MOBILE
Agenda

- Hands-On List
- Proliferation of Mobile
- Screen Technology
- Cameras
- Internal Components
- Networks
- Form Factors
- Software
Hands-On

Amazon
- Kindle Touch 3G
- Kindle HDX
- Kindle Fire 9 HD

Apple
- iPad Air
- iPad Mini
- iPhone 5C
- iPhone 5S
- iPhone 5

ASUS
- Nexus 7 (2013)
- Transformer

LG
- Nexus 5
- Nexus 4
- G2
- G Flex

Motorola
- Moto X
- Droid MAXX

Others
- BlackBerry Z10 & Q10
- HTC One
- Nokia Lumia 920
- Microsoft Surface Pro 2
- Dell Venue 8 Pro
- Lenovo ThinkPad Tablet 2

Samsung
- Galaxy Note 2
- Galaxy Note 3
- Galaxy Note 8
- Galaxy Note 10.1
- Galaxy Gear
- Galaxy S4
- Nexus 10
Smartphone Product Announcements

- Apple
- Samsung
- Samsung (WP)
- LG
- LG (WP)
- HTC
- HTC (WP)
- Motorola
- Sony
- Nokia (WP)
- Nokia (Android)
- BlackBerry

Graph showing the number of product announcements per year for each company from 2008 to 2014.
Display Technology
Some Examples

- Apple iPhone 5S – 4” 16:9 LED-Backlit IPS TFT 1136x640 ‘Retina’ LCD
- Samsung Galaxy S5 – 5.1” 16:9 Pentile RGBG Full HD Super AMOLED
- Nokia Lumia 1020 – 4.5” 15:9 AMOLED RGBG Pentile ClearBlack
- HTC One – 4.7” 16:9 Full HD Super LCD 3 RGB Matrix
- Motorola Moto X – 16:9 4.7 HD AMOLED
- Amazon Kindle Paperwhite – 6” Carta e-paper technology
Terminology

• LCD: Liquid Crystal Display
  • S-LCD: Super
  • TFT: Thin Film Transistor
  • IPS: In-Plane Switching
• OLED: Organic Light-Emitting Diodes
  • AMOLED: Active-Matrix Organic Light-Emitting Diodes
    • SAMOLED: Super
• Epaper
• Mirasol

Keywords

• Bezel
• Contrast Ratio
• Viewing Angle
• Black Level
• Nits
• Burn-in
• Resolution
• Color gamut
• Oleophobic
• Ultrasensitive
• Subpixels
  • RGB
  • PenTile (RGBG, RGBW)
LCD vs OLED
LCD vs OLED

YOUM

- Thinner
- Lighter
- Unbreakable

OLED

- Polariser
- Encap(Glass)
- Organic Layer
- TFT(Glass)
## LCD vs OLED

<table>
<thead>
<tr>
<th>Feature</th>
<th>LCD</th>
<th>OLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backlight</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Power Efficiency</td>
<td>Yes (white)</td>
<td>No (black)</td>
</tr>
<tr>
<td>Thickness</td>
<td>Thicker</td>
<td>Thinner</td>
</tr>
<tr>
<td>Weight</td>
<td>Heavier</td>
<td>Lighter</td>
</tr>
<tr>
<td>Black Level</td>
<td>Dark Grey</td>
<td>Black</td>
</tr>
<tr>
<td>Color Accuracy</td>
<td>Superior</td>
<td>Above 1M:1</td>
</tr>
<tr>
<td>Contrast Ratio</td>
<td>15K:1</td>
<td>Better in Darkness</td>
</tr>
<tr>
<td>Brightness</td>
<td>Better in Sunlight</td>
<td>More Glare</td>
</tr>
<tr>
<td>Viewing Angle</td>
<td>60% decrease @ 30°</td>
<td>20% decrease @ 30°</td>
</tr>
<tr>
<td>Motion Blur</td>
<td>1-16ms response</td>
<td>&lt;.01ms response</td>
</tr>
<tr>
<td>Life Span (Burn-in)</td>
<td>~10 Years</td>
<td>~5 Years</td>
</tr>
<tr>
<td>Cost</td>
<td>$$$$</td>
<td>$$$</td>
</tr>
<tr>
<td>Sub pixel Arrangement</td>
<td>RGB</td>
<td>RGB, Pentile (RGBG, RGBW)</td>
</tr>
<tr>
<td>Variants</td>
<td>Super LCD, IPS</td>
<td>Super AMOLED</td>
</tr>
</tbody>
</table>
Have an AMOLED display? Use Dark Apps & Backgrounds
Resolution

- **SD**: 720 x 576
- **HD**: 1280 x 720
- **FHD**: 1920 x 1080
- **QHD**: 2560 x 1440
- **UHD**: 3840 x 2160
- **4K**: 4096 x 2160
LCD vs OLED (Subpixels)
RGB vs PenTile RGBW
Inverse-tan(.5/11)=2.60°

11 inches
14.2 inches
two inches
half inch
one inch

iPhone 4 display - 326 PPI - 62.6 PPD

22 inches

3.7” OLED 800x480 display - 252 PPI - 62.6 PPD

20/20 eye limit = 30 cycles per degree
Theoretical eye limit = 50 cycles per degree
YOUR CENTRAL VISUAL FIELD

COLOR VISION:
- WE DON'T SEE MUCH COLOR OUTSIDE THE CENTER OF OUR VISION - OUR EYES KEEPER TRACK OF WHAT OUR THINGS ARE AND TELL IT IN FORKS.
- SATURATION INDICATES COLOR RECEPTOR DENSITY
- WE HAVE FEW BLUE-SENSITIVE CONE CELLS, BUT THEY'RE FOUND OUT AT THE EDGE OF OUR VISION.
- BLUE-SKY SPRITES: THESE SUNNY, DARING BRIGHT SPOTS, VISIBLE AGAINST SMOKE BLUE BACKGROUNDS, ARE WHITE CELLS MOVING IN THE BLOOD VESSELS OVER THE RETINA.
- FLOATERS: SOME TYPES OF FLOATERS ARE CAUSED BY BREAKDOWN OF YOUR EYEBALL COAT AS YOU AGES, BUT THIS TYPE IS SOMETHING KIND OF DESIRS NEAR THE RETINA. I DON'T KNOW WHAT.

LEFT EYE BUND SPOT

RIGHT EYE BUND SPOT

DETAI
- ONLY SEE AT HIGH RESOLUTION OVER A SMALL AREA IN THE CENTER OF OUR VISION WHERE RETINAL CELLS ARE DENSEST (HIGHLIGHT).
- IF YOU STARE AT THE CENTER OF THE MARKERS, YOUR EYES ARE SEEING ALL THESE PANELS AT ROUGHLY THE SAME LEVEL OF DETAIL.
- NORMAL LIGHT
- LOW LIGHT
- CONE CELLS (HUMAN COLOR VISION) DON'T WORK IN LOW LIGHT, BUT RED CELLS (MONOCHROME, LUMEN-RES, NON-CENTRAL) DO. THIS IS WHY YOU CAN MAKE OUT THINGS IN DAY LIGHT, BUT NOT READ. IT'S WHY YOU CAN SPOT A FIRE BY LOOKING NEXT TO THEM.
- HUMANS CAN SEE POLARIZATION - STARE AT A WHITE AREA ON AN LCD DISPLAY WHILE ROTATING IT (OR YOUR HEAD) LIKE THIS: 

* NOT PICTURED: T-FOOD BUND SPOT, CHILLO BUND SPOT.
Higher Density Displays: Coming Very Soon

- LG QuadHD Display
  - Announced 8/21/13
  - AH-IPS LCD
  - 2560x1440, 5.5”
  - 538 PPI
  - 1.21 mm thin
  - 1.2 mm bezel

- Impact
  - Exceeds visual limit?
  - Battery life?
  - Higher screen size to device ratio
ePaper

Appearance of pixels (seen from above through transparent electrode layer)

- Transparent Electrode Layer
- Liquid Polymer Layer Containing E-ink Capsules
- Lower Electrode Layer
Make More Sense?

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  • RGB
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Camera Technology
Some Examples

- Apple iPhone 5S – 8MP Dual LED 1/3” BSI F/2.2 DIS
- Samsung Galaxy S5 – 16MP LED 1/2.5” F/2.2 DIS
- Nokia Lumia 1020 – 41MP LED/Xenon 1/1.5” F/2.2 OIS
- HTC One – 4MP LED 1/3” F/2.0 OIS
- Motorola Moto X – 10MP LED 1/2.6” F/2.4 DIS
Terminology

- Attributes
  - Aperture
  - Resolution
  - Sensor Size
  - Pixel Pitch
  - Shutter Speed
  - Sensitivity (ISO)
  - Back-Illuminated Sensor (BSI)
  - Flash
    - LED (Dual LED)
    - Xenon
  - Video recording
    - 4K
- Technologies
  - Image Stabilization
    - Optical (OIS) vs Digital
  - Lytro
  - Attachables
- Software Improvements
  - HDR
  - SlowMo/Frame Rate
  - HTC Zoe
  - Nokia Pro Cam
Sensor Size

<table>
<thead>
<tr>
<th>Relative Sensor Size</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1.2&quot;</td>
<td>Nokia 808</td>
</tr>
<tr>
<td>1/1.5&quot;</td>
<td>Nokia Lumia 1020</td>
</tr>
<tr>
<td>1/1.83&quot;</td>
<td>Nokia N8</td>
</tr>
<tr>
<td>1/2.3&quot;</td>
<td>Sony Xperia Z1</td>
</tr>
<tr>
<td>1/2.3&quot;</td>
<td>Galaxy S4 Zoom</td>
</tr>
<tr>
<td>1/3&quot;</td>
<td>HTC One</td>
</tr>
<tr>
<td>1/3&quot;</td>
<td>Nokia Lumia 920</td>
</tr>
<tr>
<td>1/3&quot;</td>
<td>Apple iPhone 5s</td>
</tr>
<tr>
<td>1/3.2&quot;</td>
<td>Samsung Galaxy S4</td>
</tr>
<tr>
<td>1/3.2&quot;</td>
<td>HTC One X</td>
</tr>
<tr>
<td>1/3.2&quot;</td>
<td>Nokia N9, Lumia 800</td>
</tr>
</tbody>
</table>
Pixel Size

- HTC: ≤ 4 μm²
- 13MP: ≤ 1.3 μm²
- 8MP: ≤ 2 μm²
- 4MP: ≤ 11 μm²

Leading Competition
Aperture

f/2.6
Galaxy S3

f/2.4
iPhone 5

f/2.0
HTC
OIS (Optical Image Stabilization)
Nokia Lumia 1020
Lytro

A complex arrangement of lenses captures all incoming light, preserving as much optical data as possible.

A sensor fitted with a microlens array records the color, light, and direction of about 11 million light rays.

A processor converts information from the sensor into a database that can be analyzed to extract images.
Lytro in Smartphones?
QX100

• 1" sensor
• 3.6x f/1.8 Carl Zeiss Optical zoom lens
• Connects to your smartphone
• NFC/Wi-Fi for smartphone connection
• Manually control shots via smartphone display
• Saves images on both camera and phone
• High-quality 1080/30p HD video with lower noise
Nokia Pro Cam

White Balance  Sensitivity  Exposure
Capture the Right Moment
Terminology

• Attributes
  • Aperture
  • Resolution
  • Sensor Size
  • Pixel Pitch
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• Software Improvements
  • HDR
  • SlowMo/Frame Rate
  • HTC Zoe
  • Nokia Pro Cam
Internal Components
Terminology

- CPU – Central Processing Unit
- SoC – System on a Chip
- RAM – Random Access Memory
- Bluetooth
- WiFi – Wireless Fidelity
- NFC – Near Field Communications
- Qi Wireless charging – Magnetic Induction
- Sensors
Faster Processors, More RAM

64-bit
World’s first and only smartphone

2-step approach:
- AP with ARM’s 64-bit core
- AP with Samsung’s own 64-bit core

64-bit Snapdragon
by Qualcomm
SoC vs CPU

The CPU is only ~15% of a modern SoC

- KRAIT CPUs
- MULTIMEDIA (Audio, video, and gestures)
- ADRENO GPU
- CONNECTIVITY (4G LTE, WiFi, USB, BT and FM)
- HEXAGON DSP
- DISPLAY/LCD
- SENSORS
- ISPs
- IZat NAVIGATION

Basic computing

Innovative user experiences

Always on

Required for mobile
Qualcomm Snapdragon

Krait 400 CPU features 28nm HPM process technology, superior 2GHz performance

Adreno 330 for advanced graphics

Hexagon QDSP6 for ultra low power applications and custom programmability

Integrated 802.11ac, USB 3.0 and BT 4.0 offers broad array of high-speed connectivity

Ultra HD Capture and Playback
DTS-HD and Dolby Digital Plus audio
Expanded Gestures

55MP with dual ISP
Support for up to 2560x2048 display
Miracast 1080p HD support

IZat GNSS with support for three GPS constellations

600 PROCESSOR

Krait 360 CPU provides improved, sustained performance in a mobile power profile

Speed enhanced Adreno 320 GPU

Hexagon QDSP6 for ultra low power applications

Integrated 802.11ac, USB 2.0 and BT 4.0 offer broad array of high-speed connectivity

1080p HD Capture and Playback
DTS-HD and Dolby Digital Plus audio

Up to 21MP

Support for up to 2560x1536 + 1080p external display

IZat GNSS
Motorola X8
Apple M7

Continuously measures motion data

Accelerometer, gyroscope, compass

Enables a new generation of health and fitness apps
Apple M7

Bosch Sensortech BMA220 3-axis accelerometer
STM 3-axis gyroscope

AKM's AK8963 Compass IC

M7 Co-Processor
NXP LPC18A1
Sensors

- GPS
- WiFi
- Bluetooth
- Accelerometer
- Gyroscope
- Magnetometer
- Barometer
- Proximity
- Light Sensor
Hidden Innovation in the GALAXY S4

GALAXY S4 gets you closer to what matters in life, bringing your world together.

- **Gesture Sensor:** Recognizes the user’s hand movements using infrared rays
  - Air Gesture

- **Proximity Sensor:** Recognizes whether the mobile phone is located near the user by using infrared rays
  - Direct Call

- **RGB Light Sensor:** Measures the red, green, blue, and white intensity of the light source
  - Samsung Adapt Display

- **Hall Sensor:** Recognizes whether the cover is open or closed
  - S View Cover

- **Barometer:** Identifies the atmospheric pressure at the user’s current location
  - S Health: Walking Mate

- **Gyroscope (Gyro Sensor):** Detects the mobile phone rotation state based on three axes
  - Smart Rotation

- **Accelerometer:** Detects the mobile phone movement state based on three axes
  - S Health: Walking Mate

- **Magnetometer (Geomagnetic Sensor):** Detects magnetic field intensity based on three axes
  - Digital Compass MAP

- **Temperature and Humidity Sensor:** Checks temperature and humidity levels
  - S Health: Comfort Level
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• Sensors
Form Factor
Terminology

• Modular Design
• Curved/Flexible
• Hardened
  • Water/Dust Proof
Form Factor (Size)

- **Tablet**: >9"
- **Small Tablet**: 7”<9"
- **Phablet**: 5”<7"
- **Smartphone**: <5”
Modular Devices
Curved and Flexible Displays
Hardened Devices

• Flexible
• Water Proof
• Self-healing
Terminology

• Modular Design
• Curved/Flexible
• Hardened
  • Water/Dust Proof
Networks
Terminology

- LTE
  - VoLTE
  - LTE-A
- HSDPA+
- GSM
- CDMA
- WIMAX
LTE – Worldwide Adoption (2013)
Software
Terminology

• Android skins
  • Samsung TouchWiz Nature UX 2.5 & Magazine UI
  • HTC Sense 5
  • LG
  • Motorola
  • Sony Xperia UI

• Launcher

• ROM

• Root/Jailbreak

• Voice Controls
Motorola Software – Capability Requirements

• AMOLED Screen
• SoC Always-On Cores
  • Language
  • Contextual Computing
Latest OS Updates
Apple iOS

• Redesigned UI
• Added features
  • Multitasking
  • Notifications
  • Enterprise
• Activation Lock

App Store license management.
The App Store Volume Purchase Program now offers businesses the ability to assign apps to their users while keeping full ownership and control over app licenses.
Taking Back Android

- Google has begun to implement rolling releases for critical components of Android.
- Doing so improves the efficiency of over-the-air (OTA) updates.
- Now has 64 applications in the Play store.
Samsung
Human Interface

- No digging required.
  Cards appear when they’re needed most, organizing the things you need to know and freeing you up to focus on what’s important to you.

- Get just the right information, at just the right time.
  Just swipe up, and you’ve got the latest information you want to see, when you want to see it.

- Next appointment:
  Lunch with Bred @ 1:30pm

- You’re in control.
  Choose exactly which cards you see. You control whether you get personalized results from your calendars, locations and searches after opting in.

- Siri. Beta
  Siri makes your device smarter, more helpful and more personal.
Q&A
Thank You!

Ted Moskalenko
TedMosk@isc.upenn.edu
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- Kindle HDX
- Kindle Fire 9 HD

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Other Trends and Data