Event Data Recorder - Compliance Assessment

RATIONALE

SAE J1698/3 has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

This SAE Recommended Practice defines procedures intended to be used to validate that relevant EDR output records conform within specified limits to measured sensor input to the device.

1.1 Purpose

Vehicle EDRs exist to enable the analysis of vehicle crash and crash-like events that meet specified trigger criteria. Government and vehicle manufacturer laboratory crash testing provides a basis for assessment of conformance. This recommended practice outlines methods which may be employed to assess conformance for select EDR output parameters. The limitations of these methods are also described.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J211-1   Instrumentation for Impact Test - Part 1 - Electronic Instrumentation

SAE J1698-1   Event Data Recorder - Output Data Definition

SAE J2570   Performance Specifications for Anthropomorphic Test Device Transducers

2.1.2   Government Publications

Copies of these documents are available online at http://quicksearch.dla.mil.

49 CFR Part 563[Docket No. NHTSA–2011–0106]; response 2011

49 CFR Part 563[Docket No. NHTSA–2008–0004]; EDR Final Rule Response

FMVSS Standard 208 Occupant Crash Protection

FMVSS Standard 214 Side Impact Protection

3.   DEFINITIONS

Reference SAE J1698 for definitions.

Unique definitions / terms for this procedure:

3.1   ARRAY

An arrangement of data elements in a defined method. In an EDR, an array will consist of an arrangement of data elements sampled at a defined time instance for a defined duration.

3.2   COMPLIANCE

The act adhering to, and demonstrating adherence to, a standard or regulation.

3.3   LCL

Lower Control Limits: Used to define the bottom limit for compliance testing of a variable.

3.4   UCL

Upper Control Limits: Used to define the upper limit for compliance testing of a variable.

3.5   WINDOW

A region of acceptance defined as the values between the UCL and LCL for a given variable. This may include parameters for a single or multiple variables.

Unless otherwise noted, x axis refers to longitudinal components (of acceleration or velocity), y axis refers to lateral components, and z axis refers vertical components.

4.   GENERAL ACQUISITION PARAMETERS

4.1   General Conditions

Acceleration signals used to derive Longitudinal Delta-V and its related parameters (Maximum Value and Time to Maximum Value) are acquired during FMVSS2xx Testing (xx=08,14), including those called out in Part 563 compliance tests. To assess the compliance and accuracy of these reported parameters, these tests must be conducted with instrumentation that allows a post-test comparison of the EDR output and corresponding laboratory signals. The instrumentation should consist of reference accelerometer(s) installed and monitored under the following conditions:

4.1.1   Attachment method and location

The placement and orientation of the reference sensor(s) shall comply with SAE J211 guidelines to maximize desired signal transmission, and insure off-axis signals, transmissibility, and other factors are met. The accelerometer shall be installed in a manner such that the attachment method of the reference signal provides the full signal content that can be realized by the sensor. The x reference signal used to compute the upper and lower control limits should be located close to the EDR's accelerometer location, on a similar mounting surface to provide 'equivalent' signal coupling. If this is not possible, additional tolerances may be required to satisfy compliance due to other factors that affect the signals and attenuations, i.e., non-rigid body parameters, especially for events containing multiple vector inputs. For this scenario, consultation with the vehicle manufacturer is recommended. If squib current measurements are used for correlating events and times, an acceptable method, as agreed with the OEM, shall be utilized.

The vehicle manufacturer shall provide recommended accelerometer placement based upon internal test practices, and support interface recommendations for the squib monitoring method(s).

4.1.2   Signal acquisition

An example of a typical reference signal and acquisition requirements would be:

Variable	Ref	Requirement
Frequency class	SAE J211-1	Class 1,000 (1000 Hz cut-off).
Range (amplitude) class	SAE J211-1, SAE J2570	Class 1,000 g's; appropriate for the location noted.
Resolution	SAE J211-1	.5g or greater. Digital word lengths of at least 12 bits (including sign) shall be used to be assured of reasonable accuracy in processing. The least significant bit shall correspond to no greater than 0.2% of the CAC (channel amplitude class).

The vehicle manufacturer may provide recommended accelerometer parameters based upon internal test practices.

4.1.3   Reference sensor validation

In the course of applicable laboratory crash testing, it may be necessary to confirm that the reference signal is valid if the EDR and reference signal do not demonstrate compliance to the limits defined within this practice, or determine a valid alternate source for compliance testing. The following assessments are recommended for this purpose.

4.1.3.1   Clipping

Evaluate the reference signal for signs of clipping. If evident, this signal may not be a valid source to establish compliance to the limits defined within this practice.

4.1.3.2   Comparison with related parameters

Compare the reference signal with related parameters (e.g., target vehicle speed, measured speed at time of impact, etc.). If the reference signal demonstrates reasonable correlation with these related parameters, then the reference signal may be deemed valid.

If the primary reference signal does not demonstrate correlation with related parameters, consider alternate vehicle-mounted sensors that may be expected to yield an output similar to that of the primary (target) reference signal (e.g., accelerometers mounted in close proximity to the primary reference sensor). If this alternate reference signal demonstrates reasonable correlation with the related parameters described herein, then this reference signal may be used as a substitute for the primary reference. However, it is noted that appropriate adjustment of the compliance limits may be required to allow for the differences in location. Specifically, the alternate location may introduce additional errors in the delta-V slope and or timing of this signal when compared to the EDR (reference) location that may require additional tolerances added to the noted values to provide compliance to the limits defined in this practice due to different signals occurring in that area, or due to the type of event tested.

4.1.4   General certification of other parameters

Many tests elements noted in Part 563 Table I include variables that are not reasonably tested at the point of crash certification (i.e., Table III parameters, accuracies for Speed vehicle indicated, throttle position, etc.). For these instances, refer to the vehicle manufacturer / supplier for a compliance report on the requirements of the appropriate variables.

4.2   Vehicle System Considerations

It is noted that vehicle systems are designed to optimize restraint performance. In some cases, these designs may impose constraints on the ability to comply with specific Part 563 requirements. Examples of these constraints are provided in the following sections.

4.2.1   Sensor signal clipping

The EDR may incorporate sensor designs that are optimized for discrimination performance and thus, may not satisfy the requirements denoted in Part 563 for some elements during an impact event. An example of this may be element g range, which could result in clipping and correlation differences when compared to a (laboratory) reference sensor captured during a test event. This error may translate into deviations for those elements denoted in Part 563. The saturation of the (EDR) internal sensor may be demonstrated with processing of the reference sensor to the (modeled) internal sensor signal and/or EDR acceleration data. Incorporation of an internal flag within the EDR denoting the time of saturation from the trigger may also be used to indicate this occurrence.
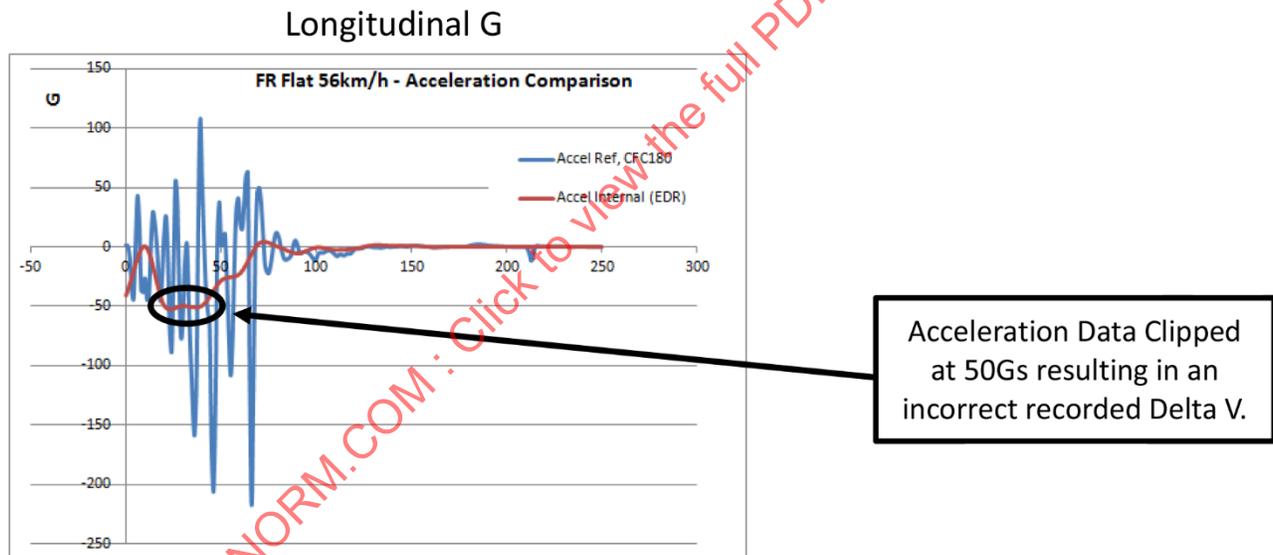
An example illustration of this is provided below:

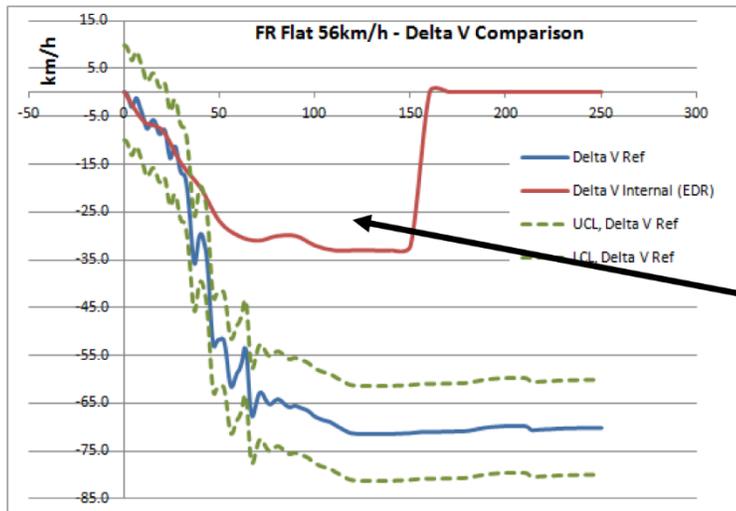**Figure 1 - Example of event with clipped acceleration signal.**

Figure 2 - Example of event with velocity difference based on clipped acceleration signal.

4.2.2   Spurious input signals during test

The method of conducting vehicle certification tests may create additional signals during the test that may be interpreted by the system as a trigger (may be either at (0) and/or initiate a 'wake-up' signal to the algorithm that may increase the stored time records for a given test condition). Such signals may be created by vehicle tow systems, or other methods used to conduct the specific test.

4.2.3   Other

The following is a list of additional test conditions that may introduce error when comparing the reference and EDR signals.

a.   Reference Sensor location / signal coupling concerns (with respect to module internal sensors).

b.   Signal acquisition concerns; Sampling, ranges, filtering.

c.   Reference sensor faults. Non-consistent reference sensor signal responses (erratic, rail), clipping, etc.

d.   Translational errors due to the positioning of reference sensors with respect to the module internal sensors (cross-axis, dynamic signals due to 'non rigid-body' dynamics).

e.   Test event variations; including vehicle rotation during test, or signals from off-axis coupling into the primary axis during test, or variations during test.

If any of these concerns are suspected, consult with the vehicle manufacturer for review and/or recommendations.

5.   LONGITUDINAL DELTA-V PARAMETERS

5.1   Delta V Longitudinal

Data Element Name	Recording interval/time (relative to time zero)	Data Sample Rate (samples per second)	Minimum Range	Accuracy	Resolution
Delta–V, longitudinal	0 to 250 ms, or 0 to End of Event Time plus 30 ms, whichever is shorter.	100	-100 km/h to + 100 km/h	±10% (of full scale value)	1 km/h

To verify that the EDR output conforms with the requirements stated, the EDR output is compared with the reference accelerometer sensor data according to the following process:

(Unless otherwise noted, the t_deploy is the first deployed restraint)

EXAMPLE:

Consider an example crash longitudinal acceleration signal:
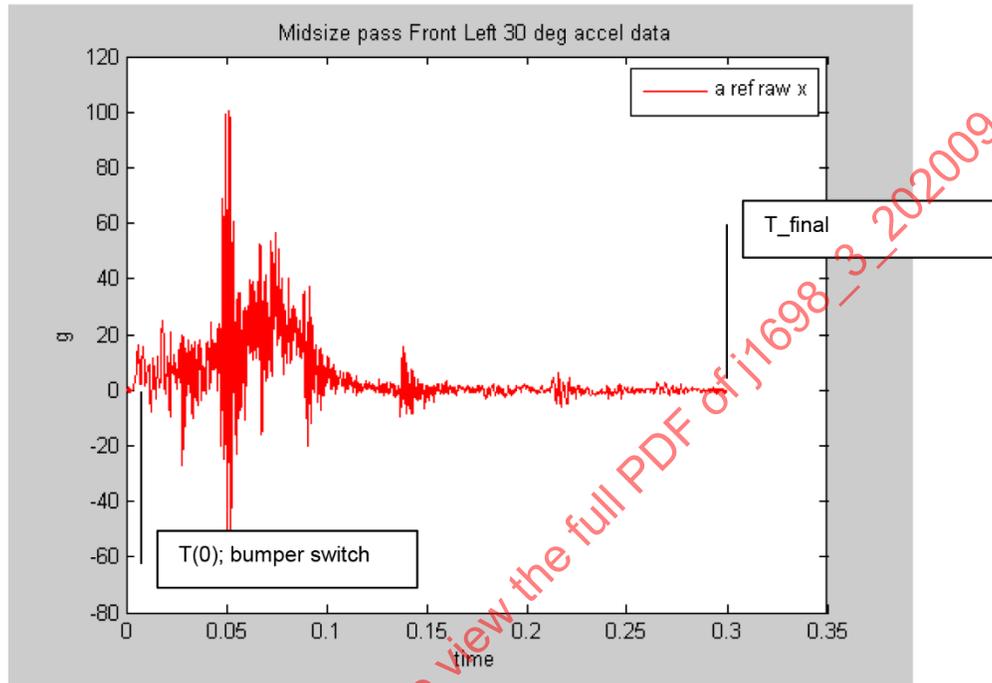
Figure 3 - Example (x) crash acceleration signal

Equation 1: delta_v_x calc; ref 1

$$V\_ref(km/h) = 35.304 * \sum_{t(0)}^{t\_final} a\_ref\_raw(t)dt$$

(Eq. 1)

Where:

V_ref = Delta velocity of the reference signal (in kilometers per hour)

t_final = t(0) + 0.3sec

t(0) = vehicle contact with barrier (typically derived from related contact switch)

a_ref_raw = the acceleration reference sensor signal captured during the event under the prescribed conditions. (g's)

t = time (seconds)

This yields the following example longitudinal velocity curve for the given acceleration signal:

Midsize pass Front Left 30 deg integrated g data; V

Figure 4 - Example (x) delta velocity signal

The reference signal is processed as shown in Equation 2 & 3, to derive the upper and lower control limits for the EDR longitudinal velocity record:
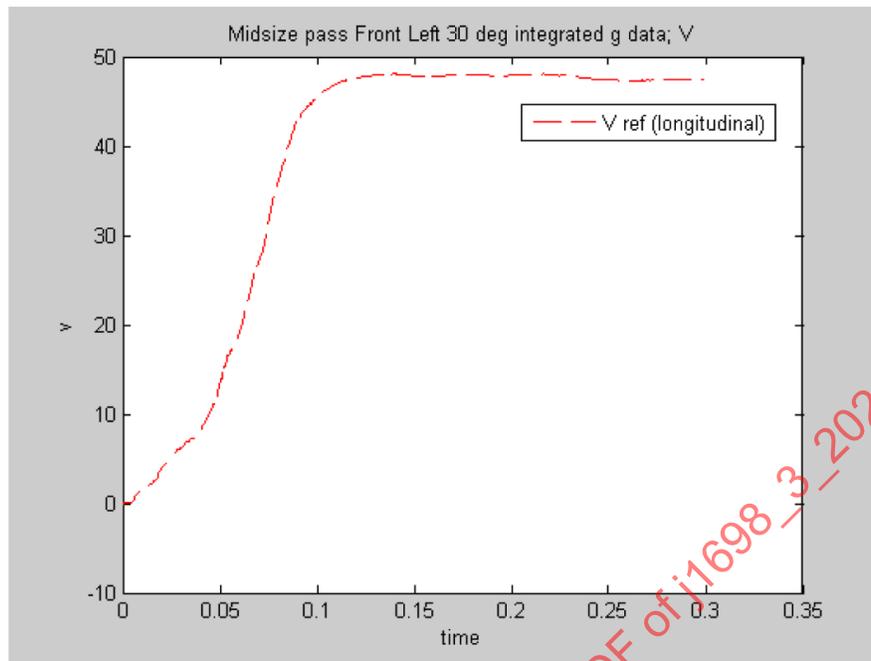
Equation 2: Upper Control Limit equation for upper delta velocity window

$$UCL = 35.304 * \sum_{t(0)}^{t\_final} a\_ref\_raw(t)dt + 10km/h$$

(Eq. 2)

Equation 3: Lower Control Limit equation for lower delta velocity window

$$LCL = 35.304 * \sum_{t(0)}^{t\_final} a\_ref\_150Hzfilt(t)dt - 10km/h$$

(Eq. 3)

Where:

UCL = Upper Control Limit for delta velocity allowance

LCL = Lower Control Limit for delta velocity allowance

t_final = t(0) + 0.3 seconds

t(0) = vehicle contact with barrier (typically derived from related contact switch)

a_ref_raw (g's)= the acceleration reference sensor signal captured during the event under the prescribed conditions.

a_ref_150Hzfilt (g's)= acceleration reference sensor signal captured during the event, under the prescribed conditions and passed through a 150Hz 2 pole Butterworth filter.

t = time (seconds)

Equation 4 : 150Hz 2 pole Butterworth low-pass filter (for 10kHz sample rate)

$$
\begin{aligned}
a\_ref\_150Hzfilt\,(n) = \ & 0.00208057 * a\_ref\_raw\,(n) \\
& +0.00416113 * a\_ref\_raw\,(n-1) \\
& +0.00208057 * a\_ref\_raw\,(n-2) \\
& +1.86689228 * a\_ref\_150Hzfilt\,(n-1) \\
& -0.87521455 * a\_ref\_150Hzfilt\,(n-2)
\end{aligned}
$$

(Eq. 4)

The 10 km/h is derived from the 10% tolerance for the 100 km/h allowed in Table III for Longitudinal delta-V in Part 563

NOTE: The UCL upper control limit uses 'raw" to provide for variance in the filtering performed on the reference sensors. This UCL will provide a maximum rise time and incorporate the peak velocity signal. The LCL uses the 'filtered' signal to provide for the potential delay due to filtering (in time), allowing for the slower rise time and incorporates the minimal velocity amplitude envelope.
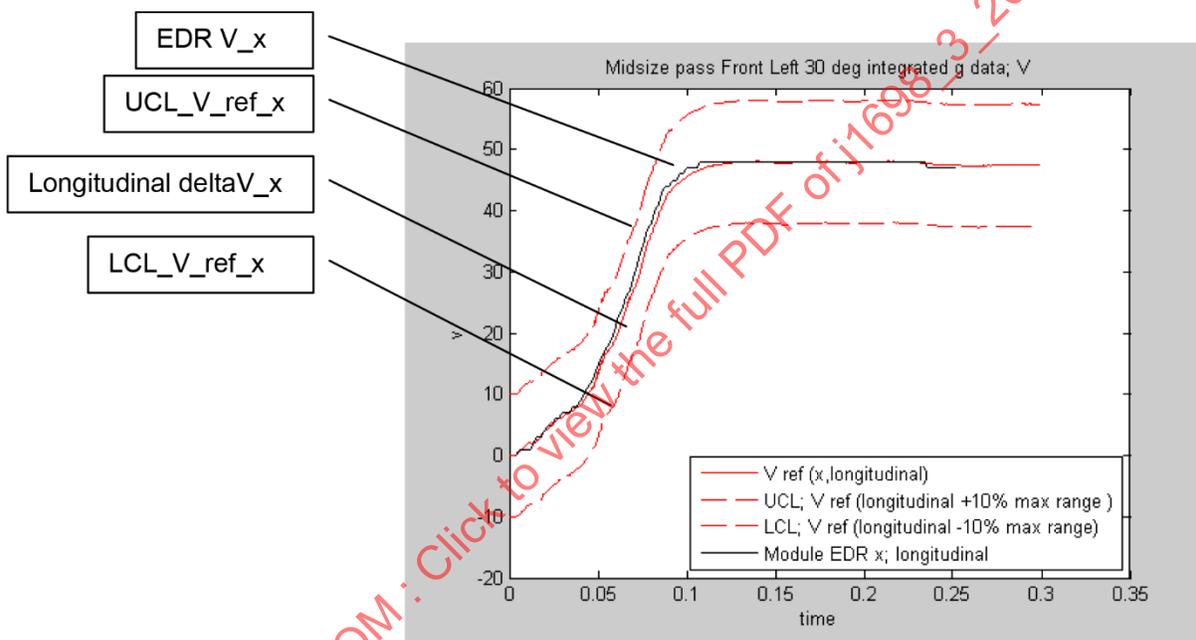

Figure 5 - Example (x) delta velocity signal with UCL and LCL

Having established the upper and lower control limits based upon the reference signal, the EDR record is superimposed to establish compliance with those limits. However, since the EDR record and the reference signal have differing t(0) criteria, it is necessary to superimpose these traces using a common time reference. This can be done one of two ways depending on the manner in which the EDR classifies t(0) (per Part 563 "continuously running" method, or based upon "airbag deployment").

METHOD 1: The first method is based upon the Part 563 definition of t_zero for "continuously running" algorithms which states:

"time_zero_longitudinal is the first point in the interval where a longitudinal, cumulative delta-V of over 0.8 km/h (0.5 mph) is reached within a 20 ms time period"
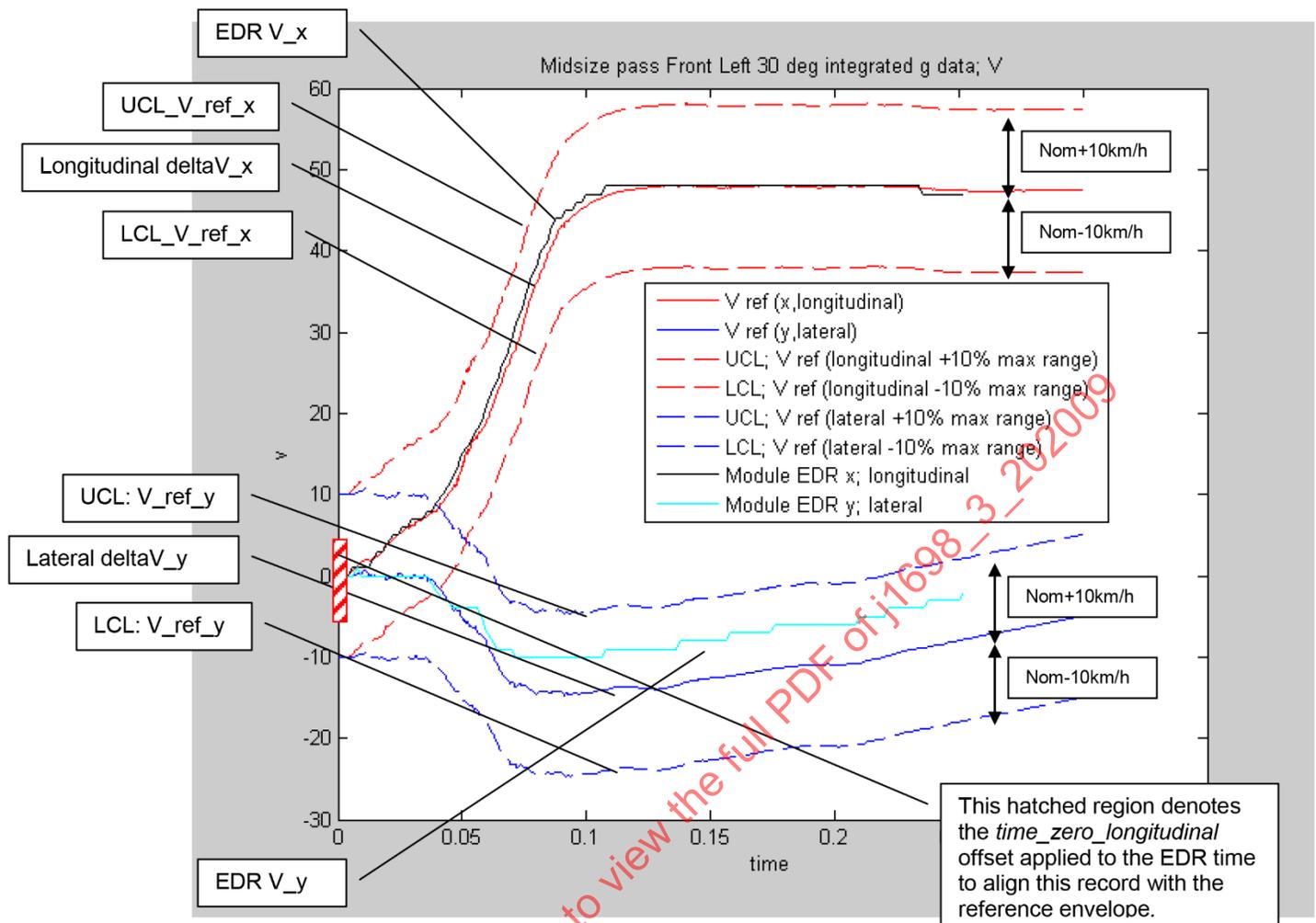
Figure 6 - Example (x,y) delta velocity signal with UCL and LCL and EDR data

METHOD 2: The second method defining a common time reference is developed for the case where t(0) is the time at which an airbag is deployed (t_deploy). In this scenario, the restraint deployment is used to align the signals. The time to deploy recorded by the squib current monitoring device (t_squib) is used for the laboratory reference. It is noted that sufficient time must be allowed for a 'pre-capture of data to the t_squib condition to insure the full event is captured. This may be done with a contact switch or a sufficient buffer depth in the data acquisition unit. Note that this method can only be employed for impact events that yield restraint deployment.

EXAMPLE:

Consider the same example used in Method 1:

This example utilizes the module EDR "time_zero_longitudinal" as the "reference time (0). For this method, we then calculate the reference sensor curve and align the data to t_squib. For alignment, we use the EDR records for t_deploy and longitudinal deltaV. We then find the corresponding values for the reference sensor and align to this intersection point:

Ie. (Longitudinal delta v (EDR) = longitudinal delta v (ref)) & (T_deploy (EDR) = t_squib (ref))

The UCL and LCL is then calculated and plotted using the t_squib to align the data as done above.

The EDR data is plotted as recorded.

The graph should then show overlap of the signals with time to deploy as the common point for both cases.

Testing of the values to the requirements are then performed as derived from Method 1.

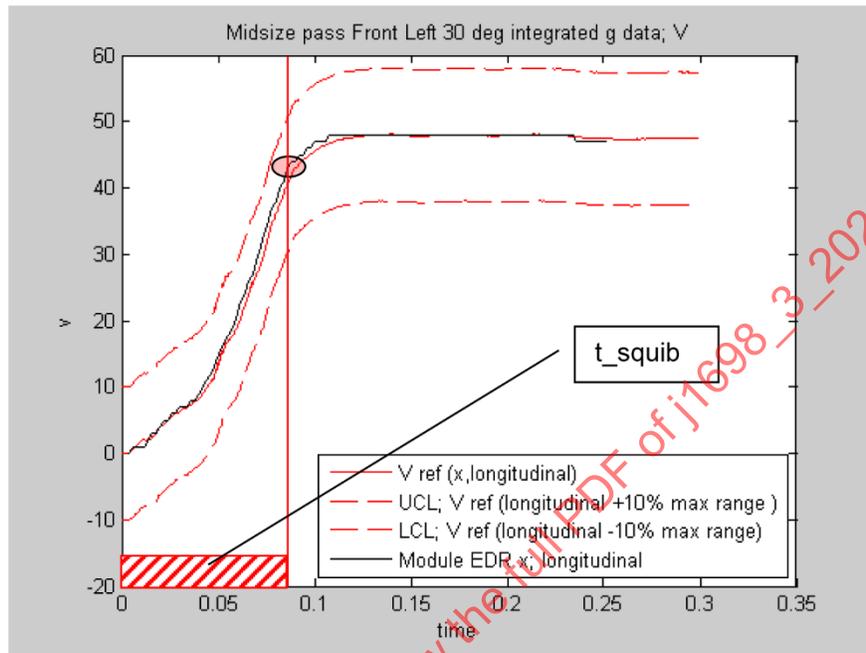We can then evaluate the compliance of the reference and internal signal values.

Figure 7 - Example (x) delta velocity signal with t_squib alignment

The alignment with the Longitudinal delta v (EDR) = longitudinal delta v (ref) & T_deploy (EDR) = t_squib (ref) along with the UCL/LCL plots is depicted in Figure 7. Verification to the other parameters will be performed as noted in Method 1 with appropriate modifications based on the new noted curves.

METHOD 3:   A third method for defining a common time reference is provided to allow a method to calculate a t(0) "time_zero_longitudinal" based on the EDR record and the t_squib time. This method can only be employed for impact events that yield restraint deployment. This method will perform calculations and metrics based on the t_squib parameter only, and align the data accordingly. Obtain the EQUIVALENT "time_zero_longitudinal" for the reference sensor signal by taking t_squibintit – the EDR time to deploy record. This will create an EQUIVALENT "time_zero_longitudinal" point for the reference sensor data. Plot the reference sensor output using this data. Note the time to deploy or t_squib on the graph. Plot the corresponding UCL and LCL curves as defined in Method 1 with the changes noted here for alignment to time_zero_longitudinal. Plot the EDR data using the recorded data. The EDR time_zero_longitudinal is used "as recorded". This provides for alignment to the "time_zero_longitudinal" as performend in Method 1.

5.2   Maximum Delta V longitudinal

Data Element Name	Recording interval/time (relative to time zero)	Data Sample Rate (samples per second)	Minimum Range	Accuracy	Resolution
Maximum delta–V, longitudinal	0 to 300 ms, or 0 to End of Event Time plus 30 ms, whichever is shorter.	N/A	-100 km/h to + 100 km/h	±10%	1 km/h

From the EDR record, identify the time at which maximum delta-V occurs. Create an acceptance window with the upper and lower control limits (UCL and LCL) around this point as defined by:

- Acceptance Window = Maximum delta-V, longitudinal_EDR ± tolerance limit (for UCL and LCL respectively);

- tolerance limit = (10% of lat_v_max OR long_v_max OR 10% of max range (10km/h)

- | Maximum Delta_v_max_ref – Delta_v_max_edr | < tolerance limit

Verify compliance is met by insuring that the EDR for Delta_v_max is within the reference signal Upper and Lower Control limit values (UCL and LCL).

Alternatively, the user could define compliance as having the value stored as the "Maximum delta-V longitudinal" being within the Delta-V longitudinal array values (cannot have a higher value).

Example: Maximum delta-V, longitudinal $\geq$ max | delta-v longitudinal (t) |;

In this approach, the longitudinal array consists of the elements of delta_v longitudinal versus the required sample time interval. A similar array could be formed from the acceleration signal elements.

Example illustration (using same example as in prior study but only considering the longitudinal for the test case).

[1] At the time of this writing, the preferred interpretation is 10% of the range for delta-V; however, some vehicle manufacturers are performing 10% of the maximum of longitudinal OR lateral for internal reasons and/or based on their interpretations. Both are included here, with emphasis on the 10% of the maximum the 'required' criteria, and the other as a reference test.
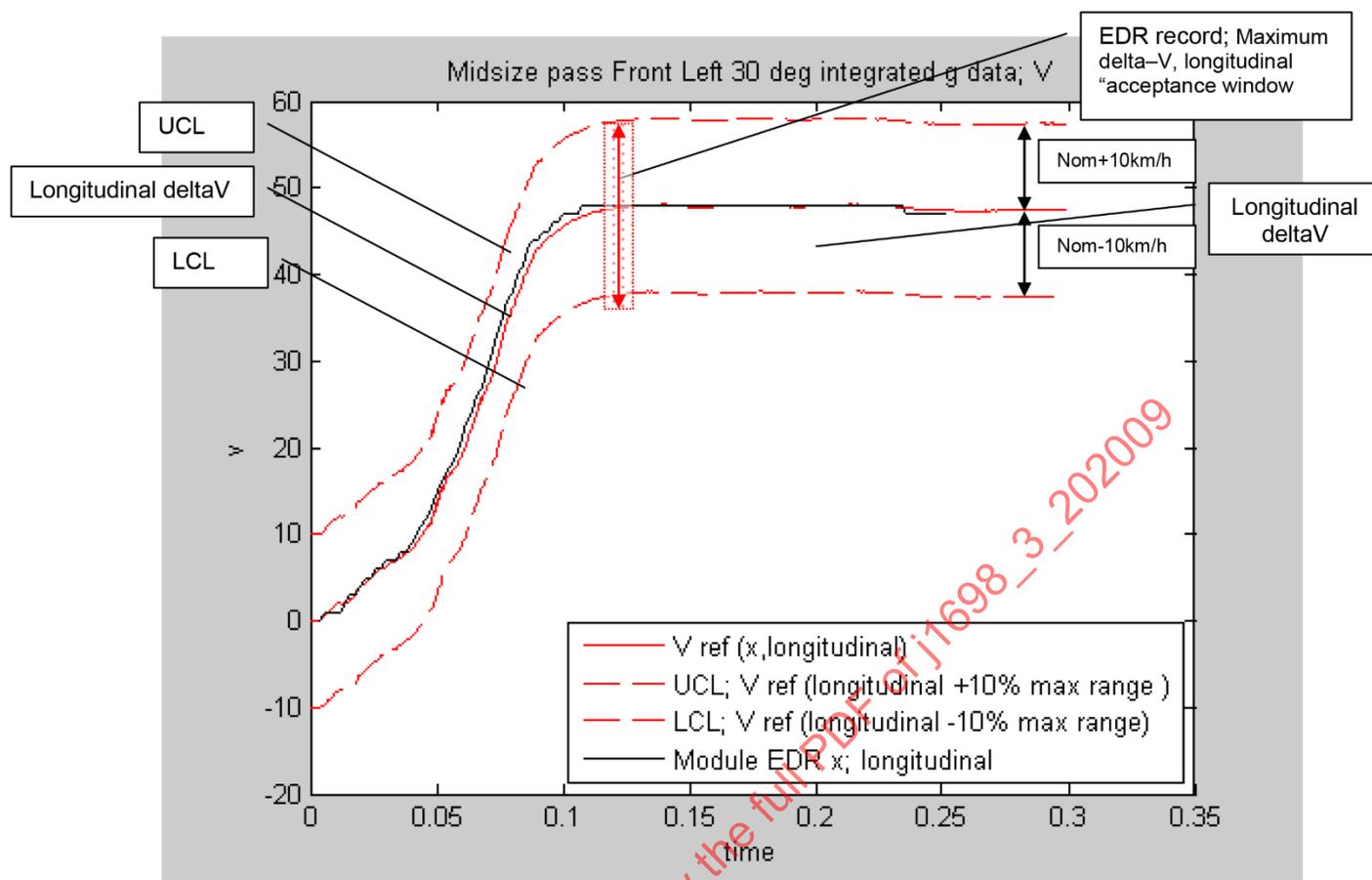
Figure 8 - Example (x) delta velocity signal with UCL and LCL and EDR data; with Maximum Delta V longitudinal

5.3   Time, maximum delta V

Data Element Name	Recording interval/time (relative to time zero)	Data Sample Rate (samples per second)	Minimum Range	Accuracy	Resolution
Time, maximum delta–V	0 to 300 ms, or 0 to End of Event Time plus 30 ms, whichever is shorter.	N/A	0—300 ms, or 0—End of EventTime plus 30 ms, whichever is shorter	±3 ms	2.5 ms

This data element is defined as the reported time at which the EDR records a maximum delta-V. Observing sample delta-V signals, note that peak values often occur as the signal begins to approach a steady-state value, but this may not always be the case. During this phase of the signal, the maximum value may simply represent a minor fluctuation from the mean value. Accordingly, the timing associated with this value may vary and may not be repeatable from test-to-test. Further, the reported maximum timing for the maximum delta_V EDR may not 'directly' correlate with the maximum delta-V from the external reference sensor. For these reasons, conformance is assessed using either of the following methods:

Method 1: We will use what was defined for the UCL and LCL for the delta-V longitudinal (vs time), and the maximum delta V from the reference sensor signal, to evaluate versus the value stored in the EDR record. The EDR record is used as the 'control' here to define the Time, maximum delta-V. An acceptance window is created around the time, maximum Delta_v_edr point as defined by:

Acceptance window = Time, maximum delta-V_EDR ± tolerance limit; tolerance limit ± 3ms