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**Flight dynamics — Vocabulary —**  
**Part 8:**  
**Dynamic behaviour of aircraft**

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 8, *Aerospace terminology*.

This second edition cancels and replaces the first edition (ISO 1151-8:1992), which has been technically revised.

The main changes are as follows:

- new terms related to types of aircraft motion have been added.

A list of all parts in the ISO 1151 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Flight dynamics — Vocabulary —

## Part 8: Dynamic behaviour of aircraft

### 1 Scope

This document defines terms related to the concepts and quantities characterizing some classes of aircraft motion and their fundamental dynamic characteristics.

The aircraft is assumed to be rigid, of constant mass and of constant inertia. It is not equipped with systems modifying its natural dynamic behaviour. However, most of the definitions can be applied to the case of a flexible aircraft, of variable mass and of variable inertia.

The general concepts defined in this document are applicable to the atmospheric flight phase.

### 2 Normative references

There are no normative references in this document.

### 3 Terms and definitions

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1 General

##### 3.1.1

##### **flight variable**

physical quantity, the value of which as a function of time characterizes aircraft motion

##### 3.1.2

##### **flight state**

set of values of the *flight variables* (3.1.1)

Note 1 to entry: This concept should not be confused with that of *flight point* (ISO 1151-7:1985, 7.5.5).

##### 3.1.3

##### **steady flight state**

*flight state* (3.1.2) in which the *flight variables* (3.1.1) considered remain constant with time

##### 3.1.4

##### **quasi-steady flight state**

*flight state* (3.1.2) in which the *flight variables* (3.1.1) considered vary so slowly with time that their variations can be disregarded in the study

##### 3.1.5

##### **unsteady flight state**

*flight state* (3.1.2) in which at least one of the *flight variables* (3.1.1) considered varies so rapidly with time that its variations cannot be disregarded in the study

### 3.1.6

#### **reference flight state**

*flight state* (3.1.2) chosen as reference in a given study

Note 1 to entry: In most cases, a *steady flight state* (3.1.3) or a *quasi-steady flight state* (3.1.4) is chosen as reference.

Note 2 to entry: In a study covering a certain period of time, it is normal to choose the flight state immediately prior to this period as a reference.

### 3.1.7

#### **control input**

action on aircraft intended to alter or to maintain the *flight state* (3.1.2)

### 3.1.8

#### **disturbance**

involuntary action which results in a modification in the *flight state* (3.1.2)

Note 1 to entry: The nature of this action can be, for example:

- human;
- atmospheric;
- mechanical.

### 3.1.9

#### **input variable**

element of the set of quantities characterizing the *control input* (3.1.7) or *disturbance* (3.1.8)

### 3.1.10

#### **output variable**

element of the set of *flight variables* (3.1.1), the developments of which over time characterize the response of aircraft to the *control input* (3.1.7) or *disturbance* (3.1.8) considered

## 3.2 Types of aircraft motion

### 3.2.1

#### **flight-path trajectory**

three-dimensional locus of origin of the flight-path axis system, usually the centre of mass, relative to the Earth

### 3.2.2

#### **aircraft plane motion**

motion of aircraft characterized by a *flight-path* (3.2.1) contained within a plane

### 3.2.3

#### **straight flight**

*aircraft plane motion* (3.2.2) characterized by a straight *flight-path* (3.2.1)

### 3.2.4

#### **horizontal flight**

*aircraft plane motion* (3.2.2) characterized by a *flight-path* (3.2.1) contained within a horizontal plane

### 3.2.5

#### **symmetrical flight**

*flight state* (3.1.2) of aircraft with zero angle of sideslip

Note 1 to entry: The angle of sideslip is defined in ISO 1151-1:1988, 1.2.1.1.

Note 2 to entry: The geometry of aircraft and the flow are not necessarily symmetrical.

**3.2.6****turn**

motion of aircraft resulting in a change of *flight-path* (3.2.1) azimuth angle

Note 1 to entry: The flight-path azimuth angle is defined in ISO 1151-2:1985, 2.3.1.

**3.2.7****horizontal turn**

*turn* (3.2.6) in *horizontal flight* (3.2.4)

**3.2.8****steady turn**

*horizontal turn* (3.2.7) for which the airspeed and the load factor are held constant

Note 1 to entry: If the wind speed,  $V_w$  (ISO 1151-2:1985, 2.2.3), is zero, the *flight-path* (3.2.1) is circular.

**3.2.9****longitudinal motion****isolated longitudinal motion**

motion characterized by variations of *flight variables* (3.1.1), related to the three degrees of freedom in the aircraft plane of symmetry

Note 1 to entry: Longitudinal motion is characterized by variations in relation to a *reference flight state* (3.1.6) of

- angle of attack,  $\alpha$  (ISO 1151-1:1988, 1.2.1.2),
- inclination angle,  $\theta$  (ISO 1151-1:1988, 1.2.2.2),
- airspeed,  $V$  (ISO 1151-1:1988, 1.3.1),
- *flight-path* (3.2.1) inclination angle,  $\gamma$  (ISO 1151-2:1985, 2.3.2), and
- rate of pitch,  $q$  (ISO 1151-1:1988, 1.3.6),

while the variations of

- angle of sideslip,  $\beta$  (ISO 1151-1:1988, 1.2.1.1),
- rate of roll,  $p$  (ISO 1151-1:1988, 1.3.6), and
- rate of yaw,  $r$  (ISO 1151-1:1988, 1.3.6)

are zero or negligible.

**3.2.10****lateral motion****isolated lateral motion**

motion characterized by variations of *flight variables* (3.1.1), related to the three degrees of freedom outside of the aircraft plane of symmetry

Note 1 to entry: Lateral motion is characterized by variations in relation to a *reference flight state* (3.1.6) of

- angle of sideslip,  $\beta$  (ISO 1151-1:1988, 1.2.1.1),
- bank angle,  $\Phi$  (ISO 1151-1:1988, 1.2.2.3),
- azimuth angle,  $\Psi$  (ISO 1151-1:1988, 1.2.2.1),
- rate of roll,  $p$  (ISO 1151-1:1988, 1.3.6), and
- rate of yaw,  $r$  (ISO 1151-1:1988, 1.3.6),

while the variations of

- angle of attack,  $\alpha$  (ISO 1151-1:1988, 1.2.1.2),

- airspeed,  $V$  (ISO 1151-1:1988, 1.3.1),
- *flight-path* (3.2.1) inclination angle,  $\gamma$  (ISO 1151-2:1985, 2.3.2), and
- rate of pitch,  $q$  (ISO 1151-1:1988, 1.3.6)

are zero or negligible.

### 3.2.11

#### **aerodynamic stall**

aerodynamic loss of lift caused by the angle of attack,  $\alpha$ , exceeding its critical value

Note 1 to entry: The angle of attack,  $\alpha$ , is defined in ISO 1151-1:1988, 1.2.1.2.

### 3.2.12

#### **aeroplane upset**

*flight state* (3.1.2) characterized by aircraft *flight variables* (3.1.1) unintentionally exceeding their limits normally experienced in line operations or training

Note 1 to entry: Aeroplane upset is normally defined by the existence of at least one of the following parameters:

- inclination angle,  $\theta$  (ISO 1151-1:1988, 1.2.2.2) (pitch attitude), greater than  $25^\circ$ , nose up;
- inclination angle,  $\theta$  (ISO 1151-1:1988, 1.2.2.2) (pitch attitude), less than  $-10^\circ$ , nose down;
- absolute value of bank angle,  $\phi$  (ISO 1151-1:1988, 1.2.2.3), greater than  $45^\circ$ ;
- within the above parameters, but flying at airspeed,  $V$  (ISO 1151-1:1988, 1.3.1), inappropriate for the conditions.

## 3.3 Types of aircraft motion and natural modes of aircraft motion

### 3.3.1

#### **short period oscillation**

oscillatory longitudinal motion characterized by variations in the angle of attack,  $\alpha$ , and the rate of pitch,  $q$ , at a nearly constant airspeed,  $V$ , with a frequency,  $f$ , higher than that of the *phugoid* (3.3.2) mode

Note 1 to entry: The angle of attack,  $\alpha$ , is defined in ISO 1151-1:1988, 1.2.1.2. The rate of pitch,  $q$ , is defined in ISO 1151-1:1988, 1.3.6. The airspeed,  $V$ , is defined in ISO 1151-1:1988, 1.3.1.

Note 2 to entry: The *damping coefficient*,  $\delta$  (3.4.2), of short period oscillation is generally large.

Note 3 to entry: The modes considered correspond to small motions superimposed on a steady or quasi-steady reference flight state. These are motions of aircraft following a control input or disturbance.

### 3.3.2

#### **phugoid**

#### **phugoid oscillation**

oscillatory *longitudinal motion* (3.2.9) characterized by variations in the horizontal and vertical components of the aircraft velocity,  $\vec{V}$ , and the inclination angle,  $\theta$ , of the aircraft, at a nearly constant angle of attack,  $\alpha$

Note 1 to entry: The aircraft velocity,  $\vec{V}$ , is defined in ISO 1151-1:1988, 1.3.1. The inclination angle,  $\theta$ , is defined in ISO 1151-1:1988, 1.2.2.2. The angle of attack,  $\alpha$ , is defined in ISO 1151-1:1988, 1.2.1.2.

Note 2 to entry: The frequency,  $f$ , and the *damping coefficient*,  $\delta$  (3.4.2), are generally low.

Note 3 to entry: The modes considered correspond to small motions superimposed on a steady or quasi-steady reference flight state. These are motions of aircraft following a control input or disturbance.

**3.3.3****aperiodic longitudinal mode**

*longitudinal motion* (3.2.9) characterized by variations in the vertical component of the aircraft velocity,  $\vec{V}$

Note 1 to entry: The aircraft velocity,  $\vec{V}$ , is defined in ISO 1151-1:1988, 1.3.1.

Note 2 to entry: The *damping coefficient*,  $\delta$  (3.4.2), is generally large.

Note 3 to entry: The modes considered correspond to small motions superimposed on a steady or quasi-steady reference flight state. These are motions of aircraft following a control input or disturbance.

**3.3.4****roll mode**

*aperiodic lateral motion* (3.2.10) characterized by variations in the bank angle,  $\Phi$ , at nearly zero angle of sideslip,  $\beta$ , and rate of yaw,  $r$

Note 1 to entry: The bank angle,  $\Phi$ , is defined in ISO 1151-1:1988, 1.2.2.3. The angle of sideslip,  $\beta$ , is defined in ISO 1151-1:1988, 1.2.1.1. The rate of yaw,  $r$ , is defined in ISO 1151-1:1988, 1.3.6.

Note 2 to entry: The *damping coefficient*,  $\delta$  (3.4.2), is generally large.

Note 3 to entry: The modes considered correspond to small motions superimposed on a steady or quasi-steady reference flight state. These are motions of aircraft following a control input or disturbance.

**3.3.5****Dutch roll****Dutch roll oscillation**

*oscillatory lateral motion* (3.2.10) characterized by variations in the angle of the sideslip,  $\beta$ , the bank angle,  $\Phi$ , and the azimuth angle,  $\Psi$

Note 1 to entry: The angle of sideslip,  $\beta$ , is defined in ISO 1151-1:1988, 1.2.1.1. The bank angle,  $\Phi$ , is defined in ISO 1151-1:1988, 1.2.2.3. The azimuth angle,  $\Psi$ , is defined in ISO 1151-1:1988, 1.2.2.1.

Note 2 to entry: The modes considered correspond to small motions superimposed on a steady or quasi-steady reference flight state. These are motions of aircraft following a control input or disturbance.

**3.3.6****spiral mode**

*aperiodic lateral motion* (3.2.10) characterized by slow variations in the bank angle,  $\Phi$ , and the angle of sideslip,  $\beta$

Note 1 to entry: The bank angle,  $\Phi$ , is defined in ISO 1151-1:1988, 1.2.2.3. The angle of sideslip,  $\beta$ , is defined in ISO 1151-1:1988, 1.2.1.1.

Note 2 to entry: The *damping coefficient*,  $\delta$  (3.4.2), positive or negative, has generally a small absolute value.

Note 3 to entry: The modes considered correspond to small motions superimposed on a steady or quasi-steady reference flight state. These are motions of aircraft following a control input or disturbance.

**3.4 Characteristic parameters of individual modes of motion****3.4.1****amplitude**

$A$

time function, defined by

$$A = |A_0| \cdot e^{-\delta t}$$

where

$\delta$  is the *damping coefficient* (3.4.2);

$A_0$  is the initial value of the *flight variable* (3.1.1)

### 3.4.2 damping coefficient

$\delta$

quantity defining the decreasing or increasing of the *amplitude* (3.4.1) with time

Note 1 to entry: Damping coefficient is linked to the amplitude,  $A$ , by the following formula:

$$\delta = -\frac{1}{A} \cdot \frac{dA}{dt}$$

### 3.4.3 time constant

$\tau$

quantity defined by

$$\tau = -\frac{1}{\delta}$$

where  $\delta$  is the *damping coefficient* (3.4.2)

Note 1 to entry: Where  $\delta$  is positive,  $\tau$  is the time interval during which the *amplitude*,  $A$  (3.4.1), is divided by  $e$ , the base of natural logarithms ( $1/e = 0,367\ 9$ ).

Note 2 to entry: Where  $\delta$  is negative,  $\tau$  is the time interval during which the amplitude,  $A$ , is multiplied by  $e$ .

Note 3 to entry: Where the amplitude,  $A$ , is constant,  $\tau$  is not defined.

### 3.4.4 time to half amplitude

$\tau_{1/2}$

time interval during which the *amplitude* (3.4.1) is reduced by half where the amplitude,  $A$ , is a decreasing function of time (*damping coefficient* (3.4.2)  $\delta > 0$ )

Note 1 to entry:  $\tau_{1/2}$  is a constant linked to the damping coefficient,  $\delta$ , by the following formula:

$$\tau_{1/2} = \frac{\ln(1/2)}{\delta} = \frac{0,693\ 1}{\delta}$$

### 3.4.5 time to double amplitude

$\tau_2$

time interval during which the *amplitude* (3.4.1) has doubled where the amplitude,  $A$ , is an increasing function of time (*damping coefficient* (3.4.2)  $\delta < 0$ )

Note 1 to entry:  $\tau_2$  is a constant linked to the damping coefficient,  $\delta$ , by the following formula:

$$\tau_2 = -\frac{\ln(2)}{\delta} = -\frac{0,693\ 1}{\delta}$$

### 3.4.6 oscillation period

$T$

period of the sinusoidal factor of the oscillatory function

Note 1 to entry:  $T$  is a constant linked to the *oscillation frequency*,  $f$  (3.4.7), by the following formula:

$$T = \frac{1}{f}$$

Note 2 to entry: The period of the oscillatory function is the time interval separating two successive passages through zero in the same direction.

Note 3 to entry: The term "pseudo-period" can be used to point out that an oscillatory function is not strictly periodic.

### 3.4.7

#### oscillation frequency

$f$

frequency of the sinusoidal factor of the oscillatory function

Note 1 to entry:  $f$  is a constant linked to the *oscillation period*,  $T$  (3.4.6), by the following formula:

$$f = \frac{1}{T}$$

### 3.4.8

#### logarithmic decrement

$\Lambda$

product of the *damping coefficient*,  $\delta$  (3.4.2), and the *oscillation period*,  $T$  (3.4.6)

$$\Lambda = \delta \cdot T$$

Note 1 to entry: The logarithmic decrement is the natural logarithm of the ratio of the *amplitude*,  $A$  (3.4.1), at time  $t$  to the amplitude at time  $(t + T)$ :

$$\Lambda = \ln \frac{A(t)}{A(t+T)}$$

## 3.5 Standard input signals

### 3.5.1

#### step

input signal, equal to zero before initial instant  $t_0$  and maintained to equal to constant value starting from initial instant  $t_0$

Note 1 to entry: The input signal changes as time function in accordance with the following formula:

$$\Gamma_i(t_0) = \begin{cases} = 0 & \text{if } t < t_0 \\ = a & \text{if } t \geq t_0 \end{cases}$$

where

$a$  represents a constant value;

$i$  characterizes the input quantity considered;

$t_0$  represents the initial instant of the signals.

Note 2 to entry: See [Figure 1](#).

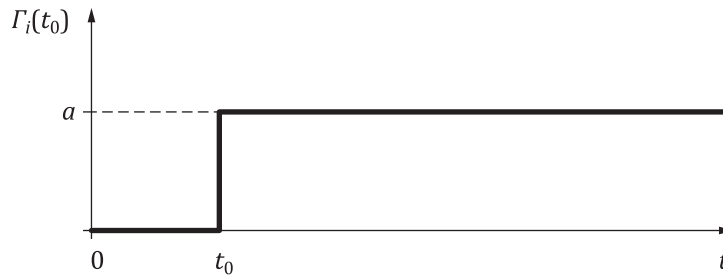


Figure 1 — Step

### 3.5.2

#### rectangular input signal

input signal, equal to zero before initial instant  $t_0$  and maintained to equal to constant value during the basic time interval  $\Delta t$ , then maintained to equal zero again

Note 1 to entry: The input signal changes as time function in accordance with the following formula:

$$\Pi_i(t_0, \Delta t) = \begin{cases} = 0 & \text{if } t < t_0 \\ = a & \text{if } t_0 \leq t \leq t_0 + \Delta t \\ = 0 & \text{if } t > t_0 + \Delta t \end{cases}$$

where

$a$  represents a constant value;

$i$  characterizes the input quantity considered;

$\Delta t$  characterizes the duration of the basic time interval;

$t_0$  represents the initial instant of the signals.

Note 2 to entry: See [Figure 2](#).

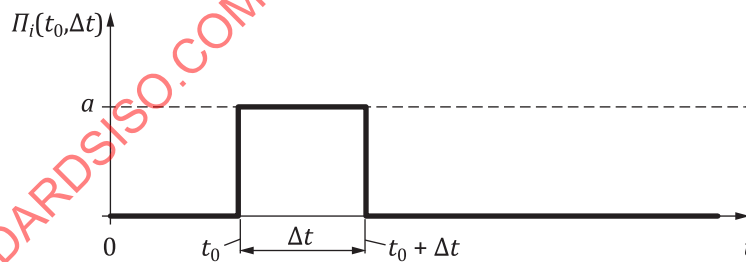


Figure 2 — Rectangular input signal

### 3.5.3

#### Dirac impulse

input signal, started at the initial instant  $t_0$  and similar to *rectangular input signal* ([3.5.2](#)) with duration  $\Delta t$  goes to zero while product  $(\Delta t \cdot a)$  is maintained to equal 1

Note 1 to entry: The input signal changes as time function in accordance with the following formula:

$$\delta_i(t_0) = \begin{cases} = 0 & \text{if } t \neq t_0 \\ = \infty & \text{if } t = t_0 \end{cases},$$

$$\text{with } \int_{-\infty}^{+\infty} \delta_i(t_0) dt = 1$$

### 3.5.4

#### limited ramp

input signal, equal to zero before the initial instant  $t_0$ , then gradually changed to a set value during the basic time interval  $\Delta t$  and finally maintained to equal to a constant value

Note 1 to entry: The input signal changes as time function in accordance with the following formula:

$$\rho_i(t_0, \Delta t) = \begin{cases} = 0 & \text{if } t < t_0 \\ = \frac{a(t-t_0)}{\Delta t} & \text{if } t_0 \leq t \leq t_0 + \Delta t \\ = a & \text{if } t > t_0 + \Delta t \end{cases}$$

where

$a$  represents a constant value;

$i$  characterizes the input quantity considered;

$\Delta t$  characterizes the duration of the basic time interval;

$t_0$  represents the initial instant of the signals.

Note 2 to entry: See [Figure 3](#).

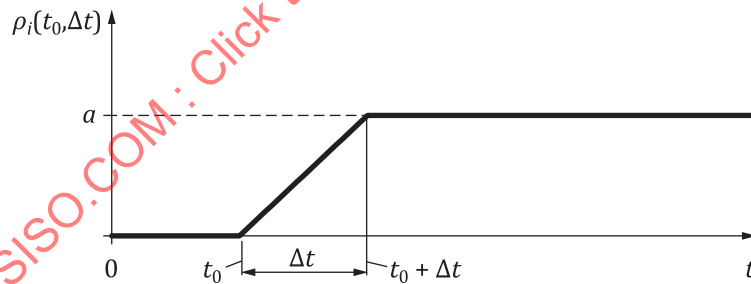


Figure 3 — Limited ramp

### 3.5.5

#### sinusoidal input signal

oscillatory input signal, started at the initial instant  $t_0$  and value-based by the *oscillation frequency* (3.4.7) and constant *amplitude* (3.4.1),  $a$

Note 1 to entry: The input signal changes as time function in accordance with the following formula:

$$\Sigma_i(t_0) = \begin{cases} = 0 & \text{if } t < t_0 \\ = a \sin \omega t & \text{if } t \geq t_0 \end{cases}$$

where

$a$  represents a constant value;

$i$  characterizes the input quantity considered;

$t_0$  represents the initial instant of the signals;

$\omega$  is a constant linked to the oscillation frequency (3.4.7),  $f$ , by the following formula:

$$\omega = 2\pi f.$$

### 3.5.6

#### rectangular doublet

input signal, started at the initial instant  $t_0$  as a sequence of two rectangular input signals (3.5.2) in opposite directions, each with the basic time interval  $\Delta t$

Note 1 to entry: The input signal changes as time function in accordance with the following formula:

$$\Delta_i(t_0, \Delta t) = \begin{cases} = 0 & \text{if } t < t_0 \\ = a & \text{if } t_0 \leq t < t_0 + \Delta t \\ = -a & \text{if } t_0 + \Delta t \leq t < t_0 + 2\Delta t \\ = 0 & \text{if } t \geq t_0 + 2\Delta t \end{cases}$$

where

$a$  represents a constant value;

$i$  characterizes the input quantity considered;

$\Delta t$  characterizes the duration of the basic time interval;

$t_0$  represents the initial instant of the signals.

Note 2 to entry: See Figure 4.

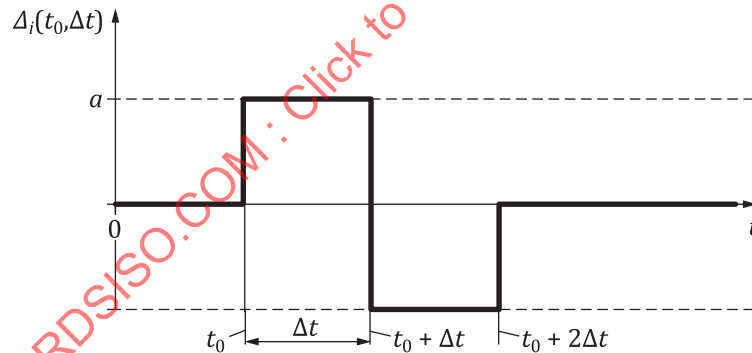


Figure 4 — Rectangular doublet

### 3.5.7

#### triangular input signal

input signal, started at the initial instant  $t_0$ , then gradually changed to a set value and back to zero during the basic time interval  $\Delta t$  and finally maintained to equal to zero

Note 1 to entry: The input signal changes as time function in accordance with the formula:

$$\Lambda_i(t_0, \Delta t) = \begin{cases} = 0 & \text{if } t < t_0 \\ = \frac{2a(t-t_0)}{\Delta t} & \text{if } t_0 \leq t < t_0 + \frac{\Delta t}{2} \\ = 2a\left(1 - \frac{t-t_0}{\Delta t}\right) & \text{if } t_0 + \frac{\Delta t}{2} \leq t < t_0 + \Delta t \\ = 0 & \text{if } t \geq t_0 + 2\Delta t \end{cases}$$

where

$a$  represents a constant value;

$i$  characterizes the input quantity considered;

$\Delta t$  characterizes the duration of the basic time interval;

$t_0$  represents the initial instant of the signals.

Note 2 to entry: See [Figure 5](#).

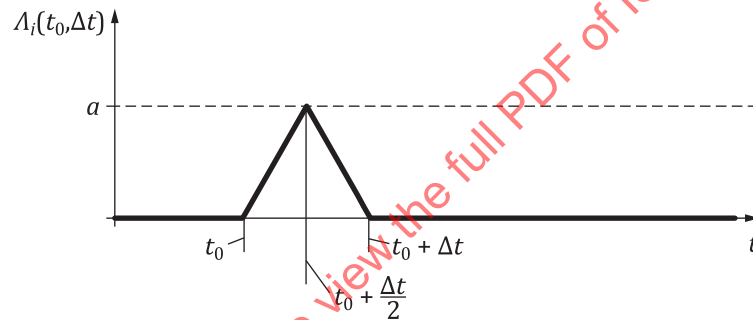


Figure 5 — Triangular input signal

### 3.6 Response of aircraft to a step

#### 3.6.1

##### step response

function of time representing the difference between the *output variable* ([3.1.10](#)) considered, caused by a *step* ([3.5.1](#)) on an *input variable* ([3.1.9](#)), and its value in the initial steady state

#### 3.6.2

##### steady-state response

difference between the value of the *output variable* ([3.1.10](#)) in the final steady-state condition, where this exists, and its value in the initial steady state

Note 1 to entry: see [Figure 6](#).

#### 3.6.3

##### transient response

function of the time representing the difference between the *step response* ([3.6.1](#)) and the *steady-state response* ([3.6.2](#))

#### 3.6.4

##### response time

time taken for the *step response* ([3.6.1](#)) to reach, for the first time, a given percentage of the *steady-state response* ([3.6.2](#))

Note 1 to entry: See [Figure 6](#).

### 3.6.5

#### **overshoot**

extreme value of the *transient response* (3.6.3) having the same sign as the *steady-state response* (3.6.2)

Note 1 to entry: See [Figure 6](#).

### 3.6.6

#### **relative overshoot**

quotient of the *overshoot* (3.6.5) by the value of the *steady-state response* (3.6.2)

### 3.6.7

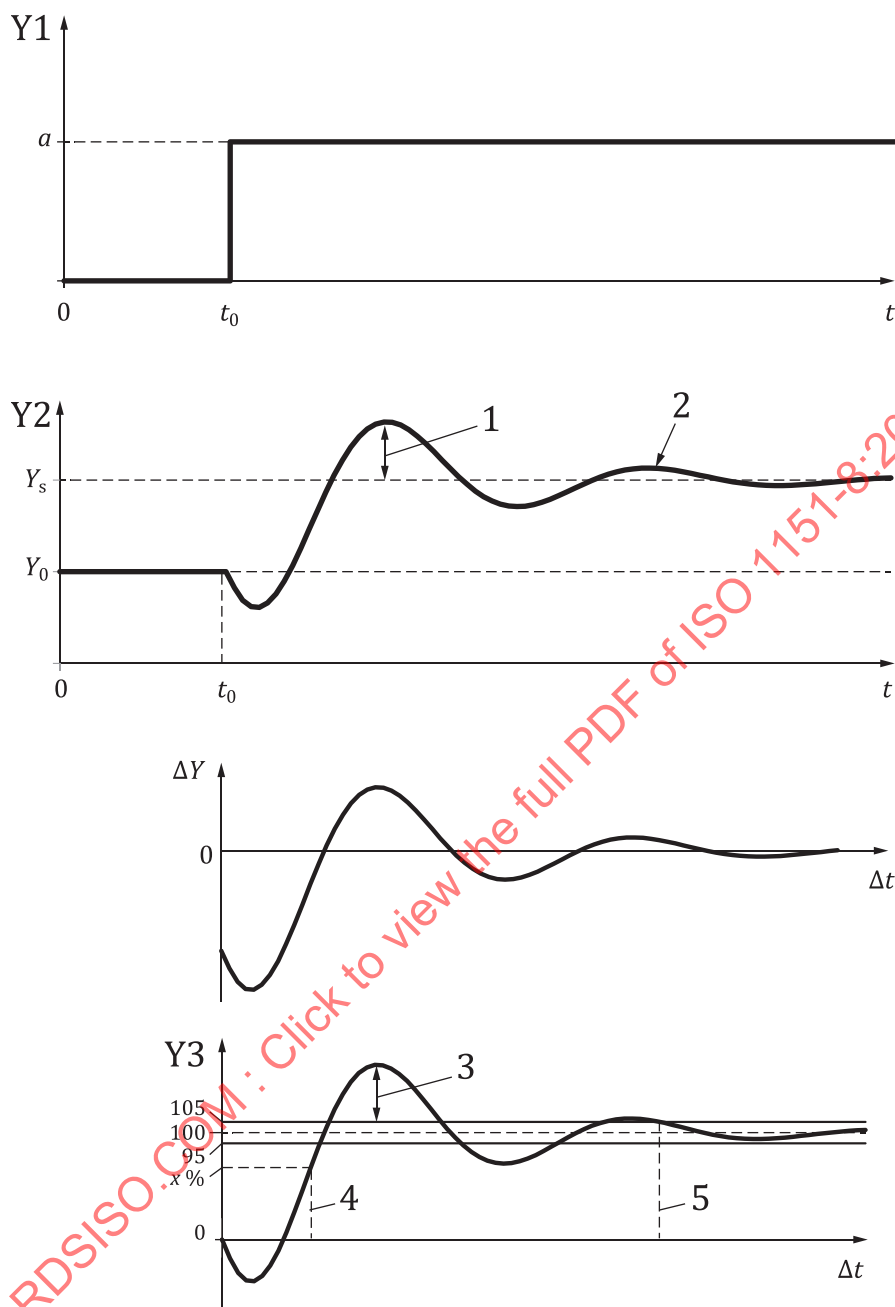
#### **settling time**

time after which the absolute value of the *transient response* (3.6.3) no longer exceeds a given percentage of the *steady-state response* (3.6.2)

Note 1 to entry: See [Figure 6](#).

Note 2 to entry: The percentage often used is 5 %.

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**Key**

- Y1 input variable
- Y2 output variable
- Y3  $100 \times (\text{step response} / \text{steady-state response})$
- $t$  time
- $t_0$  initial instant of the input signals
- $\Delta t = t - t_0$
- $Y_s$  output value in the final steady state
- $Y_0$  output value in the initial steady state
- $\Delta Y = Y_s - Y_0$  transient response
- 1 overshoot
- 2 step response
- 3 relative overshoot
- 4 response time at  $x\%$