Benefits of Simultaneous Data Acquisition Modules

When choosing a data acquisition board, many different selection criteria are used. Speed, resolution, accuracy, and number of channels are all important considerations. In addition, there are different architectures used within the data acquisition device itself that can affect your decision. The particular analog input architecture that you choose will affect how often the input channels are sampled and the accuracy of your results.

The two most common architectures in analog input design are multiplexed and simultaneous. Multiplexed converters use one A/D converter for many channels. Conversely, a simultaneous converter uses an individual A/D converter for each channel.

Simultaneous A/D Converters

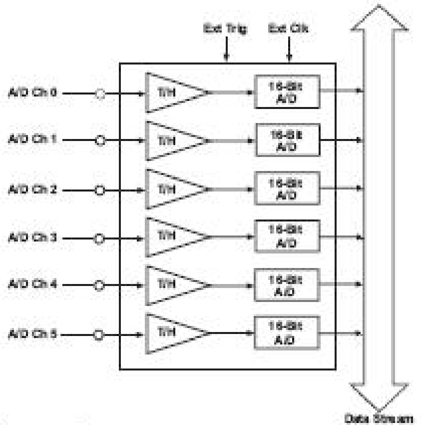


FIGURE 1

Simultaneous Converter: One A/D converter per channel.

Conventional Multiplexed A/D Converter

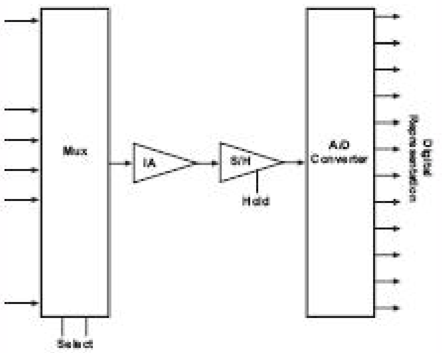
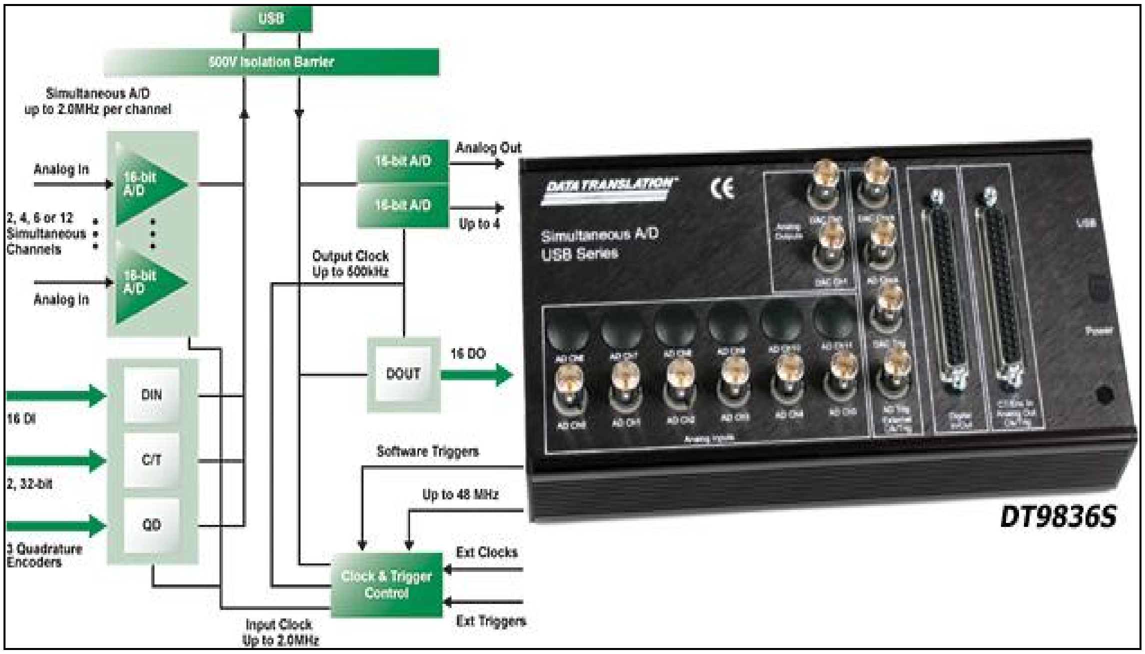


FIGURE 2

Conventional Multiplexed Converter: One A/D converter multiplexs into many channels.

For many applications, a simultaneous acquisition device is certainly the architecture of choice due to its inherent speed and accuracy but, until recently, the cost of these devices was somewhat prohibitive. Times have changed and simultaneous devices are now as cost effective as a multiplexed device for most users.



A series of simultaneous modules are available, including the DT9836S module (pictured above) which offers 6 simultaneous channels capable of sampling at 800kHz on each channel.

Data Translation has designed a series of simultaneous data acquisition modules for USB 2.0. Useful in the following applications, the Simultaneous Series provide high speed, highly accurate measurements:

- Semiconductor device testing
- Nanotechnology testing
- Drug discovery
- Scientific analysis
- Automotive testing

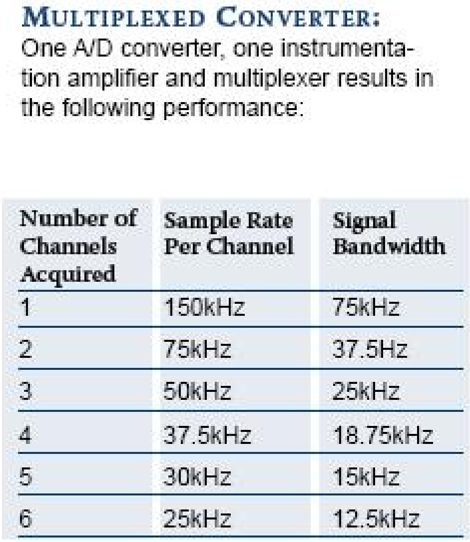
The Simultaneous Series modules from Data Translation provide a 16-bit A/D converter for each analog channel. This allows the user to correlate ultra high-speed measurements of up to 10MHz at the exact same instant in time. These modules are also designed with ±500V galvanic isolation to maximize signal integrity and protect the PC. This series was developed for customers seeking to correlate highly accurate, high-speed measurements while eliminating phase noise from channel-to-channel acquisition.

With this series a common clock and trigger are used for simultaneous and synchronous sampling of all inputs. This means that all functions of the data acquisition modules (A/D, D/A, DIO, Counter/Timers, and Quadrature Decoders) can be simultaneously triggered internally or externally. The data can then be clocked either internally or externally and streamed synchronously to host memory. The synchronous operation allows all I/O data to be processed and correlated for all inputs and outputs. This is very valuable in determining the response across a device-under-test (DUT) to stimuli at the same exact instant.

A more detailed discussion of the benefits of simultaneous acquisition versus the multiplexed approach is provided here to help you make your buying decision.

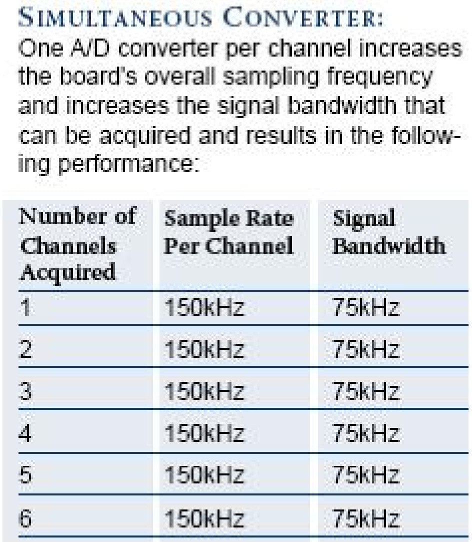
Signal Bandwidth Increased

Simultaneous acquisition dramatically increases signal bandwidth because each channel uses the full throughput of an individual A/D converter. Compare the following tables for a 150 kHz module in a multiplexed and simultaneous architecture. You can see that the signal bandwidth is consistent across all channels with the simultaneous architecture, while it decreases linearly with each additional channel in the multiplexed architecture.



MULTIPLEXED CONVERTER:
One A/D converter, one instrumentation amplifier and multiplexer results in the following performance:

Number of Channels Acquired	Sample Rate Per Channel	Signal Bandwidth
1	150kHz	75kHz
2	75kHz	37.5Hz
3	50kHz	25kHz
4	37.5kHz	18.75kHz
5	30kHz	15kHz
6	25kHz	12.5kHz

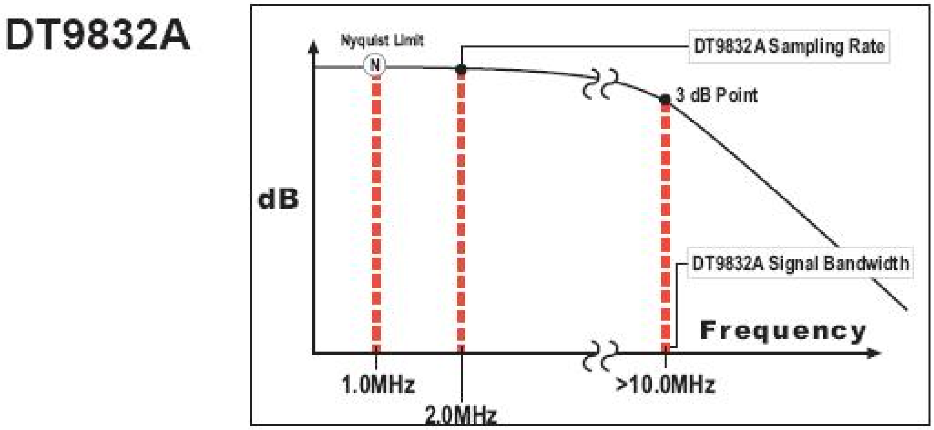


SIMULTANEOUS CONVERTER:
One A/D converter per channel increases the board's overall sampling frequency and increases the signal bandwidth that can be acquired and results in the following performance:

Number of Channels Acquired	Sample Rate Per Channel	Signal Bandwidth
1	150kHz	75kHz
2	150kHz	75kHz
3	150kHz	75kHz
4	150kHz	75kHz
5	150kHz	75kHz
6	150kHz	75kHz

Additionally, the Simultaneous Series from Data Translation is designed to accurately measure higher bandwidth signal components. To accurately measure 16-bit accuracy, the front-end input amplifier has a bandwidth of ten times the Nyquist limit. Below is an example of these design characteristics for the DT9832A.

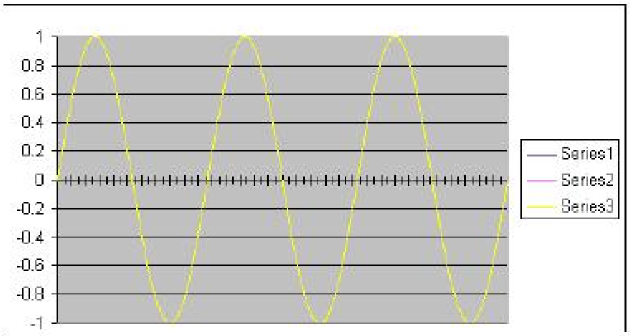
The DT9832A has a sampling rate for each channel of 2.0 MHz. This means that the Nyquist limit allows signal frequencies up to 1.0 MHz to be adequately measured. The analog input components have a signal bandwidth that is ten times the Nyquist limit or in this case, greater than 10.0 MHz to minimize roll-off and phase errors.



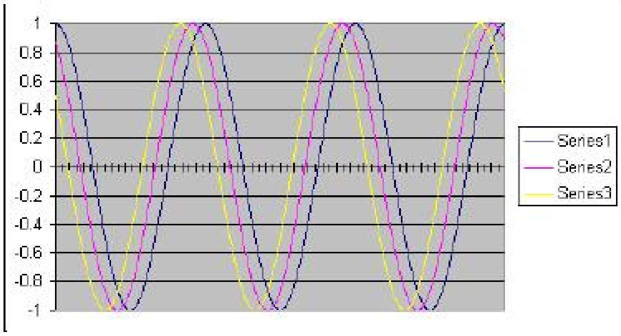
Channel to Channel Skew Eliminated

As you can see from the figures below, since multiplexed devices use one common amplifier and A/D converter to sample all the input channels being used, it results in a time delay or skew between samples. This phase noise is all but eliminated when using a single A/D converter per channel as does the Simultaneous Series modules.

Simultaneous Sampling
eliminates time skew between channels and simplifies both time and frequency based analysis techniques.

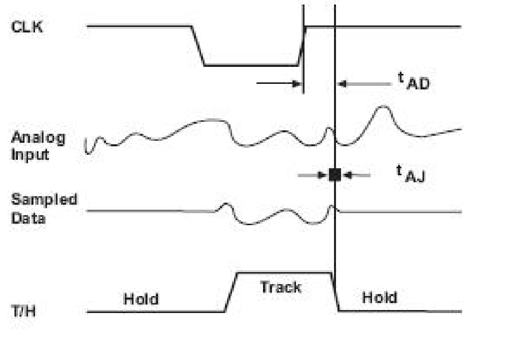


Sequentially (Multiplexed) Sampling
may require software correction for detecting certain patterns.



Built In Accuracy

With a simultaneous A/D converter, all signal inputs are sampled at the exact same instant in time. A common clock and trigger for all channels lets you accurately correlate signals using a single pulse of the clock to acquire all channels. The hardware architecture has accuracy built in. A maximum aperture delay of 35ns (the times it takes the A/D on the module to switch from track to hold mode) is well matched at 5ns across all six track-and-hold circuits, virtually eliminating the channel-to-channel skew that is associated with multiplexed inputs. A maximum aperture uncertainty of 1ns (the "jitter", or variance in aperture delay) virtually eliminates time skew between channels and simplifies both time and frequency- based analysis techniques (aperture skew of less than 30picoseconds).



t_{AD} = Aperture Delay of 35 ns
t_{AJ} = Aperture Jitter (Uncertainty) of 1 ns
The time between each channel (Aperture Delay Matching) is 5 ns maximum.

FIGURE 3

Higher Accuracy at High Speed

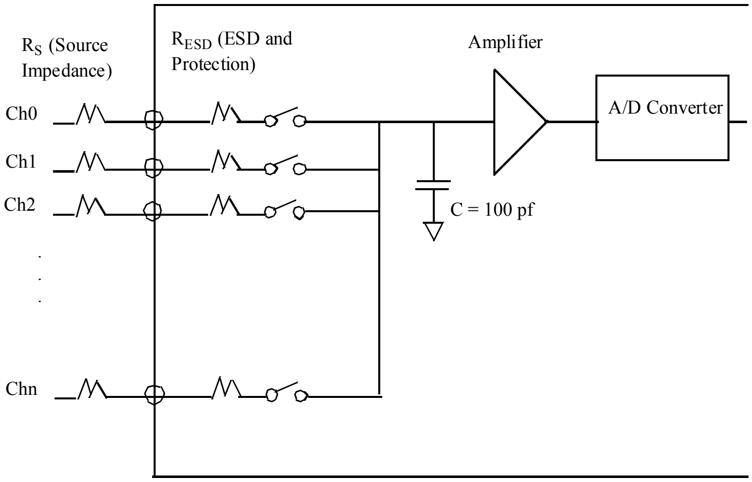
Simultaneous A/Ds are far more accurate than multiplexed A/Ds, especially at high speed, because they eliminate several sources of error, including residual settling time, high-source impedance, and channel-to-channel crosstalk, explained below.

Residual Settling Time

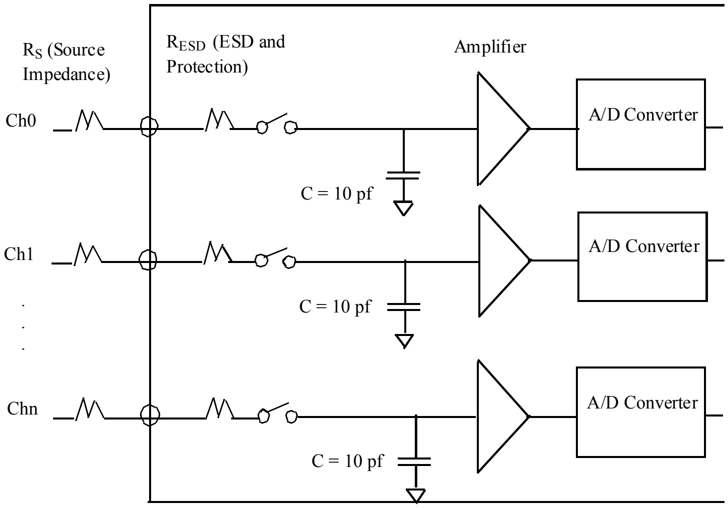
Not only is the channel-to-channel skew virtually eliminated with the simultaneous A/D architecture, but so is the time needed to discharge the built-up capacitance on each input of a multiplexed A/D.

Figure xx shows an equivalent RC circuit for a multiplexed A/D versus a simultaneous A/D.

Multiplexed



Simultaneous



$t=RC$

t = Time, R = Resistance, C = Capacitance

In a multiplexed A/D, each channel is tied to the same A/D, so the settling time for each channel is additive. If, for example, you have 16 analog inputs and each channel takes 100 ns to settle, the total settling time is 16 * 100 ns.

Source Impedance

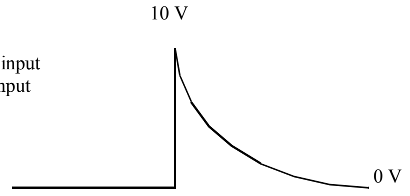
Let's look at the multiplexed A/D a little closer. Source impedance (Rs) and capacitance (C), when multiplied together, determine one time constant (t).

Assume that you have a 10 V input on channel 0 and a 0 V input on channel 1. Also assume that the input impedance on channel 1 is 1 kOhm (Rs = 1 kOhm). Since it typically takes 9 time constants for the multiplexer to settle to within 0.01% accuracy of the voltage you want, the time that it takes to settle when switching from 10 V on channel 0 to 0 V on channel 1 is 9 * 100 ns (1kOhm * 100pf), or 900 ns.

Now, assume that you have a source impedance of 10 kOhm (Rs = 10 kOhm) on channel 1. If the current is 100 pf, the settling time for one channel is 9 * 1 us (10kOhm * 100pf) or 9 us – a large source or error if you're sampling too fast!

The Effect of Input Impedance on Settling Time for Multiplexed A/Ds

Ch 0 has 10 V input
Ch 1 has 0 V input



t = R*C

For 1 kOhms of input source impedance,
t = 1kOhm * 100 pf = 100 ns
To achieve 0.01% accuracy, 9 time constants are required or 900 ns.

For 10 kOhms of input source impedance,
t = 10kOhm * 100 pf = 1 us
To achieve 0.01% accuracy, 9 time constants are required or 9 us.

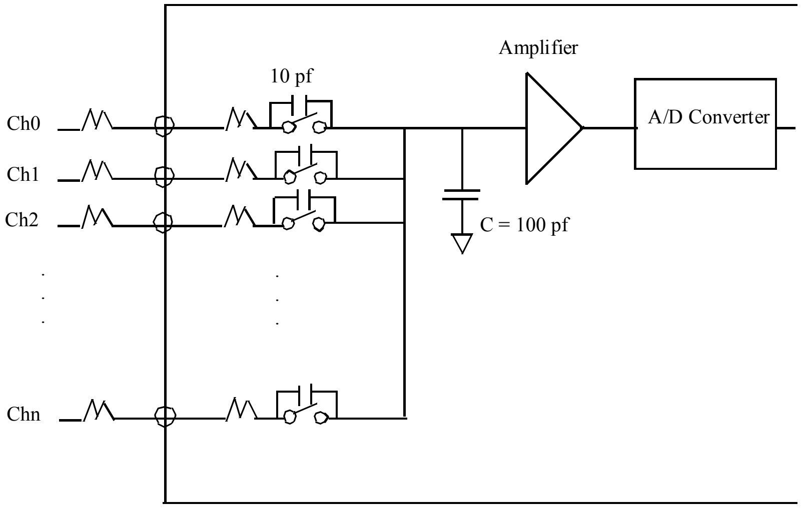
High-speed simultaneous A/D modules do not have this problem since each signal is measured by it's own A/D converter.

Channel-to-Channel Crosstalk

When sampling high-speed signals using a multiplexed A/D, the built-up capacitance charge can "crossover" to the next channel if there is not enough settling time between switching. This can give erroneous readings. High-speed simultaneous A/D modules do not have this problem since each signal is measured by it's own A/D converter.

Figure xx shows an example of channel crosstalk, where the capacitor can cause cross talk between channels (up to 70 pf when off).

Channel Cross talk



Adding a Large Op Amp to the Input

Another problem with multiplexed systems that is eliminated with simultaneous A/Ds occurs when adding large op amp to your input.

In a multiplexed system, adding a large op amp to your input can cause ringing of the input, because it takes time for the voltage to settle, as shown in Figure xx.

Less Aperture Jitter

Aperture jitter (uncertainty) can be measured by simultaneously inputting a +/- 10 volt sinusoidal signal at a specified frequency across all A/D channels. The sampled data is then analyzed to characterize the A/D converter's ability to sample all channels at precisely the same moment.

Since a sinusoidal signal's rate-of-change is greatest at the zero-crossings (locations on the signal where negative-to-positive voltage transitions occur), aperture jitter is most effectively measured there.

A sinusoid is determined by the following equation:

$$V(t) = pSin(2\pi ft)$$

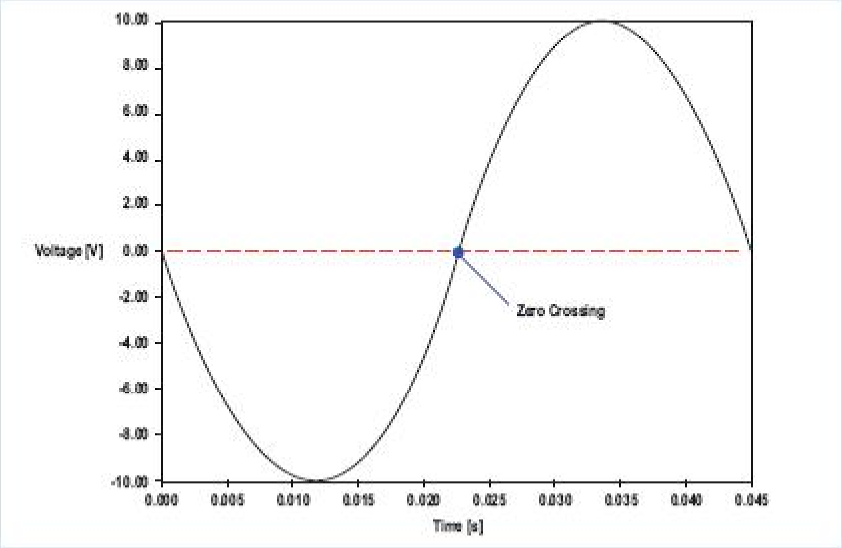
where,

p = peak voltage of sine wave
f = frequency of sine wave
V = voltage
t = time (in seconds)

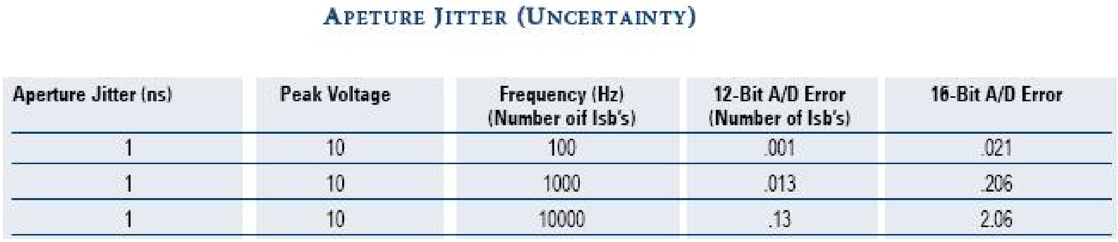
In order to find the voltage change near the zero-crossing, take the derivative of the above equation evaluated at t = 0.

$$\frac{dV}{dt} = 2xfp$$

Using this equation with an aperture uncertainty of 1 ns, a 10 kHz signal should yield a voltage change near the origin of 628 uV or ~2 bits of error for a 16-bit A/D converter.



Aperture jitter is most effectively measured where the signals rate of change is greatest, which is the zero crossing as illustrated above.



APETURE JITTER (UNCERTAINTY)

Aperture Jitter (ns)	Peak Voltage	Frequency (Hz) (Number oif lsb's)	12-Bit A/D Error (Number of lsb's)	16-Bit A/D Error
1	10	100	.001	.021
1	10	1000	.013	.206
1	10	10000	.13	2.06

The following modules offer the benefits of simultaneous data acquisition:

Model	Image	Applications	Throughput Rate	Features	±500V Isolation
DT9816		Low cost, Portable General Purpose	750 kHz/ch	16-bit, 6 A/D, 16 DIO, 1 C/T	—
DT9824		Highest Precision Highest Stability	4800 Hz/ch	24-bit, 4 A/D, 10ppm accuracy, ±0.05µV/°C, CMRR>150dB, ISO-Channel	X
DT9826		Highest Density Portable	41.6 kHz/ch	24-bit, 16 A/D, 16 DIO, 2 C/T, 1 Tach	X
DT9832		Very High Throughput	2 MHz/ch	16-bit, 4 A/D, 2 D/A, 32 DIO, 2 C/T, 3 QD	X
DT9836		High Throughput	800 kHz/ch	16-bit, 12 A/D, 4 D/A, 32 DIO, 2 C/T, 3 QD	X
DT9837		Sound & Vibration Portable	105.4kHz/ch	24-bit, 4 A/D, 1 D/A, 1 Tach, IEPE	—
DT9862		Ultra-High Throughput Sub-sampling Version (300 MHZ Bandwidth)	10 MHz/ch	16-bit, 2 A/D, 2 D/A, 32 DIO,2 C/T, 3 QD, all simultaneous operation	X