SAW Products

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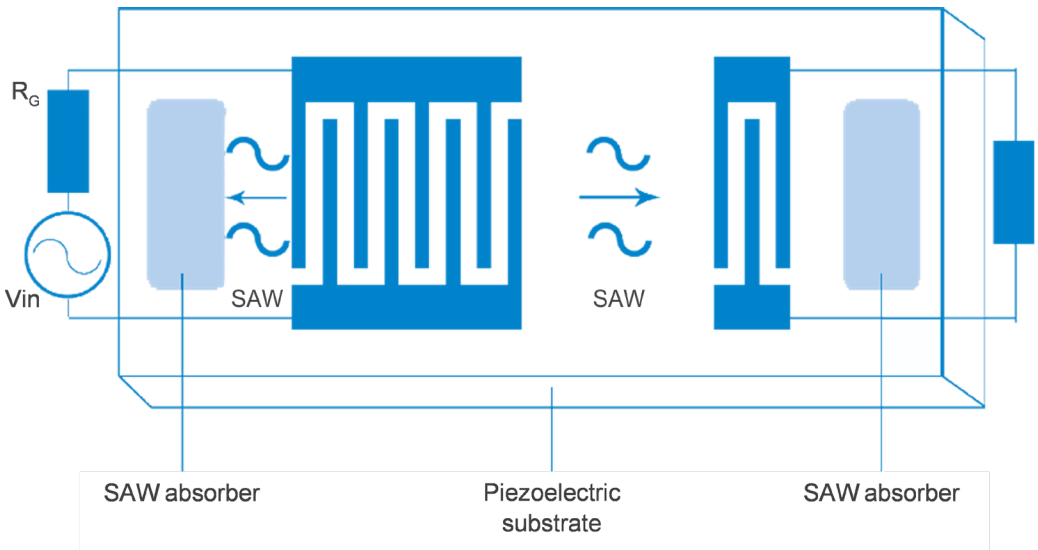
SAW Products

- SAW modules
- SAW IF, RF and integrated multi-band filter solutions
- Frequency range from 30 MHz to 2.7 GHz
- High-Q SAW narrow-band filters
- High-volume, cost-efficient manufacturing capabilities
- Dispersive and non-dispersive SAW delay lines
- Voltage-controlled SAW oscillators (VCSOs)

How Do SAW Filters Work?

Surface Acoustic Wave (SAW) devices deploy Inter-Digital Transducers (IDTs) to convert electrical signals (MHz range) into mechanical acoustic waves (µm range) and back again into electrical signals. The conversion makes use of piezoelectric properties to generate and detect acoustic waves. These acoustic wavelengths are 100,000 times shorter than wavelengths of electromagnetic signals at the same frequency. Therefore, highly miniaturized filters can be created for Radio Frequency (RF) signal processing.

We offer a wide variety of SAW solutions to help you find the right solution for your individual application. These solutions support the full range of requirements for very-narrowband (low-loss) to very-wideband (low-shape-factor) designs.



SAW Filter Impedance-Matching Networks

The frequency response of IDTs in a SAW device can be approximated as a combination of a static capacitance between IDT electrodes and a highly frequency-dependent dynamic response related to the electro-acoustic conversion. Depending on the strength of the dynamic part of the response and the design approach used, some SAW filters require impedance-matching networks to compensate their capacitive behavior and achieve their optimum frequency response. Intermediate Frequency (IF) filters regularly require these reactive matching networks (typically two-element L/C networks), while RF filters for front-end applications are typically designed to operate in a predefined impedance environment (for instance, 50Ω, 100Ω, 200Ω) without external circuitry.

We provide SAW filters with integrated balun (conversion balanced to single-ended) functionality and solutions for different terminating impedances at input and output ports (for instance, 50Ω to 200Ω). In addition to these common impedance levels, we have special solutions to match customized and complex terminating impedance or high-impedance-level open-collector circuits.

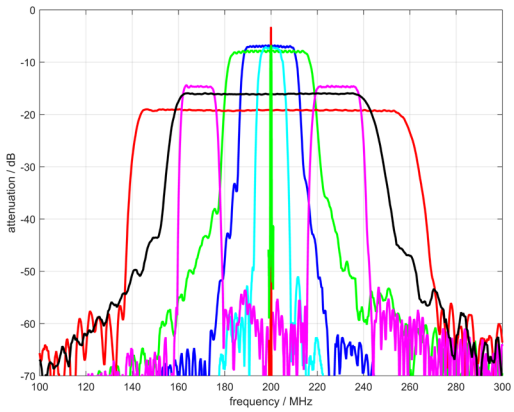
IF Filters

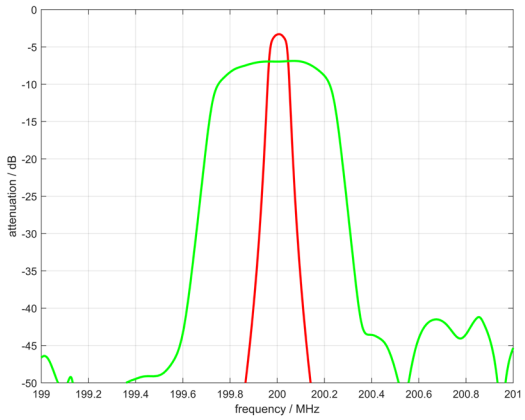
High-performance heterodyne RF transceiver systems require highly selective filters for the IF stage. System designers focus on highly linear amplitude and phase response within the desired filter pass band, as well as the steepest possible roll-off to achieve maximum adjacent channel suppression. To fulfill these requirements for all kinds of applications, we use a large variety of SAW filter design approaches with a focus on moderate insertion loss to limit amplification requirements and power consumption in the IF stage.

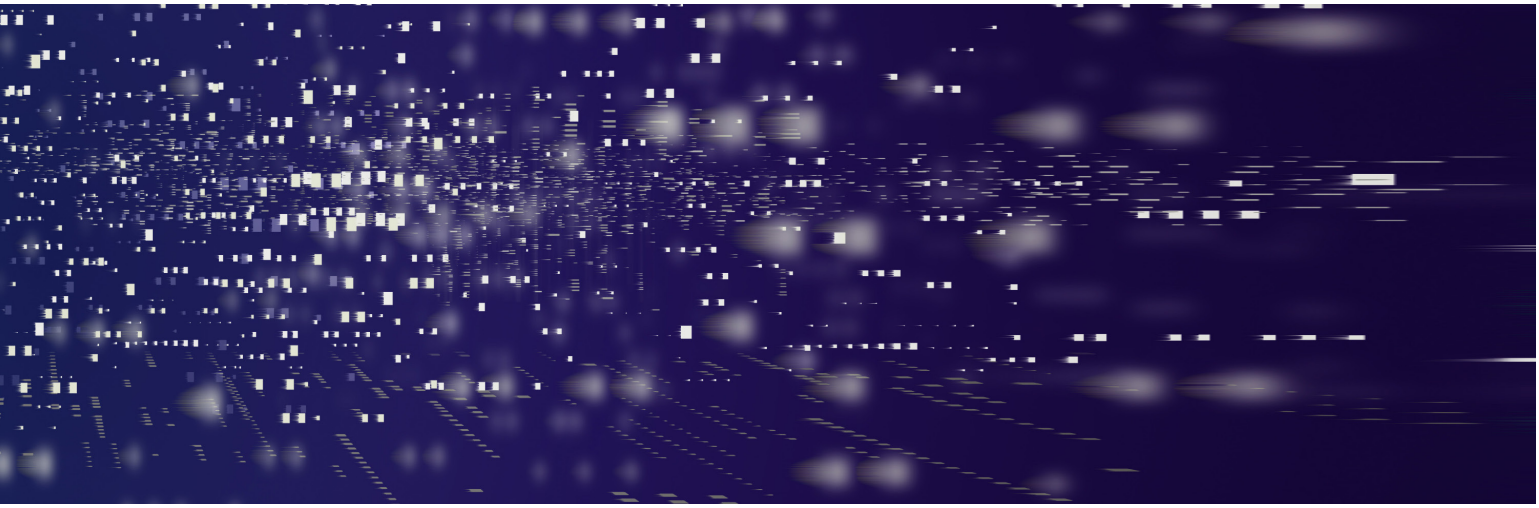
Extensive use of resonant and recursive design approaches, known in the digital world as Infinite Impulse Response (IIR) filters, ensures maximum performance and minimum size. Design approaches equivalent to Finite Impulse Response (FIR) filters can be used to create filter shape factors (ratio of stopband and pass band width) that are very close to the theoretical limit (that is, below 1.05).

Our SAW IF filters are found in high-performance RF systems used in communications, aerospace and defense systems, medical and industrial electronics and countless other applications.

We offer hundreds of off-the-shelf IF filter solutions in frequency ranges from 30 MHz to 1 GHz and covering fractional bandwidth ranges from 0.01% to > 50%. The images below show selected wide- (left) and narrow-band (right) examples at a center frequency of 200 MHz.







RF Filters

The strong influence of a front-end filter's insertion loss on the transceiver system's performance requires the application of low-loss filter design principles utilizing a variety of electrically or acoustically coupled high-Q SAW resonators.

We use numerous design techniques to provide the required solutions. While filter solutions consisting of a network of one-port SAW resonators offer advantages in terms of minimum insertion loss and RF power handling capabilities, filter principles with acoustically coupled resonators can be used for high out-of-band rejection and for applications requiring integrated impedance transformation (for instance, 50Ω to 200Ω) or balun (single-ended to balanced) functionality. A combination of both approaches provides an optimal design to suit many applications.

In addition to our comprehensive and constantly growing portfolio of RF front-end filters for communication applications—for example, most 3GPP frequency bands—we also offer highly temperature-stable filters for narrow-band RF filtering applications, covering fractional bandwidth ranges of less than 0.1%. These solutions, which function as filtering devices and high-Q frequency-determining components for high-frequency oscillators, are widely used in professional communications applications, military radio systems and test and measurement applications.

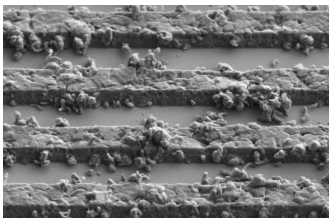
Power Handling Capabilities

Increased signal power level is a key approach when good signal–to–noise ratio in RF transmission systems or outstanding noise floor in oscillator signals is required.

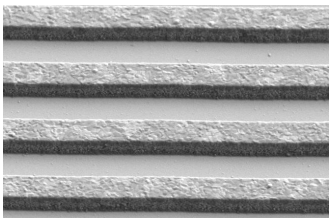
While small size is one of the major advantages of SAW filters when compared to competing technologies, the combination of high power levels and small size results in high power densities and, therefore, reduces the risk of premature failure for highly miniaturized solutions.

A SAW device's power-handling capability depends on numerous factors, such as the design approach used, the device's center frequency, the exposure signal's frequency and modulation scheme and its duty cycle or the ambient temperature.

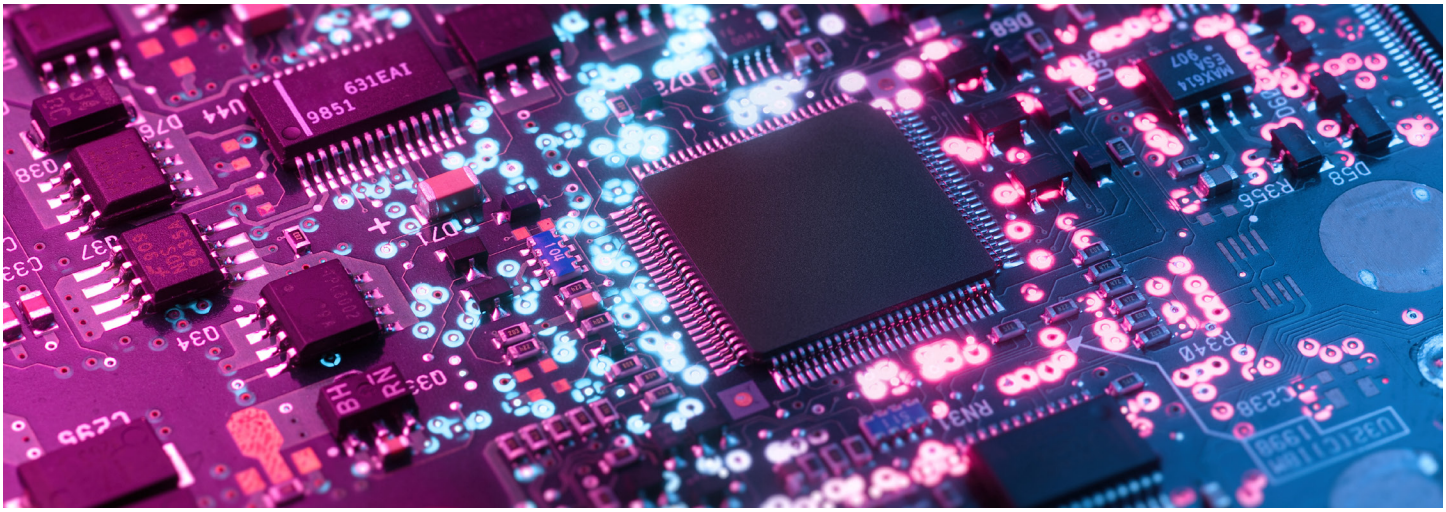
Our innovative high-power technology significantly reduces degradation effects of micro-acoustic stress caused by high RF signal power, allowing us to offer SAW filters with substantially improved power handling capabilities and superior lifetime to help achieve your design's performance goals.



Standard SAW IDT After Extended High-Power Exposure

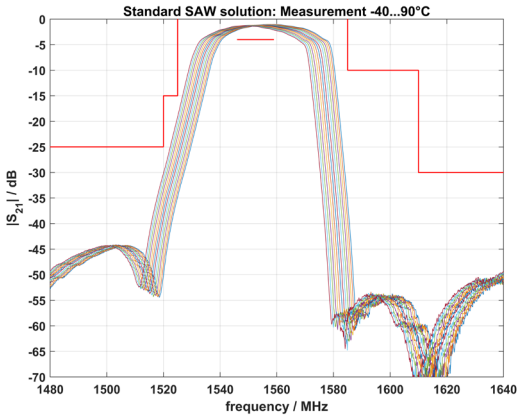


IDT in Our High-Power SAW Technology After Comparable Exposure

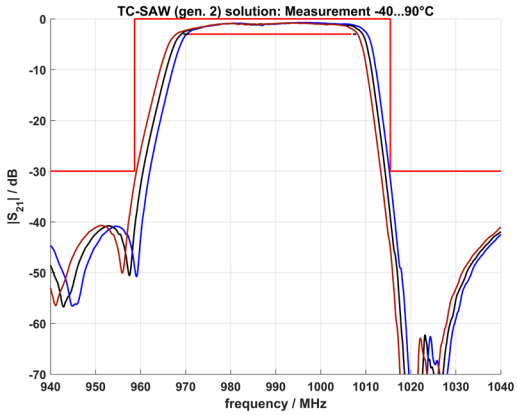


Temperature-Compensated SAW (TC-SAW) Solutions

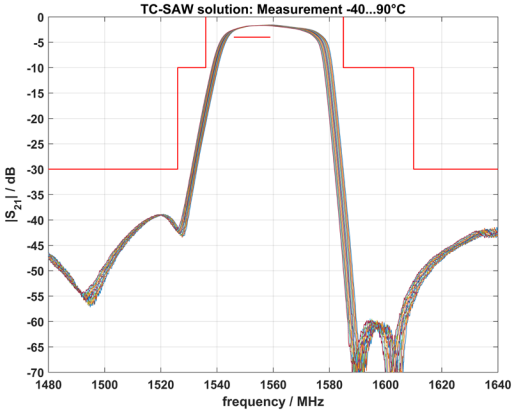
The continuously increasing data traffic in wireless networks requires the maximum utilization of the available RF spectrum, which cuts into the available transition bands between existing and newly defined RF communication bands. To address these increasing coexistence requirements, which require steeper guaranteed filter roll-off, we have developed advanced technologies to minimize the process tolerances and temperature sensitivity of our RF SAW solutions. Depending on the application, these solutions can be employed to significantly reduce the temperature sensitivity of RF SAW devices to deliver excellent performance stability across the operating temperature range in combination with moderate (TC-SAW) or increased (TC-SAW Gen 2) filter bandwidth.



Standard SAW

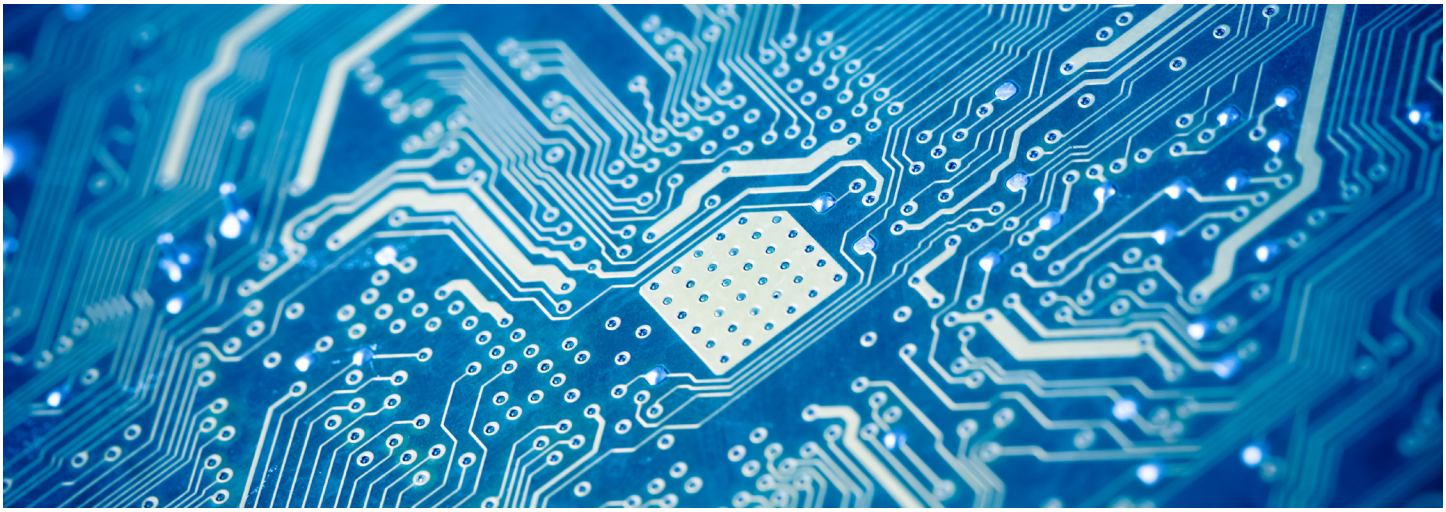


TC-SAW Gen 2



TC -SAW

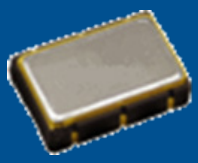
Solutions Measured Between −40°C and 90°C



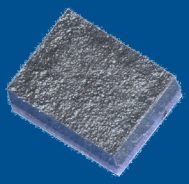
Packaging Technologies for RF SAW Filters

We offer a variety of advanced packaging options for SAW filters to help you find the optimum solution for your application in terms of reliability and Size, Weight and Performance (SWaP). In addition to through-hole and connectorized options that may be used in mission-critical applications, we offer hermetic multi-layer ceramic packages for various dimensions down to 2 × 1.6 mm and chip-scale micro SAW filter (µSF) solutions in dimensions of 1.4 × 1.1 mm.

3 × 3 mm



2 × 1.6 mm



1.4 × 1.1 mm

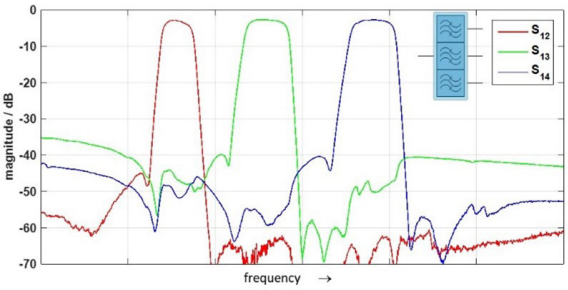
Popular Packaging Solutions for RF SAW Filters

Integrated Filter Solutions

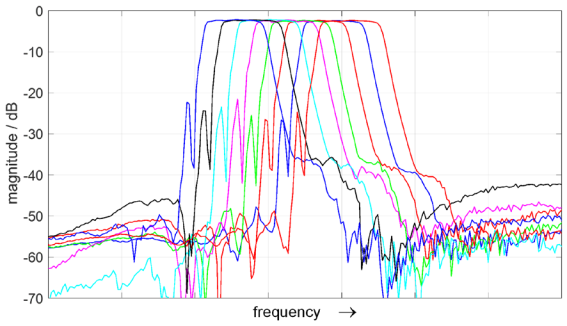
The complexity of RF transceiver systems is increasing with the integration of numerous frequency bands into one radio unit. We offer multi-band SAW filter solutions to address the challenges of decreasing guard bands between radio channels and multi-channel usage within single radio frontends.

We offer passive and active multiplexing solutions. Passive options include diplexer, duplexer, triplexer or multiplexer solutions.

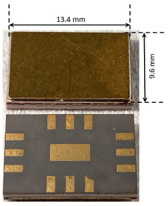
In addition to our passive solutions, we offer custom-designed discrete or integrated filter bank solutions to support radio architectures with multiple transmission bands. These solutions combine high-performance SAW filtering with increased integration density.



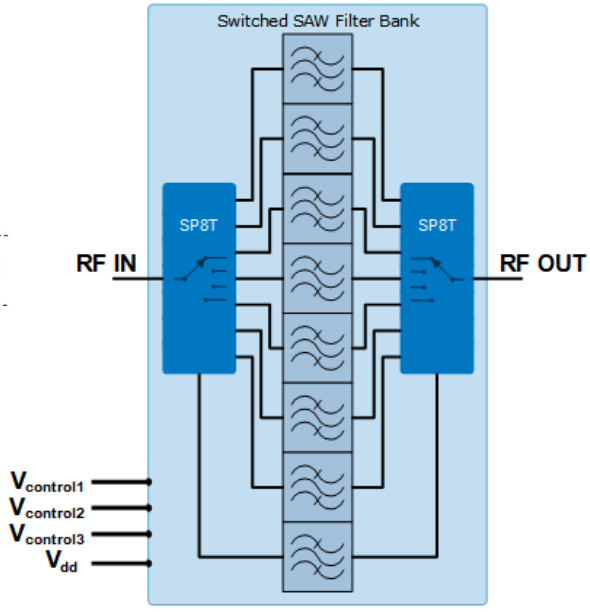
Transfer Characteristics of Triplexer



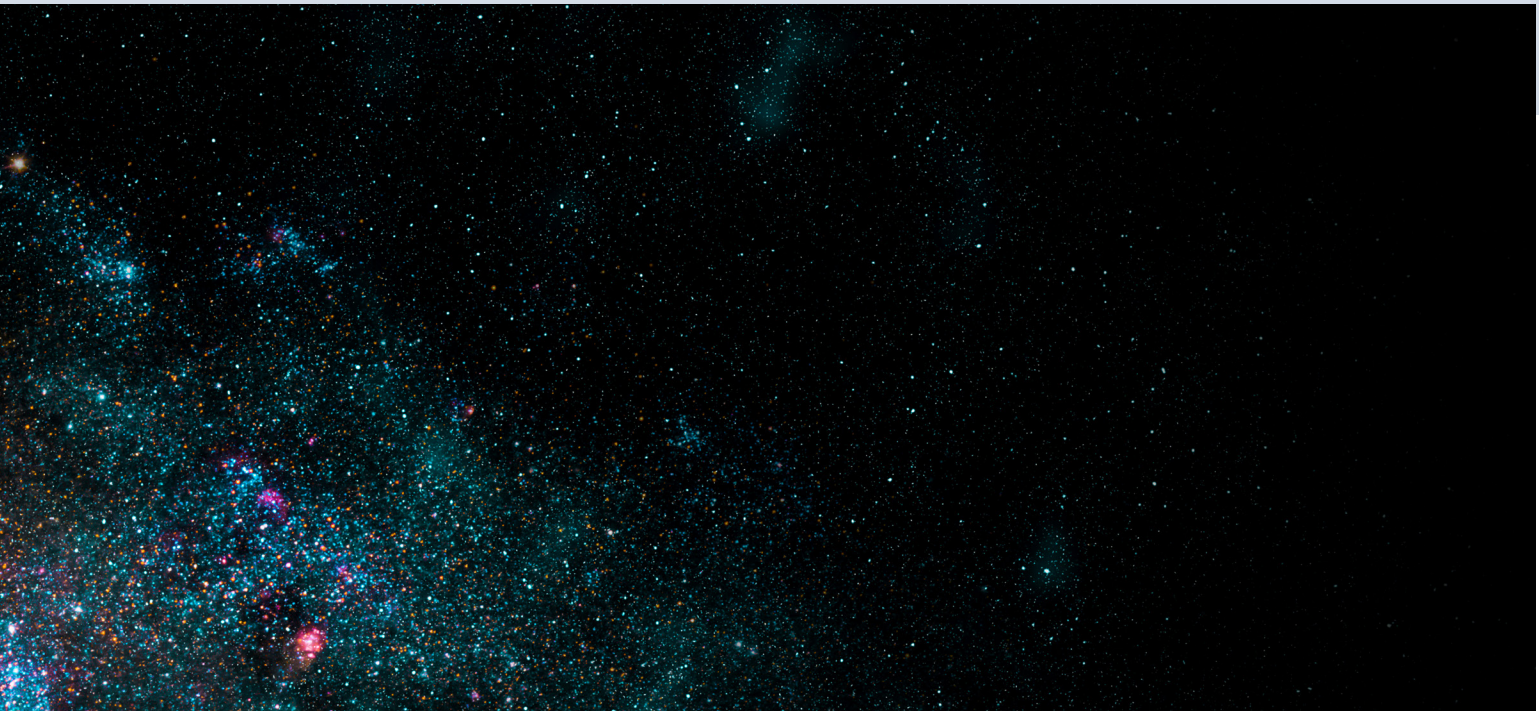
Eight-Channel Switched Filter Bank Solution



Package Outline



Switched SAW Filter Bank Block Diagram



Delay Lines

Dispersive and non-dispersive delay lines can be used in electronic warfare, radar and communications applications.

Dispersive Delay Lines (DDLs) are used as matched filters to implement signal-to-noise improvement in pulsed systems. Linear Frequency Modulation (LFM) is the most frequently used waveform, although non-linear frequency modulation and phase shift keying are also used. For an LFM signal, the matched filter gain is 10*log(TB), where T is the signal dispersion and B is the signal bandwidth.

This matched filter gain is a consequence of conservation of energy. We can implement dispersive delay lines with $T \bullet B$ products exceeding 10,000, resulting in 40 dB of signal-to-noise improvement. For radar applications, the waveform bandwidth determines the range resolution of the system. We have implemented bandwidths up to 667 MHz.

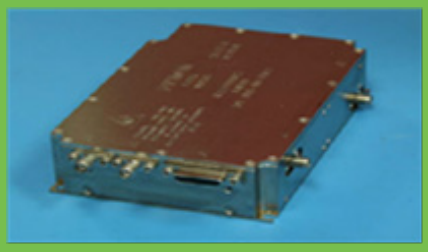
Non-dispersive delay lines implement high dynamic range memory for signal processing. Applications include radar clutter rejection, calibration, jamming, and frequency discrimination and buffering for gain control in analog-to-digital conversion. We offer delays over 100 µs and fractional bandwidths exceeding 70%. Propagation attenuation increases with frequency, so there will be a tradeoff between frequency, delay and device attenuation. We will be happy to review your specific application and advise on relevant design considerations.

Modules

We can integrate any of our SAW components into a higher level of assembly to offer you plug-and-play convenience. Our modules may contain one or more SAW components, impedance matching, amplification, switching, ovenization, non-SAW filtering, voltage regulation and calibration memory.

The most common applications for these modules are multi-mode dispersive delay lines, switched filter banks and multi-channel delay lines. Applications that incorporate multiple SAW devices frequently require matching and/or tracking of loss, phase and delay performance channel-to-channel and over-temperature. We support and comply with comprehensive automated performance testing over temperature. We also offer popular screening testing per MIL-STD-883 including burn-in, shock, random vibration and thermal cycling.

Four-Channel Delay Line With Matching



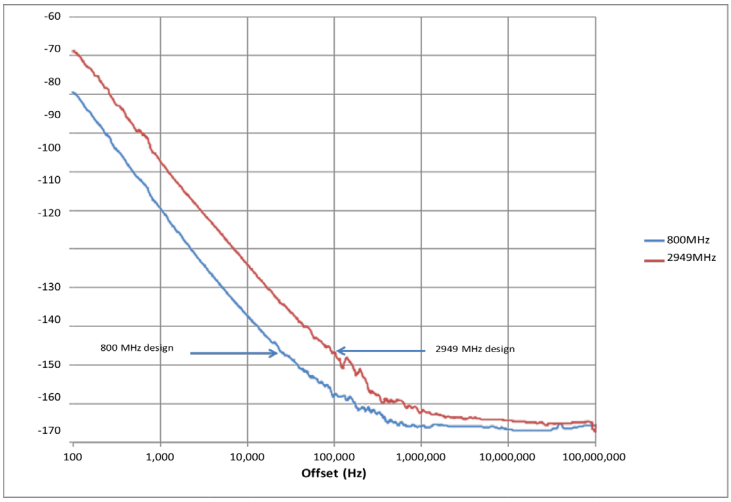
Multi-Mode DDL With Oven

Voltage-Controlled SAW Oscillators (VCSOs)

SAW oscillators offer a superior solution over lower-frequency crystal oscillators for clocking applications that require high frequencies and low phase jitter. Using much higher fundamental mode frequencies than a crystal resonator, SAW oscillators reduce or eliminate the need for frequency multiplication to reach the desired output frequency, which results in less or no (sub-) harmonics and better noise floor.

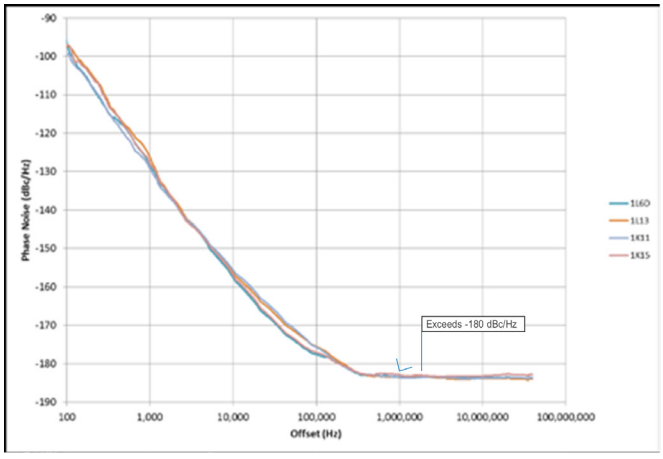
VS-800 Series VCSOs

The VS-800 series of VCSOs is an excellent choice for high-performance data converters, Optical Transport Network (OTN), wireless network and wireless applications. It offers sub-10 fs jitter performance (12 kHz–20 MHz integration bandwidth) in a hermetic 5.0 × 3.2 mm ceramic package and a frequency range of 800 MHz to 3200 MHz. Using an internal SAW element eliminates sub-harmonics in the frequency range up to 1600 MHz. We also offer differential or single-ended output configurations in this series of devices.

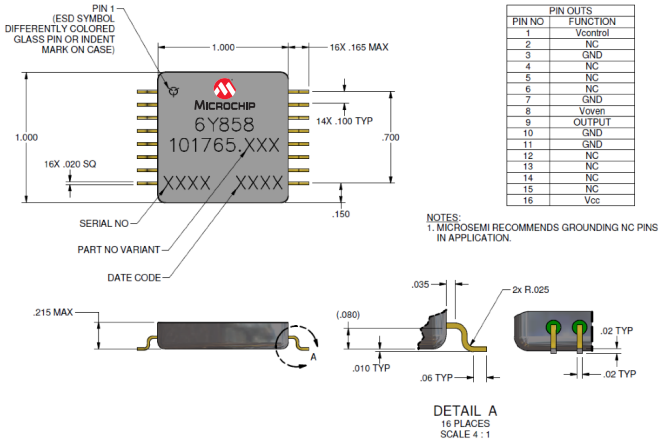


101765 Series VCSOs

The 101765 series of VCSOs targets radar and instrumentation applications that require the best phase noise performance available. Our patented micro-oven technology allows us to use higher-Q resonators in our designs while meeting modest Size, Weight and Power (SWaP) requirements. This enables us to achieve better phase noise performance for frequencies below 1 GHz, as compared to non-ovenized solutions.



Example Performance at 750 MHz



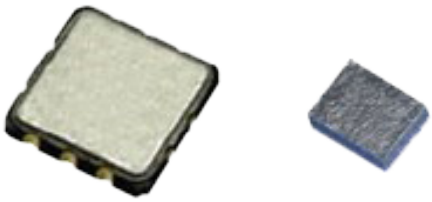
101765 Outline Drawing

Applications

Industrial, Scientific and Medical Applications

SAW filters with low insertion loss are necessary for high power efficiency in many RF systems for Industrial, Scientific and Medical (ISM) applications. Using resonant or recursive SAW filter design principles can help you meet your specification's goals, such as lowest insertion loss or steep filter transitions.

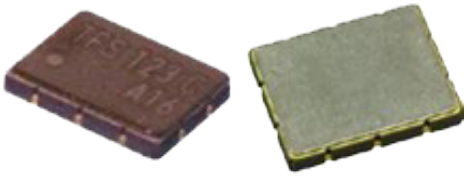
We have a variety of solutions for ISM- and Medical Implant Communication Service (MICS)-band applications that can meet filtering requirements related to insertion loss, stop-band rejection and transition regions.



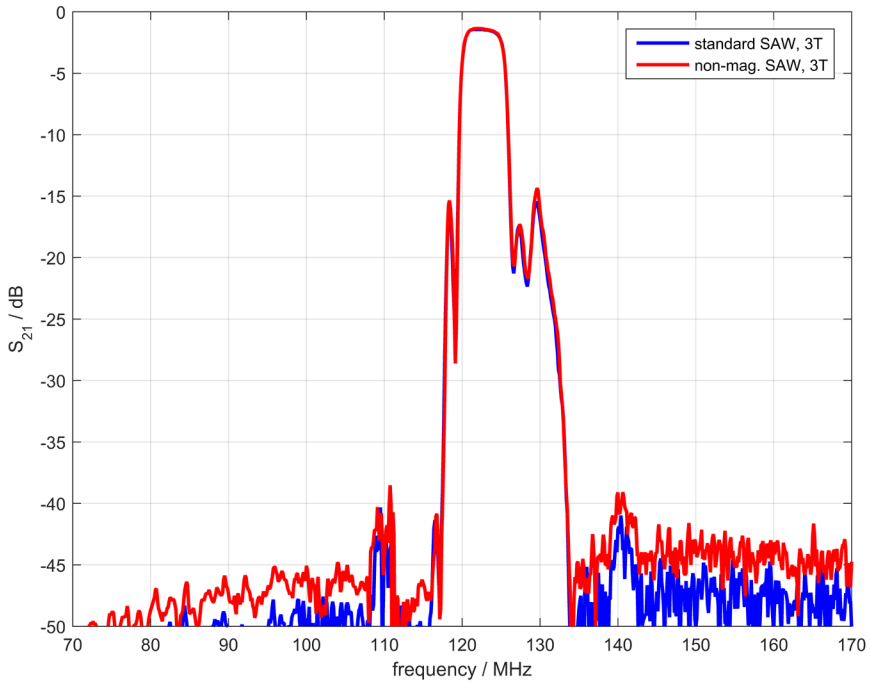
Product	Center Frequency (MHz)	Bandwidth (MHz)	Insertion Loss (dB)	Package Size (mm²)
TFS403A	403.5	3	5.5	3.8 × 3.8
TFS403B	403.5	3	2.5	3.8 × 3.8
TFS403L	403.5	3	4	2.0 × 1.6
TFS433V	433.92	0.32	3	3.8 × 3.8
TFS868H	868.3	0.6	3.8	3.8 × 3.8
TFS869N	869	2	3.5	3.0 × 3.0
TFS866D	866.5	9	3	3.0 × 3.0
TFS915Z	915	0.3	5.5	3.8 × 3.8
TFS915L	915	0.7	5.5	3.8 × 3.8
TFS915D	915	7	3	3.0 × 3.0
TFS915P	915	26	2.9	3.0 × 3.0

SAW Solutions for MRI Applications

The trend in modern Magnetic Resonance Imaging (MRI) systems to integrate increasing portions of the signal processing chain into the receiver coil units requires the implementation of non-magnetic electronic components to ensure negligible distortions of the magnetic fields. We have developed SAW filter solutions at typical required Larmor frequencies around 63 MHz and 127 MHz, designed for 1.5T and 3T systems, that combine small size, highest filter performance and completely non-magnetic assembly technology.



Non-Magnetic (Left) and Standard (Right) Package



Navigation Applications

Our extensive family of RF front-end and inter-stage filters, as well as our fully integrated front-end diplexers that target Global Navigation Satellite System (GNSS) applications, support the full range of single- and multi-mode (GPS, GLONASS, Galileo and BeiDou) and single- and multi-band (lower/upper L-band) system applications.

GNSS Band	fstart	fstop	Single-Band Solutions	Multi-Band Solutions		
E5a	1164	1189	TFS1176 (se)	TFS1188 (se)		TFS1210D (bal)
E5b	1189	1214	TFS1204A (se)			
B2	1192.14	1222.14		TFS1237 (se)	TFS1225D (bal)	
L2	1215	1237	TFS1227H (se)	TFS1237C (bal)		TFS1210F (se)
			TFS1227C (bal)			
G2	1237	1254	TFS1245A (bal)			
B3	1248.52	1288.52				
E4	1254	1258				
E6	1260	1300	TFS1278C (se)			
L-band	1525	1559	TFS1542D (se) TFS1552B(se)		TFS1555 (se)	
SAR	1544	1545				
B1	1555.42	1595.42	TFS1575Z (se)			
E2	1559	1563		TFS1575Z (se)		
L1	1563	1587	TFS1575AC (se)			TFS1590 (se)
L1 C/A	1574.22	1576.62	TFS1575AD (se)			
E1	1587	1591				
G1	1593	1610	TFS1601A (bal)			

Systems:

GPS	Glonass	Beidou	Galileo	others

'se' - single-ended (unbalanced operation)

'bal' - balanced (differential operation)

We also offer IF filters that are designed for high isolation between signals in professional multi-mode navigation systems.

GNSS Band	fstart	fstop	Multi-Band Solutions			Diplexers		
E5a	1164	1189	TFS1191 (se)		TFS1225C (se)	TDX1210	TDX1209B	
E5b	1189	1214						
B2	1192.14	1222.14	TFS1191C (bal)	TFS1238 (se)				
L2	1215	1237	TFS1255A (se)					TDX1227
G2	1237	1254						
B3	1248.52	1288.52						
E4	1254	1258						
E6	1260	1300						
L-band	1525	1559						
SAR	1544	1545		TFS1578 (se)				
B1	1555.42	1595.42	TFS1575AG (se)		TFS1581A (se)			
E2	1559	1563					TDX1209B	
L1	1563	1587			TFS1581B (bal)			TDX1227
L1 C/A	1574.22	1576.62		TFS1575AV				
E1	1587	1591			TFS1584B (bal)			
G1	1593	1610						

Oscillator and Narrow-Band Filtering Applications

Our unique portfolio of narrow-band, high-Q and temperature- and aging-stable filters in frequency ranges up to 2.5 GHz are well-suited for professional and high-reliability narrow-band filtering or extreme-precision SAW-based oscillator applications.

Wireless and Telecommunication Applications

Our SAW filter solutions are designed to meet the requirements of modern communication systems that function within the communication bands defined in the 3GPP standard. These RF SAW filter solutions are available in high-reliability packaged versions.

All our RF filter products are optimized toward the lowest insertion loss and steepest filter transitions to support highest signal-to-noise ratio requirements.

We also offer a variety of SAW IF filters for multiple communication applications, ranging from kHz-bandwidth narrowband signals to full-band LTE IF filtering applications. These solutions are available in various frequency ranges and support popular chipset designs.

Our portfolio also includes single-band LTE RF filters and diplex filters for several common dual-band combinations.

Please visit our **RF and Microwave Products page** to learn more about our comprehensive selection of SAW solutions for wireless and telecommunications applications.

Band	Center Frequency Uplink/MHz	Center Frequency Downlink/MHz	Mode	Bandwidth/MHz	Uplink	Downlink
1	1950	2140	FDD	60	TFS1950F	TFS2140D
2	1880	1960	FDD	60	TFS1880D	TFS1960F
3	1747.5	1842.5	FDD	75	TFS1747	TFS1842G
4	1732.5	2132.5	FDD	45	TFS1732A	TFS2132
5	836.5	881.5	FDD	25	TFS836G	TFS881D
7	2535	2655	FDD	70	TFS2535D	TFS2655B
8	897.5	942.5	FDD	35	TFS897G	TFS942G
10	1740	2140	FDD	60	TFS1747	TFS2140D
11	1437.9	1485.9	FDD	20	TFS1437	
12	707.5	737.5	FDD	17	TFS707	TFS737B
13	782	751	FDD	10	TFS782A	TFS751
14	793	763	FDD	10	TFS793	
15	1910	2610	FDD	20	TFS1910B	
16	2017.5	2592.5	FDD	15	TFS2017B	
17	710	740	FDD	12		TFS740
19	837.5	882.5	FDD	15	TFS837	
20	847	806	FDD	30	TFS847B	TFS806A
23	2010	2190	FDD	20	TFS2010	
24	1643.5	1542	FDD	34	TFS1643D	TFS1542E
27	815.5	860.5	FDD	17		TFS860E
28	725.5	780.5	FDD	45	TFS725B	
29	--	722.5	FDD	11		TFS722A
31	455	465	FDD	5	TFS455D	TFS465B
33	1910	--	TDD	20	TFS1910B	
34	2017.5	--	TDD	15	TFS2017B	
35	1880	--	TDD	60	TFS1880D	
36	1960	--	TDD	60	TFS1960F	
38	2595	--	TDD	50	TFS2595A	
39	1900	--	TDD	40	TFS1900	
41	2593	--	TDD	194	TFS2593A	
45	1457	--	TDD	20	TFS1457	
65	1965	2155	FDD	90		TFS2155
66	1745	2155	FDD	70		TFS2155
70	1702.5	2007.5	FDD	15/25		TFS2007A
71	680.5	634.5	FDD	35		TFS634
73	452.5	462.5	FDD	5	TFS452F	TFS462A
87	412.5	422.5	FDD	5	TFS412C	TFS422A

Aerospace and Defense

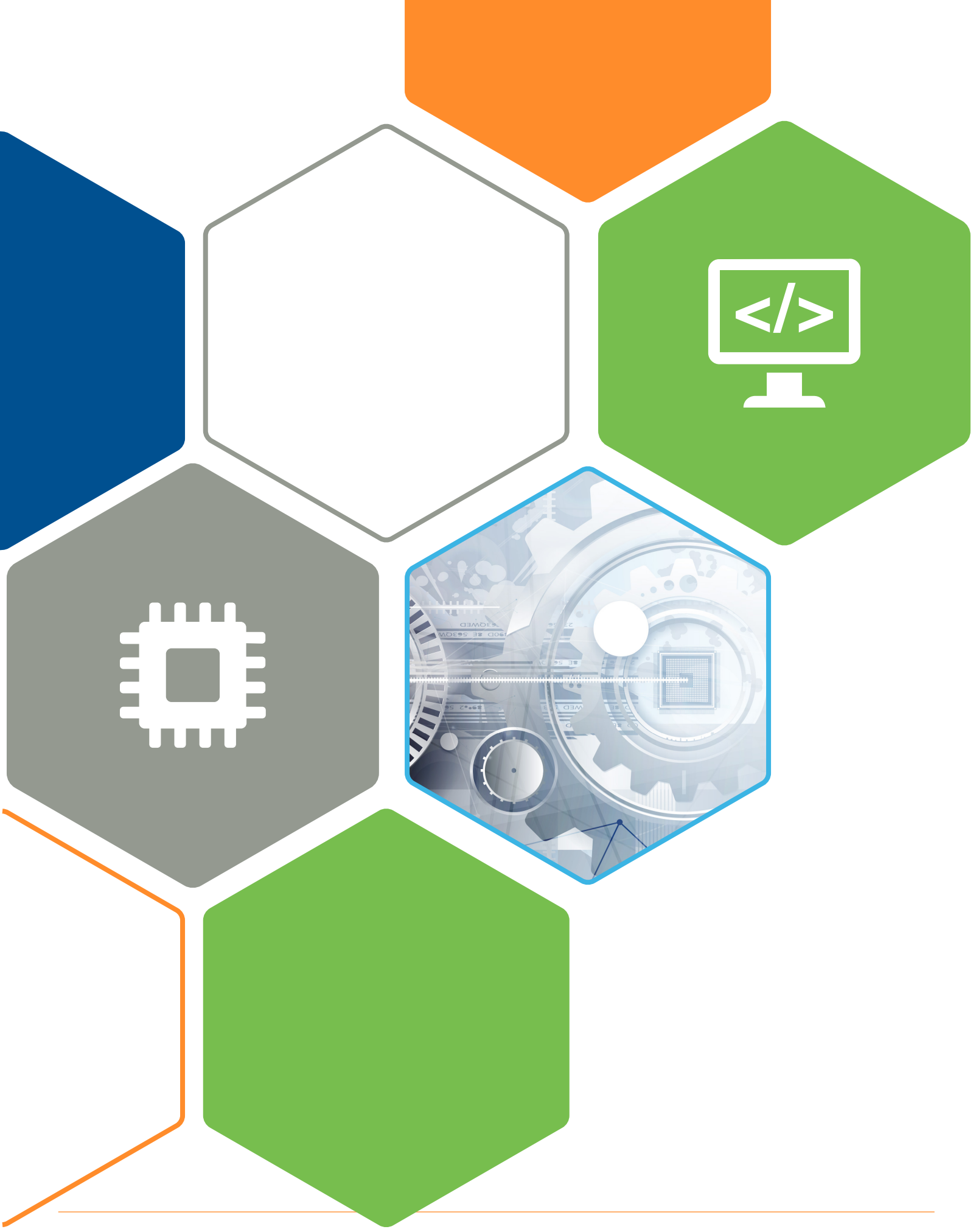
Aerospace and Defense

Our family of SAW products for aerospace and defense applications offers the highest reliability levels for harsh and mission-critical environments. They are available in a wide range of package options for ruggedized applications and support a center frequency range from 30 MHz to 2.7 GHz. We can address ITAR, EAR and classified specifications/hardware to meet your security requirements.

Some key benefits of these products include:

- Surface-mount, through-hole and connector-type packages available
- Qualification according to MIL-STD-883 and/or pre-defined (for instance, ESCC 3502) or custom space qualification plans
- Ruggedized SAW modules with internal matching
- High-reliability versions of standard designs available

Featuring multi-layer ceramic and metal can assembly technologies, our packages offer integrated matching circuitry in electrically and environmentally isolated cavities to deliver superior electrical performance and environmental reliability.



Microchip Technology Inc. | 2355 W. Chandler Blvd. | Chandler AZ, 85224-6199 | microchip.com

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