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

- Facial recognition
- Motion tracking & Gesture Control
- Augmented Reality and Virtual Reality (AR & VR)
- Simultaneous Localization And Mapping (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)

Depth Measuring Technique

- Indirect Time-of-Flight
  - Calculate the distance by measuring the phase shift between emitted and received laser signals

System Constraints

- Low Cost
- High Efficiency
- Safe

Objective

Find the best architecture for modulating the light with:
- The best electrical efficiency
- The smallest depth error
- The smallest chip area

Specifications

<table>
<thead>
<tr>
<th>Driver Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>STMicroelectronics 130nm CMOS technology</td>
</tr>
<tr>
<td>Package</td>
<td>W25P</td>
</tr>
<tr>
<td>Modulation type</td>
<td>Square wave</td>
</tr>
<tr>
<td>Wavelength</td>
<td>850nm or 940nm</td>
</tr>
<tr>
<td>Max signal frequency</td>
<td>150MHz</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>50%</td>
</tr>
<tr>
<td>Average optical power</td>
<td>1W</td>
</tr>
<tr>
<td>Peak current</td>
<td>2.5A</td>
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<tr>
<td>Electrical efficiency</td>
<td>&gt; 70%</td>
</tr>
<tr>
<td>Temperature</td>
<td>[-40°C; 85°C]</td>
</tr>
<tr>
<td>Battery</td>
<td>Lithium-ion for mobile phone</td>
</tr>
<tr>
<td>Voltage Charge</td>
<td>(2.35; 4.8V) 3000mAh</td>
</tr>
</tbody>
</table>

Current-mode Buck-Boost Converter

- Best efficiency
- Total PCB footprint = 29 mm²
- Silicon area = 6 mm²
- Number of IOs = 28
- Overall system efficiency = 81% (use case)
- Typical dissipated power in IC = 600 mW
- Systematic depth error = 3 mm

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

- Smallest silicon area
- Lowest efficiency
- 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

Modified Buck Converter

- Smallest depth error
- Highest consumption in IC
- Total PCB footprint = 26 mm²
- Silicon area = 6 mm²
- Number of IOs = 28
- Overall system efficiency = 73% (use case)
- Typical dissipated power in IC = 900 mW
- Systematic depth error = 1 mm

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