TDK Systems, Acoustics, Waves Business Group (SAW)
TDK Corporation is a leading electronics company. Our portfolio includes electronic components, modules and systems, power supplies, magnetic application products as well as energy devices, flash memory application devices, and others. TDK focuses on demanding markets in the areas of information and communication technology and consumer, automotive and industrial electronics. The company has a network of design and manufacturing locations and sales offices in Asia, Europe, North and South America.

### TDK at a glance

**Key info** (Fiscal 2015, ending March 31)

| Business | • Passive components  
|          | • Magnetic application products  
|          | • Film application products  
|          | • Others |
| Headquarters | Tokyo, Japan |
| Sales | JPY 1,083 billion |
| Sites | More than 110 factories, R&D and sales offices in more than 30 countries |
| Employees | 88,000 |

### Evolution

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>TDK (Tokyo Denki Kagaku Kogyo = Tokyo Electric &amp; Chemical Industries) established in Japan to manufacture and commercialize ferrites</td>
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<tr>
<td>1986</td>
<td>SAE Magnetics acquired</td>
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<tr>
<td>2005</td>
<td>Amperex Technology Limited (ATL) acquired</td>
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<td>2005</td>
<td>TDK-Lambda Corporation established</td>
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<tr>
<td>2007</td>
<td>Recording Media Business sold</td>
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<td>2008</td>
<td>EPCOS AG acquired</td>
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</table>
We offer a broad product portfolio

<table>
<thead>
<tr>
<th>Passive Components</th>
<th>Magnetic Application Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive Devices</td>
<td>Magnets</td>
</tr>
<tr>
<td>High-Frequency Devices</td>
<td>Recording Devices</td>
</tr>
<tr>
<td>Ceramic Capacitors</td>
<td>Power Supplies</td>
</tr>
<tr>
<td>Aluminum Electrolytic and Film Capacitors</td>
<td>Applied Films</td>
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<tr>
<td>Piezo and Protection Devices</td>
<td>Energy Devices</td>
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<tr>
<td>Sensors</td>
<td>Others</td>
</tr>
<tr>
<td></td>
<td>Flash Memory Applied Devices</td>
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<td></td>
<td>Radio Wave Anechoic Chambers</td>
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<td></td>
<td>Manufacturing Equipment</td>
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</table>
Worldwide manufacturing and R&D presence – We are near to the customer
We provide advanced solutions for Information & Communication Technology

You are experiencing TDK.
# Systems, Acoustics, Waves Business Group at a glance

<table>
<thead>
<tr>
<th>Key data</th>
<th>Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headquarters</td>
<td>SAW and BAW filter products for</td>
</tr>
<tr>
<td></td>
<td>Mobile communication devices</td>
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<tr>
<td>Number of plants</td>
<td>Telecommunication infrastructure</td>
</tr>
<tr>
<td>Employees total</td>
<td>Automotive electronics</td>
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<tr>
<td>Management</td>
<td>Industrial electronics</td>
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<tr>
<td></td>
<td>Multimedia products</td>
</tr>
<tr>
<td>Christian Block</td>
<td>Modules for cellular and connectivity</td>
</tr>
<tr>
<td>CEO &amp; CTO</td>
<td>Power management modules</td>
</tr>
<tr>
<td>Otto Graf</td>
<td>Multilayer HF components</td>
</tr>
<tr>
<td>COO &amp; Deputy General Manager</td>
<td>Isolators and circulators</td>
</tr>
<tr>
<td>Kohei Wada</td>
<td>CFO</td>
</tr>
<tr>
<td>Deputy General Manager</td>
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</tbody>
</table>
Comprehensive product portfolio

- SAW and BAW filter products for
  - Mobile communication devices
  - Telecommunication infrastructure
  - Automotive electronics
  - Industrial electronics
  - Multimedia applications
- Modules for cellular and connectivity
- Power management modules
- Multilayer HF components
- Isolators and circulators
Global manufacturing presence

- Germany: Munich
- Japan: Konoura
- China: Dalian, Wuxi, Chang An
- Austria: Deutschlandsberg
- Singapore
SAW SN at a glance

Location: WTC 6, 1090 route des crêtes 06560 Valbonne Sophia Antipolis
Since Sept 25th, 2015

The team: 47 people, including 42 design engineers, 1 PhD, 1 technician, 1 business dev engineer, 1 admin assistant and 1 director

Missions: Design services to the BU’s of the SAW BG and Innovation projects

Objectives
To bring SAW, BAW, MO design skills to BU’s to contribute to their product development targets
To contribute to the mid term R&D plan of the SAW Business Group
To bring know-how and new ideas to contribute to Discrete and Modules roadmaps

The skills:
SAW & BAW Product design: All RF and IF filters and duplexers, RF duplexer modules
SAW & BAW resonator design: very high Q low TCF and low noise structures
R&D and innovative projects: cooperation with Institutes, Design Software improvement, new materials and new SAW structures, collaborative projects with French and European partners
Power durability measurements
TDK
Systems, Acoustics, Waves enabling mobile phone
Smartphones are changing consumer behavior

Result of immediacy, portability, and connectedness

Smartphones are changing consumer behavior

Result of immediacy, portability, and connectedness

Attracting Tomorrow

http://www.gsmamobileeconomy.com/

GLOBAL MARKET

UNIQUE SUBSCRIBERS

2015 4.7bn
2020 5.6bn

2015 - 2020 3.9% CAGR
2020 72% PENETRATION RATE

GLOBAL CONNECTIONS

2015 7.3bn
2020 8.9bn

2015 - 2020 3.9% CAGR

MOBILE OPERATOR REVENUES

2015 $1.1tn
2020 $1.2tn

MOBILE CONTRIBUTING TO ECONOMIC AND SOCIAL DEVELOPMENT ACROSS THE WORLD

Delivering digital inclusion to the still unconnected populations
Mobile internet penetration 2015: 44%
2020: 60%

Delivering financial inclusion to the unbanked populations
270 live services in 90 countries as of December 2015

Delivering innovative new services and apps
Number of M2M connections to reach 1bn by 2020

ACCELERATING MOVES TO MOBILE BROADBAND NETWORKS AND SMARTPHONE ADOPTION

Mobile broadband connections to increase from 47% of total in 2015 to 71% by 2020

By 2020, there will be 5.8bn smartphones, growth of 2.6bn from the end of 2015

Data traffic to grow by a CAGR of 49% over the period 2015-2020

MOBILE INDUSTRY CONTRIBUTION TO GDP

2015 $3.1tn
GROWING TO $3.7tn BY 2020

4.2% GDP

PUBLIC FUNDING

Mobile ecosystem contribution to public funding (before regulatory and spectrum fees)

$430bn 2015

$480bn 2020

EMPLOYMENT

Jobs directly supported by mobile ecosystem

17M JOBS 2015

20M JOBS 2020

Plus an additional 16M indirect jobs supported by 2020
How to support data traffic increase

- Continuous increase of number of bands
- Carrier aggregation
- MIMO
Mobile phone architecture (no CA)

- For each FDD band: 1 duplexer + 1 diversity filter
- For each TDD band: 1 post PA filter + 1 diversity filter
- For each connectivity band (GPS, WiFi,...): 1 filter
Why acoustic filter?

- Acoustic wave velocity = 3 000 m/s
- Light wave velocity = 300 000 000 m/s

Acoustic wave resonators are $10^5$ smaller than EM based resonator (cavity filter, microstrip)
BAW layerstack

Section drawing

Top electrode
Passivation layer
Tuning layer
Piezo layer
Acoustic mirror λ/4layer
Bottom electrode

Substrate
Technologies & Applications

Capable of mixed technologies

**TCSAW**
- 100mm → 150mm Wafer
- 270um height
- <30ppm → <10ppm

**SAW**
- 150mm Wafer
- 250um height
- <40ppm/C

**BAW**
- 200mm Wafer
- 250um height
- <25ppm → <10ppm

**CERAMIC**
- 2GHz to 6GHz

- 400MHz to 1GHz
- 1GHz to 2GHz
- 2GHz to 6GHz
Filter packaging evolution

Compact
Cavity needed to allow surface to move
Connection via LGA for discrete and BGA for module

⇒ Component size close to chip size
Module integration

16 Diversity filter + 1 switch + 15 SMDs in one 5.6 x 4.1 mm².

- Compact
- Complete function optimum design
- Complexity shifted from customer to supplier
Simulation tool

Schematic, Layout, EM and Final Response Co-Exist
SAW / BAW Internal Foundry DRC in Place
Production capacity

- > 2 B mobile phone manufactured in 2016
- Worldwide filter production > 20 B / year.