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EVOLUTION OF SAW TECHNOLOGY FROM DISCRETE DEVICES TO FUNCTIONAL RF BUILDING BLOCKS

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ABSTRACT

A brief history of the advances in Surface Acoustic Wave (SAW) technology as it relates both to device design and system application is presented. The progression from discrete SAW devices to a variety of functional building blocks is demonstrated with the latest advance being the development of monolithic RF functions incorporating SAW devices.

INTRODUCTION

SAW technology has now advanced through several generations as have the many applications in which SAW devices are being used. This paper will outline the progress from the early SAW devices through the latest SAW technology that has resulted in new device types and new applications. It is no longer necessary to design products using discrete SAW devices as many of the performance advantages offered by SAW technology can now be obtained as packaged functions. New products featuring multiple SAW devices and the development of monolithic RF functions will be discussed.

EVOLUTION OF SAW TECHNOLOGY

A review of Table I indicates the direction that SAW technology has taken and of its impact on system design. Since the earlier SAW devices and applications are generally understood, we will focus first on the most recent SAW device developments and their uses. Following will be a discussion of the new RF functions now made possible through the use of SAW technology, including SAW based hybrid circuit assemblies and monolithic RF assemblies using SAW devices.

TABLE 1. DISCRETE SAW COMPONENTS AND RF BUILDING BLOCKS FEATURING SAWS

SAW COMPONENTS	APPLICATIONS
DELAY LINES	RADAR RECEIVERS OSCILLATORS
TRANSVERSE FILTERS	TV RECEIVERS RF DATA MODEMS
TAPPED DELAY LINES	SPREAD SPECTRUM DATA TRANSMISSION
DISPERSIVE FILTERS	RADAR SYSTEMS
RESONATORS	OSCILLATORS
LOW LOSS FILTERS	SATELLITE RECEIVERS RECEIVER FRONT-ENDS
COUPLED RESONATOR FILTERS	RECEIVER FRONT-ENDS SYNTHESIZERS HIGH IF FILTERS
NOTCH FILTERS	DUPLEXERS SYNTHESIZERS
HYBRID FUNCTIONS	**APPLICATIONS**
RECEIVER FRONT-ENDS	MILITARY RECEIVERS REMOTE CONTROL RECEIVERS
TRANSMITTERS	EMERGENCY LOCATION TRANSMITTERS CONTROL & SECURITY TRANSMITTERS
FREQUENCY SOURCES	RECEIVER LOCAL OSCILLATORS ECL CLOCKS
VCSO	GPS RECEIVERS SATELLITE TV RECEIVERS
MONOLITHIC ASSEMBLIES	**APPLICATIONS**
MICRO-TRANSMITTERS	CONTROL & SECURITY TRANSMITTERS
MINIATURE UHF SOURCES	MANY POTENTIAL APPLICATIONS
MINIATURE UHF RECEIVERS	PAGERS SECURITY RECEIVERS

NEW GENERATION SAW DEVICES

The SAW Coupled-Resonator Filter is a narrow-band filter designed by arranging two or more SAW resonators on the same substrate so that they are acoustically coupled. A typical SAW coupled-resonator filter frequency response is shown in Figure 1. Center frequencies to 1500 MHz and fractional bandwidths of .05 to .25 percent are realizable. With insertion losses as low as 1.2 dB (3 dB, typical) and ultimate rejection levels of up to 60 dB available, obvious applications include single-conversion VHF and UHF receivers having a low IF or clean-up filters in frequency synthesizers that have mixer products or harmonics near the desired signal.

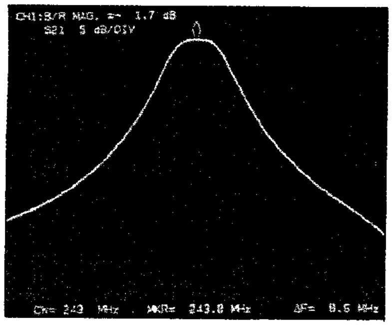


FIGURE 1. 243 MHZ COUPLED-RESONATOR FILTER

The SAW Notch Filter can be used to eliminate interference between RF systems that must operate in close proximity and for elimination of narrowband interference in such systems as satellite downlinks. Figure 2 shows the frequency response of a SAW notch filter at 1030 MHz. Notch widths of up to 5 percent can be obtained and notch depths in the range of 30 to 40 dB are practical with an out-of-band insertion loss of only 2 dB.

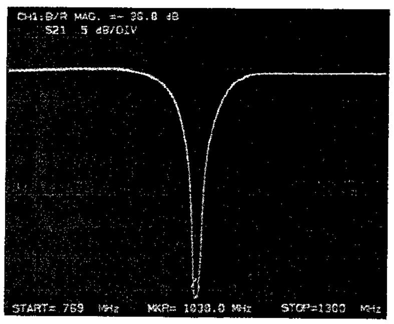
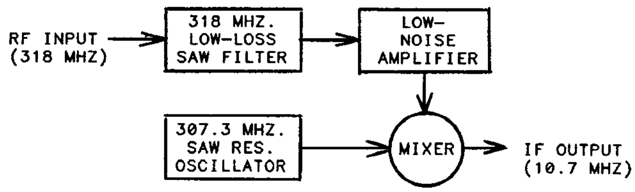


FIGURE 2. 1030 MHZ SAW NOTCH FILTER

RF FUNCTIONS THE HYBRID RECEIVER FRONT-END

One advantage of SAW technology is its ability to provide high levels of performance in small package sizes. Coupling SAW devices with hybrid assembly techniques, complete RF functions can be realized in relatively small and inexpensive assemblies. An example of this is the HR1023 Receiver Hybrid, developed for RF remote control applications. The block diagram shown in Figure 3 indicates use of a low-loss coupled-resonator filter at the front-end of a receiver converter and a SAW resonator stabilized local oscillator providing conversion from 318 MHz to an IF frequency of 10.7 MHz. The accompanying specifications show the level of performance that has been achieved in a package size of only 1.07 inches by 0.5 inches.



HR1023 SPECIFICATIONS

INPUT FREQUENCY:	318 MHz, TYPICAL
3 dB BANDWIDTH:	500 to 800 kHz
NOISE FIGURE:	7.0 dB, TYPICAL
CONVERSION GAIN:	28 dB, TYPICAL
IMAGE REJECTION:	-24 dB, MINIMUM
LO LEAKAGE:	-30 dBm, MAXIMUM
3rd ORDER INTERCEPT:	30 dBm, MINIMUM
OUTPUT FREQUENCY:	10.700+/-.055 MHz
SUPPLY VOLTAGE:	9.0 Vdc, TYPICAL
SUPPLY CURRENT:	28 mA, TYPICAL
TEMPERATURE RANGE:	-35 C to +65 C

FIGURE 3. HR1023 HYBRID RECEIVER FRONT-END BLOCK DIAGRAM AND SPECIFICATIONS

RF FUNCTIONS - THE HYBRID SAW OSCILLATOR

One frequency control application that is particularly well suited to use of hybrid SAW oscillator technology is that of IFF frequency sources, typically at 1030 MHz or 1090 MHz. Through the use of SAW resonator frequency control elements, these oscillators feature good temperature stability, excellent phase noise, small size, low power consumption and high reliability. Electrical specifications for a typical hybrid IFF frequency source are shown in Figure 4. These specifications are compatible with the parameters of high quality SAW resonators when used in suitable oscillator circuit designs. For example, the temperature performance of a 1030 MHz hybrid SAW resonator oscillator, shown in Figure 5, closely mirrors the characteristics of the SAW resonator. The high Q of the SAW resonator contributes to the excellent phase noise performance of the oscillator, shown in the graph of Figure 6.

RFM P/N:	H01080
APPLICATION:	1030 MHZ IFF SOURCE
SET-ON FREQUENCY:	1030.125+/-.050 MHz, MAXIMUM
FREQUENCY TOLERANCE:	1030.000+/-.200 MHz, MAXIMUM
TEMPERATURE:	INCLUDED ABOVE
AGING:	INCLUDED ABOVE
SUPPLY VOLTAGE:	INCLUDED ABOVE
VSWR:	INCLUDED ABOVE
TEMPERATURE RANGE:	-55 C to +105 C (OPERATING) -55 C to +125 C (STORAGE)
SUPPLY VOLTAGE:	+12.0 +/-0.25 Vdc
INPUT CURRENT:	35 mA, TYPICAL 40 mA, MAXIMUM
SSB PHASE NOISE	
1 kHz OFFSET:	-90 dBc/Hz, MAXIMUM
10 kHz OFFSET:	-110 dBc/Hz, MAXIMUM
OUTPUT POWER:	+12 dBm, +1/-2 dB
HARMONICS & SPURIOUS	
2nd:	-20 dBc, MAXIMUM
3rd & UP:	-30 dBc, MAXIMUM
NON-HARMONIC:	-80 dBc, MAXIMUM
PACKAGE TYPE:	16 PIN HERMETIC DIP
SIZE:	0.97L X 0.50W X 0.20H

FIGURE 4. H01080 IFF HYBRID FREQUENCY SOURCE SPECIFICATIONS

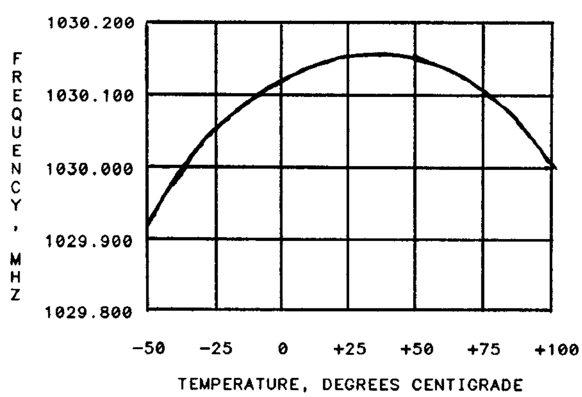


FIGURE 5. H01080 IFF HYBRID FREQUENCY SOURCE TEMPERATURE PERFORMANCE

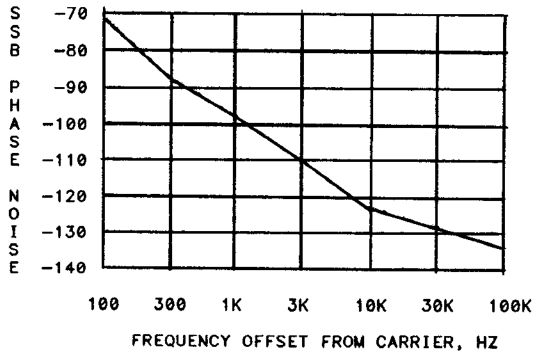


FIGURE 6. H01080 IFF HYBRID FREQUENCY SOURCE PHASE NOISE CHARACTERISTICS

RF FUNCTIONS - THE HYBRID VCSO

SAW resonators can be used to stabilize fundamental-mode oscillators up to 1500 MHz, eliminating the need for multiplier chains while providing such benefits as excellent phase noise, small size and low power consumption. However, some applications require tighter temperature performance and long-term stability than SAW resonators can currently provide. Frequency stability can be enhanced in a number of ways including temperature compensation of the oscillator circuit and temperature control of the SAW resonator or of the entire oscillator circuit. Using todays technology, however, the best solution for tight frequency tolerance applications requiring the other advantages of SAW oscillator performance is the Voltage Controlled SAW Oscillator, or VCSO, used in a PLL.

The VCSO can be either a SAW resonator or a SAW delay line controlled oscillator circuit having sufficient tuning range to track out the frequency variations caused by temperature, supply voltage, VSWR, and the manufacturing tolerance and aging of the SAW device. Because of its higher Q, the preference is for use of a SAW resonator in the VCSO in order to maintain the best phase noise performance. The required tuning range is determined by the worst case combination of those factors mentioned above, but is primarily driven by the temperature range over which the oscillator must operate. Figure 7 shows the tuning characteristics of an 800 MHz. hybrid SAW resonator VCSO over temperature. The upper and lower curves, which represent the tuning extremes of the oscillator, are situated so as to always include the desired operating frequency of the oscillator.

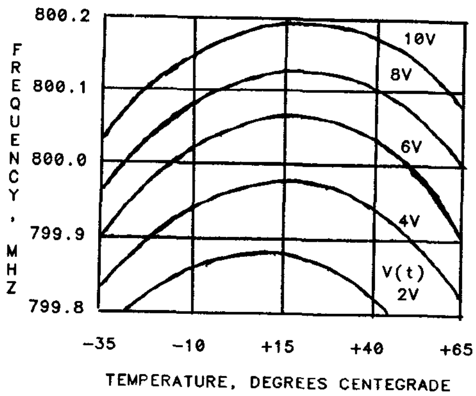


FIGURE 7. HYBRID SAW RESONATOR VCSO TUNING CHARACTERISTICS VS. TEMPERATURE

A block diagram showing such a VCSO application is shown in Figure 8. This oscillator was designed for use as a 1600.000 MHz local oscillator in a commercial satellite receiver. Since the desired output frequency of the oscillator is beyond the frequency range at which SAW resonators can be routinely manufactured, the hybrid oscillator shown here operates at 800.000 MHz and incorporates a frequency doubler in its output. A sample signal at 800.000 MHz is used to close the PLL and maintain the frequency accuracy of the lower frequency crystal source. When used in a narrow band PLL circuit, the phase noise performance of the VCSO predominates for offset frequencies outside of the loop bandwidth.

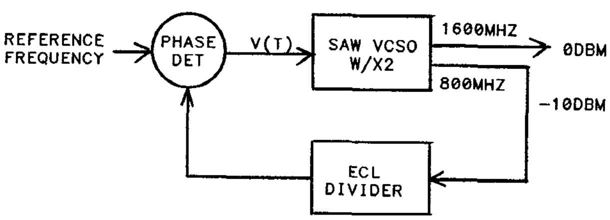
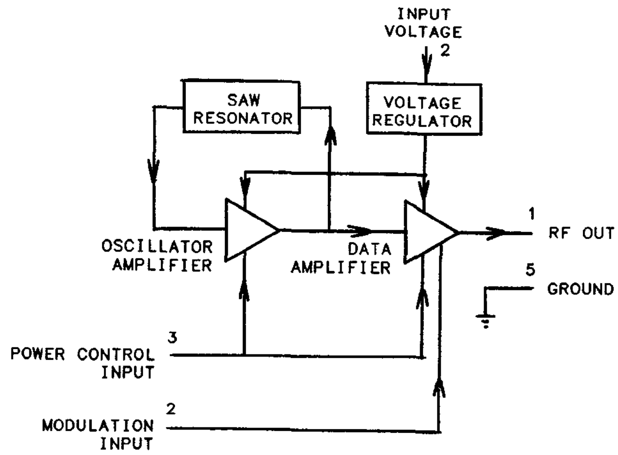


FIGURE 8. HYBRID SAW VCSO APPLICATION IN A COMMERCIAL SATELLITE RECEIVER

MONOLITHIC RF FUNCTIONS

The latest stage in the development of complete RF functions using SAW technology has arrived with the development of an AM Microtransmitter housed in a miniature TO-5 package. The microtransmitter uses a custom IC along with a special SAW resonator design matched to the parameters of the IC. A block diagram and specifications are shown in figure 9. It is interesting that while the main thrust for this development was to provide a low cost transmitter for various remote control applications such as garage door opener and wireless security transmitters, it points the way to development of a number of more sophisticated applications where small size and reliability rather than cost are the main driving functions.



MICROTRANSMITTER SPECIFICATIONS

FREQUENCY:	318.000+/-.250 MHz
OUTPUT POWER:	+7 dBm, MINIMUM
ADJUSTMENT RANGE:	10 dB, MINIMUM
POWER REQUIREMENTS:	6.0 TO 10.0 Vdc 20 mA, TYPICAL
MODULATION DEPTH:	40 dB, TYPICAL
MODULATION RATE:	< 50 kHz
RISE/FALL TIME:	< 1 uSEC
RADIATED HARMONICS:	PER FCC PART 15

FIGURE 9. SAW MICROTRANSMITTER BLOCK DIAGRAM AND SPECIFICATIONS

SUMMARY

SAW technology has matured over its history from a limited number of discrete device types seeking application outside the research labs to a wide assortment of new and exciting SAW components that have the potential to serve many needs. The applications span the range from sophisticated military systems to such common consumer products as garage door opener transmitters. The promise of complete RF functions supplied in monolithic form is now at hand and this technology is now coming to the market.