Innovate in Industrial and Optical Sensing Applications using award-winning DLP® Technology

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Agenda

• Introduction

• DLP Technology in Industrial Applications

• Optical sensing - 3D Machine Vision
  o DLP technology benefits
  o Development platforms

• Optical sensing - Spectroscopy
  o DLP technology benefits
  o Development platforms

• Q&A
TI DLP® Products: a History of Innovation

1987
Dr. Larry Hornbeck invents digital micromirror device (DMD), known as the DLP® chip

1996
First commercial DLP system ships; enables first ultra portable projector

1998
DLP Products receives first Emmy Award for Outstanding Achievement in Engineering Development

2004
DLP Products becomes highest volume MEMS supplier worldwide

2009
Consumer devices begin to ship worldwide featuring DLP Pico™ technology based projectors

2011
Half of all movie theatres converted from film to digital enabled by DLP Cinema® technology

2012
New DLP development kit launches allowing developers to use DLP technology in new markets

2013
Increasing adoption of DLP Pico solutions

2015
First automotive-qualified DLP chipset for head-up display (HUD) applications

For more than two decades, award-winning DLP Product innovations have solved some of the world’s most complex display and light control applications.
DLP MEMS technology enables many industrial non-display applications

The DMD is a fast, efficient, and reliable spatial light modulator (SLM) offering:

1) High Speed Switching – Switching of the mirrors at up to 32kHz
2) Extended Wavelength – Supporting UV and near-infrared (NIR) in addition to Visual spectrum
3) Wavelength Selection – Direct and modulate specific wavelengths of light through programmable pixel mapping

Works with lamps, LEDs, and Lasers

DLP Capabilities (Today)

- Deep UV: 363 nm
- Ultra-Violet: 420 nm
- Visible: 700 nm
- Near-Infrared: 2500 nm
“Hundreds” of Applications are possible

| Industrial | Test & Measurement  | • 3D Depth Measurement  |
|           |                    | • Spectrometers        |
|           |                    | • Food Inspection      |
|           |                    | • Fluid Analyzers      |
| Lighting  | • Stage Lighting   | • Adaptive Illumination|
| Display & Digital Signage | • Advanced 3D Displays | • Planetariums |
| Medical, Healthcare & Fitness | • 3D Dental Scanners | • Pharmaceutical Controls |
|          |                    | • Vascular Imaging     |
|          |                    | • Ophthalmology        |
|          |                    | • Hyperspectral Imaging|
|          |                    | • Phototherapy         |
|          |                    | • Microscopes          |
| Other Industrial | • PCB Lithography | • Flat Panel Lithography|
|           |                    | • LCD Repair           |
|           |                    | • Computer-to-Plate Printing|
|           |                    | • 3D Printers          |
|           |                    | • Laser Marking        |
| Factory Automation & Control | • 3D Machine Vision | • Inline Surface Inspection|
|           |                    | • Pick & Place         |
|           |                    | • Inline Chemical Process Control|
| Communication Equipment | Telecom Infrastructure | • Reconfigurable Optical Add-Drop Multiplexers (ROADM)|
|           | • Wavelength Selective Switches (WSS) | • Variable Optical Attenuators (VOA)|
| Personal Electronics | Printers & Other Peripherals | • 3D Printers |
DLP Technology – Industrial Focus Areas

3D Machine Vision Sensing
- Optical sensing
- Spectroscopic sensing

3D Printing

Lithography
Optical sensing – 3D Machine Vision
Introduction to 3D Machine Vision

What is 3D Machine Vision?

3D measurement is a fast and accurate way of gathering physical measurements of an object onto a computer in an organized manner, resulting in 3D scan data.

Once the scan data is on the computer, all of the dimensions of the object can be taken, such as length, width, height, volume, feature size, feature location, surface area, etc.

Where is 3D Machine Vision Used?

Location & Guidance
Measure & Inspect
Biometrics
Automated Optical Inspection
Medical Imaging
3D Machine Vision with Structured Light

- Patterns projected on an object inherently create identifiable features
- A camera triggered to each pattern captures these features
DLP Programmable Patterns

Programmable Patterns allow users to gain **full control** over the Structured Light System

Multiple patterns
- Binary Code
- Gray Code or N-ary Codes
- Phase Shift

Adaptive Patterns
- Varying Color/Light and Pattern depending on object response and movement

Hybrid Patterns
- Combination of several patterns
3D Machine Vision System Block Diagram
DLP Structured Light SDK

A Complete 3D Machine Vision Development Software Solution

**DLP Platform**
- Generate high speed programmable binary Gray code patterns

**Calibration**
- Projector and camera calibration generates system geometry

**Camera**
- High-speed synchronized captures

**Structured Light**
- Decode Gray coded patterns to generate disparity map

**Geometry**
- Reconstruct 3D point clouds

The DLP 3D Structured Light SDK can also be utilized on smaller (DLP LightCrafter™) and larger (DLP LightCrafter™ 6500) resolution DLP Evaluation Modules (EVMs) for portable and high resolution 3D scanning applications.
Accurate Point Cloud Generation for 3D Machine Vision Applications using DLP Technology

• Provides a 3D scanner software solution to shorten development time with DLP technology

• No software or optical development required for evaluating DLP technology for generating 3D point clouds!
  – Generates and decodes structured light patterns
  – Calibrates camera and projector

• Available design files
  – Schematic (http://www.ti.com/lit/pdf/tidr157)
  – Bill of Materials (http://www.ti.com/lit/pdf/tidr958)
  – Command-line 3D Scanner with DLP Structured Light SDK (http://www.ti.com/lit/zip/tidc535)

• Available from TI Designs
Where to Find Software, the BOM, and the Trigger Cable Assembly Guide?

1. Go to the TIDA-00254 tool page (http://www.ti.com/tool/TIDA-00254)
2. Software installer listed under Download Design Files button (executable for SDK)
3. Schematic and BOM listed under their respective buttons
Where is the 3D Scanner Application and DLP Structured Light SDK source code?

1. One tool page on ti.com for three DLP Lightcrafter EVM and controller platforms: (http://www.ti.com/tool/dlp-alc-lightcrafter-sdk)

DLP6500 1080p 3D Scanner TI Design (TIDA-00362)

- Complete set of design files
- Mechanical schematic of metal frame
- Preliminary calibration for quick evaluation
- Executable calibration and scanning program
- TI test results using this exact design
- Access to SDK
### Structured Light for PCB AOI Inline Inspection

#### How it Works

- Example system with four projectors to capture micron scale features on a PCB

#### Why choose DLP technology?

<table>
<thead>
<tr>
<th>DLP Feature</th>
<th>System Benefits</th>
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</thead>
</table>
| High speed programmable patterns up to 1KHz with 8-bits grayscale pre-stored patterns | • Area based measurement  
• Short scanning time  
• Extreme flexibility in generating patterns |
| Customized DLP hardware and software reference design | • High system lumen efficiency without the need of polarizer  
• Compact solution for size/cost reduction  
• Reduced R&D effort |
| Optical MEMS with product longevity              | • Great pattern quality with high on/off contrast ratio  
• Uniform mirrors providing excellent grayscale linearity and repeatability  
• Proven technology with shipment in millions |
| Strong DLP ecosystem                             | • Quicker time-to-market with support from DLP Design Network partners  
• Lower R&D Investment |
Optical sensing - Spectroscopy
Spectroscopy

- Spectroscopy is a powerful technique for recognizing and characterizing physical materials. It measures variations in absorption or emission for different wavelengths of light. Spectroscopy determines the degree of light interacting with the material and produces a signature known as a spectrum; the variation of light intensity as a function of wavelength.

- Example of a spectra for various plastics/polymers showing their spectral differences

- Spectrometers are used in:
  - Pharmaceuticals
  - Food
  - Agriculture
  - Petrochemical
  - Automotive Fluids
  - Manufacturing: QA/QC
  - Medical diagnostics
  - Security/counterfeit detection
  - Law Enforcement and forensics
Electromagnetic/Light Spectrum

- Spectroscopy utilizes the light from the ultraviolet (UV) to the near-infrared (NIR):

- Light energy in the near infrared region causes molecular chemical bonds to vibrate at specific frequencies. Overtones of those frequencies are observed from 650nm to 2600nm.

- There are three important and diagnostic functional groups of NIR overtones:
  1. **Hydroxy functional group**: -OH
     - Found in Water/Moisture, Carbohydrates, Sugars, Alcohols, Glycols, etc.
  2. **Amino functional group**: -NH₂
     - Found in Proteins, Polymers (Nylons, Urethanes, etc.), Dyes, Pharmaceuticals, etc.
  3. **Alkyl/Aryl functional group**: C-H aliphatic and aromatic hydrocarbons
     - Found in Fats/Lipids, Fuels, Plastics and Polymers, etc.
The following major overtones or harmonics observed in the NIR spectral region result from compounds featuring these functional groups.

Relative absorbance decreases by approximately an order of magnitude with each overtone.

Source: Metrohm “NIR Spectroscopy: A guide to near-infrared spectroscopic analysis of industrial manufacturing processes”
NIR Photodetectors

- Detection of these major overtones depends on photodetector technology:

![Diagram showing different types of detectors and their wavelength ranges.]

Silicon Detectors (650 - 1100 nm)
Standard InGaAs Detectors (900 - 1700 nm)
Extended InGaAs Detectors (1300 - 2600 nm)

Source: Metrohm "NIR Spectroscopy: A guide to near-infrared spectroscopic analysis of industrial manufacturing processes."
DLP Technology-Based Spectroscopy

Current technology: InGaAs linear array

DLP technology-based: DLP chip + single point InGaAs
# DLP Technology-Based Advantages

<table>
<thead>
<tr>
<th>Linear Array Technology</th>
<th>DLP Technology-Based</th>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear InGaAs array detector have small pixels: 7.8 - 30 um wide x 125 - 500 um tall</td>
<td>Large InGaAs detector pixel: 1 - 2 mm diameter</td>
<td>Higher Performance</td>
</tr>
<tr>
<td>Linear InGaAs array detector with limited pixels: 128, 256, 512, or 1024</td>
<td>Pixels limited by DLP micromirror array size: • 854 x 480 on DLP2010NIR • 912 x 1140 on DLP4500NIR</td>
<td>Higher Performance</td>
</tr>
<tr>
<td>Not programmable</td>
<td>Programmable: • Variable Intensity • Variable Integration Time • Resolution • Complex Hadamard Patterns • Custom Spectral Filters • Compensate Optical Distortion and Physical Misalignment</td>
<td>Higher Performance</td>
</tr>
<tr>
<td>Linear InGas photodetector cost: $1500 - $5000</td>
<td>DLP micromirror + single pixel InGaAs cost: $200 - $700</td>
<td>Lower Cost</td>
</tr>
</tbody>
</table>
DLP Mobile Spectroscopy EVM

- Illumination module
- Optical engine
- Detector board
- Sample window
- DMD board
- DLPC150 board
- Tiva™ board
Sampling Methods

- **Transmission/Transmittance**
  - Used for liquids, films, transparent, and translucent materials
    - Oils, fuels, solvents, polymers/plastics, solutions, etc.
    - Light directed through the sample and then captured by the system

- **Reflection/Reflectance**
  - Used for solids, powders, and polymers
  - Light directed onto the surface of the solid and then the reflected light is captured by system

- **Transflectance**
  - Used for liquids, slurries, gels, pastes, polymers, and thin coatings on metals
  - Used in dip-probe configuration with a fiber optic cable
  - Light directed through the sample and reflected by the background material, passing through the sample twice

- **Fiber Optic Interfacing**
  - Used for remote sampling
  - Combines a light source and sample capture in one fiber bundle
  - Transfers the light from the sample back into the system
DLP NIRscan™ Nano EVM functions as a mobile NIR spectrometer!
Spectroscopy Applications: Food

- NIR Spectroscopy can perform many measurement tasks in the food industry.
- Examples of these tasks are:
  - **Quality assessment** of food by reporting:
    - Moisture
    - Carbohydrates, Sugar content (BRIX)
    - Proteins
    - Fat
    - Alcohol content for alcoholic beverages
  - **Confirmation** of the authenticity of oils and syrups
  - **Detection** of counterfeits or adulterations in food
    - Detection of unexpected flavor components in high value samples, such as olive oil, honey, and maple syrup
    - Measurement of saturation and trans-unsaturation in oil products
    - Detection of toxic or non-nutrient materials, such as melamine as a protein enhancer or “nitrogen booster” in food products (cereals, pet foods, dairy products, etc.)
# Example NIR Spectral Signatures in Food

<table>
<thead>
<tr>
<th>Food</th>
<th>Sampling Method</th>
<th>Signature</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>Dip Probe</td>
<td>Fats, Melamine, Fillers</td>
<td>1400 - 1700 nm</td>
</tr>
<tr>
<td>Butter, Cheese, and Yogurt</td>
<td>Contact</td>
<td>Sugars, Proteins, Fats/Lactose</td>
<td>1100 - 1600 nm</td>
</tr>
<tr>
<td>White, Milk, and Dark Chocolate</td>
<td>Contact</td>
<td>Sugars, Fats</td>
<td></td>
</tr>
<tr>
<td>Meat Products</td>
<td></td>
<td>Water, Proteins, Fat</td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td></td>
<td>Proteins, Fats, Oils</td>
<td></td>
</tr>
<tr>
<td>Soft Drinks</td>
<td></td>
<td>Sugar, CO₂</td>
<td></td>
</tr>
<tr>
<td>Juices</td>
<td>Dip Probe</td>
<td>Sugars</td>
<td></td>
</tr>
<tr>
<td>Syrups</td>
<td></td>
<td>Sugars, Water</td>
<td>1100 - 1700 nm</td>
</tr>
<tr>
<td>Wine Fermentation Process</td>
<td></td>
<td>Sugars, Acid, Alcohols</td>
<td></td>
</tr>
<tr>
<td>Beer Brewing Process</td>
<td></td>
<td>Sugars, Alcohols</td>
<td></td>
</tr>
<tr>
<td>Oils</td>
<td></td>
<td>Poly/Transunsaturated Fats</td>
<td></td>
</tr>
<tr>
<td>Produce Inspection</td>
<td>Contact and Non-Contact</td>
<td>Water, Sugars, Proteins, Fats/Lactose</td>
<td></td>
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</tbody>
</table>
Development Platforms and Reference Designs for Faster Development
## Development Resources and links

### Silicon – Extensive portfolio

13 DMD chips for non-display optical sensing applications

**Featured Applications**


### Development Platforms and Software

Several EVMs starting at $599


### TI Designs and reference designs

http://www.ti.com/tool/TIDA-00362

http://www.ti.com/tool/TIDA-00554

Extensive 3P network **worldwide** 20+ companies with 40+ solutions

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