Getting Started with 3D Time-of-Flight Sensing

Session 3
Understanding the system trade-offs
What’s In the Video Series

Session 1: 3D Time-of-Flight Sensor Theory of Operation
Session 2: Recommended Design Process and Leveraging Available Design Resources
Session 3: Understanding the System Trade-Offs
Session 4: Lens Calibration
Session 5: System Offset Calibration
Session 6: Illumination Subsystem Design and Component Selections
Session 7: PCB Design and Layout Considerations
Session 8: Optical Design and Lens Selection Considerations
Session 9: Embedded Processor Selection and Integration
Session 10: Time-of-Flight Image Filtering
Session 11: Integrating TOF and RGB Camera
Session 12: Using VoxelViewer
Session 13: Introduction to Voxel SDK
Session 14: Operating in High-Ambient Environment
Session 15: Multi-Camera Operation
Session 16: Application Deep Dive – People Counting
Session 17: Application Deep Dive – Robot Navigation
Session 18: Application Deep Dive – Gesture Control
Session 19: Application Deep Dive – Scanning
Depth Sensing Quality

\[ \sigma = \frac{c}{4\sqrt{2\pi} f} \cdot \frac{\sqrt{B + A}}{c_d A} \]

\( \sigma \) Depth variance

\( A \) Amplitude

\( B \) Offset

\( c \) Speed of Light

\( f \) Modulation Frequency

\( c_d \) Modulation Contrast

Payne et al. “Multiple Frequency Range Imaging to Remove Measurement Ambiguity”
Amplitude Tradeoffs

- Amplitude ($A$)
- Offset ($B$)
- Speed of Light ($c$)
- Modulation Frequency ($f$)
- Modulation Contrast ($c_d$)
- Depth variance ($\sigma$)

**Reflectivity**

**Distance**

$$I = \frac{1}{d^2}$$

**FOV**

**Optics**

**Power**

**Frame Rate**

**Directions of increasing accuracy**
Offset Tradeoffs

\[ \sigma \quad \text{Depth variance} \]
\[ A \quad \text{Amplitude} \]
\[ B \quad \text{Offset} \]
\[ c \quad \text{Speed of Light} \]
\[ f \quad \text{Modulation Frequency} \]
\[ c_d \quad \text{Modulation Contrast} \]
Modulation Frequency Tradeoffs

\( \sigma \) Depth variance

\( A \) Amplitude

\( B \) Offset

\( c \) Speed of Light

\( f \) Modulation Frequency

\( c_d \) Modulation Contrast
Modulation Contrast Tradeoffs

\[ \sigma \quad \text{Depth variance} \]
\[ A \quad \text{Amplitude} \]
\[ B \quad \text{Offset} \]
\[ c \quad \text{Speed of Light} \]
\[ f \quad \text{Modulation Frequency} \]
\[ c_d \quad \text{Modulation Contrast} \]

Directions of increasing accuracy

\( \sim 20\text{MHz} \)

NIR LED

\( \sim 50\text{MHz} \)

TOF Imaging Sensor

Power
Depth Sensing Quality (more detail)

\[
\delta D = \frac{c}{2 \times f_m} \times \sqrt{\frac{\frac{1}{q} \times (P_A + P_{BGL}) \times A_{pix} \times t_{int} + n_{system}^2}{QE \times k_{opt} \times C_{mod}^2 \times \frac{1}{q^2} \times P_A^2 \times A_{pix}^2 \times t_{int}^2}} \times f(\phi)
\]

\(\delta D\)  \quad \text{Depth accuracy}

\(P_A\)  \quad \text{Back-scattered signal power (reflection)}

\(P_{BGL}\)  \quad \text{Background signal power (ambient)}

\(A_{pix}\)  \quad \text{Pixel area}

\(t_{int}\)  \quad \text{Integration time}

\(C_{mod}\)  \quad \text{Modulation contrast}

\(k_{opt}\)  \quad \text{Optical constant}

\(n_{system}\)  \quad \text{Systematic noise}
System designer tool

- Complete system modeling from illumination to sensor to depth processing
- Provides insight into accuracy, illumination power and other tradeoffs; enables exploring what-if scenarios
- Outputs detailed graphs and reports for multiple configurations
- Available as a Windows application
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What’s Next?

• Contact your local TI Sales Representatives or Distributors

• E-Mail support@ti.com for any questions.

• Visit http://www.ti.com/3dtof for more information.

• Check out http://e2e.ti.com/support/sensor/optical_sensors/

• Check out http://github.com/3dtof