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Fail-safe characteristic

In digital technology the F. is indicated by the distance of a stable binary condition (high level and/or low level) to the point of changeover and/or the changeover wave into the respectively opposite condition.

Far selection

Far off selection is a measure of the selectivity of filters for distant frequency components. A far off selection of 60 dB at a frequency gap of 50 Hz means, for example, that a signal component that lies 50 Hz from the average frequency of the filter, will be attenuated by 60 dB, i.e. by a factor of 1000.

Fast-Fourier-Transformation

An FFT is an efficient algorithm to compute the discrete (DFT) and its inverse. FFTs are of great importance to a wide variety of applications, from digital signal processing and solving partial differential equations to algorithms for quick multiplication of large integers.

Fatal error

An error which cannot be remedied.

Fault diagnosis

With the help of different methods of signal analysis one tries to derive an F. from the acquired measured data. An early fault diagnosis is in every case worthwhile, because one can then prepare in time for repairs.

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Fault tolerance

Name for the characteristic of hardware and software systems to completely, or in a reduced manner, maintain the capacity of the system despite arisen errors; this is usually achieved by redundancy of system components. Within the range of the hardware in general one makes redundant copies available of the same component as active (constantly operating) or passive (used only in case of failure) redundancy. With active redundancy the results of all redundant components are compared and the result is determined through “voting“. Within the range of the software F. can also be achieved by error handling, i.e. by logical redundancy.

Feedback

With F. one describes circumstances that the output of a system affects an input of the same system. Thereby a closed sphere of activity develops. A typical example is the automatic control loop. The behaviour of the system is effectively affected by the F.

Feedback, influence of sensor

F. is the change of the mechanical system and thus the measured variable by the measuring instrument, in particular by the sensor. Concerning the attaching of the sensors to the item under test and the resulting influence on the vibration which is to be measured, reference is made in DIN 45664 [70] and ISO 5348 [85].

Feedback, of a measuring instrument

Influence of a measuring instrument in its application, which causes that the quantity acquired by the measuring instrument differs from that quantity which is actually present at the input of the measuring instrument.

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Feedback, positive

A feedback, with which the output value of a circuit is fed back to the input so that the effect of the input quantity is amplified. Positive F. is used e.g. for generation of vibration in oscillator circuits.

FFT Algorithm

With the FFT algorithm the so-called discrete fourier transformation (DFT) is extremely efficiently computed. This is a discrete, finite approximation of the Fourier transform. The equation for the transform (forward transform) is:

$$G(k) = \frac{1}{N}\sum_{n=0}^{N-1} g(n)e^{-j\frac{2\pi kn}{N}}$$

and for the reverse transform:

$$g(n) = \frac{1}{N}\sum_{k=0}^{N-1} G(k)e^{-j\frac{2\pi kn}{N}}$$

$G(k)$ represents the spectral values at N discrete frequencies $k\Delta f$, and $g(n)$ represents the sample values of the time function at N discrete time points $n\Delta t$.

As a result of the finite, discrete nature of the DFT three effects arise, which must be considered:

- Alias-effect
- Leackage effect (time-window effect)
- Picket-fence effect

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FFT analyser

An instrument for frequency analysis that executes the analysis on the basis of an FFT algorithm.

FFT

Abbr. for **F**ast **F**ourier **T**ransform

Field Balancing

Balancing a rotor in its own bearings and bearing supports (in the operational condition).

Field balancing instrument

Any measuring instrument which provides information for balancing an assembled machine or rotor not mounted in a balancing machine.

Field bus

Serial transmission system within the field which networks a multiplicity of devices of automation technology. An important F. is Profi-Bus.

Filter-analyser, tunable

These spectrum analyzers consist of only one filter which is tunable over the entire frequency range. One receives the spectrum of the input signal by a display of the filter output voltage over the frequency.

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With application of a F. it must be presupposed that the spectrum of the input signal does not change while the filter is tuned. If this condition is not fulfilled, it can occur that certain spectral components (namely those which are present only if the filter is directly tuned to another frequency) will be "lost" with the measurement.

Filter chain

A filter, which consists of several sequentially switched homogenous or different individual filters.

Filter characteristic, ideal

An ideal filter would let through all signal components which lay within its range, without any attenuation, and would completely block all others. Such a filter is practically not realizable.

Filter, constant-absolute bandwidth

Filter with a fixed, absolute bandwidth given in Hz, independent of the centre frequency.

Filter, constant-percentage bandwidth

Filter with a fixed, percentile bandwidth in HZ which is dependent upon the centre frequency.

Filter, digital

Digital filter

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Filter factor Q

A higher characteristic number (also called a quality number) for the bandwidth of the passband or restricted region of electronic filters, determined by the limit frequencies of the bandwidth, translates into a larger Q number and vice versa.

Filter; Frequency filter

A linear gate which is provided to transfer component vibrations of a signal according to a specific law, in general to allow components in a certain frequency band to pass through and to attenuate components in other frequency bands.
Circuit with frequency dependent transfer behaviour.
A F. serves to emphasize a certain frequency range and suppress another range from a frequency composition. Frequencies within the range of the filter are not attenuated, or are attenuated very little, while frequencies outside the filter range are strongly attenuated. The beginning and end this filter range are given by the filter's corner frequencies, which represent the points at which the filter attenuation has reached a value of 3 dB (decibel); however different definitions are also possible. According to the position of the blocking and the passage regions, one distinguishes between four different basic types:

- The lowpass filter (in the simplest case formed from an RC-circuit) allows frequencies below the corner frequency to pass through while higher frequencies are suppressed.
- The highpass filter blocks low frequencies but allows frequencies above than the corner frequency to be passed through.
- A bandpass filter, or a bandpass, possesses a specific passband region; frequencies below or above this region are suppressed.
- With the band suppressor all frequencies will transfer above and below the restricted area; this serves for filtering certain unwanted frequencies.

Filter circuits are used in all ranges of electro-technology and electronics. In general as steep a curve of the filter characteristic as possible above and/or below the critical frequency is desired so that the more exact separation of one or more frequency regions is possible.

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This is achieved through a chain circuit (serial circuit) of RC or LC or resonant-circuit components (filter chains).

Passive filters as a rule consist of coils and condensers. With active filters a further amplifier element is available.

Filtering, digital

Filtering of signals by means of a digital filter.

Filter, ideal

Filter with an ideal characteristic

Filter, recursive

Digital filter

Filter, tunable

Filter, whose centre frequency can be steplessly tuned. Its employment is e.g. in tunable filter analysers.

Firmware

F. is a software program for building groups and devices with microprocessors (e.g. measuring instruments, modems, etc.), which is to be compared for example with the BIOS and the operating system on PCs. Typically the F. is accommodated in ROMs which are recordable. This has the advantage very simply that the F be updated in order to accommodate new functions.

First transition duration of an impulse

The duration between two points in time during which the momentary values of the impulse assume preassigned values for the first time; for example, 10% or 90% of the impulse amplitude, as long as the form of the impulse does not force a different finding.

Note: The term that has been customary until now was duration of increase.

Flat-Top window

The F. is one of the most frequently employed window function in digital signal analysers. The influence of weighting with a F. leads to amplitude values of zero at the borders of the time window and thus to the elimination of leakage in the representation of the spectrum.
The most important criteria in the selection of the F. for a practical application are:

- Maximum amplitude accuracy is achieved with a maximum error of $< 1\,\%$ (0.1 dB). It is therefore recommended for signal processing tasks where high amplitude accuracy is required.
- It has a lower frequency resolution capability and thus a correspondingly lower frequency accuracy.

Note: For better frequency resolution the Hanning window, or the Uniform window in the case of rotor-synchronous signal sampling, is more suitable.

Flexural principal mode(s)

In an undamped rotor-bearing system, the bending line which the rotor assumes at the *flexural critical speed*.

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Flexural critical speed

Speed, flexural critical

Flexural vibration

Vibration, flexural

Font character set

Complete set of typographic characters of a particular design and a particular font.

Formula characters for time-dependent variables

The definition is found in DIN 5483-2. Distinction is made with respect to symbols for instantaneous values, average values, components and values of mixed quantities as well as special values of the nth harmonics of a Fourier series.

Note: In this lexicon the display of formulae for time-dependent variables corresponds to DIN 5483-2.

Foundation

A structure, which carries a mechanical system, e.g. a concrete base structure for supporting a turbo set.

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Form factor

The F. describes the flank steepness of the transmission curve of a bandpass filter. It is the quotient of the -60 dB and -3 dB bandwidths. The lower the F., the higher is the flank steepness and thus the selectivity. In the case of the ideal bandpass filter (Uniform transmission curve), the F. reaches a value 1.0, i.e. an infinite flank steepness.

Fourier analysis; harmonic analysis

The extraction of a periodic function

$$f(t) = f(t + mT_0)$$

(T_0 period, t time, m integer) in a Fourier series

$$f(t) = a_0 + \sum_{k=1}^{\infty} a_k \cos(k\omega_0 t) + b_k \sin(k\omega_0 t)$$

Thereby

$$\omega_0 = \frac{2\pi}{T_0}$$

is the rotational frequency of the fundamental vibration and

$$a_0 = \frac{1}{T_0}\int_0^{T_0} f(t)dt$$

is the constant component. Further coefficients of the Fourier series are given by

$$a_k = \frac{2}{T_0}\int_0^{T_0} f(t)\cos(k\omega_0 t)\,dt$$

and

$$b_k = \frac{2}{T_0}\int_0^{T_0} f(t)\sin(k\omega_0 t)\,dt$$

In the sum of the Fourier series

$$a_k\cos(k\omega_0 t) = b_k\sin(k\omega_0 t) = A_k\sin(k\omega_0 t + \varphi_k)$$

describes the $(k-1)$ overtone (k^{th}harmonic). For the Fourier coefficients a_k and b_k

$$A_k = \sqrt{a_k^2 + b_k^2}$$

is valid, and further

$$tan\varphi_k = \frac{b_k}{a_k}$$

With a given function $\varphi(\omega t)$ the a_k and b_k as well as a_0 are determined by resolving the following integrals ($k = 1,2,3,\ldots$):

$$a_0 = \frac{1}{2\pi}\int_0^{2\pi} f(\omega t)d(\omega t)$$

$$a_k = \frac{1}{2\pi}\int_0^{2\pi} f(\omega t)\cos(k\omega t)d(\omega t)$$

$$b_k = \frac{1}{2\pi}\int_0^{2\pi} f(\omega t)\sin(k\omega t)d(\omega t)$$

Often a lower cost of computation results from the use of the complex component method ($k = 1, 2, 3, \ldots$):

$$a_k + jb_k = A_k^{j\varphi_k} = \underline{A}_k$$

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$$\underline{A}_k = \frac{1}{\pi}\int_0^{2\pi} f(\omega t)e^{jk\omega t}d(\omega t)$$

where from the calculation of the integrals one obtains a_k as the real part, b_k as the imaginary part, A_k as magnitude and ω_k as the phase. The limit value of the Fourier series is the Fourier integral. It forms any integratable function as the sum of an unlimited number of sinus vibrations with an unlimited small frequency spacing and is used in the Fourier transform.
One calls the totality of individual vibrations which arise as a result of the F., a frequency spectrum, or briefly: a spectrum.

Fourier-Transform

The functional transform of a time function $f(t)$ in a display function (Fourier transformed), $f(j\omega)$, whereby ω is the rotational frequency:

$$F(j\omega) = \mathcal{F}\{f(t)\} = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt$$

The display function exists only when

$$\Phi = \int_{-\infty}^{\infty} |f(t)|dt$$

is smaller than a finite value M. The reverse transform delivers the Fourier integral

$$f(t) = \mathcal{F}^{-1}\{F(j\omega)\} = \frac{1}{2\pi j}\int_{-j\infty}^{j\infty} F(j\omega)e^{j\omega t}d(j\omega)$$

(Fourier reverse transform)

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Fourier-Transform, inverse

Abbr. IFT
With the help of the inverse F. it is possible to transform a complex amplitude spectrum from the frequency domain back into the time domain.

Free running triggering

Under application of free-running triggering for the capture and analysis of vibration signals, the time data sets will be captured in the most rapid sequence possible; the spectrum will be calculated and displayed on the monitor. Since this procedure will run continuously until it is terminated, this type of triggering is also known as continuous triggering.

Free vibration; free oscillation

Vibration, free

Frequency

The number of vibrations or wave sequences in a specific time period. The F. is the most important variable for characterizing a vibration or a wave. Often the 2π-multiple of F. is used, the angular frequency ω. Inverse of the F. is the vibration period $T = 1/f$. The unit of F. is Hertz (Hz) resp. $1/s$ or $1/min$.
The latter creates an easy reference to the number of revolutions of machine shafts. By far the most frequent vibration problems arise with frequencies which have a fixed relationship to the rotational speed and these are called harmonic vibrations. One refers such frequencies to the rotational frequency, briefly referred to as the $1n$ vibration: the 2^{nd} order vibrations arise with the double rotational frequency ($2n$), the 3rd order at 3X rotational frequency ($3n$) and so on. Sub-harmonic vibrations arise at a fraction of the rotational frequency, e.g. $0.5n$, etc.

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Frequency analyser

An instrument for carrying out a frequency analysis.

Frequency analysis

The determination of the frequency components of a time function of a signal by means of the Fourier transform. If the time function of the signal is analytically present or if this can be approximated by an analytic function s(t), then a continuous Fourier transform can be used for the F.
If the time function is available only as a result of sampled values (at the time points nT_a, T_a sample time) the discrete Fourier transform, which produces a better resolution with the greater measuring time, or number of sample values, is to be used.
In machine diagnostics the individual frequencies can be assigned to the moving machine parts in many cases. With changes in these vibration components, irregularities or machine damage can be already recognized at an earlier stage. Faults from mechanical or thermally-induced unbalance, self-excited vibrations, rubbing processes, changes in the alignment, defective bearings and gears, incorrect mechanical connections, cracks in shafts and others can be the causes. Since also changes in the process or in the operating conditions of a machine can have an effect on the frequency spectrum, a clear fault assignment is possible only under some boundary conditions. Usually during the commissioning phase, or after a revision, a reference spectrum of the machine is recorded. Hereby later frequency analyses are compared, in order to determine whether a change is present.

Frequency band

A coherent range of frequencies, which lie between two given limit frequencies.

Frequency branching network

A switching configuration consisting of filters. The F. allows several generators with different frequencies to switch non-reactively over a common cable, or multiple generators to simultaneously distribute incoming frequencies to different consumers over a common cable. In general a F. contains at least one highpass filter and one lowpass filter.

Frequency converter

A crcuit which contains an oscillator and a frequency mixer, mostly followed by a bandpass filter, in order to cause the frequency conversion of a signal.

Frequency deviation

Unintentional deviation from a predetermined frequency.

Frequency divider

Non-linear circuit for the production of oscillations with frequencies which arise as a result of a division of the incoming frequency by integer numbers. An electronic circuit for the reduction of the frequency of an oscillation and/or a pulse rate (usually in an integer number divisor relationship).

Frequency division

See Frequency divisor

Frequency domain

The time signal of the vibrations can be transformed from the time domain to the F. For periodic vibrations this is possible in the form of a series development. This is known as a Fourier series (Fourier analysis) with its Fourier coefficients. The extension on non-periodic oscillations leads to the Fourier integral whose resolution by the algorithm of the discrete Fourier transform (DFT) is possible.

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This corresponds to the dismantling of the oscillation signals into a singular combination of sinus oscillations with different amplitude, zero-phase angle and frequency. Each time signal can be transferred thereby into the frequency domain. The result of the transform is a display in the F., also called a spectrum. The characteristics of a vibration signal can be clearly described in the time domain and also in the frequency domain. A reverse transform from the F. to the time domain by means of the inverse Fourier Transform (IFT) is possible without a loss of information.

Frequency evaluation

The F. is the frequency-dependent weighting received by the frequency-oriented measurement values contained in the vibration signal. The F. is a dimensionless complex function with band limitation functions (high and low-pass filters), described according to amount and phase, of the frequency response of the entire measuring equipment from the sensor to the display.

Frequency line

Individual signal components in a spectrum.

Frequency measurement

Measurement of the frequency using a frequency-measuring instrument (frequency meter).

Frequency measuring device

See frequency measurement

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Frequency meter

See frequency measurement

Frequency mixer

A non-linear circuit for the production of oscillations, with frequencies which are linear combinations of the integral multiples of frequencies of the spectral components of two oscillations or input signals.

Frequency modulation

Abbr.: FM
Angle modulation, with which the momentary frequency deviation changes in agreement with a generally linear given function of the instantaneous value of the modulating signal.
The F. is a procedure, with which the frequency of a carrier wave with constant amplitude is modulated by the amplitude of a low-frequency oscillation. Hereby the (high) frequency of the carrier frequency wave is changed into the rhythm of the transferred low-frequency oscillation within a certain bandwidth.

See also Sinus procedure, frequency-modulated

Frequency of sinusoidal vibration

The inverse of the periodic value T is called the frequency f. If one wants to emphasize the difference of this frequency in relation to the angular velocity, then it is called the period frequency. The SI-unit s^{-1} of the frequency is called Hertz (Unit symbol: Hz).

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Frequency range for digital signal analysis

Dependent upon the slope of the anti-alias filter the theoretically usable signal frequency range (zero to half-sampling rate) is reduced. Conversely this means that with a given maximum signal frequency a higher sampling rate is necessary than theoretically demanded.

Frequency resolution

See Resolution

Frequency response

A complex function, which characterizes the time performance of time-invariant linear transfer elements of the reporting, regulation and vibration technology. Such a component answers to a sinus-shaped continuous signal of angular frequency ω (input signal $x_e(t) = sin\omega t$ with a sinus-shaped output signal of the same frequency: $x_a(t) = A(\omega)\sin(\omega t + \varphi(\omega))$, but in general with altered amplitude $A(\omega)$ and $\varphi(\omega)$ as a function of $\omega(0 \leq \omega < \infty)$ called amplitude and phase response. Their summary to the complex function $F(j\omega) = A(\omega)e^{j\varphi(\omega)}, (j = \sqrt{-1})$ gives the F. its graph. The representation in the complex number plane is called an orbit curve. By means of modern signal analyzers the F is computed as a complex quotient from the values of the spectrum of the input signal and the values. Through representation of the amount and phase spectrum, damping, amplification and phase shifts are identified.

See also Vibration sensor frequency response.

Frequency spectrum

Spectrum, Fourier analysis

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Frequency sweep

The maximum change in the instantaneous value of the frequency of a harmonic vibration with frequency modulation. Due to the relationships

$$\varphi = \int \omega dt;\ \omega = \frac{d\varphi}{dt}$$

(φ phase angle, ω angular frequency) the F. can also be displayed as phase shift. With harmonic rejection and with the frequency f_1, due to

$$\omega(t) = \Delta\Omega cos 2\pi f_1 t$$

then

$$\Delta\Phi = \frac{\Delta\Omega}{2\pi f_1} = \frac{\Delta f}{f_1}$$

is valid for the phase shift, as well as

$$\varphi(t) = \Delta\Omega cos 2\pi f_1 t$$

and

$$\Delta\Omega = 2\pi f_1 \Delta\Phi = \omega_1 \Delta\Phi$$

The phase variation of a frequency-modulated oscillation is therefore inversely proportional to the frequency f_1 which is to be transferred; the frequency variation is directly proportionally to F. and the phase variation can serve for the quantitative description of phase-modulated or frequency-modulated oscillations.

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Frequency transform

Exchange of the normalized frequency $F = \frac{f}{f_g}$, or the complex frequency s, in the transmission function of a filter (e.g. a lowpass), with another frequency, whereby a new filter function is developed. For the lowpass-highpass-transform, e.g. $F \rightarrow \frac{f_g}{f}$ is valid.

Frequency translation; frequency conversion

A shift of all components of a signal from one location in the frequency spectrum into another, so that the frequency difference for each pair of components is retained in their relative amplitude and phase angle. The displacement of a signal into another frequency range. Modulation belongs in this category.

Front-end computer

A computer, integrated into a network, in which a user allows programs to operate.

See also Client-Server system

Front panel

The front side of an instrument.

Full duplex

Simultaneous data transmission in both directions.

See also Duplex

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Function generator

An electronic circuit for the production of mathematical functions, e.g. in the form of current-voltage relations. By a combination of several of such circuits, arbitrary functions can be displayed.

Fuse

A switch device, with which a conducting path is interrupted by melting of certain parts under the effect of current heat caused when the amperage exceeds determined values during a specific time.