ENERGY-PROPORTIONAL IMAGE SENSING

FOR

CONTINUOUS MOBILE VISION

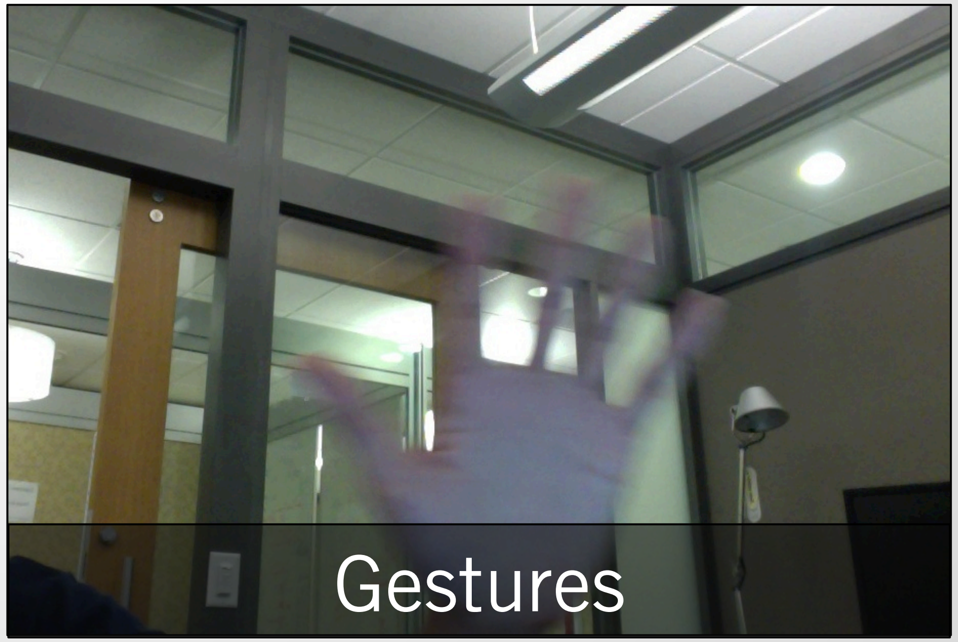
Robert LiKamWa
Bodhi Priyantha
Matthai Philipose
Victor Bahl
Lin Zhong

http://roblkw.com
http://research.microsoft.com

CONTINUOUS MOBILE VISION

The Devil Wears Prada

CONTINUOUS MOBILE VISION



BATTERY DEATH

GoPro Hero

2-3 hours

LooxCie

2-3 hours

Google Glass

2-3 hours

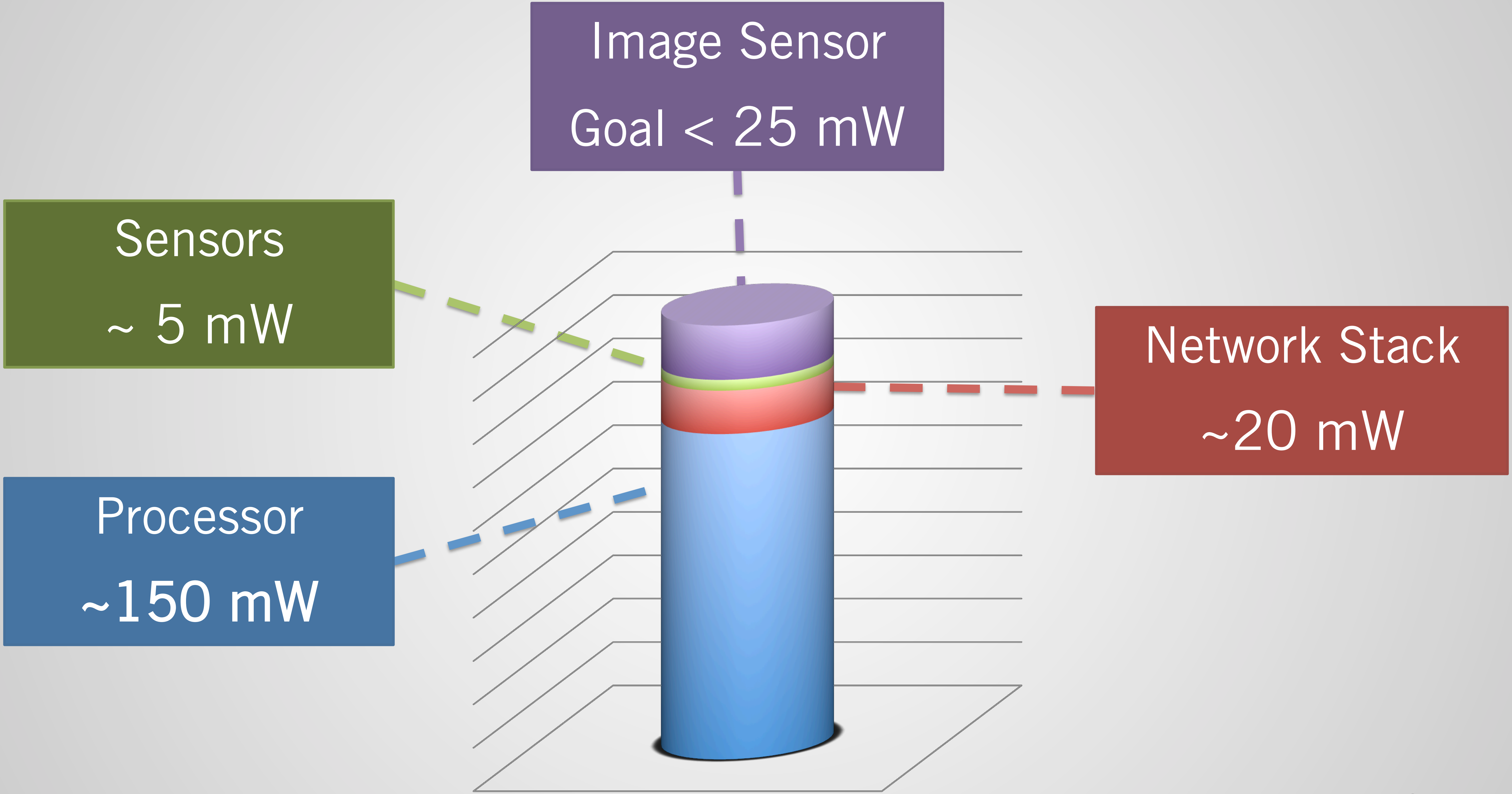


Image Sensor
Goal < 25 mW
Sensors
~ 5 mW
Network Stack
~20 mW
Processor
~150 mW

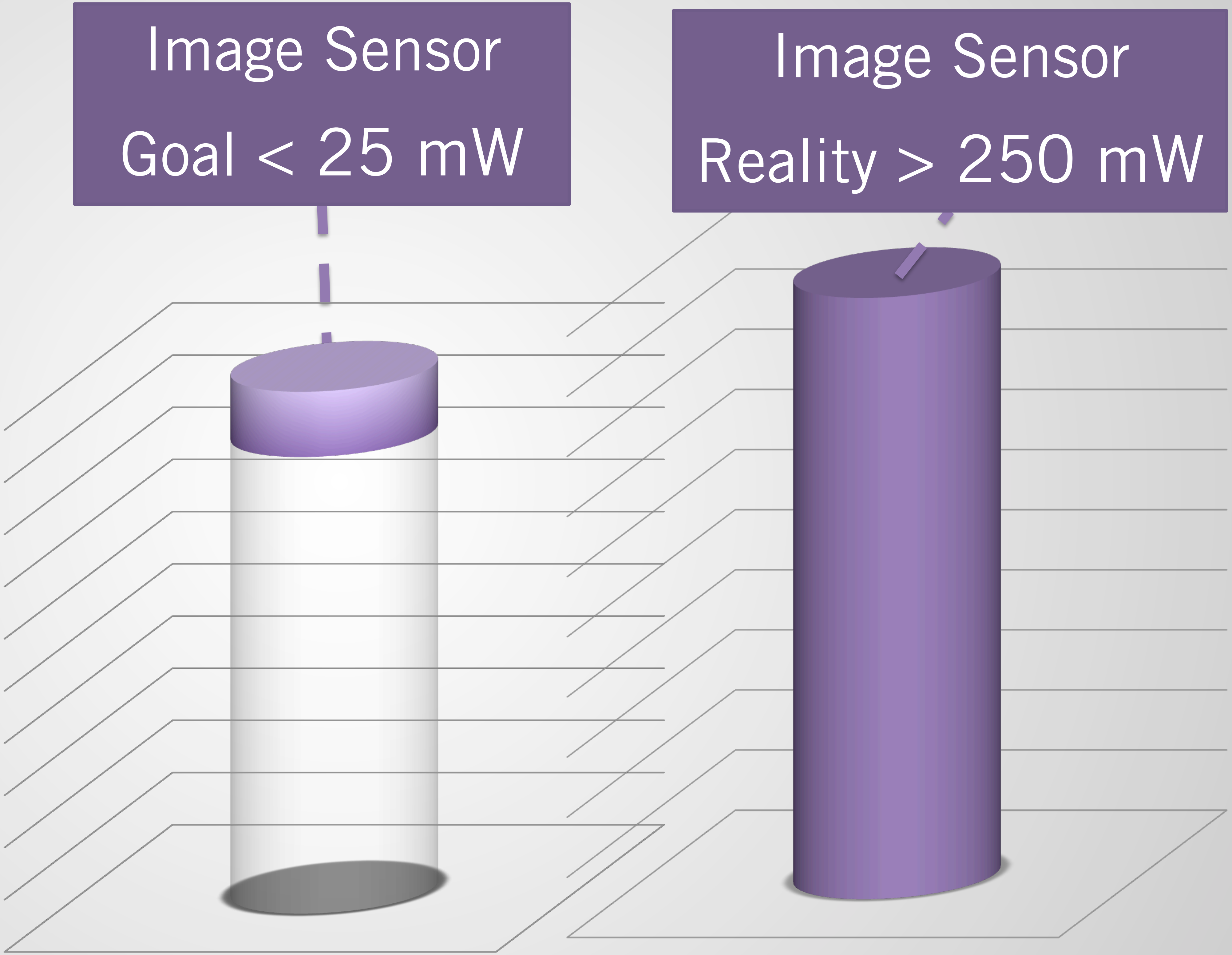
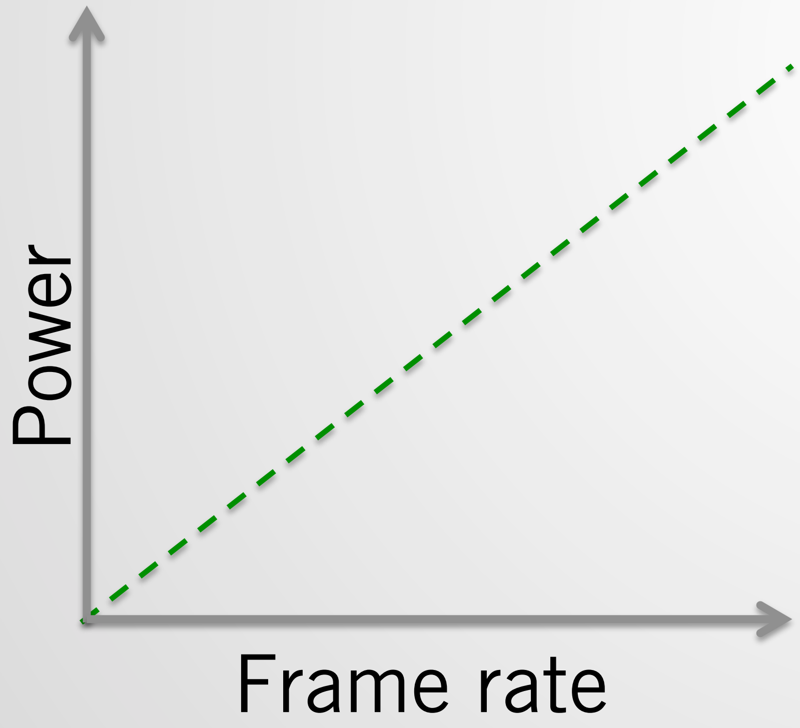
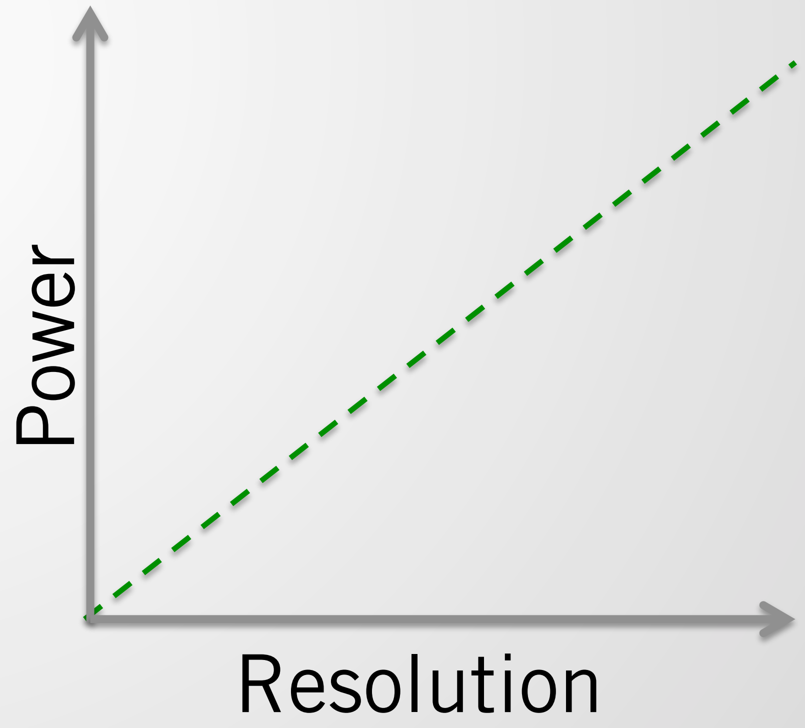


Image Sensor
Goal < 25 mW
Image Sensor
Reality > 250 mW

KEY IDEA: ENERGY α QUALITY





ENERGY PROFILE OF AN IMAGE SENSOR

Goal: < 25 mW

1 MP, 15 fps 295 mW	1 MP, 5 fps 250 mW
0.3 MP, 15 fps 245 mW	0.3 MP, 5 fps 232 mW

Reality: > 230 mW

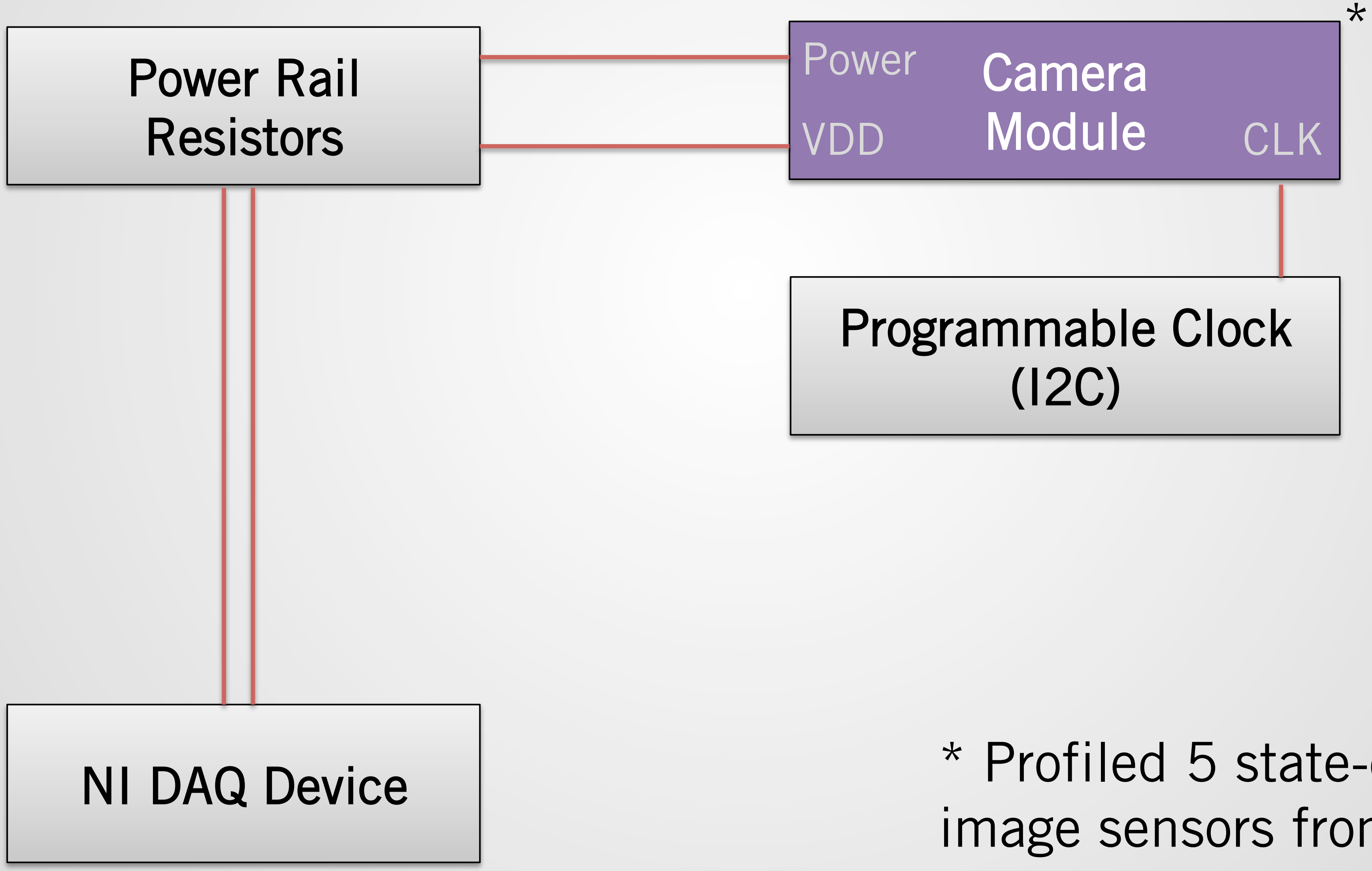
ENERGY-EFFICIENT IMAGE SENSING

Image Sensor Characterization

Energy Reduction Techniques

Energy vs. Vision Performance

IMAGE SENSOR MEASUREMENT



* Profiled 5 state-of-the-art image sensors from 2 manufacturers

IMAGE SENSOR MEASUREMENT

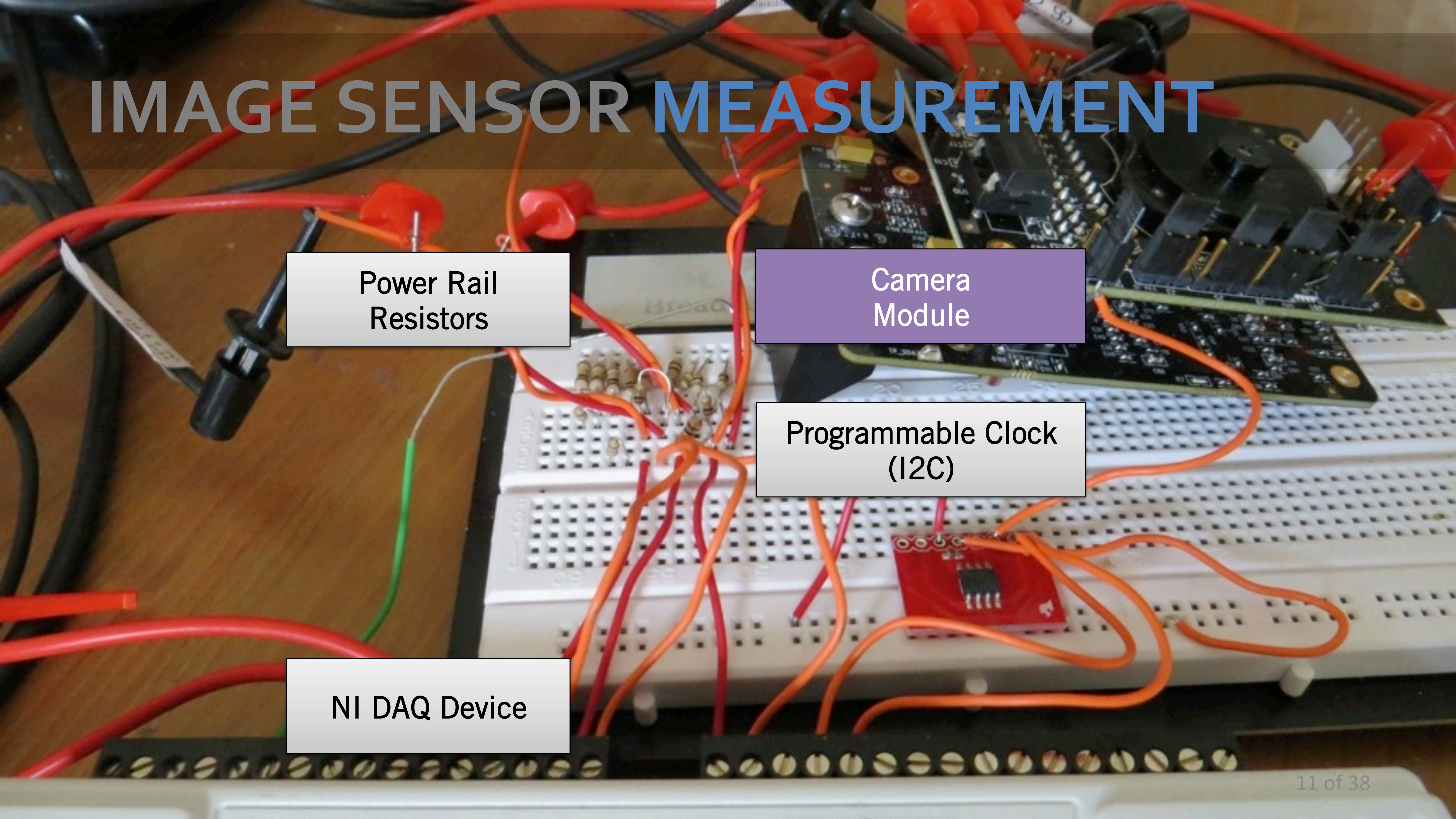


IMAGE SENSOR WAVEFORMS

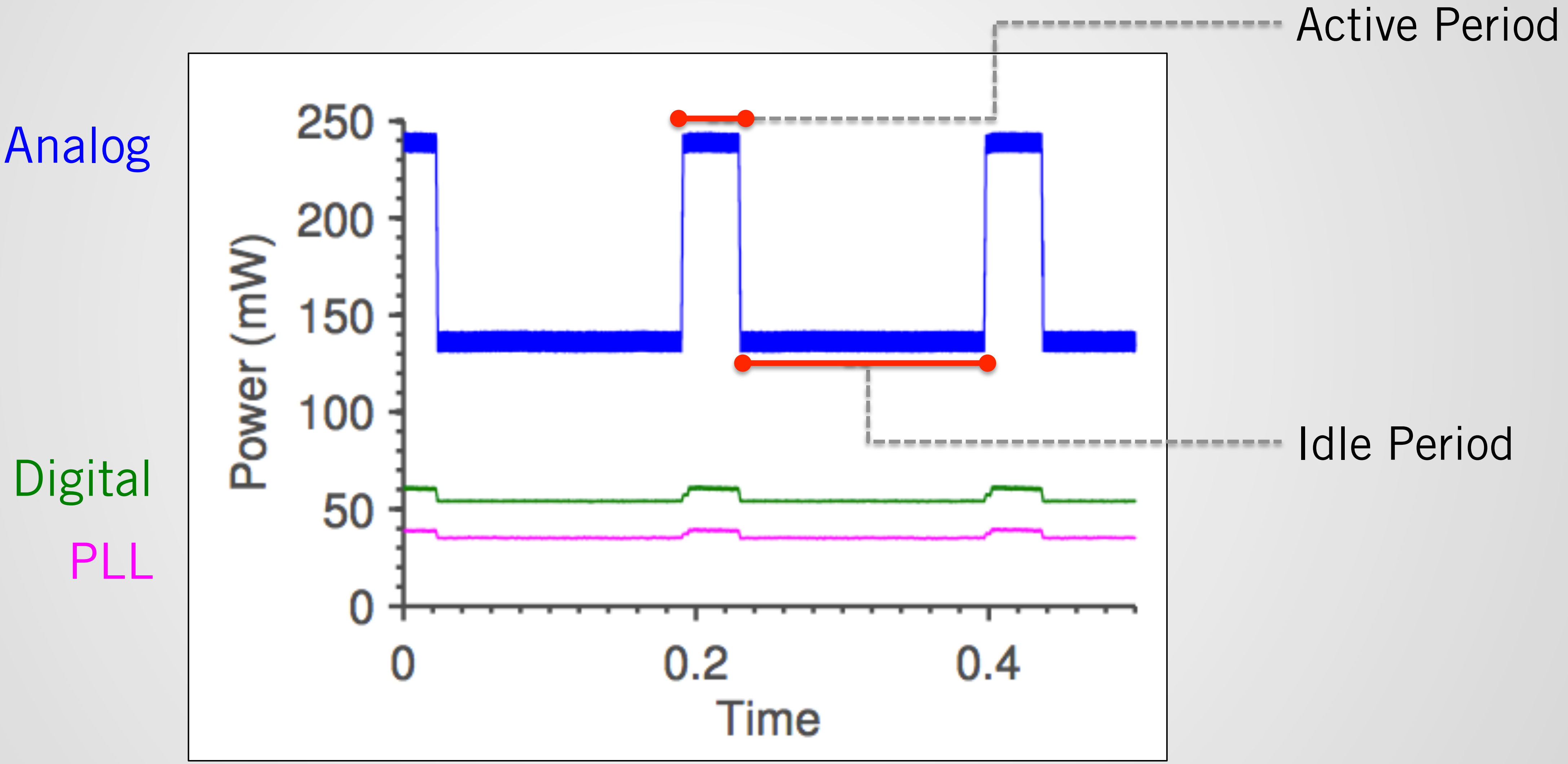
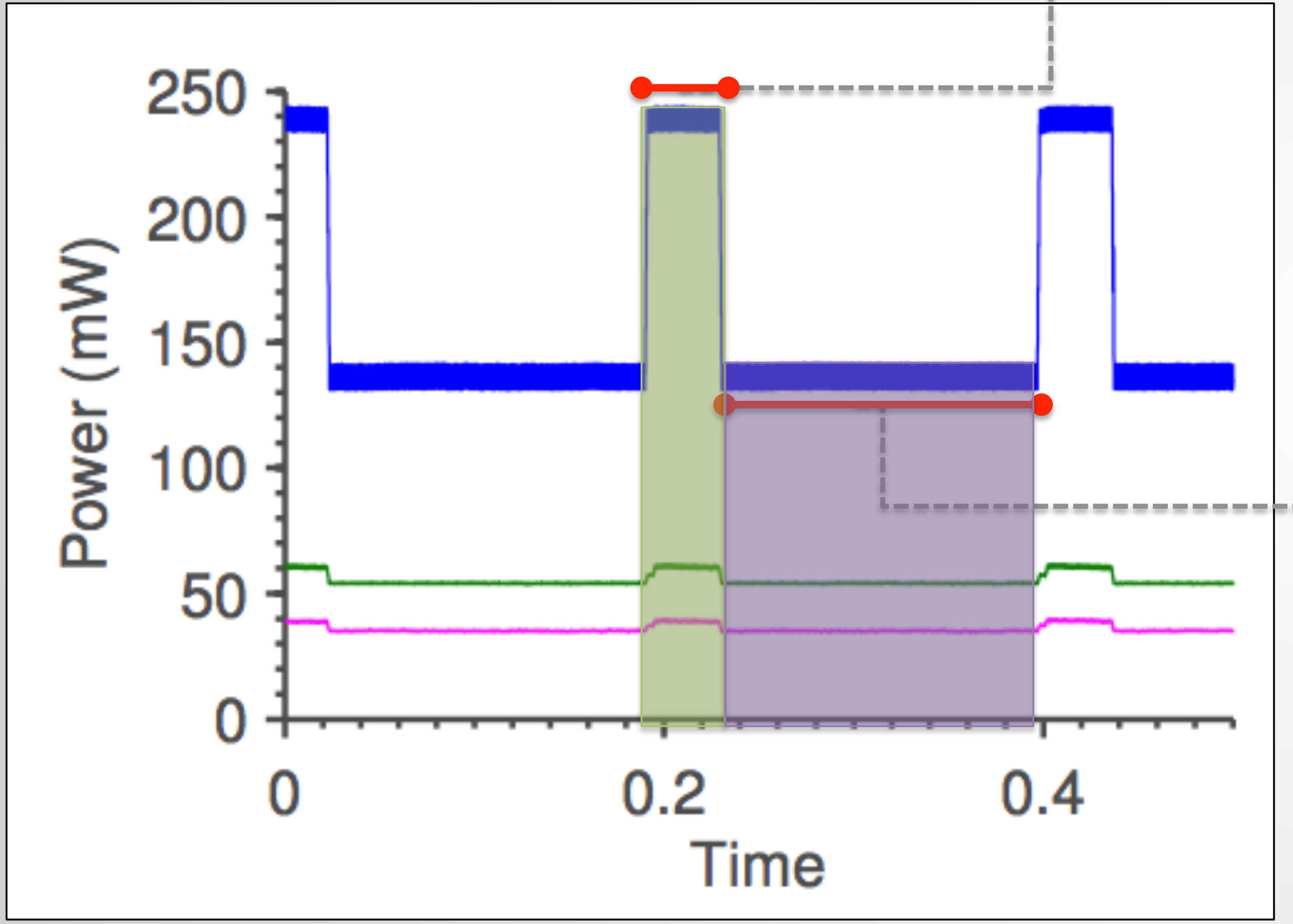


IMAGE SENSOR WAVEFORMS



Active Period

Idle Period

$$T_{active} = \frac{N}{f}$$

Pixel Count
divided by
Clock Frequency

$$T_{idle} = \frac{1}{R} - T_{active}$$

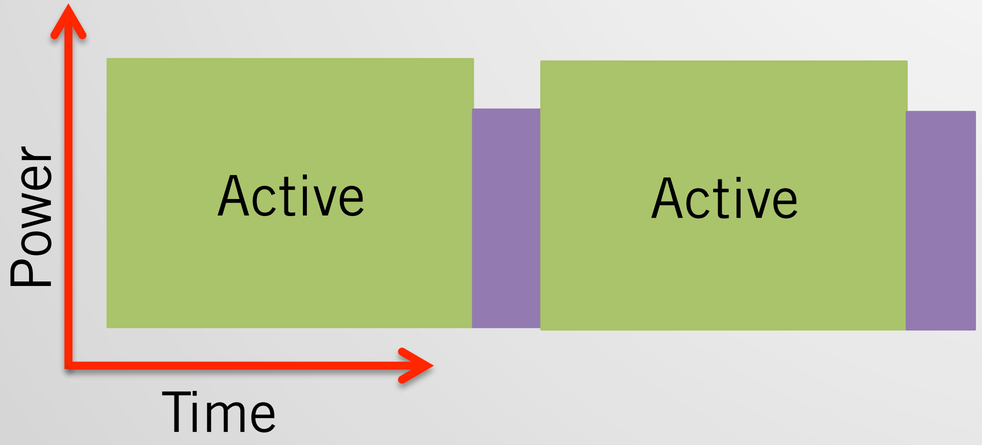
Frame Time
minus
Active Time

$$E_{frame} = P_{active}T_{active} + P_{idle}T_{idle}$$

IMAGE SENSOR PIXEL COUNT (N)

Scaled Resolution (Pixel Skipping)

Region-of-Interest (Windowing)



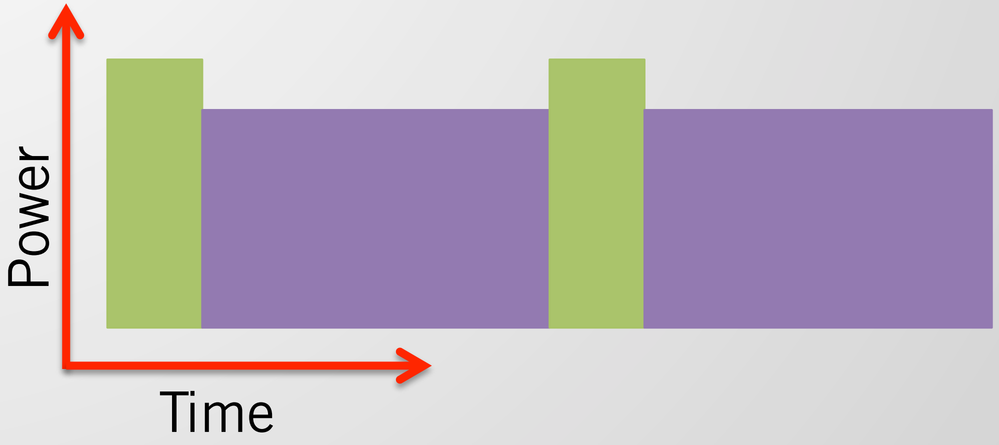
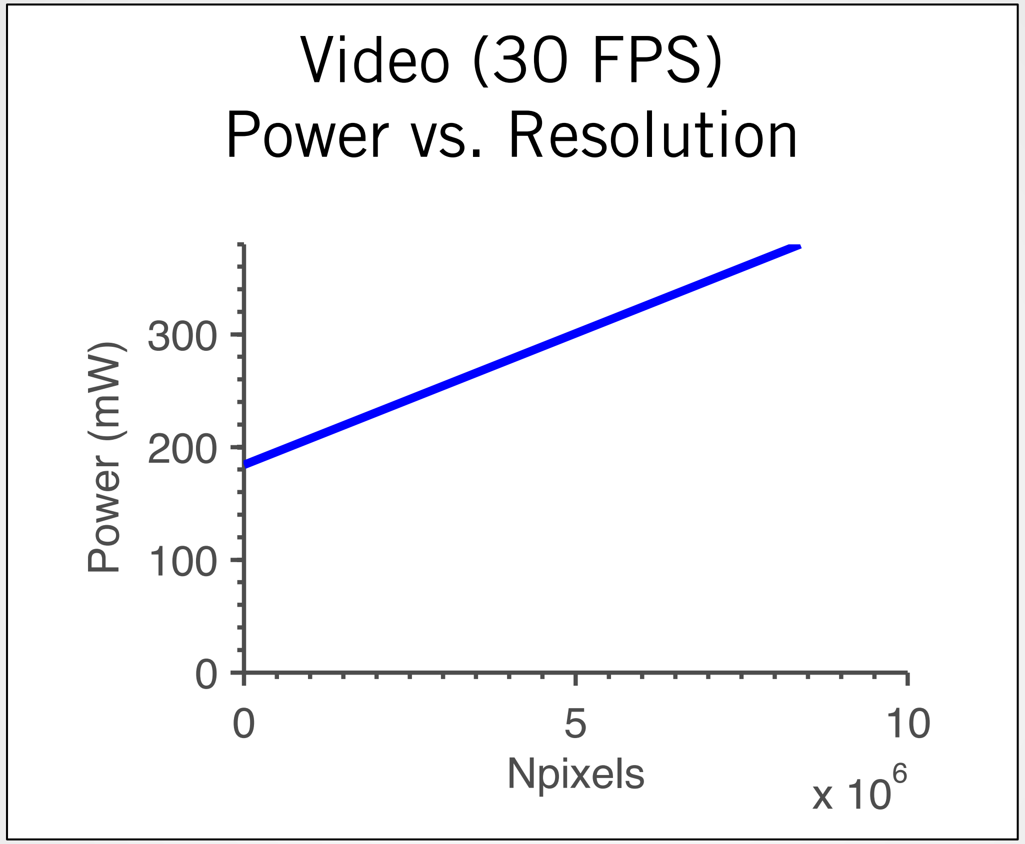
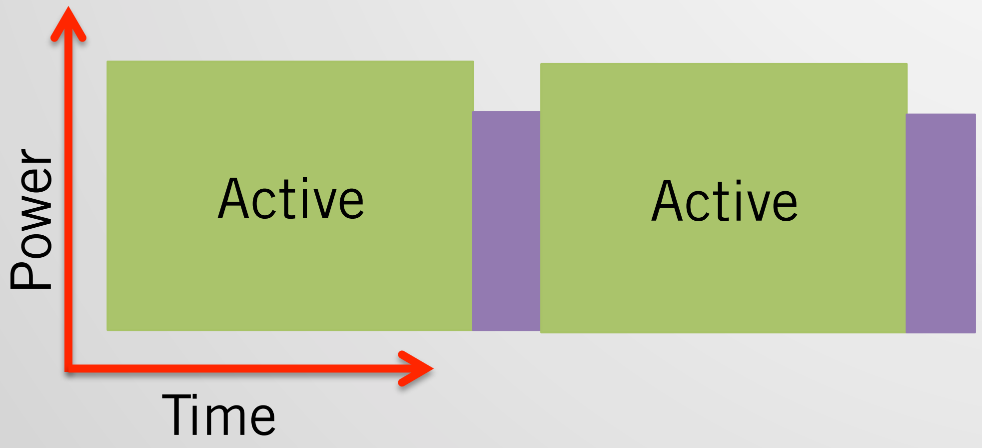


IMAGE SENSOR PIXEL COUNT (N)





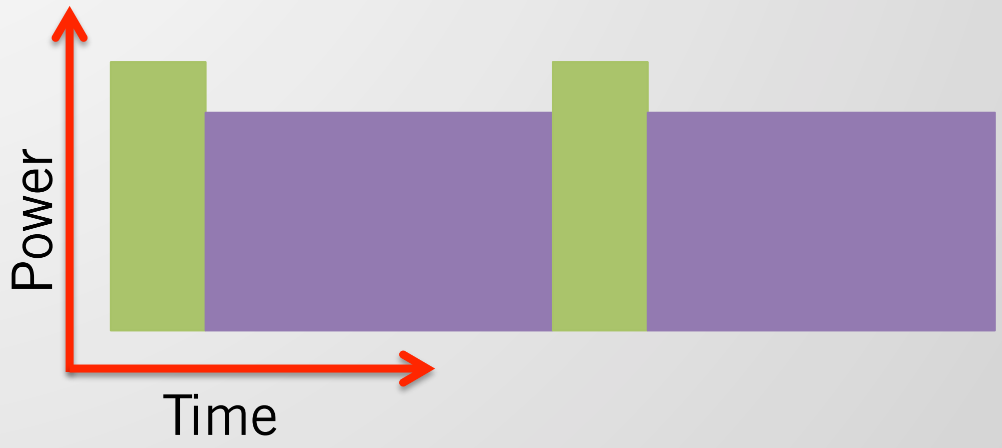
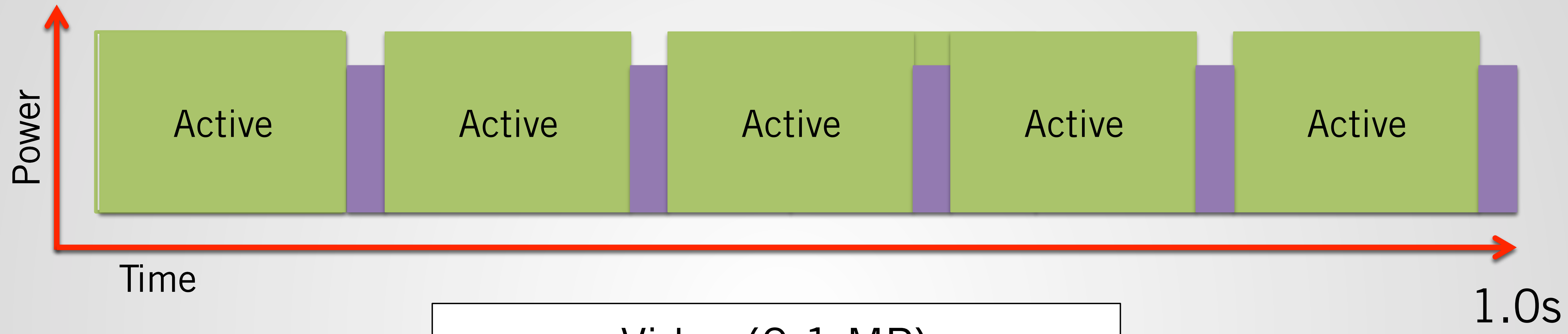
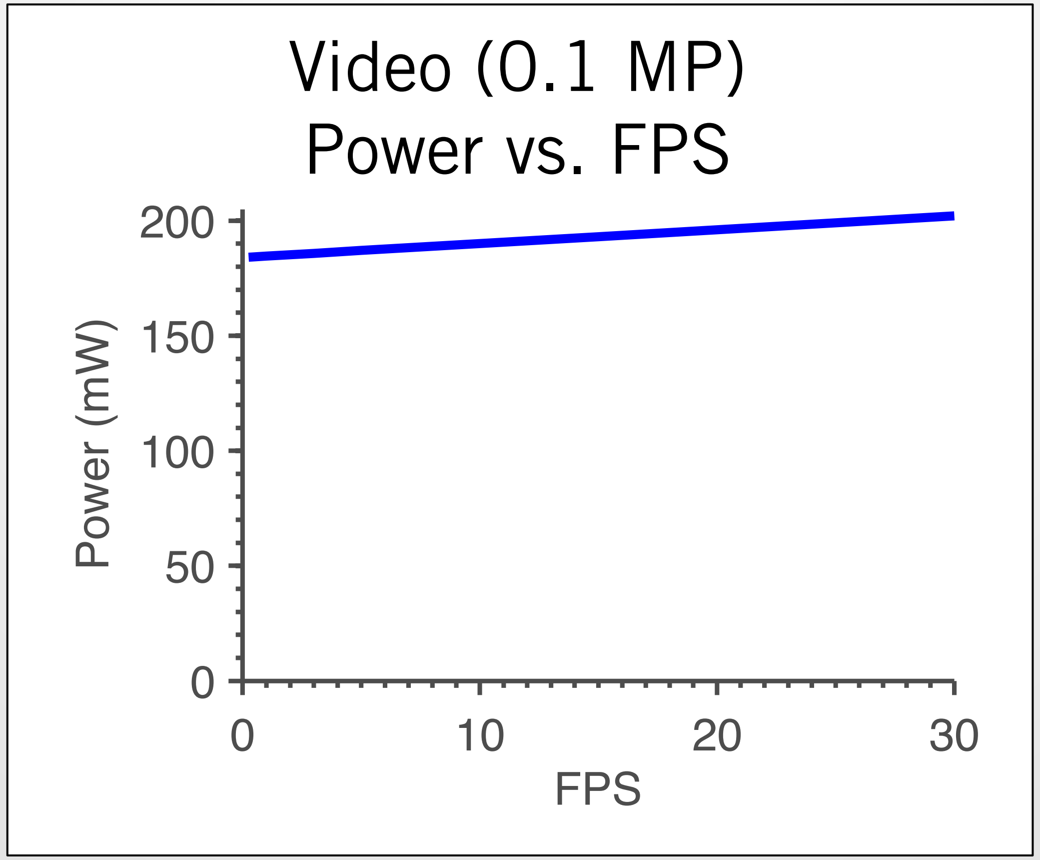


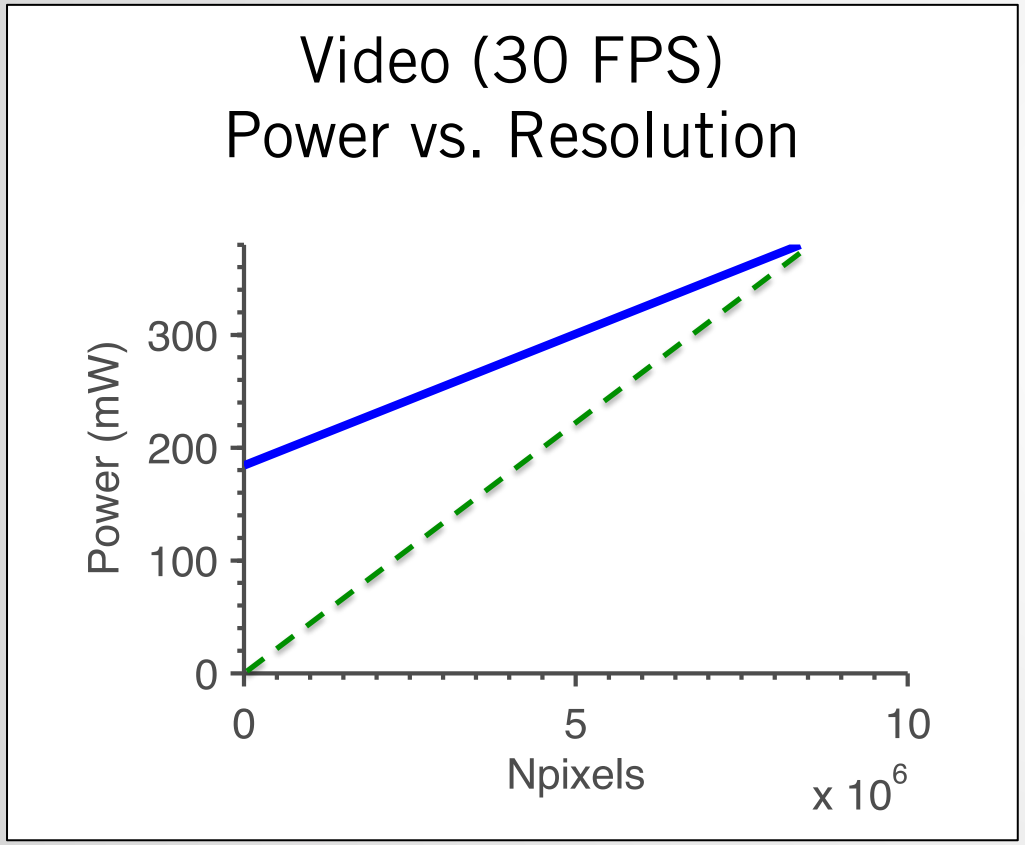
IMAGE SENSOR FRAME RATE (R)

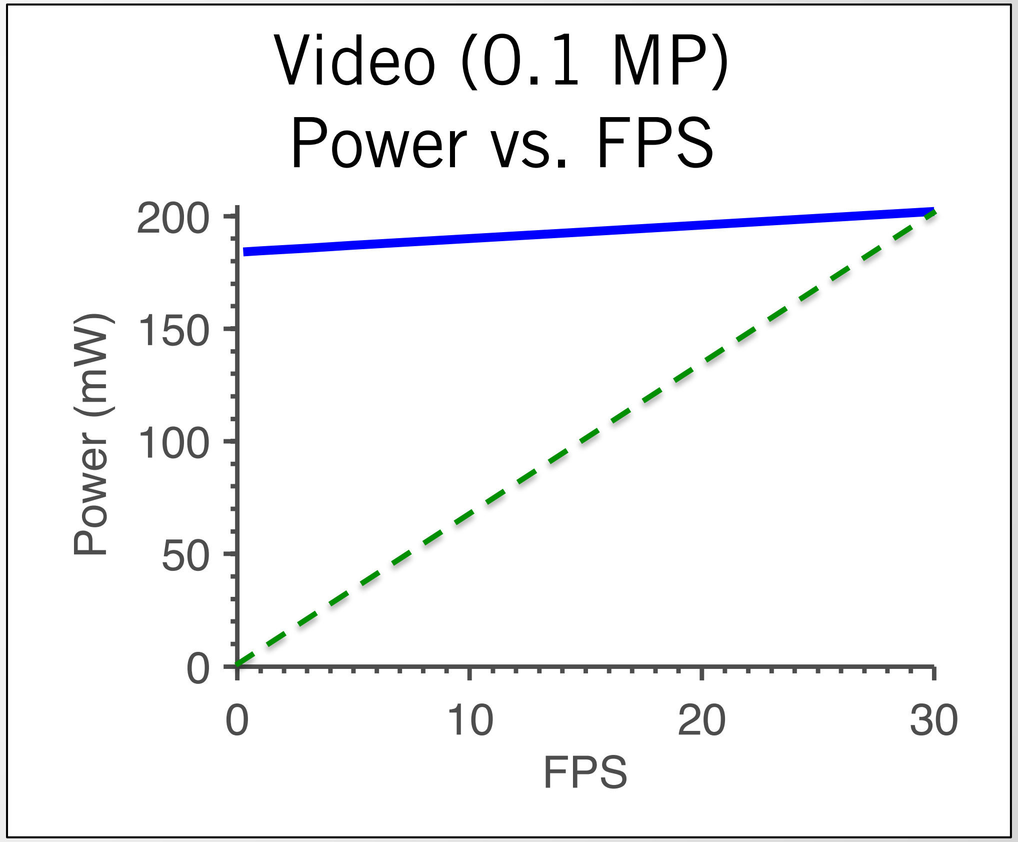




CHARACTERIZATION CONCLUSION:

NO ENERGY PROPORTIONALITY





ENERGY-EFFICIENT IMAGE SENSING

Image Sensor Characterization

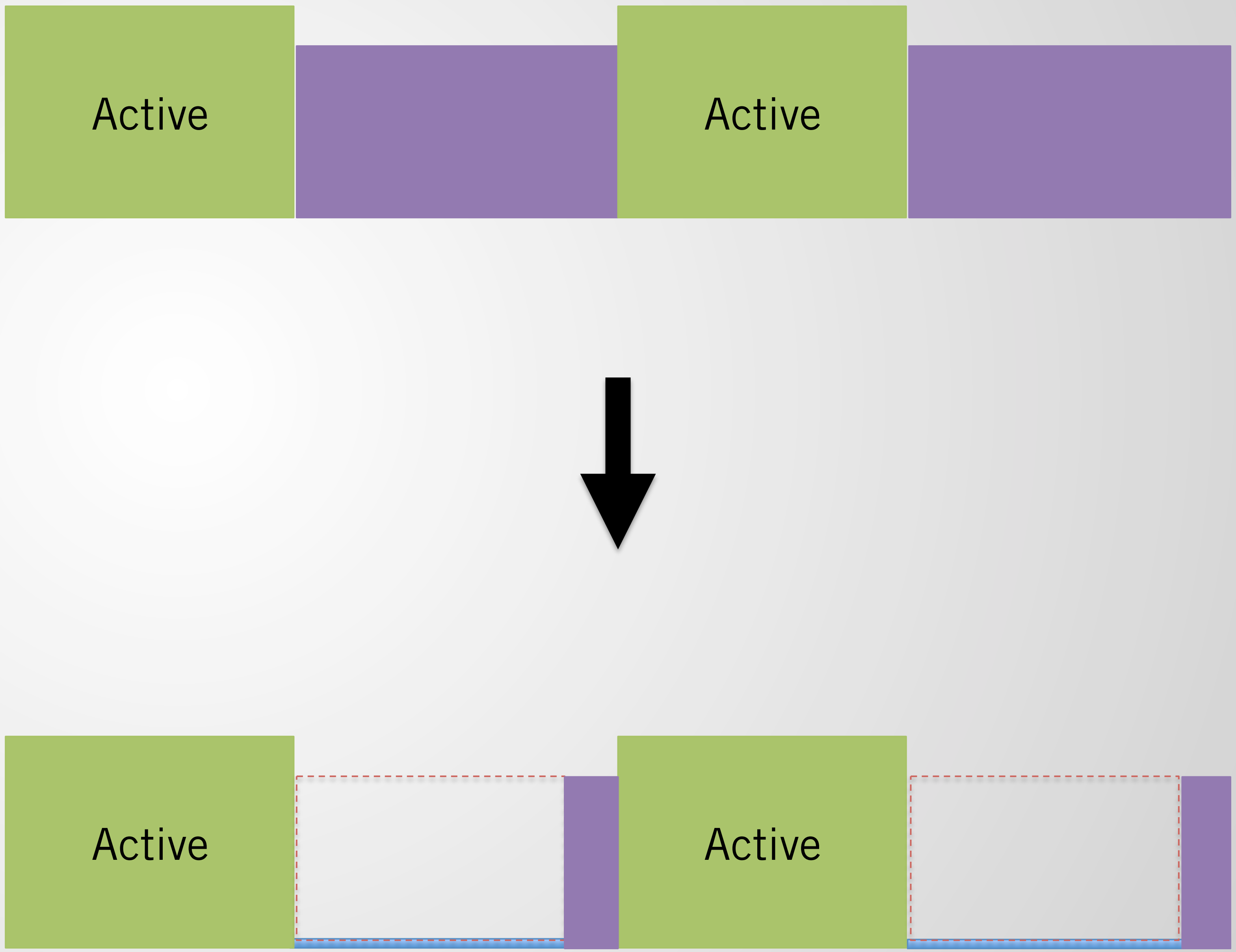
Energy Reduction Techniques

Energy vs. Vision Performance

TECHNIQUE #1: AGGRESSIVE STANDBY

$$T_{idle} = \frac{1}{R} - T_{active}$$

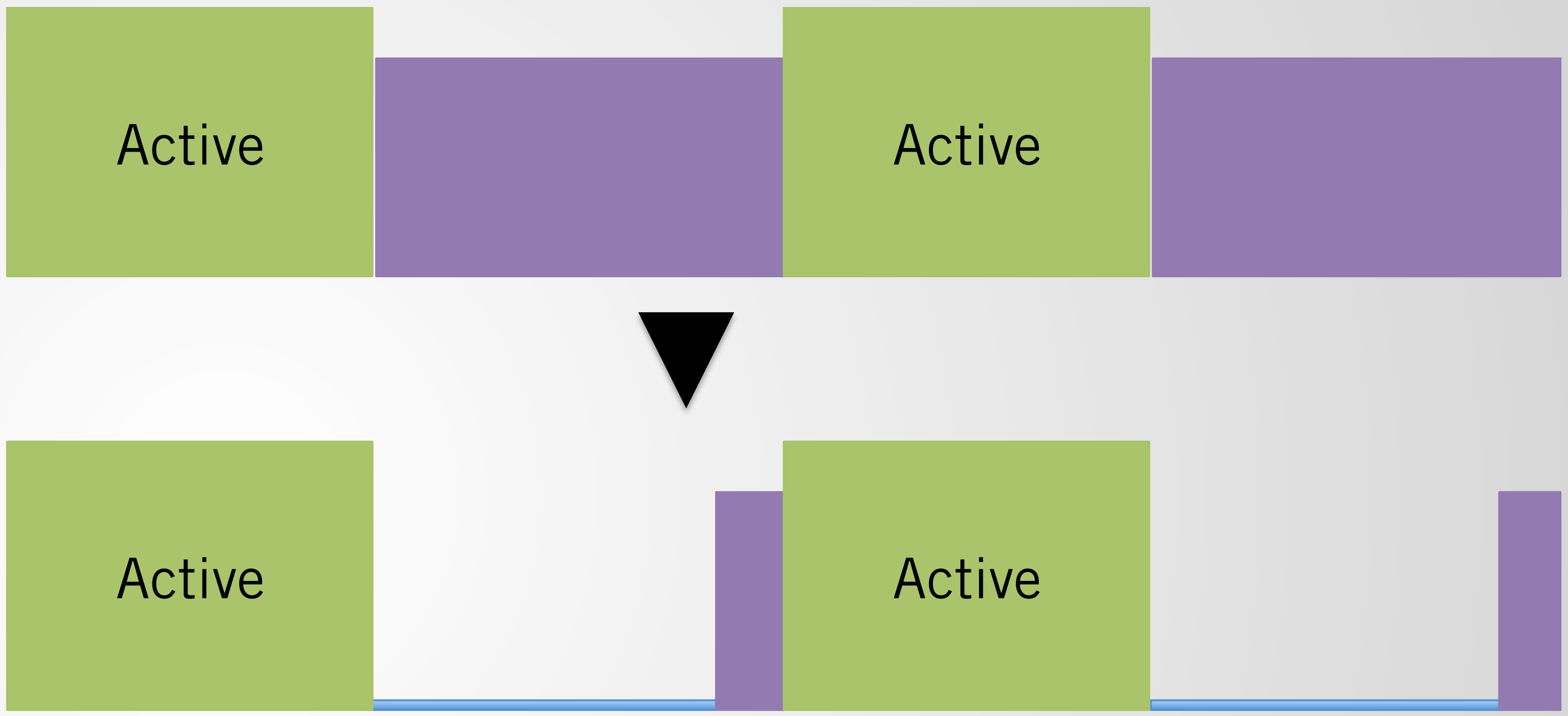
$$T_{idle} = T_{exposure}$$



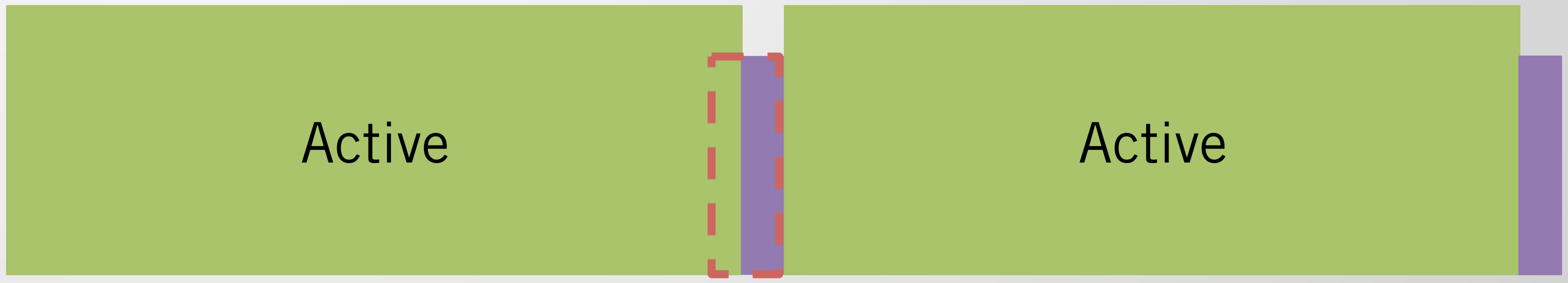
CAVEAT TO AGGRESSIVE STANDBY

$$T_{idle} = \frac{1}{R} - T_{active}$$

$$T_{idle} = T_{exposure}$$



This won't work for long active periods, i.e., high resolution, high frame rate.



Not enough exposure time

TECHNIQUE #2: CLOCK SCALING (f)

One pixel per clock period

TECHNIQUE #2: CLOCK SCALING (f)

Faster clock

- Lower Active Time ↓
- Higher Active Power ↑
- Higher Idle Power ↑

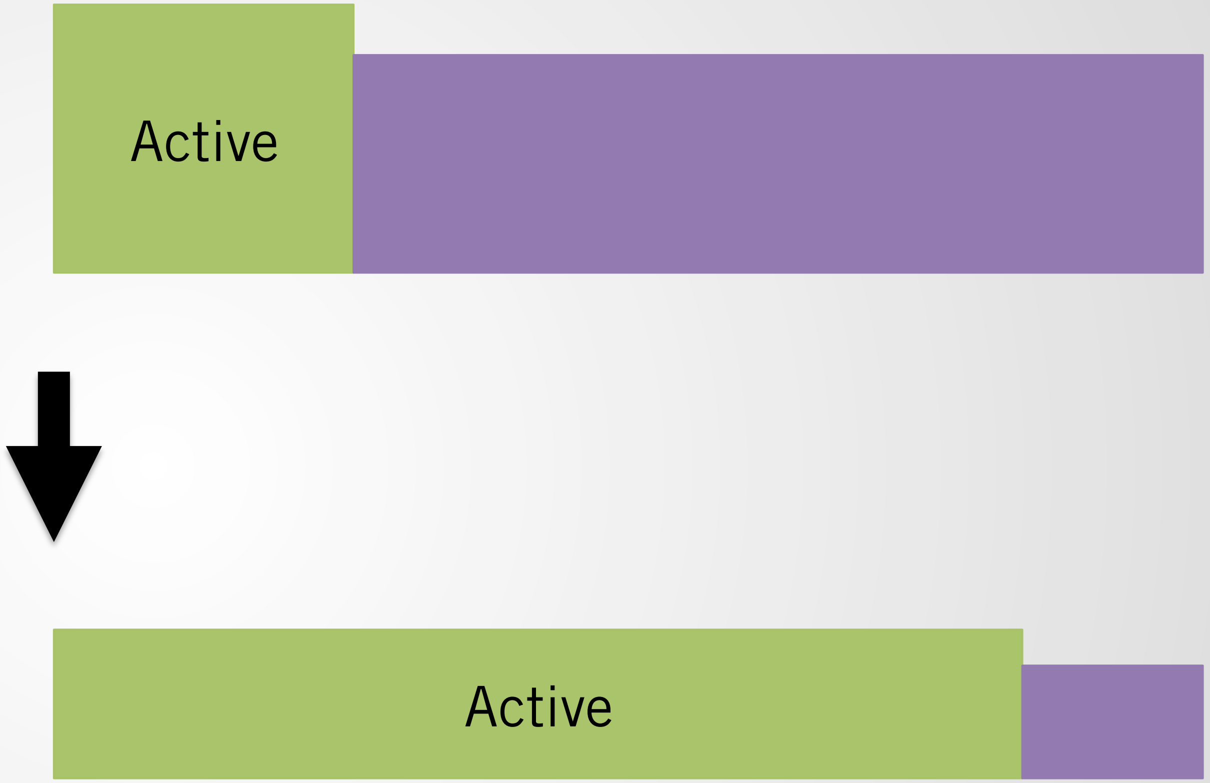
Slower clock

- Higher Active Time ↑
- Lower Active Power ↓
- Lower Idle Power ↓

TECHNIQUE #2: CLOCK SCALING (f)

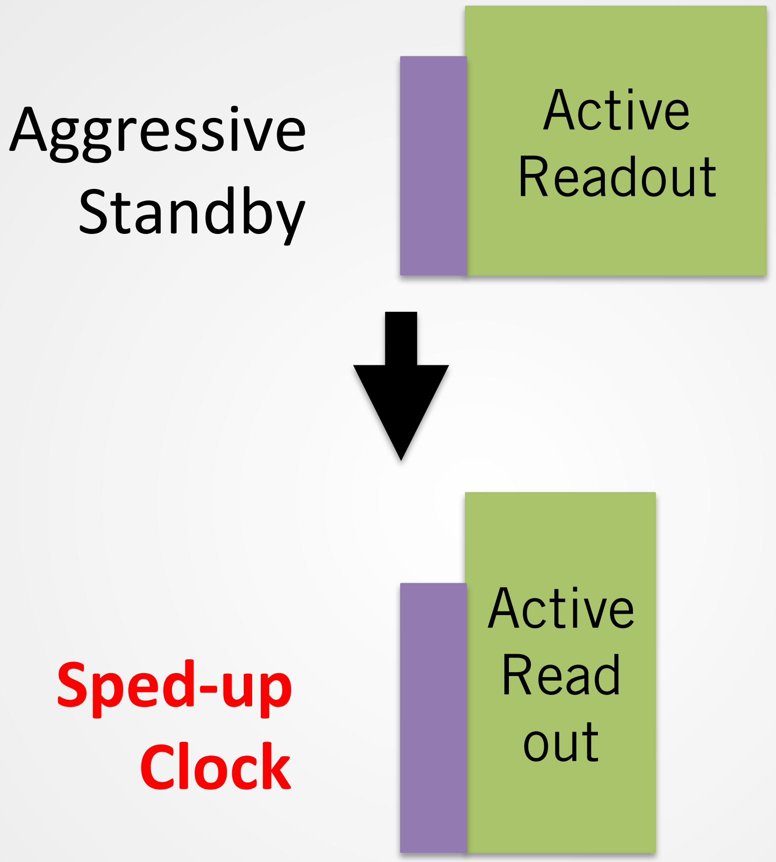
Low Pixel Count
Low Frame Rate

Slowed Clock



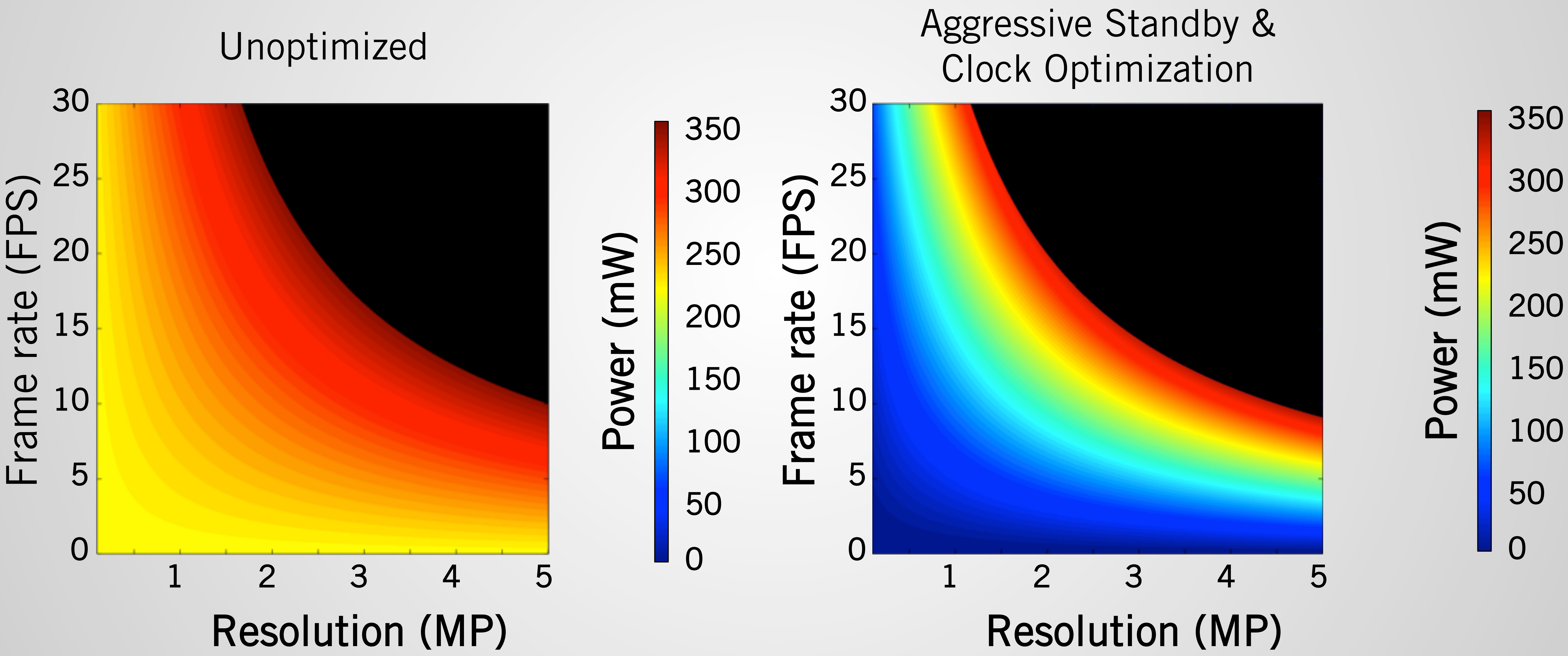
Optimal clock frequency depends on
Pixel Count & Frame Rate

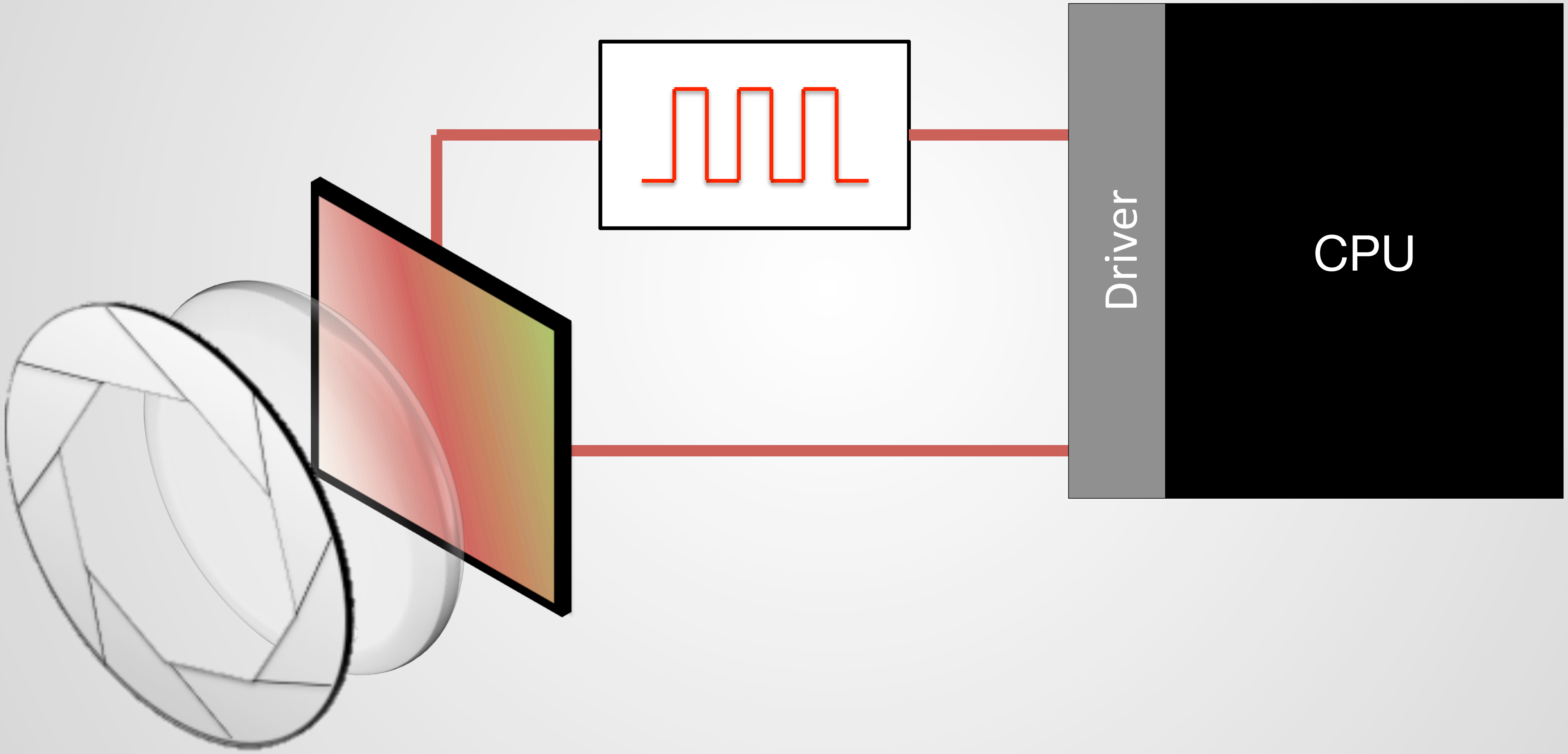
AGGRESSIVE STANDBY + CLOCK OPTIMIZATION

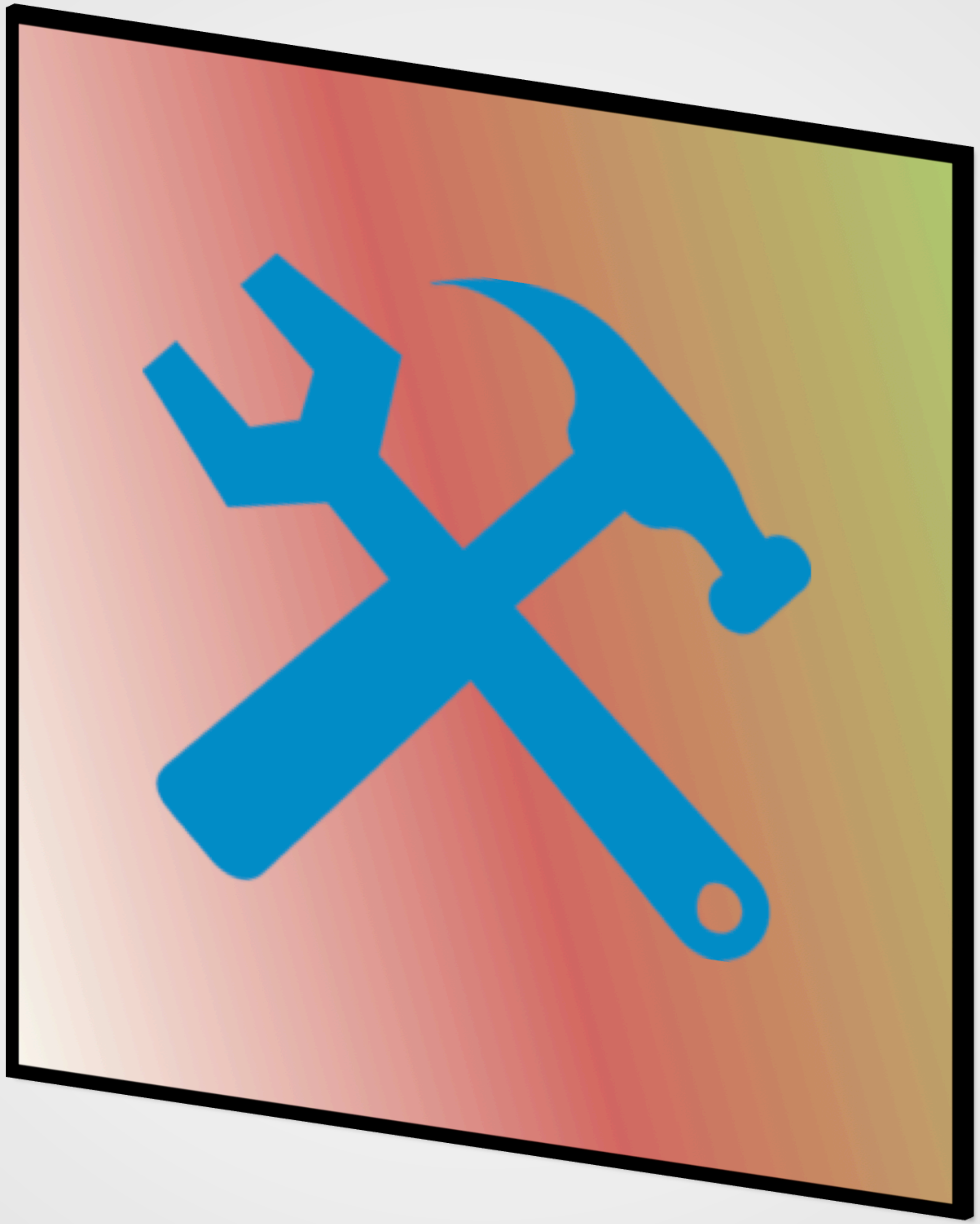


Optimal clock frequency depends on Pixel Count & ~~Frame Rate~~ Exposure Time

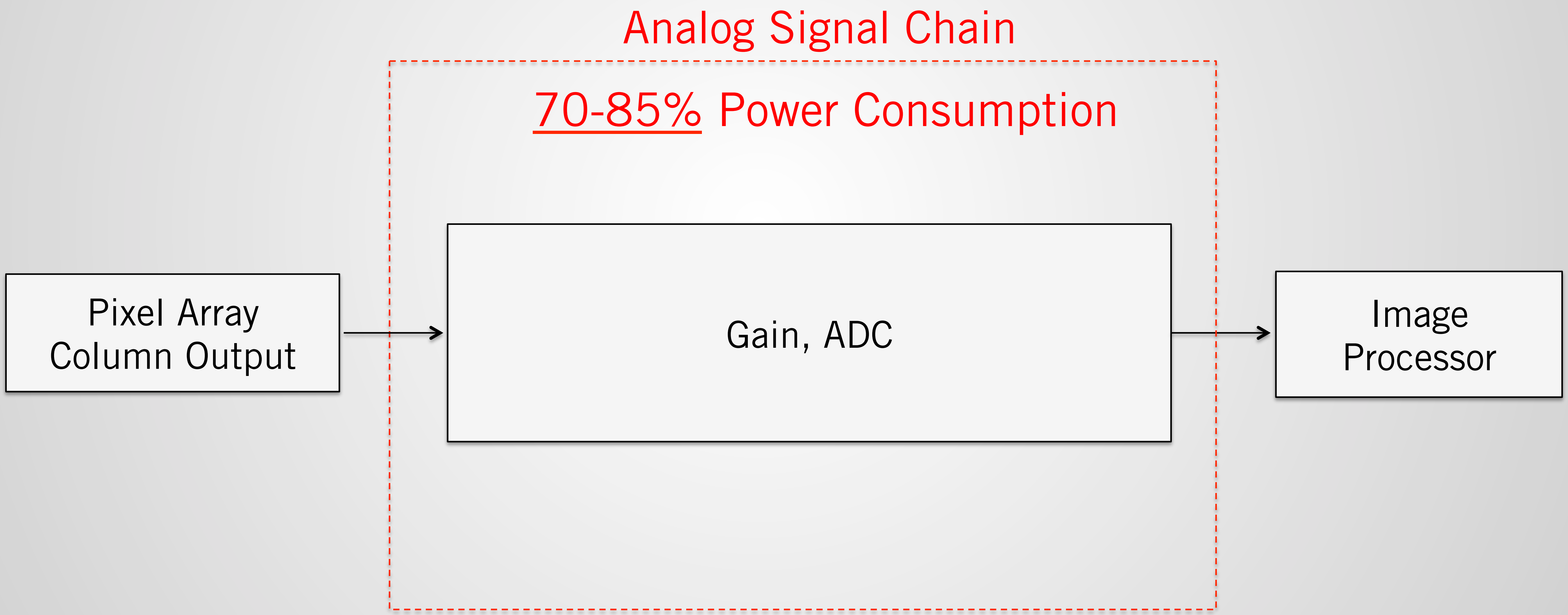
ENERGY α QUALITY



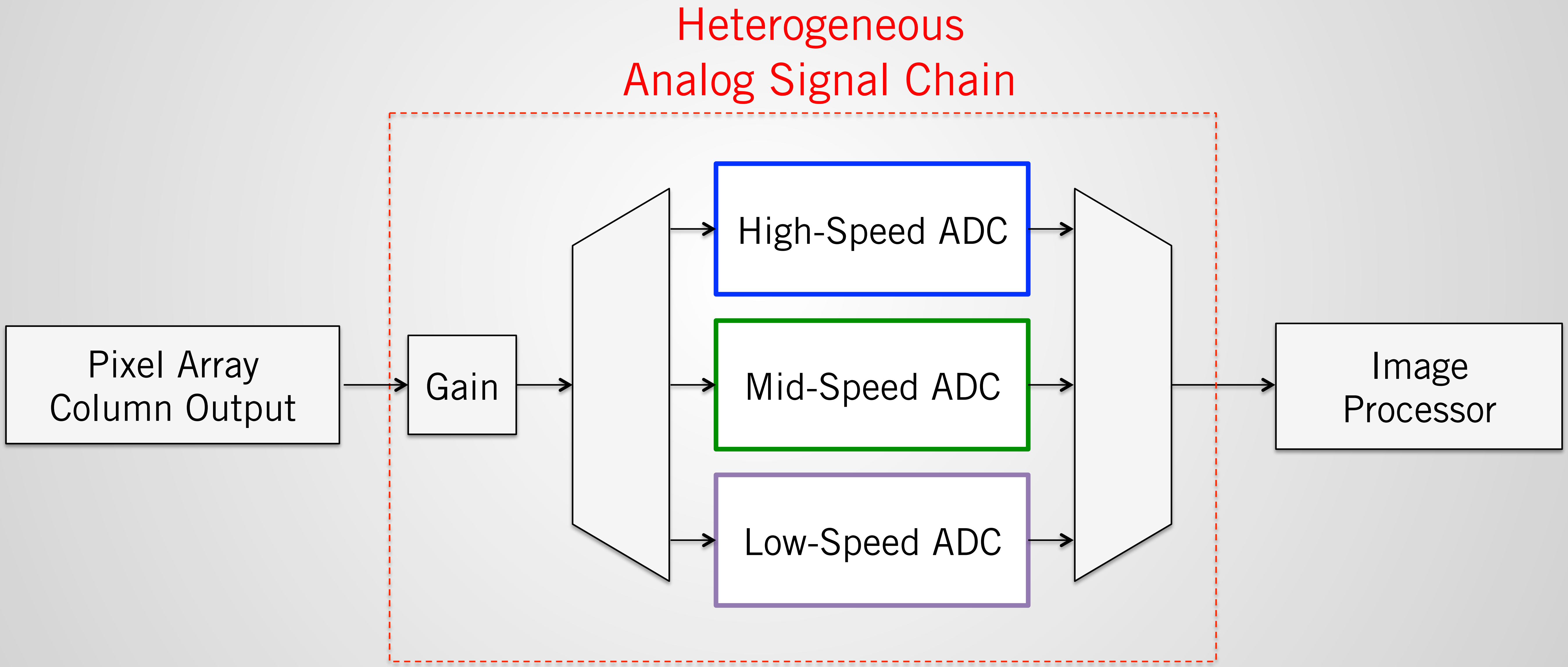

Driver
CPU



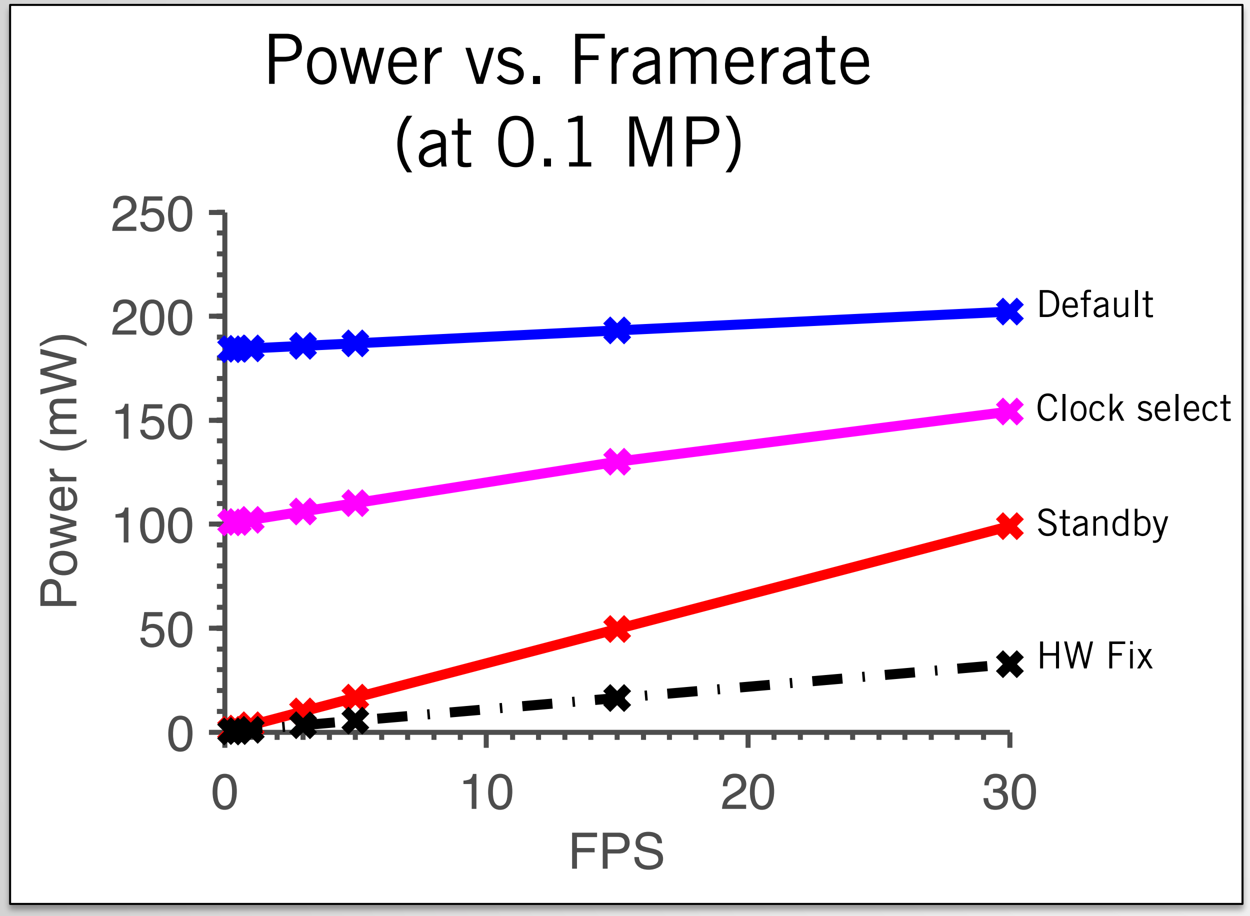
CURRENT IMAGE SENSOR DESIGN

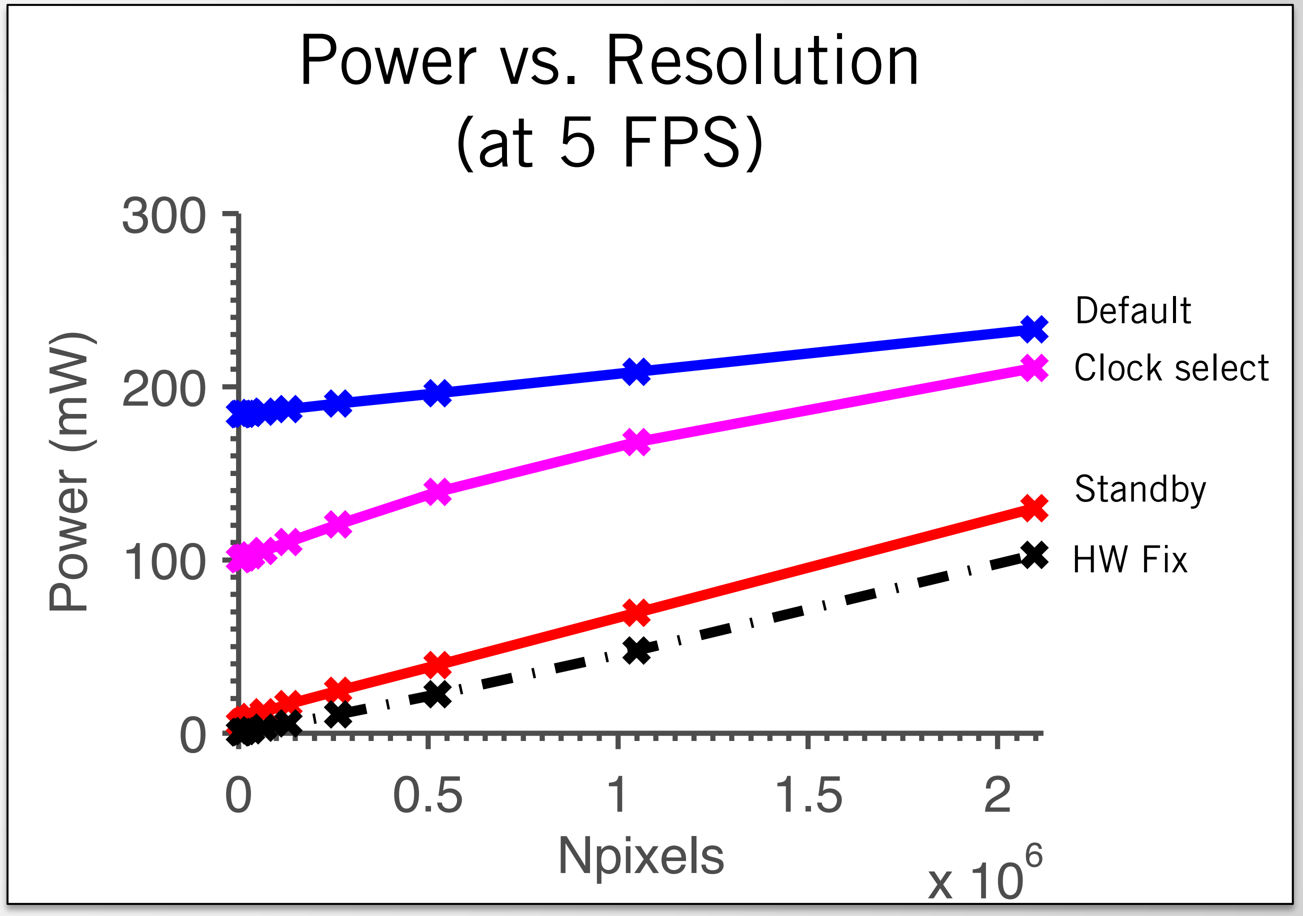


HETEROGENEOUS SENSOR DESIGN



ENERGY α QUALITY





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ENERGY vs. VISION: VISION TASK

IMAGE REGISTRATION

ENERGY vs. VISION: PERFORMANCE

	Image Registration Success	Power Reduction with software assist	Estimated Power Reduction with hardware assist
Full VGA Resolution *0.1 MP, 30 FPS*	99.9%	51%	84%
Frame Rate Reduction 0.1 MP, 3 FPS	95.7%	95%	98%
30% Window 0.06 MP, 30 FPS	96.5%	63%	91%
Subsampled by 2 0.3 MP, 30 FPS	91.8%	71%	94%

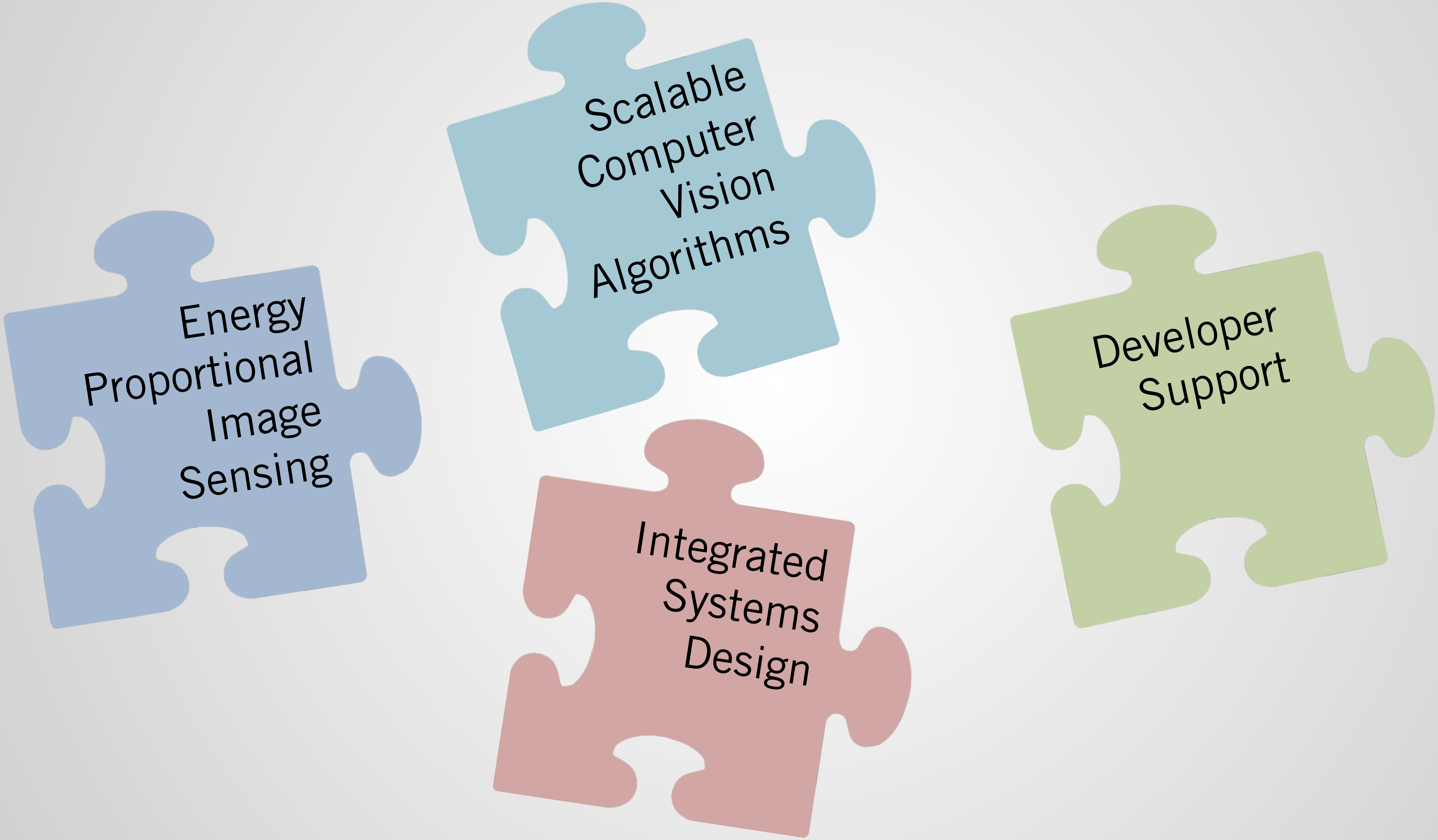
Typical Average Power
185 mW

→

With aggr. standby & optimal clock
10 mW

→

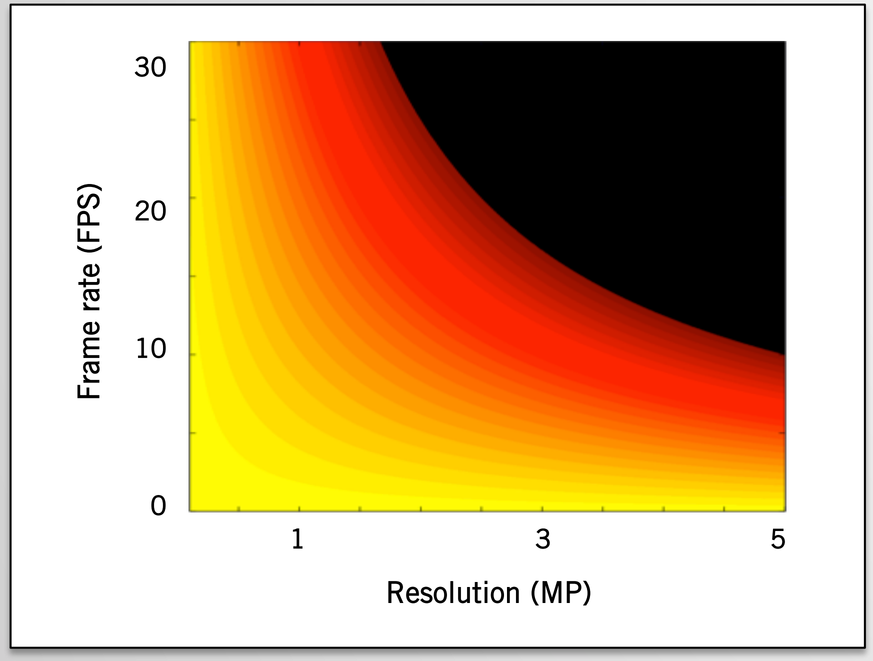
With heterogeneous analog signal chain
3 mW


Scalable Computer Vision Algorithms
Energy Proportional Image Sensing
Developer Support
Integrated Systems Design

Continuous Mobile Vision

ENERGY-PROPORTIONAL IMAGE SENSING
FOR
CONTINUOUS MOBILE VISION

Image sensors are not energy-proportional…



…but we can make them energy-proportional…

Aggressive Standby

Clock Optimization

Sensor Modifications

… and this is just the beginning.

http://roblkw.com
http://research.microsoft.com