HMI Sensors: The Next Frontier

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About Qorvo…

**Diversified and Above-Market Growth**

- Well established supplier in the wireless, wired, power and automotive market
- Strong technology leadership combined with high volume manufacturing capabilities
- 2015 merger of TriQuint & RF Micro Devices
- 2021 acquired: NextInput for HMI Sensors
- 2023 revenue: $3.6 billion
- 8,500+ global employees
- An S&P 500 company – Nasdaq: QRVO
- Recognized by the Global Semiconductor Alliance (GSA) as the most respected public semiconductor company in 2022

Source: Industry reports and management estimates.
Our Global Footprint

1. Hillsboro, OR
2. Bond, OR
3. Plymouth, MN
4. Waseca, MN
5. Hiawatha, IA
6. Princeton, NJ
7. Chelmsford, MA
8. Mountain View, CA
9. San Jose, CA
10. Torrance, CA
11. Newbury Park, CA
12. Chandler, AZ
13. Farmers Branch, TX
14. Richardson, TX
15. Greensboro, NC
16. Apopka, FL
17. Fort Lauderdale, FL
18. Heredia, Costa Rica
19. Dublin, Ireland
20. Reading, United Kingdom
21. Paris, France
22. Colomiers, France
23. Toulouse, France
24. Nice/Sophia-Antipolis, France
25. Zele, Belgium
26. Utrecht, Netherlands
27. Nørresundby, Denmark
28. Nuremberg, Germany
29. Munich, Germany
30. Helsinki, Finland
31. Bangalore, India
32. Dezhou, China
33. Beijing, China
34. Seoul, South Korea
35. Osaka, Japan
36. Shanghai, China
37. Taipei, Taiwan
38. Zhubei City, Taiwan
39. Zhongshan, China
40. Shenzhen, China
41. Hong Kong, China
42. Hanoi, Vietnam
43. Ipoh, Malaysia
44. Singapore
45. Biñan, Philippines

NextInput => SFBU
Agenda

Background of HMI Sensors

HMI Sensor Applications

Technical Details

Examples

Q&A
Background of HMI Sensors

Human-Machine Interface Sensors
First Market Driver – Apple’s Innovation (The Start)

Cap (Capacitive) Touch or Force Touch by Apple

iPhone 6s first featuring Force Touch Technology

- Requires a solid back plate to host the capacitive sensing array
- Sensitivity changes significantly if structure deforms
- High manufacturing cost

Capacitive sensors in iPhone 6s
Qorvo’s HMI Sensor Solution (The Next)

Force Sensor by Qorvo (for Blackshark Gaming Phone)

- Requires a solid back plate
- Sensitivity changes after deformation
- High manufacturing cost

Improvements:
- Flexible design
- Less changes when deformed
- Less costly

Capacitive sensor array in iPhone 6s
HMI Sensors Applications
Smart Phone/Watch, TWS, Automotive etc.
Benefits of the Force Sensing in HMI

Comparing to Mechanical Buttons / Capacitive Sensors

Limit false touches:
- Limiting false touch with customizable multiple force levels
  Example: Smart phones/watches, Smart screen on cars
- When you cannot see it, you must apply some force
  Example: TWS earbuds

Allow seamless interface:
- Sense through gapless metal
  Example: headphones, earbuds
- Sense glove or in any watery environments
  Example: screen on motorcycles/cars

Add additional user interface:
- Adding “select” feature to a touch screen
  Example: any touch screen in phones/cars
- Deep press, half press slider (PoC for now)
  Example: Smart screen on cars, headphones
Smart Phone Applications

Force Sensor by Qorvo

(Cap+) Force Sensitive Screen

Virtual Button Under Display

Seamless Side Slider

Localized Haptic Button
Consumer, TWS and Automotive Applications

Force Sensor by Qorvo (Products in Production)

- Fitbit Sense/Versa 3
- Charge 6
- Various TWS (True Wireless Stereo)
- Latest Tesla Model S/X and Other Car Models:

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Qorvo Sensor Fusion Solutions

Enabling Innovative Human Machine Interface Solutions

CMOS + PZR MEMS sensors

• Highest sensitivity (up to 200 gauge-factor)
• Smallest size (1.77mm\(^2\), down to 0.9mm\(^2\))
• Lowest power (<10\(\mu\)A operating)
• Multi level actuations

Enabling new human machine interface capabilities

• Any material, shape, thickness (plastic, steel, wood)
• Any input method (finger, glove, stylus)
• Any environment (hot/cold, wet, dirty, grime)
Technical Details

Hardware, Software and System Integration
Force Sensor Mechanism – PZR Transducer

Differential Wheatstone Bridge

Keep features:

- Piezoresistive elements formed by Boron implant
- Inherent common mode rejection/temperature compensation
- Robust sensing technology

Representative Circuit:

\[
Sp = \frac{R + \Delta R}{2R} V_{drv}\\
Sn = \frac{R - \Delta R}{2R} V_{drv}
\]

\[
Sp - Sn = S_v = \frac{\Delta R}{R} V_{drv}
\]
Preloaded Force Sensor (1st Category) Output

Vertical Compression

- Linear Sensitivity: 3.6 mV/V/N
- Saturated Sensitivity: 2.3 mV/V/N
- Linearity: 0.99+
- Range: 10 N
- Bias: 1 - 3.63 V
Suspended Sensor (2\textsuperscript{nd} Category)

Bending

Sensor Structure

Application Example

Force

Sensing Surface

FPC/PCB

Sensor

Stress Distribution

Sensor Chip

Bump
MEMS Force Sensor Families & Stack-up
Flexibility to Meet Sensitivity & Manufacturing Needs of Any Application

Pre-Loaded
(Requires contact on both sides)

Pseudo Pre-Loaded
(Contact on one side)

Suspended
(Contact on one side)

Vertical Compression

Bending
Enablement Tools
Dev-Kits, GUI, Drivers (Software)

MEMS Force
FT-4100PCK

Integrated
DF-8800PCK

NX-10500PCK
Simple Demo with a Brick & the Dev Kit

https://www.youtube.com/embed/IL2_OAJXzDY?feature=oembed&skip_registered_account_check=true
Sensing Solutions

Comprehensive Support to Enable Customer Success

Silicon Sensors
- Discrete, integrated, and hybrid sensors
  - Force
  - Gauge
  - AFE ASIC
  - Integrated Gauge + AFE
  - IR + Gauge + AFE

Software
- Drivers & algos that run on host MCU
  - Button
  - Smartphone
  - Slider
  - Wearables
  - 2D (X/Y)
  - Auto
  - 3D (X/Y/Z)
  - Consumer/IoT

System Integration
- Design examples, service, & support
  - Stack-up reference designs
  - Blackbox sensitivity models
  - Layout & simulation support
  - Electro-mechanical modeling
HMI Sensor Examples & Demos

With or Without Capacitive Touch Sensors
Door Handle – Force Sensor Only (Section View)

Plastic Housing

- Shore 70A Silicone Rubber
- Suspended Force Sensor for Unlock Function
- Suspended Force Sensor for Lock Function
- PCB
- Shore 70A Silicone Rubber

Compressed Rubber is used to ensure contact between PCB and Touch Surfaces.
Capacitive + Force Bracket Floating Concept

Bracket Module

Pre-loaded Force Sensor for Positioning

Sensor Bracket Module

Capacitive Touch Surface