Since its introduction in 2006, the DTS ARS has become very popular. We have received a lot of feedback from the field including some frequently-asked questions regarding aspects of its performance.

What are the different versions and how should they be used?

There are two primary factors that determine the ability of the DTS ARS to measure motion: range (deg/sec) and bandwidth or frequency response (Class 600, etc.).

Components can be adjusted to achieve many different combinations of range and bandwidth performance and we had to make some decisions in order to develop a standard product line. The current offering was no accident—the decisions were made for very specific reasons.

The ARS-1500 was specifically targeted to fit the need for measurements in accordance with FMVSS 202a, the rear impact dynamic test standard where the angle difference between the head and torso in a simulated rear impact is quantified. Our specification of 1500 deg/sec and Class 600 came straight from communications with NHTSA and industry experts.

The ARS-12K is Class 1000 compliant and was developed for applications where rates in the 5,000+ deg/sec range are likely. These test applications include dummy heads and limbs where impact with hard objects is likely. This also includes vehicle component measurements in crash tests.

The ARS-300 exists because certain applications require lower rates and lower noise. The ARS-300 is great for applications like vehicle handling/braking tests. The Class 60 response is not suitable for impact testing, but results in much lower noise for slow speed applications.

The ARS-8K is our latest offering. After studying feedback from the field, we developed this unit for quantifying vehicle pitch and roll angles in impact tests such as frontal, side and rollover tests. The ARS-8K has a measurement range that is high enough so it will be not be saturated by high level transients that occur when, for example, the vehicle body contacts the pavement in a rollover test. The Class 180 response is much lower than the Class 1000 response of the ARS-12K. Class 180 is fine for vehicle body measurements and results in much lower noise.

While the applications are pretty straightforward, testing environments are often unique. If you have any questions about the correct ARS specification for your environment, please contact DTS for help.

Is the DTS ARS reverse polarity protected?
Yes. Reverse connection of normal excitation sources (i.e., 5-10 volts, <100 mA) will not damage the unit.

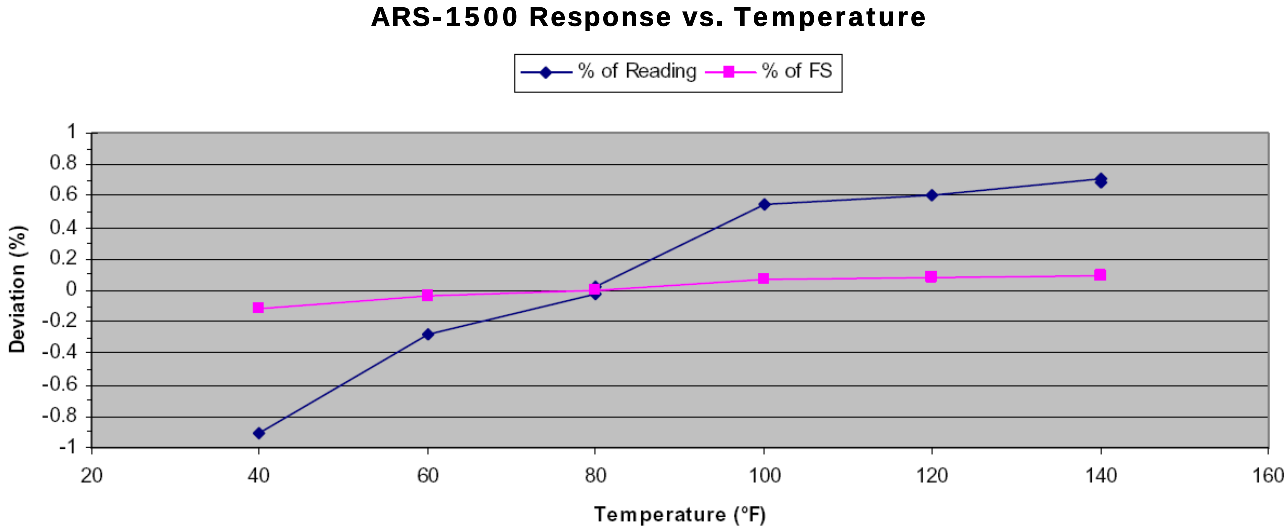
How do I verify that the DTS ARS is working properly?
This is easy to do if you are using TDAS Control software. Since the DTS ARS generates a signal that represents how quickly the angle of the sensor changes, create a calculated channel that integrates the rate data to obtain angle data. Then collect a few seconds of data while you turn the sensor some known angle (e.g., 90˚ or 180˚). The calculated angle output should agree very closely with the real world. It's that simple. Additionally, you can convert to angular acceleration by differentiating the rate data. If you need help, call us!

How do I mount the DTS ARS?
DTS offers a block that that allows mounting up to three DTS ARS units along with up to three Endevco 7264 or equivalent accelerometers in a Hybrid III head. This block can also be used to mount and protect the DTS ARS for vehicle and other applications.

How does the DC offset affect the data?
The DC offset does not affect DTS ARS accuracy since the linear output is simply centered around the natural offset. Our offset spec was designed to conservatively cover the full range of ARS devices we make. For example, all of the ARS units rated for 1,500 deg/sec and higher fit within the window of ±50 mV for DC offset. Roughly 90% have natural offsets less than ±20 mV, far below the ±200 mV spec.

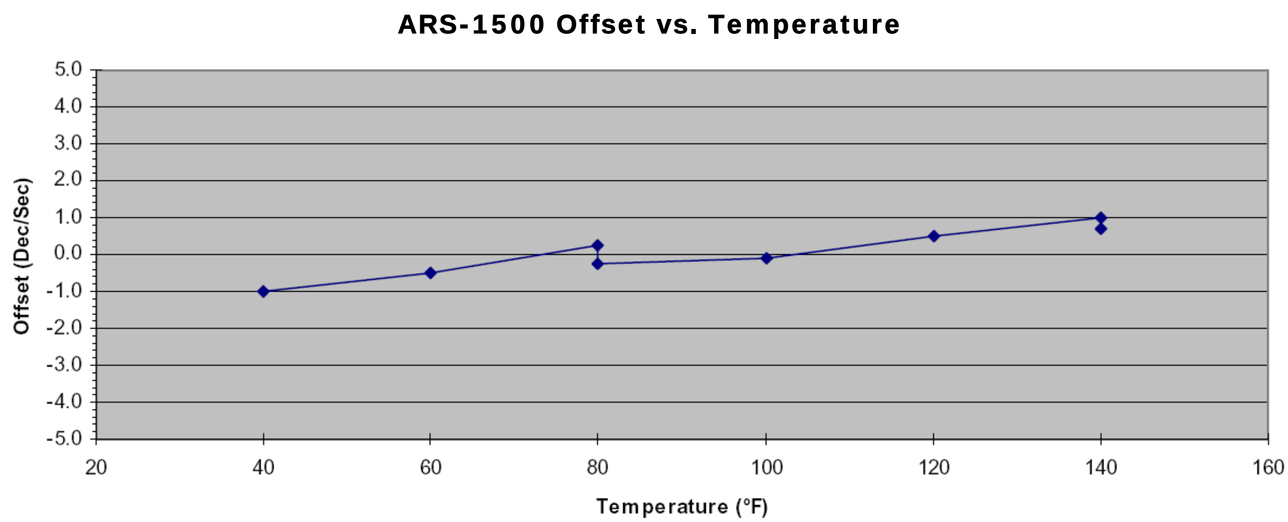
Are there any temperature studies for the DTS ARS?
Yes. DTS ARS products are rated for operation from -40 to 85°C based upon the manufacturer's ratings of the components used inside the ARS. DTS performed testing to assess the real-world performance of the ARS over the temperature range of 40 to 140°F (4 to 60°C).

<u>Sensitivity Change Over Temperature</u>
DTS used a precision rate table to generate known angular rates while changing the temperature of the ARS under test. The results are presented below and indicate that less than a ±1% change in sensitivity is expected over the temperature range indicated. Over the narrower temperature range required for most safety testing applications which employ test dummies, the performance is much better than ±0.5%. The overall thermal coefficient appears to be less than 300 ppm/°C.



Offset Level Change with Temperature

Virtually all sensors have some offset from zero volts with no mechanical stimulus applied. The DTS ARS exhibits some offset level change over temperature which is quantified below (1 deg/sec is equivalent to 0.07% of full-scale).



How does linear acceleration affect angular rate sensors generally and the DTS ARS specifically?

All angular rate sensors have some sensitivity to linear acceleration. There are three potential ways that a rate sensor can be “fooled” by linear acceleration.

1. The sensor does not have sufficient bandwidth and responds in a non-linear fashion to the acceleration.

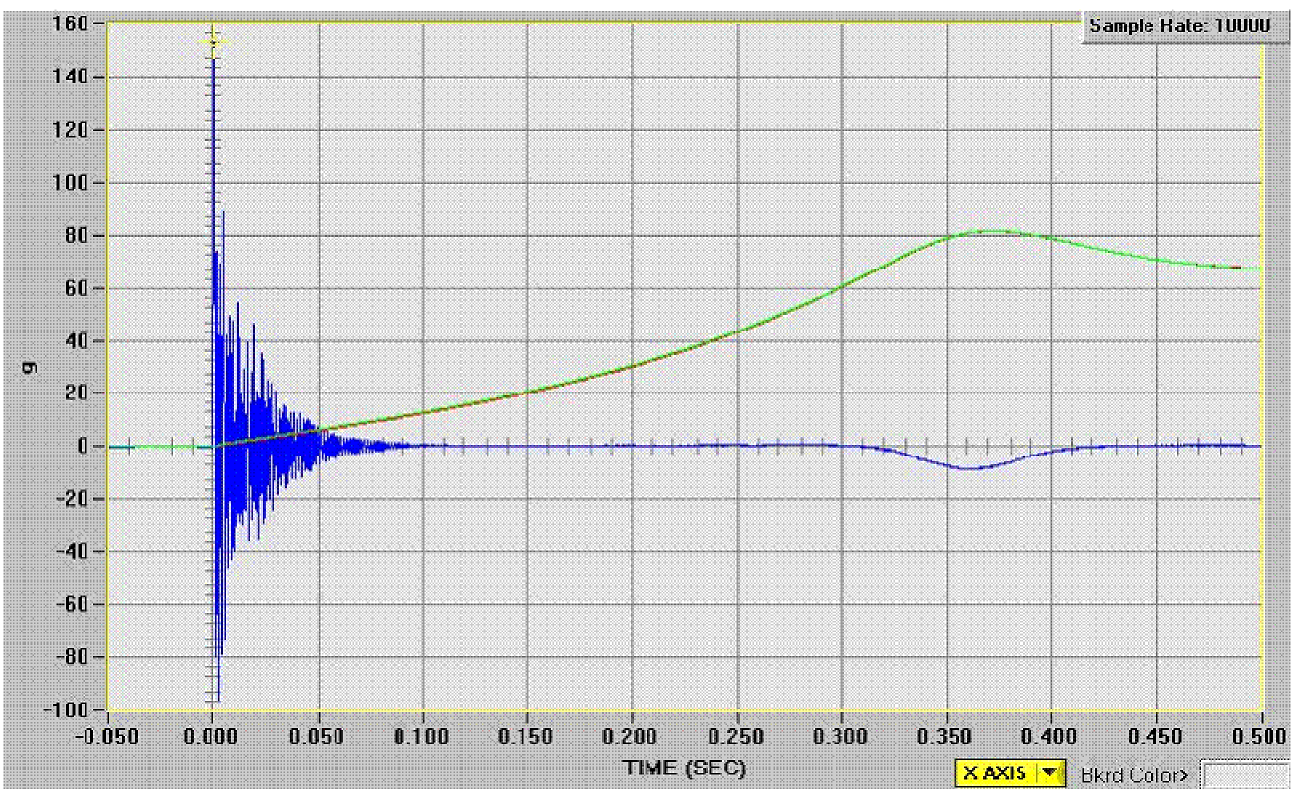
The DTS ARS has the highest bandwidth available and is rated for <0.2 deg/sec per g maximum from any direction. The actual value is generally much less than the rated spec.

2. The sensor does not have sufficient range and becomes saturated, thus offsetting the integration.

To provide the broadest coverage for a variety of testing applications, DTS offers four standard ARS versions. There are several key factors to consider when specifying an ARS for use in your environment including shock level/transient acceleration spikes, required range, and frequency of motion. For example, in high shock environments the ARS-12K may be necessary even if the low frequency component of motion does not seem to justify the high range. In another case, a customer using the ARS-1500 for rollover testing saw occasional distortions when the vehicle body hit the ramp or ground. The ARS-8K was developed to address this issue.

3. The sensor simply does poorly in an acceleration environment.

The DTS ARS does very well. The graph below illustrates the effects of high linear acceleration on an ARS-12K. The sharp, resonant hammer impact and the "soft" deceleration when the pendulum hits the rubber stop at 90 deg are clearly identifiable.



Blue = acceleration; Red = potentiometer; Green = integral of ARS output

Independent evaluations also indicate very good results.

The subject of linear acceleration and rate sensing is of great interest to many users. We believe we have done more work on this subject than any of our competitors and have worked with customers to develop test procedures to quantify the effects. If you would like additional information, please contact us.

What are the significant differences between the DTS ARS and similar sensors? Are there any comparison studies available?

In a side-by-side comparison of an ARS-300 and an ATA MHD ARS-01S at slow rotations (less than 360 deg/sec), the ATA sensor output was much lower than the ARS-300 and when the rotation stopped abruptly, it overshot grossly in the opposite direction before returning to zero. Close examination of the ATA datasheet shows that the frequency response actually starts to deviate from flat (0 dB) at around 3 Hz. In follow-on testing, we observed that integrations started to deviate from actual angles at rates below 4 Hz.

While the ATA sensor design is good, it simply does not produce data that can be used for integrations for things like vehicle or dummy positions. At first glance it may appear that the ATA sensor can be used to virtually DC, especially if software correction is applied, but without DC response, the integrations fall apart. (We have also heard that the ATA recommended software compensation doesn't do much.)

The ARS-12K competes with the ATA rate sensors that have ~11,400 deg/sec full-scale range. Our sensor has more noise than the ATA, but the advantages are many:

- Much lower power requirements,
- Much smaller,
- DC response,
- Much lower cost.

DC response is a key benefit of our ARS. It works for most integration-to-angle calculations where the ATA sensors do not.

Another manufacturer, IES, recently launched a single axis version of their triax ARS that is very similar in size to the DTS ARS. A comparison of features is shown in the table below.

Parameter	IES	DTS ARS
Input Voltage	10-15 VDC	4.9-14 VDC; output not proportional to excitation
Current	15 mA	6 mA
Maximum Range	4,800 deg/sec	12,000+ deg/sec
Shock Survival	1000 G	2000 G
Shunt Test	Yes, but ratiometric to input V	Coming soon (and better!)

The new shunt test feature on the IES unit is ratiometric (varies with excitation voltage) while the sensitivity does not. This is problematic because it means that a single sensor must be treated as two different sensor types in the same test set-up if you want to make best use of the shunt feature. Most DAS software will not support this. Additionally, none of the current in-dummy systems support more than 5 V excitation, making the IES unit unusable for that application.

It is also important to note that we have been evaluated by several independent organizations with very good results. The following is an excerpt from the NHTSA technical report, "Evaluation of Angular Rate Sensor Technologies for Assessment of Rear Impact Occupant Responses," released in May 2007.

> "The completed experiments demonstrate that the IES rate gyro outperforms the MHD in all three test environments. The DTS [ARS-1500] rate gyro seems to outperform the IES rate gyro and the MHD, but it was subjected to a very limited set of rear impact sled tests. Although the use of optical tracking as a benchmark may contain inherent accuracy limitations, the well-controlled test conditions and the variety of dynamic modes under which the sensors have been tested have given us sufficient confidence in comparing their relative performance. In particular, all the sensors have been evaluated under the rear impact environment of the occupant-seat interaction that is most relevant for the dynamic option of the FMVSS202a."