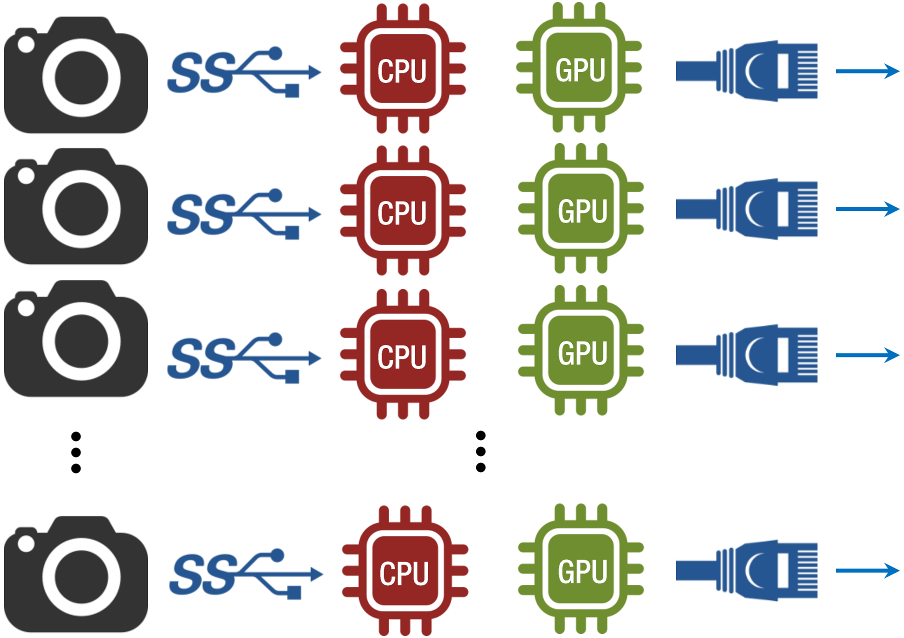


RAW image (3184 SIFT points)

JPEG image (3134 SIFT points)

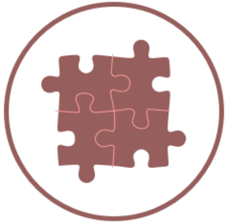

CPU
260 MB/sec
JPEG compression

Modularity



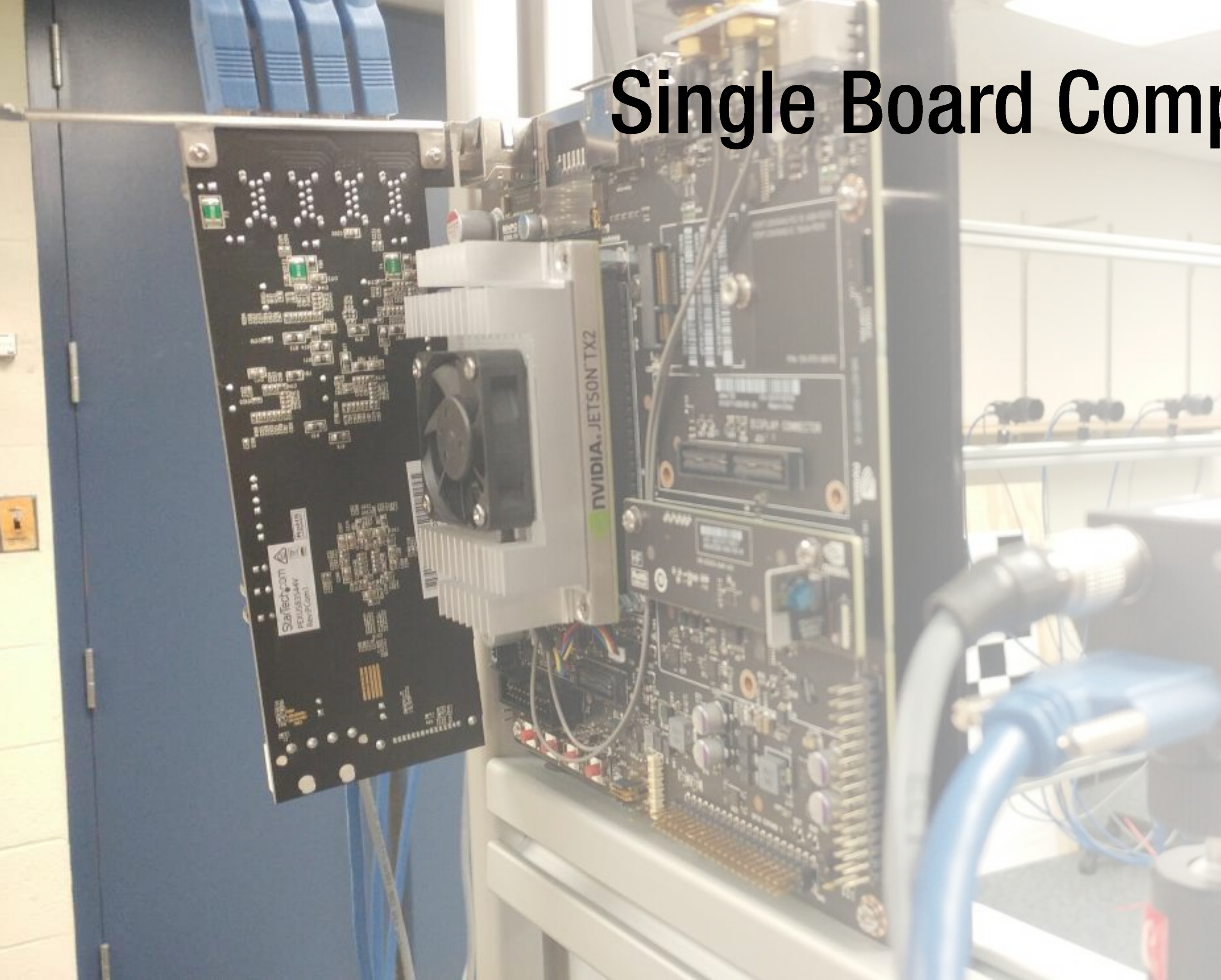
260 MB/sec

JPEG compression + CNN



Diversity

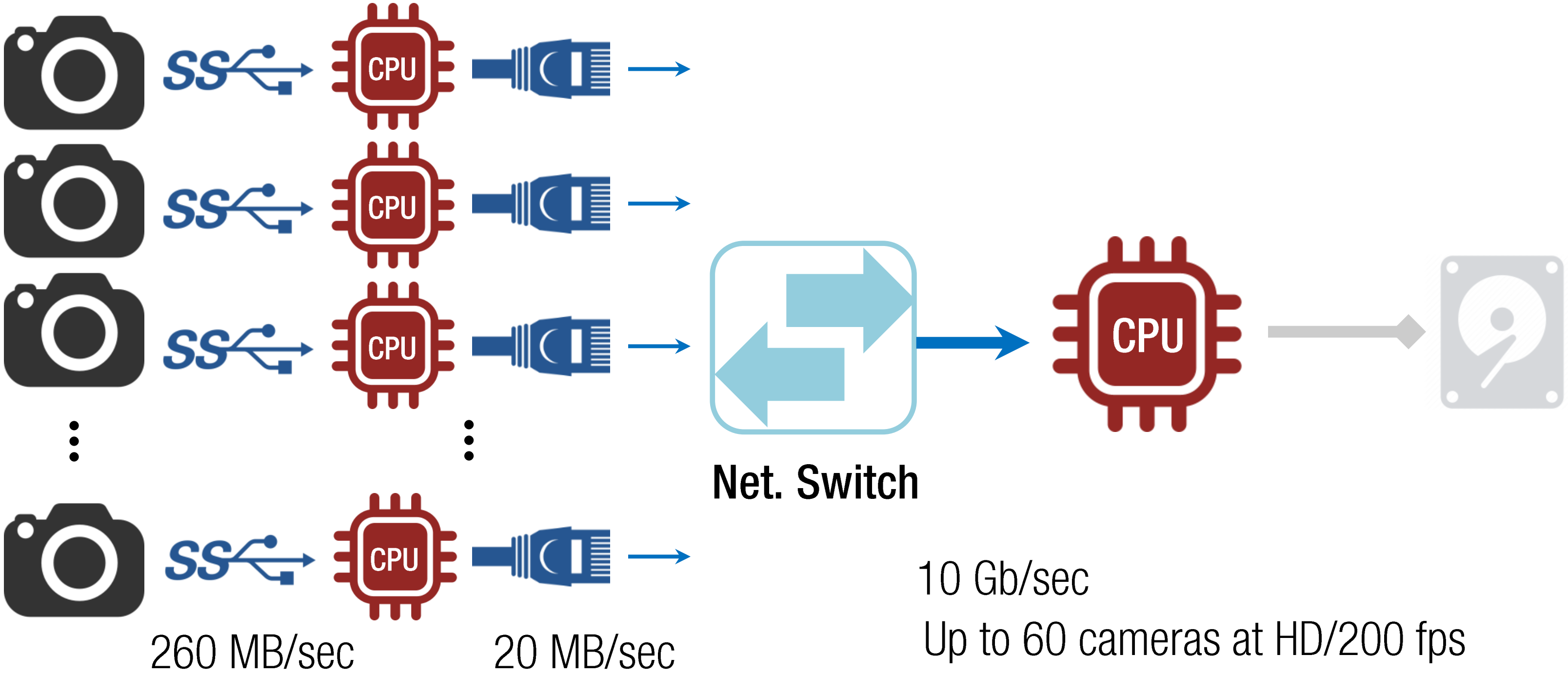
Single Board Computer (SBC)



nVidia TX2

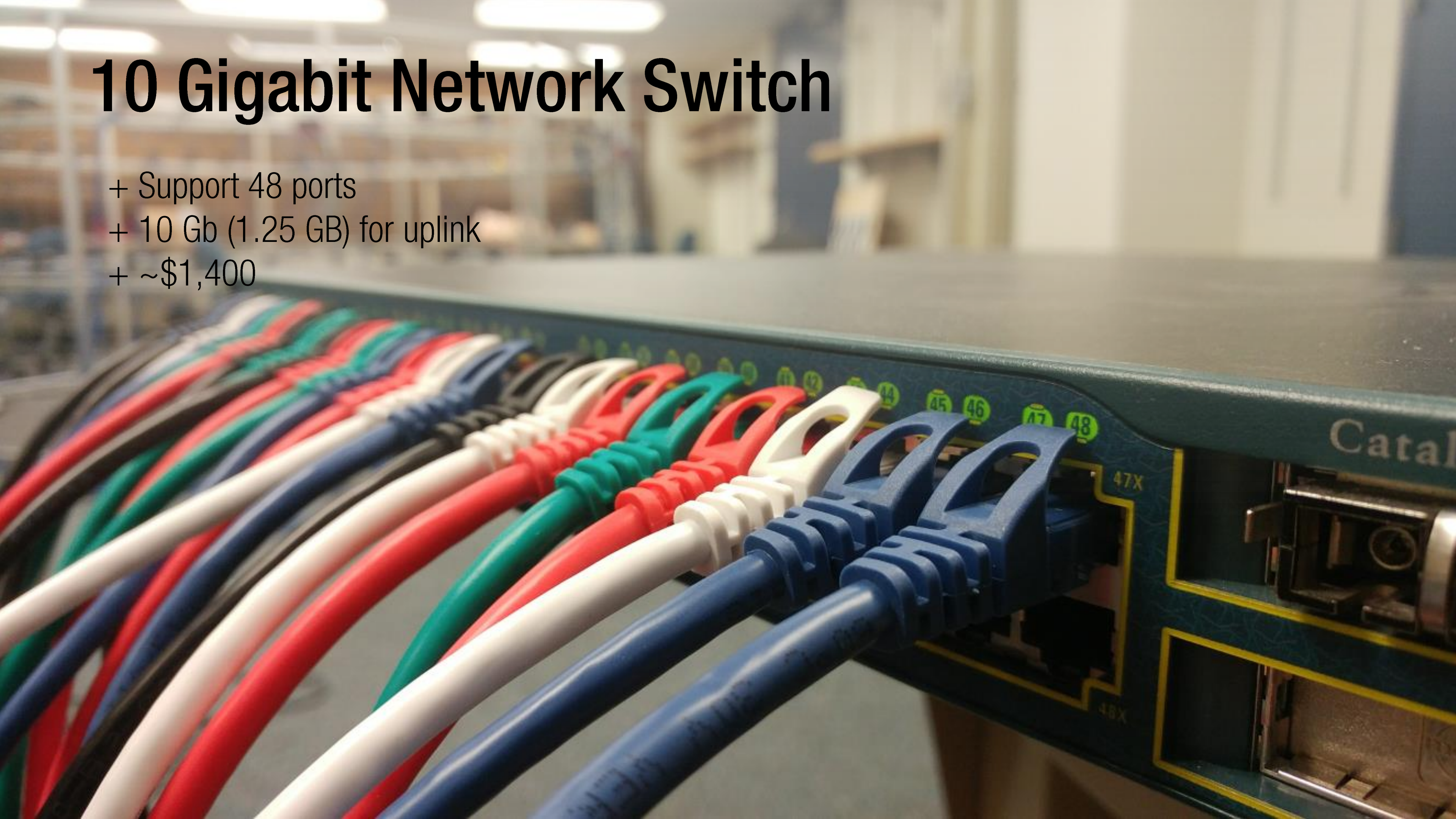
+ 256 CUDA cores
+ ARM based 4 cores
+ 8 GB memory
+ PCIe (4 USB 3.0)
+ Gigabit Ethernet port
+ WIFI module
+ ~$600

DIY: Distributed Computing

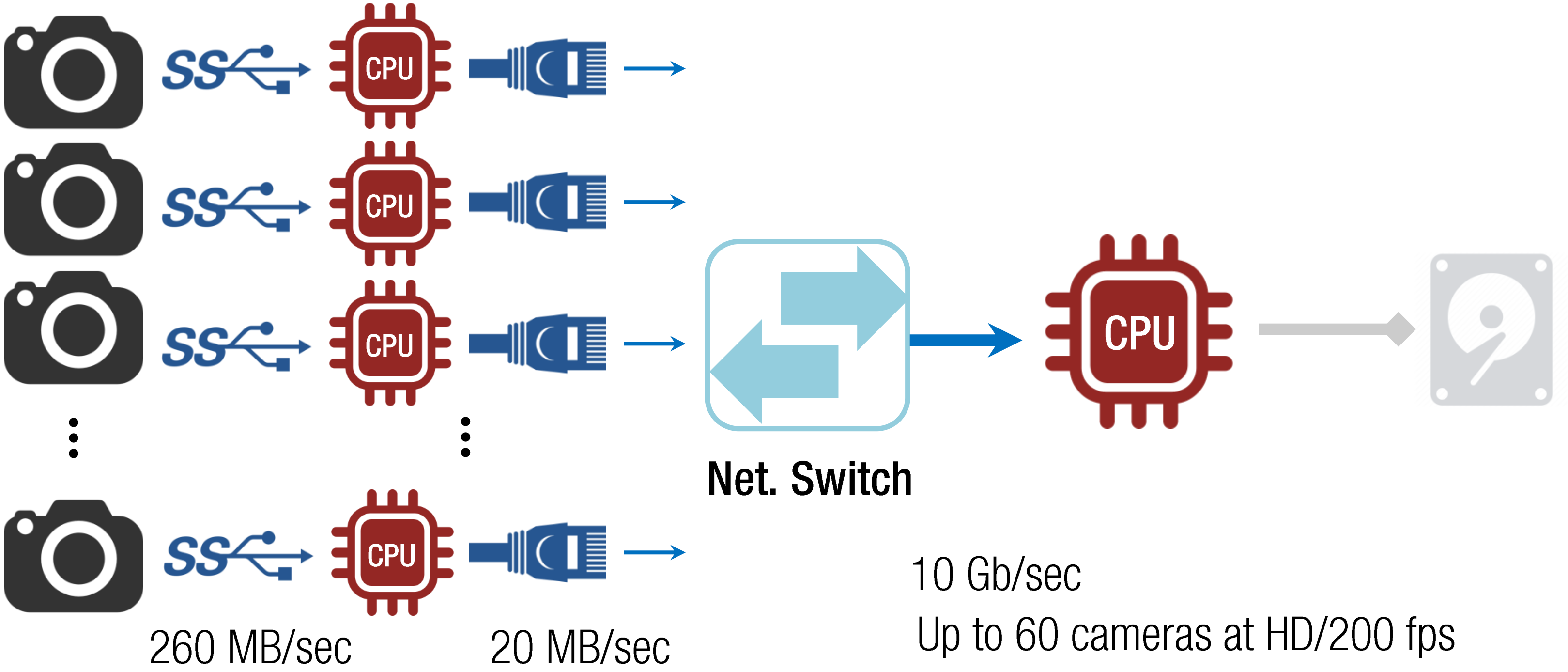


10 Gigabit Network Switch

+ Support 48 ports
+ 10 Gb (1.25 GB) for uplink
+ ~$1,400



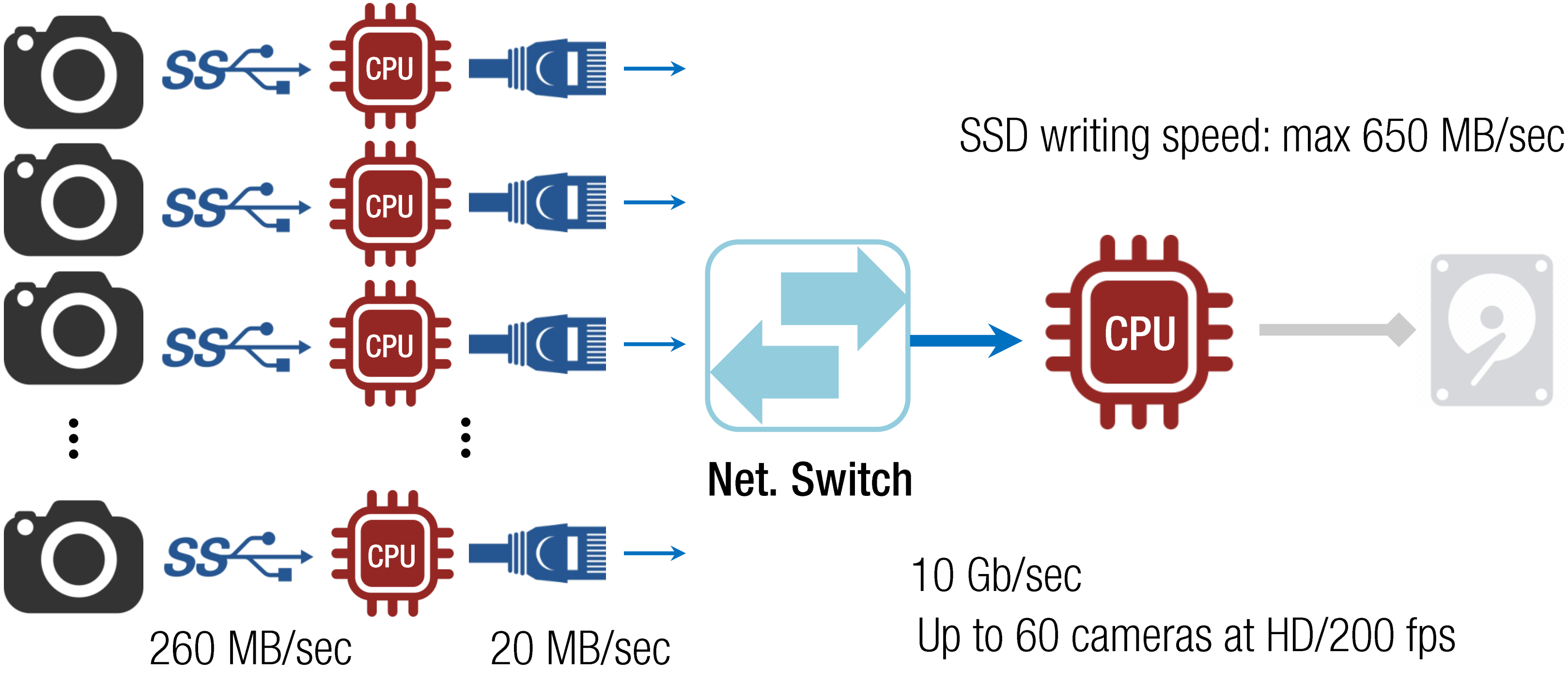
DIY: Distributed Computing



10 Gb/sec
Up to 60 cameras at HD/200 fps

Centralized: 15.6 GB/sec
Decentralized: 1.2 GB/sec

DIY: Distributed Computing



Up to 60 cameras at HD/200 fps

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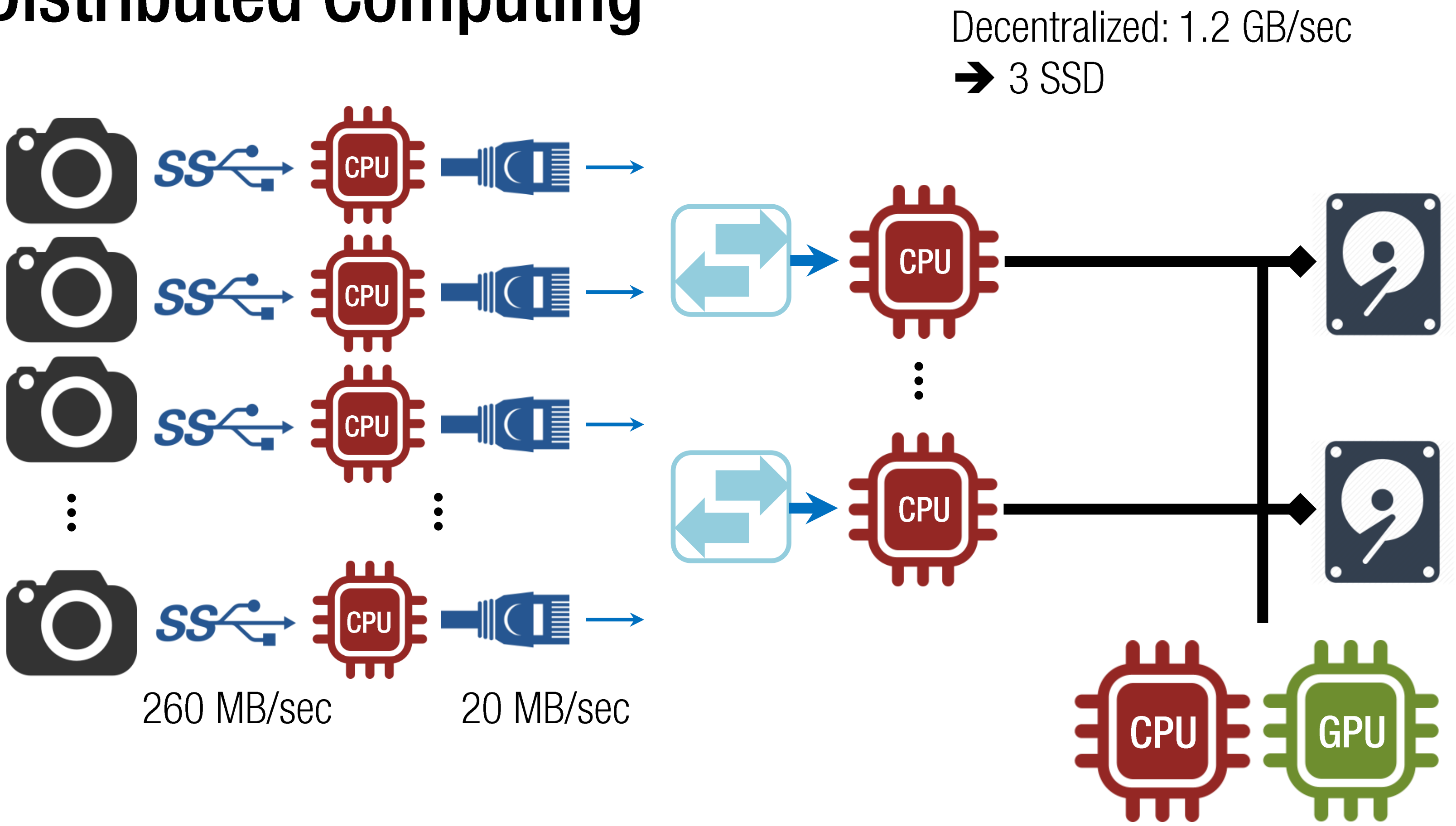
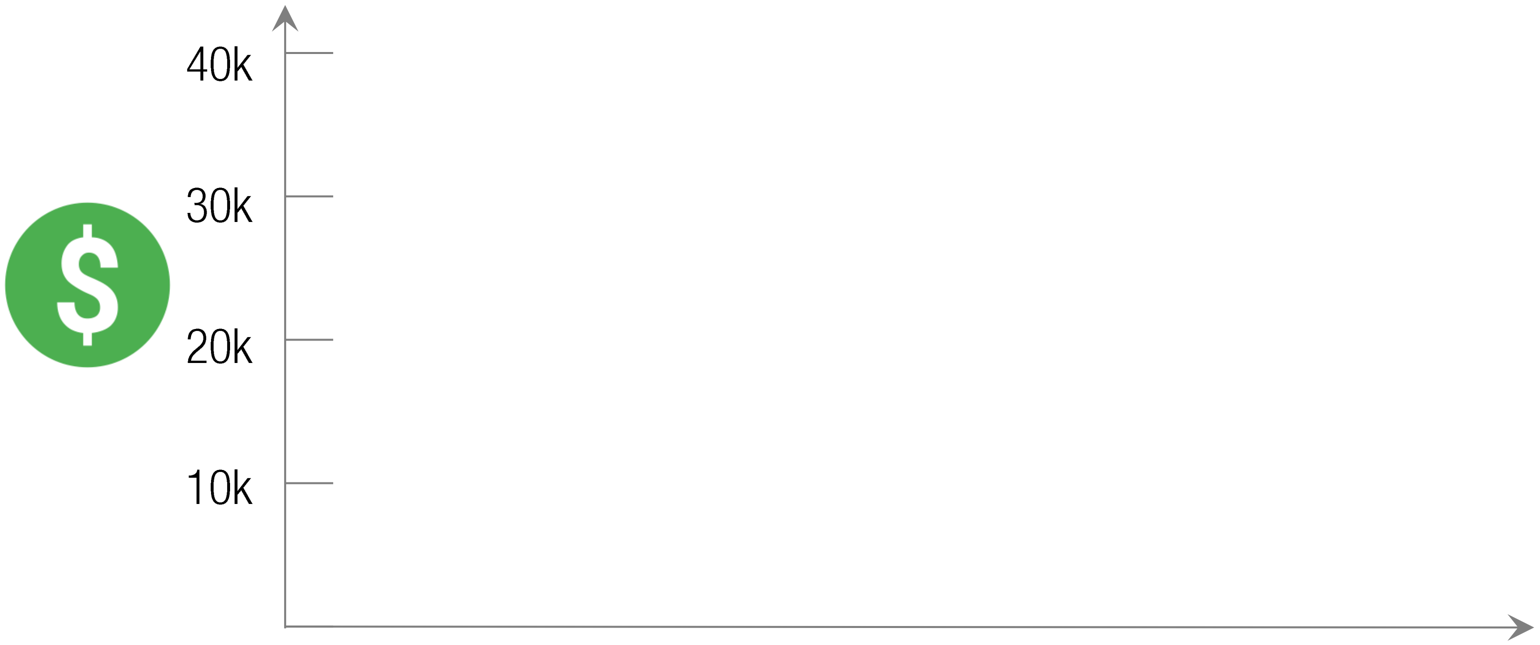
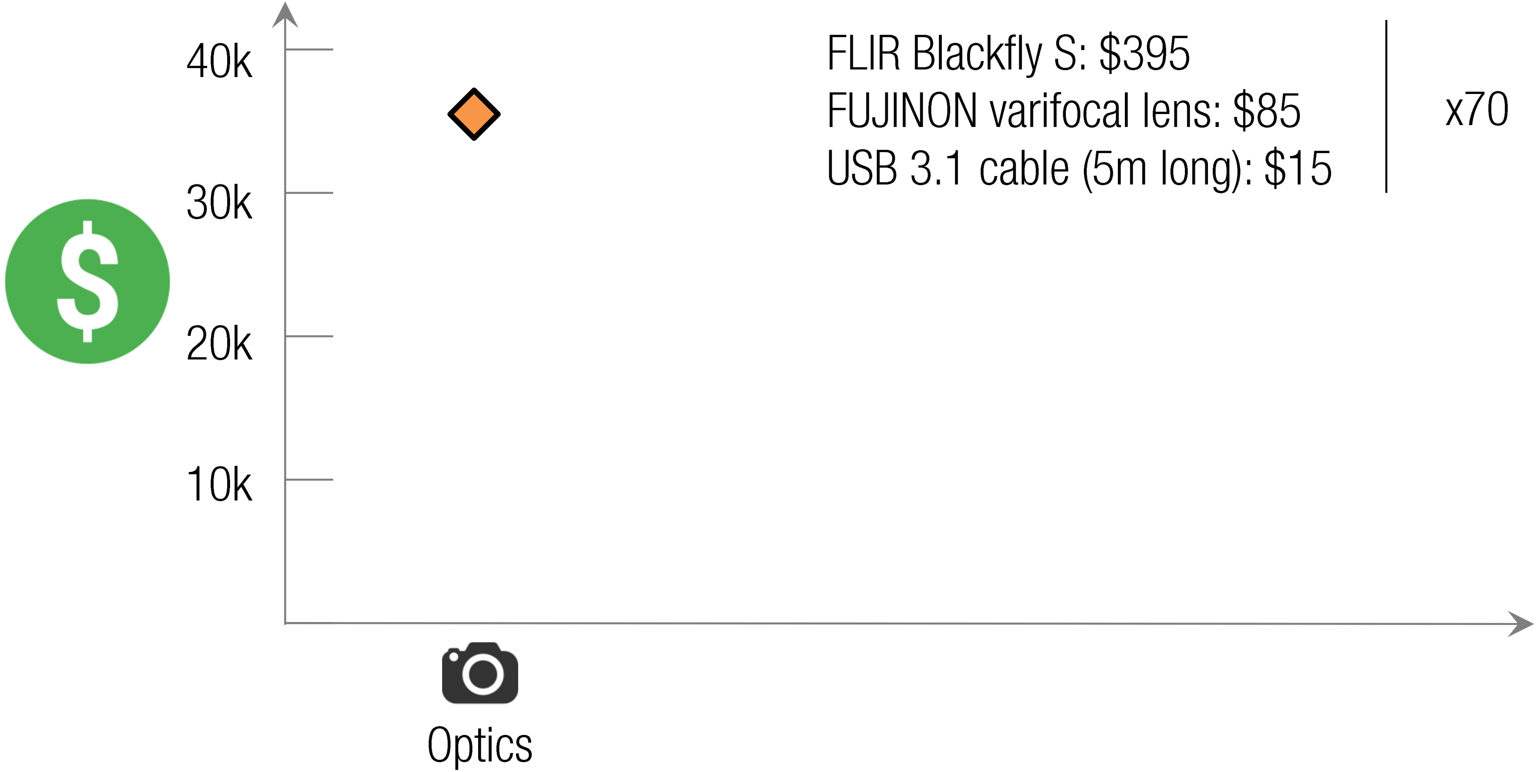
DIY: Distributed Computing



70 Camera System Cost



70 Camera System Cost

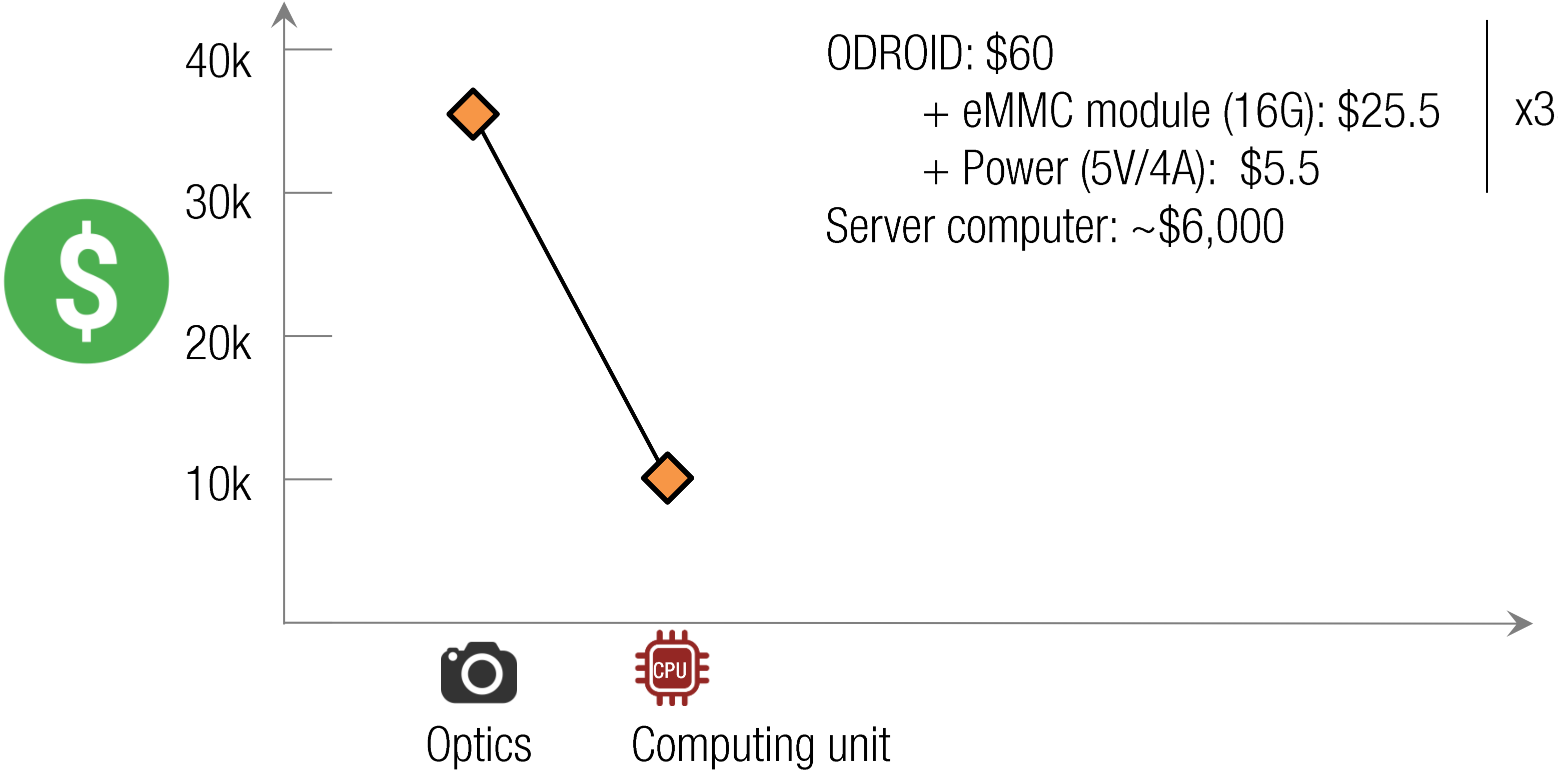


70 Camera System Cost

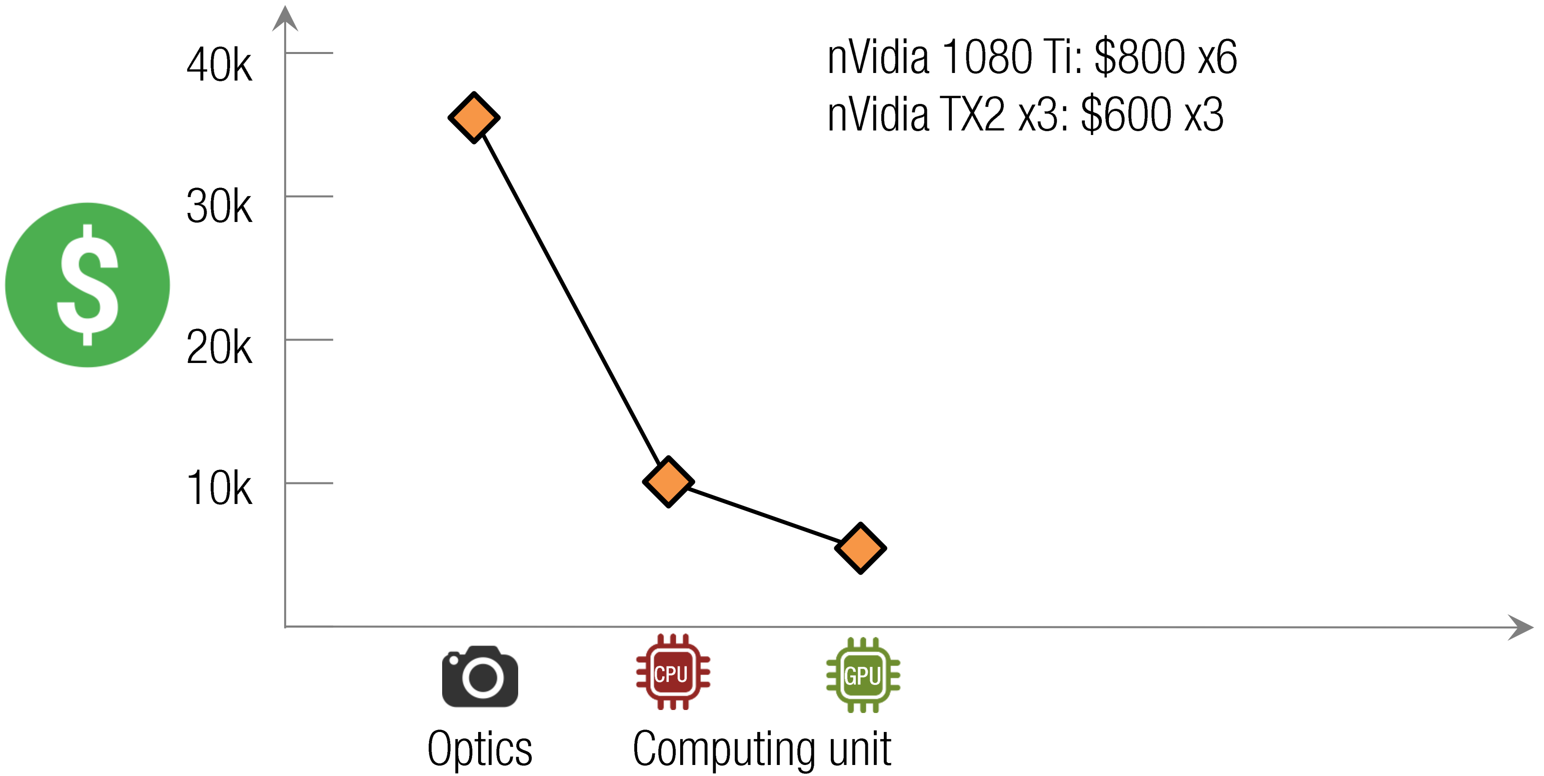
ODROID: $60
+ eMMC module (16G): $25.5
+ Power (5V/4A): $5.5

x35

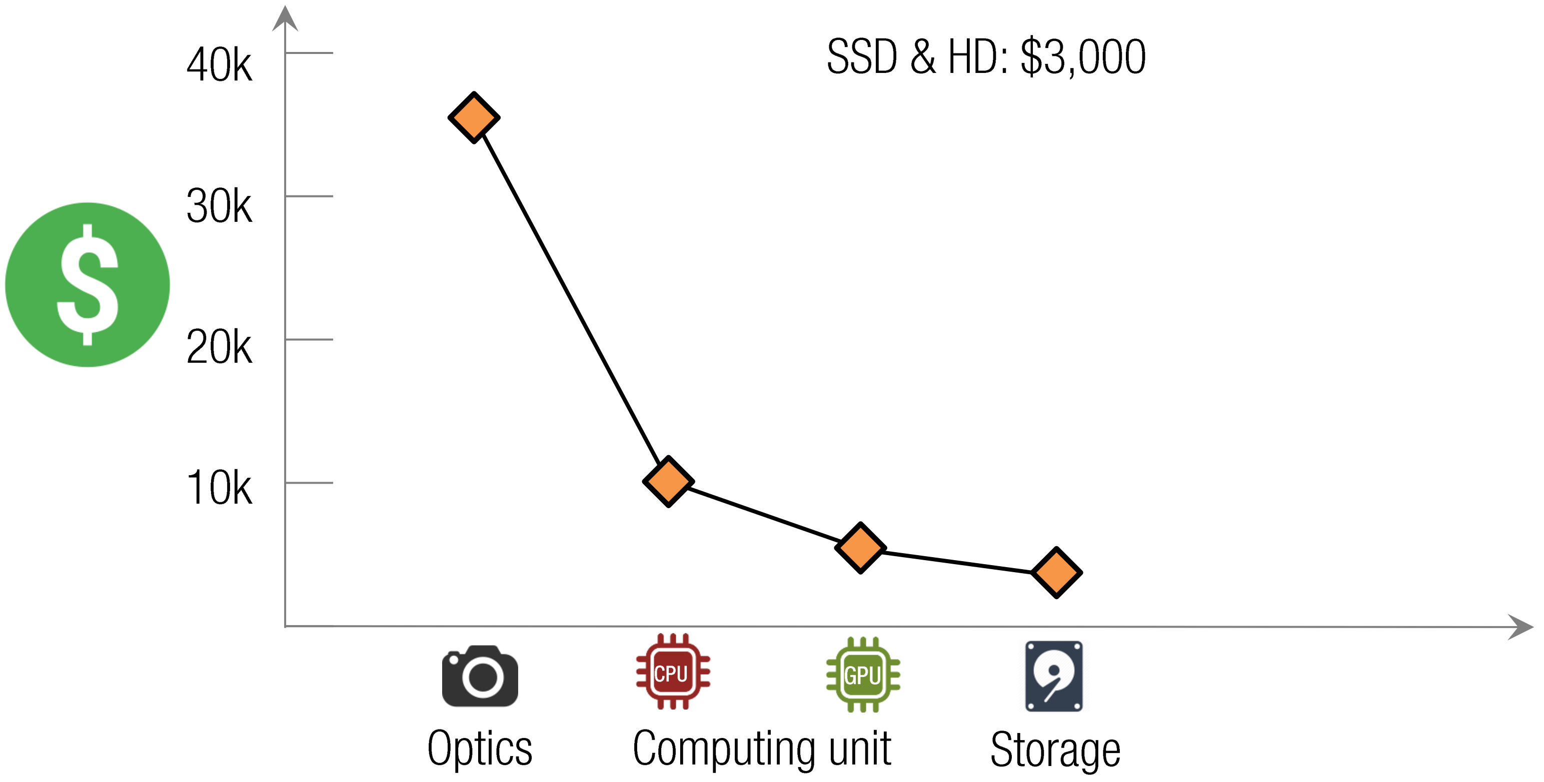
Server computer: ~$6,000



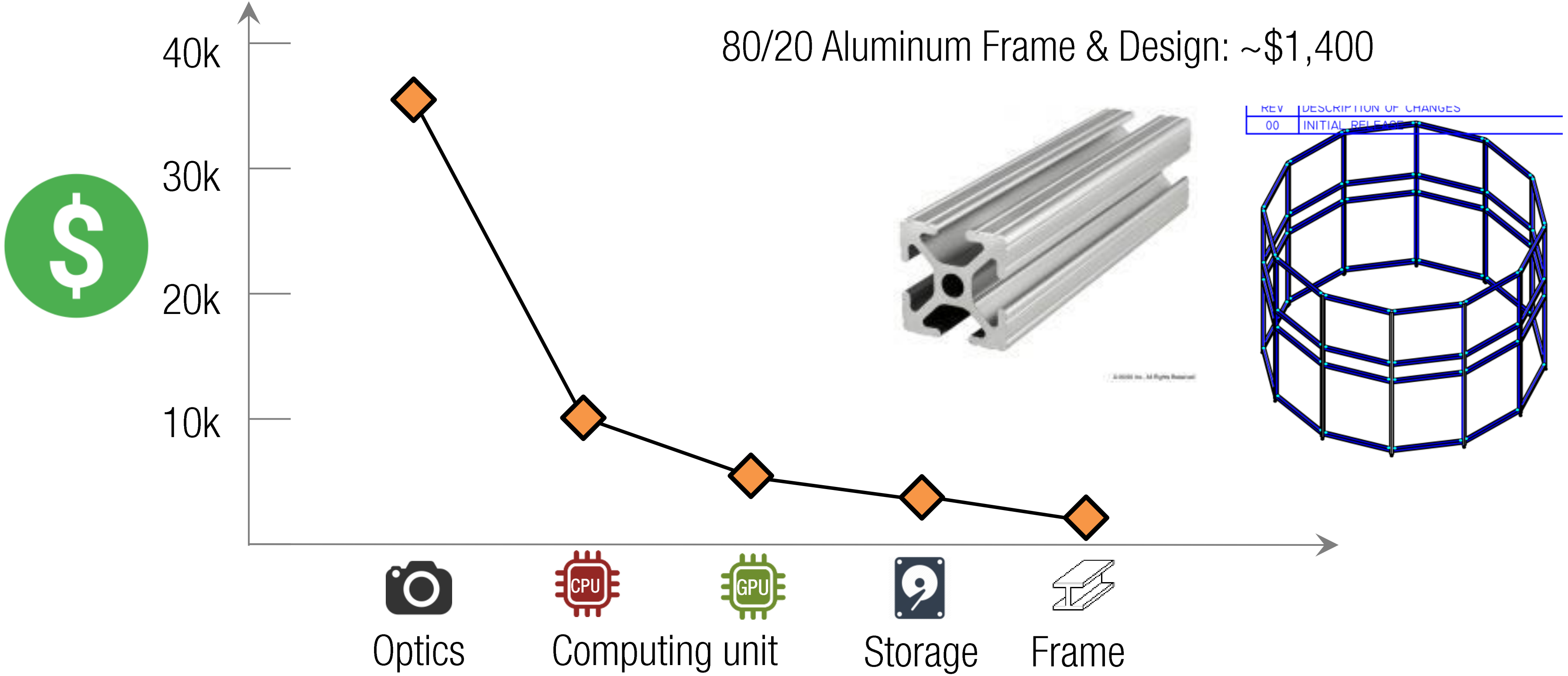
70 Camera System Cost



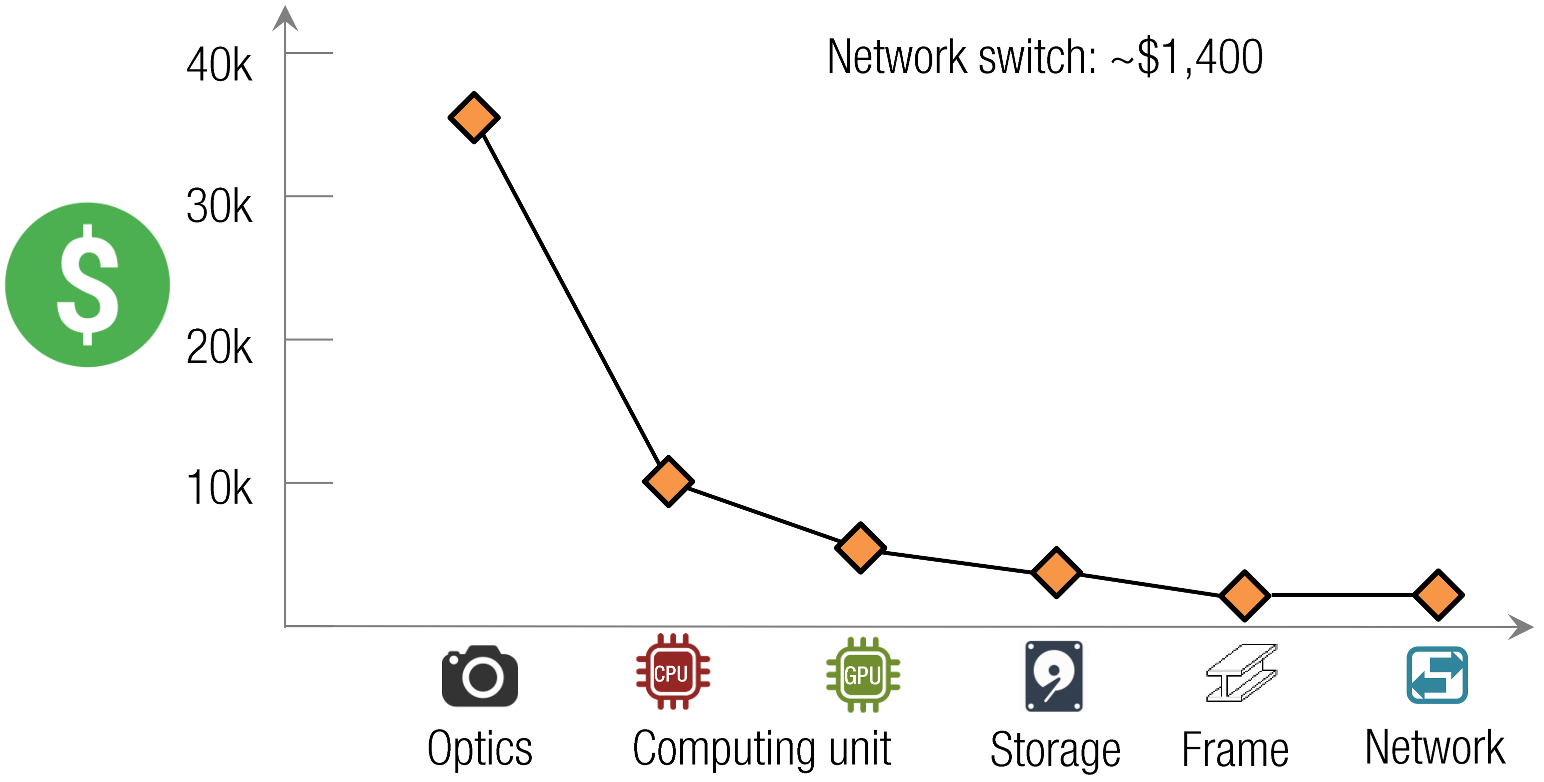
70 Camera System Cost



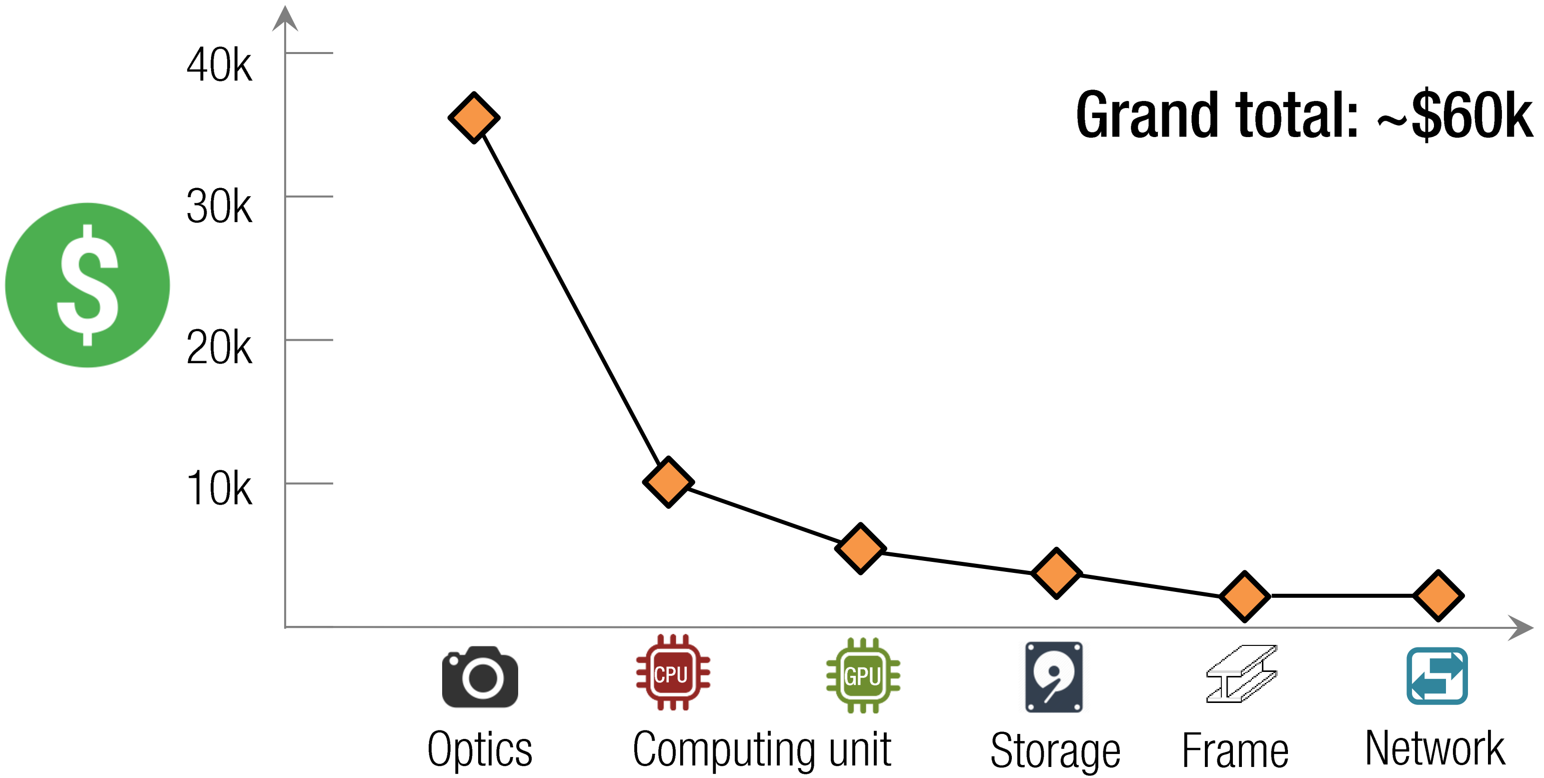
70 Camera System Cost



70 Camera System Cost

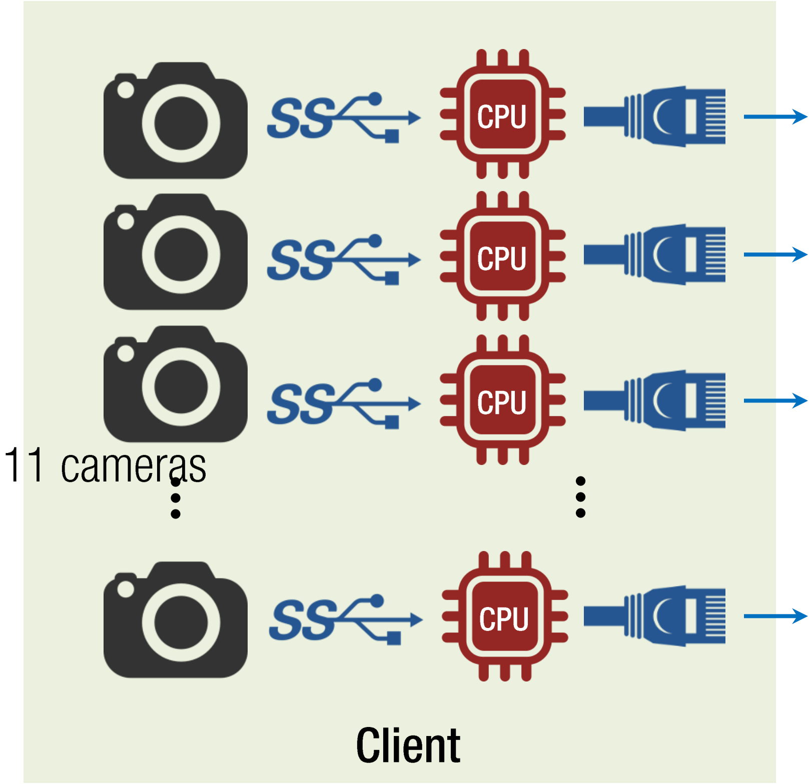


70 Camera System Cost

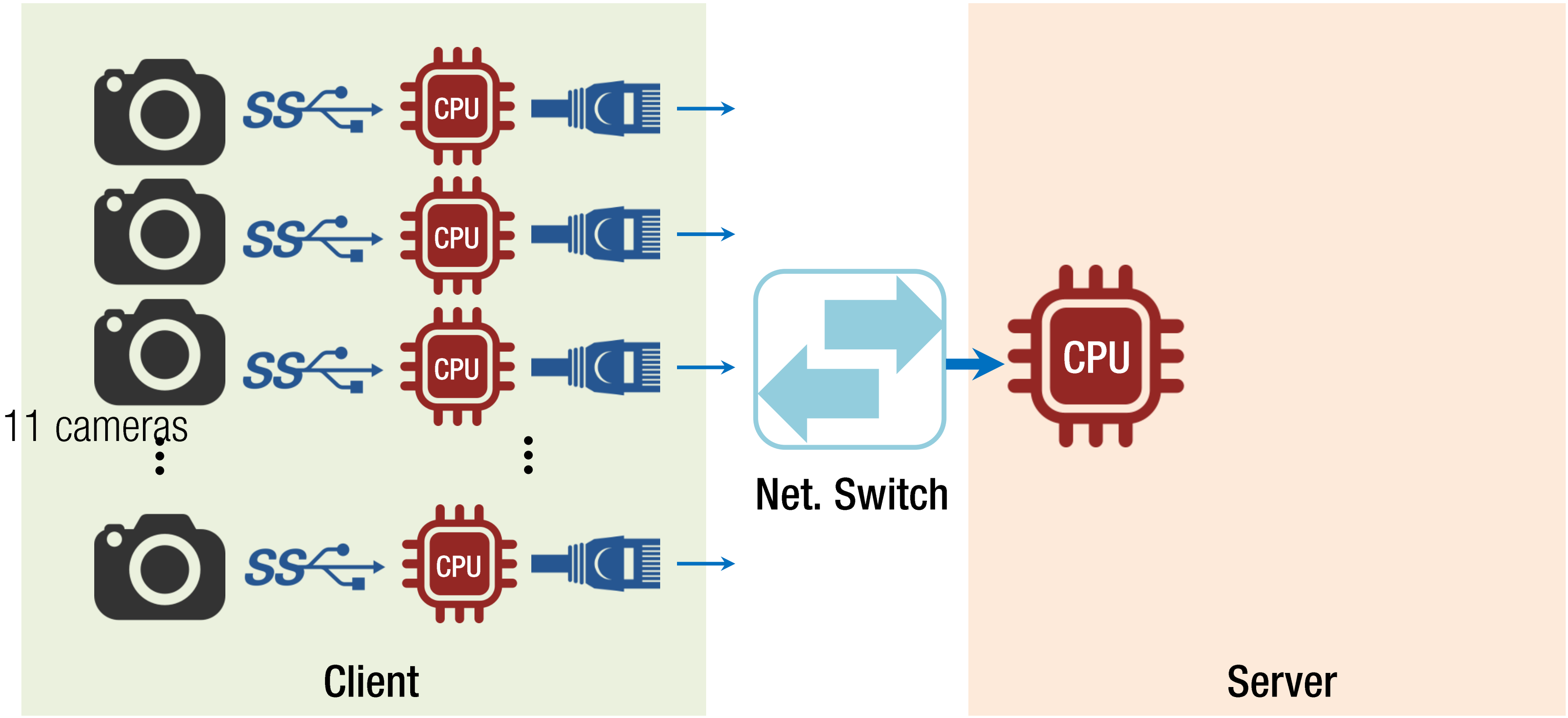


Demo:
Realtime Markerless Motion Capture

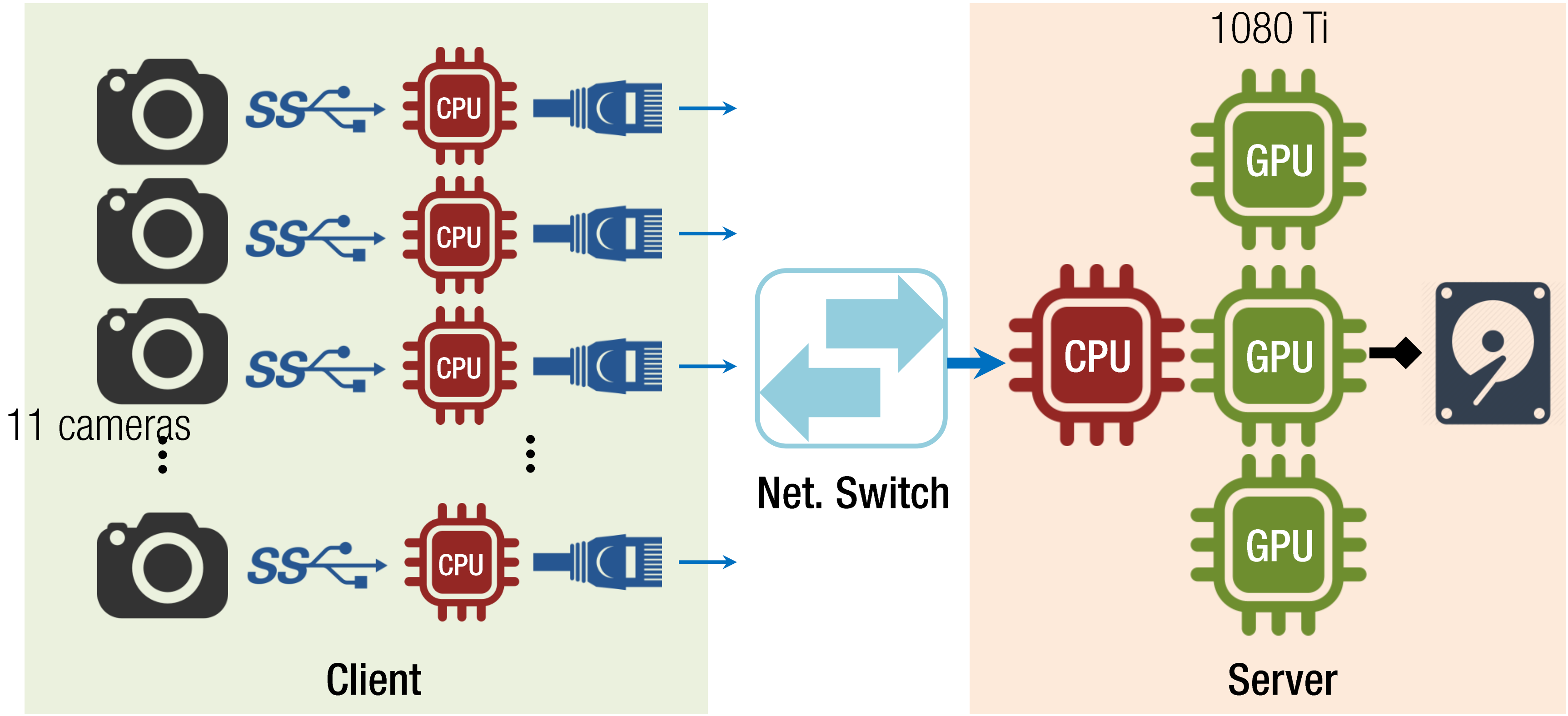
Demo system configuration



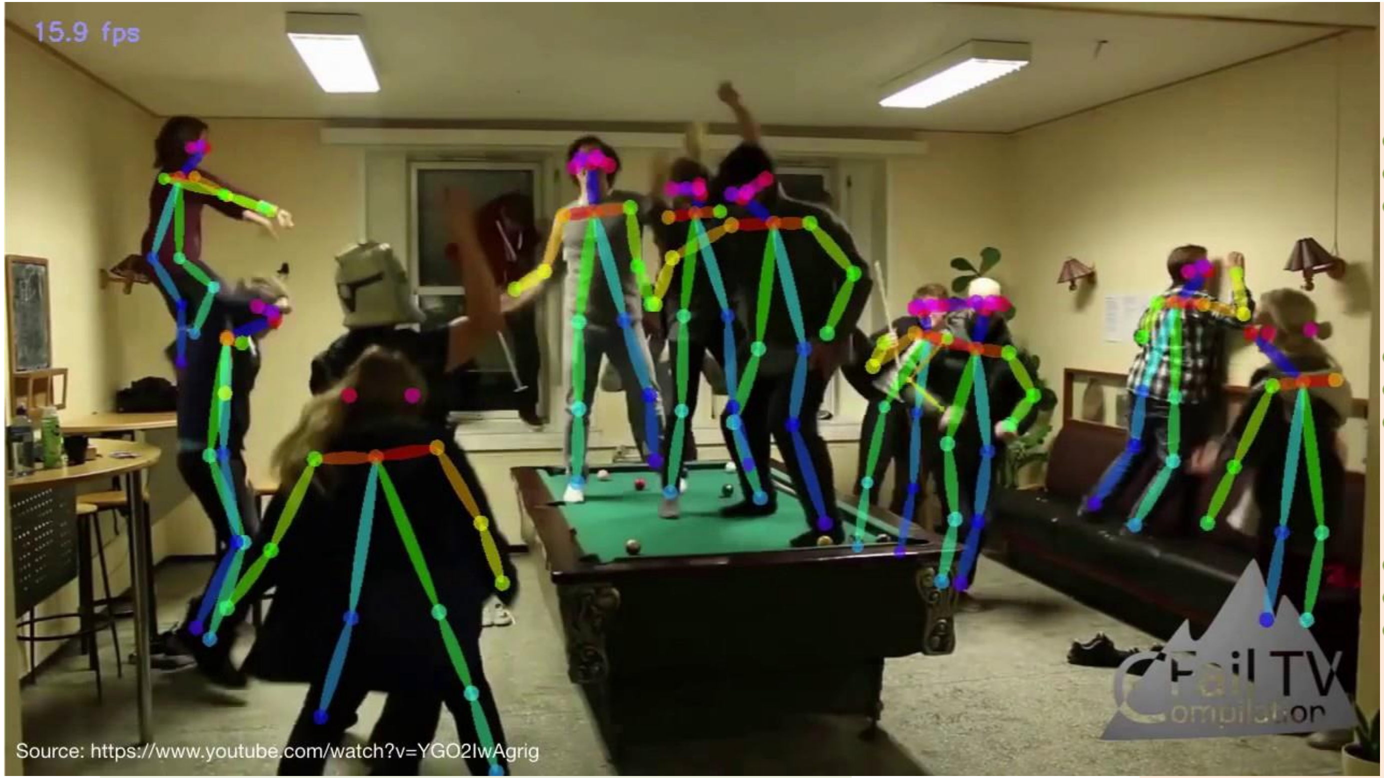
Demo system configuration

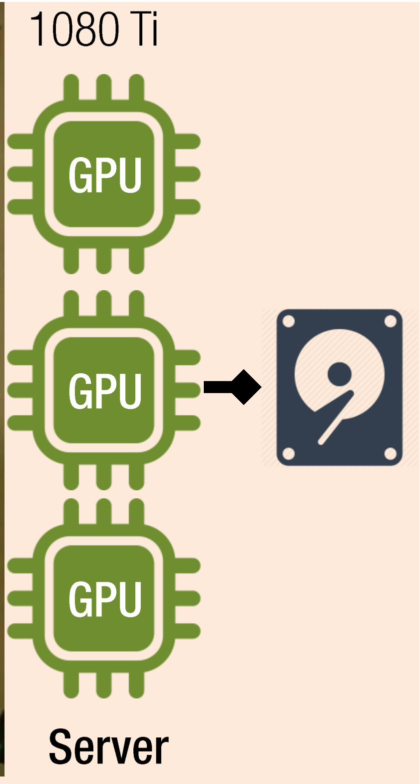


Demo system configuration



Demo system configuration





Demo: Calibration

- 3D extrinsic parameter calibration using SfM
  - Source code available at:
    - https://github.com/hspark-umn/MulticameraSoftware.git

  Image undistortion

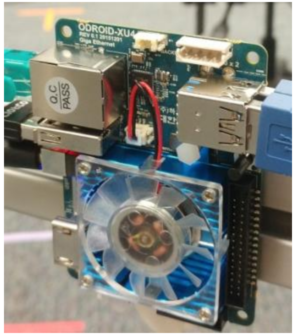
  SIFT detection

  Matching

  Bundle adjustment using Ceres solver

3D camera extrinsic calibration

Demo: Recording Software (Client)



- Opensource ARM based camera driver
- Two modes:
  - Secure FTP: transmitting and writing to server
  - TCP/IP: transmitting by feeding to server's software
- Source code is available at:
  - https://github.com/hspark-umn/MulticameraSoftware.git

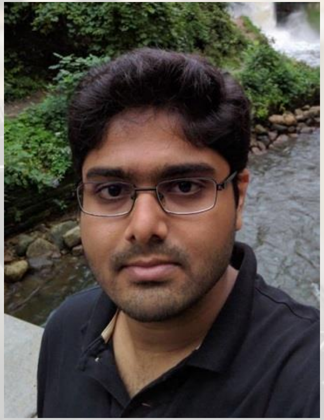
Demo: Recording Software (Server)

- Multithreading odroid access
- Realtime 3D body pose reconstruction
  - OpenPose for each image
  - Triangulation given camera matrices

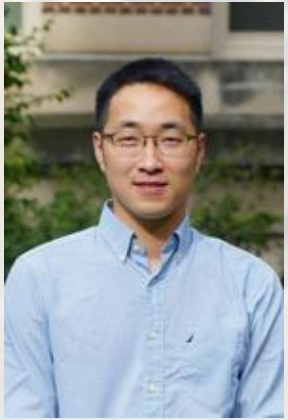
Do It Yourself: Multicamera Engineering

Youbing Wang

Ziwei Li



Shishir Pagad



Hyun Soo Park

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