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Study and Design of an Integrated CMOS VCSEL Driver (150MHz, 1W) for an iToF-based 3D CMOS Image Sensor

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3D Imaging in Consumer Electronics and Mobile Applications

Emerging Applications

- Facial recognition
- Motion tracking & Gesture Control
- **A**ugmented **R**eality and **V**irtual **R**eality (AR & VR)
- **S**imultaneous **L**ocalization **A**nd **M**apping (SLAM)

3D Image Sensor

Purpose

Take a 3D picture of the surrounding area by measuring the depth

Challenges

- Up to 3m (accuracy < 0.5% of range)
- Without scanning
- Mainly indoor
- With a QVGA-resolution (320x240 pixels)

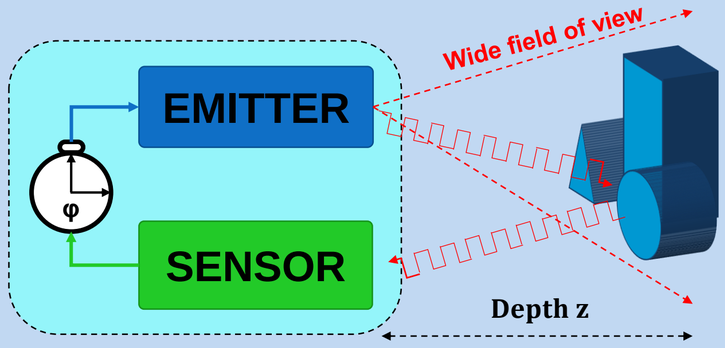
System Constraints

Compact | Low Cost | High Efficiency | Safe

Depth Measuring Technique

Indirect Time-of-Flight

Calculate the distance by measuring the phase shift between emitted and received laser signals



$$\Rightarrow z = \frac{c}{4\pi f}\varphi$$

z : depth
c : light speed (299 792 458 m/s)
f : signal frequency
φ : phase shift

Study and Design of the integrated CMOS VCSEL Driver (150MHz, 1W)

Objective

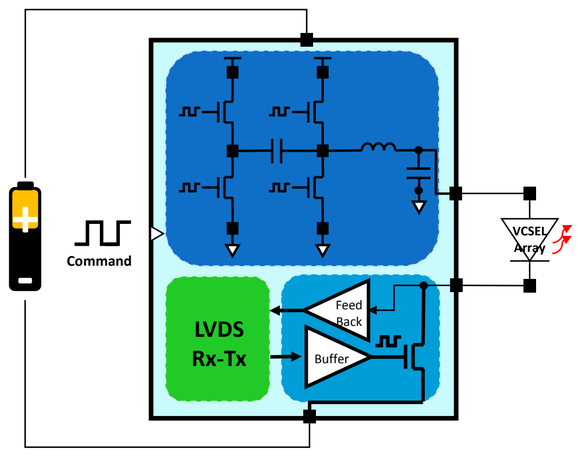
Find the best architecture for modulating the light with:

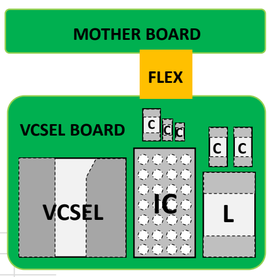
- ✓ **The best electrical efficiency**
- ✓ **The smallest depth error**
- ✓ **The smallest chip area**

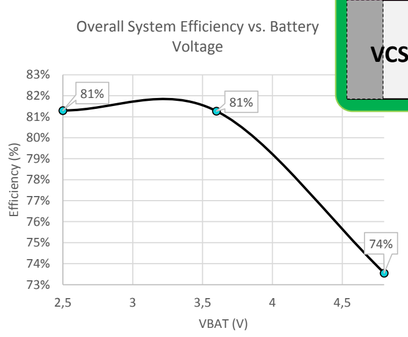
Specifications

Driver Specification		Value	
Process		STMicroelectronics 130nm CMOS technology	
Package		WLCSP	
Modulation type		Square wave	
Wavelength		850nm or 940nm	
Max signal frequency		150MHz	
Duty cycle		50%	
Average optical power		1W	
Peak current		2.5A	
Electrical efficiency		≥ 70%	
Temperature		[-40°C ; 85°C]	
Battery		Lithium-ion for mobile phone	
Voltage	Charge	[2.5V ; 4.8V]	3000mAh

Current-mode Buck-Boost Converter



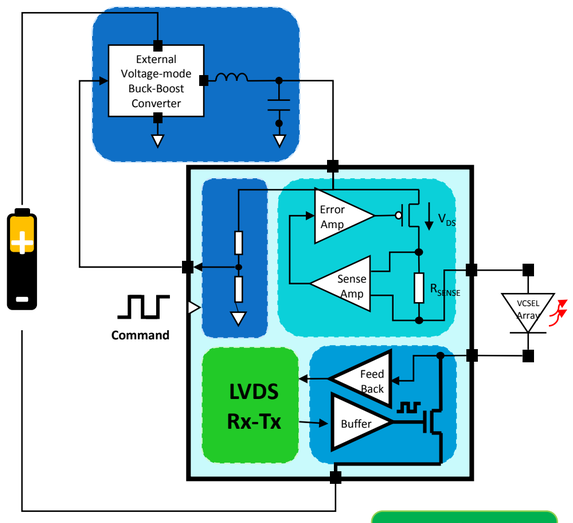


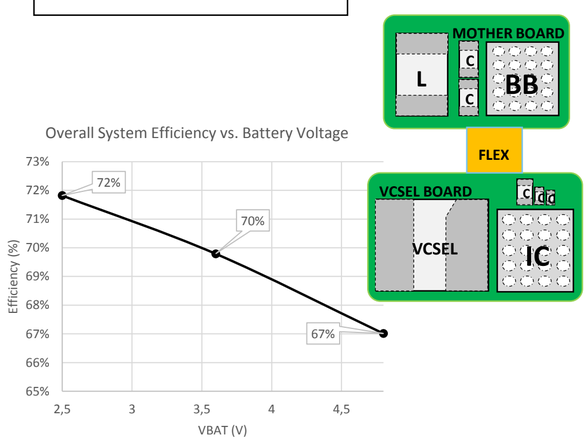


Total PCB footprint = 29 mm²
Silicon area = **8 mm²**
Number of IOs = 28
Overall system efficiency = **81%** (use case)
Typical dissipated power in IC = **600 mW**
Systematic depth error = **3 mm**

Best efficiency
Best compromise ✓

External Voltage-mode Buck-Boost Converter + Current-mode Linear Regulator

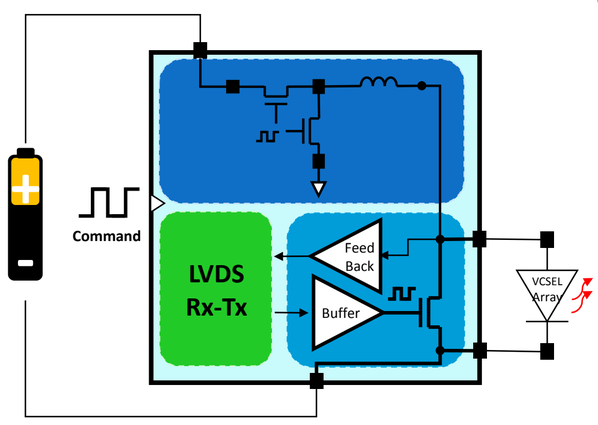


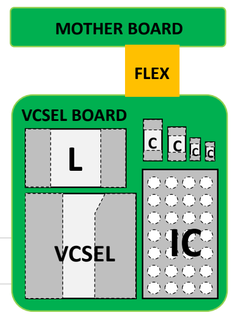


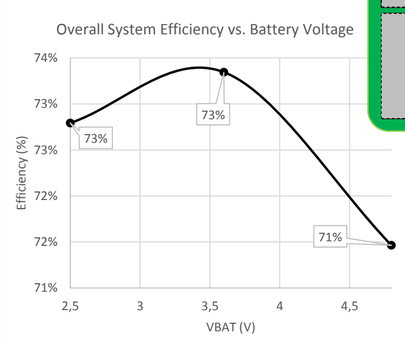
Total PCB footprint = 29 mm²
Silicon area = **6 mm²**
Number of IOs = 20
Overall system efficiency = **70%** (use case)
Typical dissipated power in IC = **700 mW**
Systematic depth error = **2 mm**

Smallest silicon area
Lowest efficiency

Modified Buck Converter







Total PCB footprint = **26 mm²**
Silicon area = **8 mm²**
Number of IOs = 28
Overall system efficiency = **73%** (use case)
Typical dissipated power in IC = **900 mW**
Systematic depth error = **1 mm**

Smallest depth error
Highest consumption in IC

CONCLUSION

Current-mode Buck-Boost Converter is the best solution:

- ✓ **Best efficiency**
- ✓ **Smallest dissipated power**

FUTURE

- ❑ Test chip under development
- ❑ Electrical and optical bench under development
- ❑ Improved electrical and optical modeling of the VCSEL in progress
- ❑ Laser “class 1” certification in progress