E16 Systems for High Safety Speed Monitoring, all with Triple Modular Redundancy. A choice of versions to meet various demands. Compliant with SIL3 / IEC 61508 and/or API 670.

Outstanding Characteristics
- At no point does safety depend on only a single element, and the machine cannot be tripped by an individual error. Thereby enhanced safety and protection against a false trip. Reduces costs and increases machine availability.
- Fast reaction within 15 milliseconds to an overspeed situation, including the safety relay response.
- The ready wired 2of3 voted system output provides 2 parallel and isolated trip circuits by safety relay contacts.
- The safety relays actuate two isolated trip alarm contacts plus another contact for a true response check by the system.
- Each channel provides an extra input accepting an external signal for an alternative condition (temperature, pressure, flame), for possible inclusion into the voted trip.
- Sensor monitoring, channel comparison, and plausibility check for the measurements detect a failure in its early stage, releasing a separate warning.
- Alarms memory: An overspeed alarm, and a detected failure can be programmed to remain memorized for a later identification.
- Our test routine as designed under IEC 61508 SIL3 exempts the user from the otherwise required periodic checks and the associated documentation.
- One extra alarm as standard with each channel, freely programmable for speed setpoint and response.
- Input repeating isolated pulse output to other device, powered to a 24 volts push-pull level.
- Input frequency divider balances irregularities of the target profile. Programmable 001 through 256.

Structure of the E16 Systems providing true Triple Modular Redundancy
- 3 monitoring channels. Each realized by a plug-in Monitor Module encompassing the full channel function from sensor input and signal process, up to and including the safety trip relay outputs. Also includes all the other standard or optional functions.
- Every monitor operates independently, but in constant comparison to both its neighbours.
- Every monitor within the system is placed in a plug-in socket, allowing its replacement under full operation.
- The safety trip relay contacts of the 3 Monitors are ready hard wired on the back plane of the system to terminals, providing 2 isolated breaking trip circuits with a 2of3 voting, or separately from each monitor, as option.

Optional Test Module
The three channels can be augmented by an independent Test Generator Module. This enables under load response checks by sequentially applying its speed simulating frequency signal to each channel. This can be carried out manually by push buttons at the system, or optionally as an automatic test routine following a programmed test cycle, under full operation of the turbine. Each channel's reaction to the test is observed, and a failure signal released if the response is not as expected.

More functions as option
To meet further demands, additional functions are available, to each of the 3 channels (alarms then with an additional 2of3 voter on request):
- up to 8 setpoint alarms,
- up to 3 analog outputs,
- PROFIBUS data interface,
- detector for the direction of rotation,
- acceleration monitor
- monitor for speed and difference of an additional drive (turn gear, for instance)
- isolating barriers to intrinsically safety sensors, located in a hazardous (Ex-)area.

E16 - a very flexible series of systems. Available with any required safety characteristics and additional functions.
E16 groups meet different safety requirements – their Nomenclature and Compliance to Standards

By two groups of versions the E16 provides optimum adaptation to the safety grade and comfort as appropriate for the application. Both groups E16x3 and E16x4 have the 3-channel architecture with its safety in trip release and protection against erratic tripping. All with the functional safety and specific advantages as described for the monitors. Both groups offer the same options regarding their mechanical design and data interface mode.

Several additions are available for both groups: analog outputs, more speed alarms, forward/reverse detection, comparison with another drive, and accelerator monitor, all making use of the safeguarded channel inputs.

- The E16x3 group is designed to comply to the highest safety level, and is approved to SIL3 according to IEC 61508, with intrinsic double self-check facility. All versions within this include a Test Generator Module. If equipped to perform the periodic test routine it exempts the user from the otherwise required periodic checks and the associated documentation, thereby saving service labour cost.

- The E16x4 group covers applications not affording this high testing comfort. However, they provide the same safety degree complying to the API 670 Standard. Also in this group, a Test generator is available and recommended as option.

See the below nomenclature defining the core versions and additional functions

<table>
<thead>
<tr>
<th>Mechanical design</th>
<th>available additions</th>
</tr>
</thead>
<tbody>
<tr>
<td>E = 19-inch rack file</td>
<td>acceleration monitor</td>
</tr>
<tr>
<td>A = Surface Mount Version</td>
<td>0 = none</td>
</tr>
<tr>
<td>G = NEMA4 IP65 enclosure</td>
<td>1 = 1 in channel A</td>
</tr>
<tr>
<td></td>
<td>3 = 1 in each channel</td>
</tr>
<tr>
<td></td>
<td>4 = 3 with 2of3 voting</td>
</tr>
<tr>
<td>Functional Group</td>
<td>speed/difference monitor to another drive</td>
</tr>
<tr>
<td>3 = highest level SIL3 of IEC 61508</td>
<td>0 = none</td>
</tr>
<tr>
<td>4 = versions compliant with API670</td>
<td>1 = 1 with own speed input and comparison to A</td>
</tr>
<tr>
<td></td>
<td>2 = 2 with own speed input and comparison to A, B</td>
</tr>
<tr>
<td></td>
<td>3 = 3 with own speed input and comparison to A, B, C</td>
</tr>
<tr>
<td></td>
<td>4 = like 3, with 2of3 voting</td>
</tr>
<tr>
<td>Trip output circuits</td>
<td>sense of rotation monitors</td>
</tr>
<tr>
<td>1 = wired to twin 2of3 circuits</td>
<td>0 = none</td>
</tr>
<tr>
<td>2 = direct from each channel</td>
<td>3 = 1 in each channel with direct output</td>
</tr>
<tr>
<td></td>
<td>4 = like 3, with 2of3 voting</td>
</tr>
<tr>
<td></td>
<td>5 = one with own independent input</td>
</tr>
<tr>
<td></td>
<td>7 = three with own independent inputs</td>
</tr>
<tr>
<td></td>
<td>8 = like 7, with 2of3 voting</td>
</tr>
<tr>
<td>Test generator</td>
<td>additional setpoint alarms</td>
</tr>
<tr>
<td>0 = none</td>
<td>0 = none</td>
</tr>
<tr>
<td>3 = manually operated</td>
<td>3 = 4 alarms assigned to channel A, with direct output</td>
</tr>
<tr>
<td>4 = with periodic automatic routine</td>
<td>4 = all alarms with 2of3 voting</td>
</tr>
<tr>
<td>Data interface mode</td>
<td>Mechanical design options</td>
</tr>
<tr>
<td>5 = RS232</td>
<td>- Surface Mount (A) to place on the rear plate inside a cabinet. Access to terminals from front side. Protection grade IP20 (open).</td>
</tr>
<tr>
<td>6 = PROFIBUS</td>
<td>- 19-inch rack file (E) ready to insert into an existing rack. Access to terminals from rear. Protection grade IP20 (open).</td>
</tr>
<tr>
<td>Monitors input to sensors</td>
<td>- Outdoor enclosure (G) to mount on a plate or post. Inside a swing open rack file (as under E). Protection grade IP65 (NEMA 4).</td>
</tr>
<tr>
<td>7 = standard to AS5. and equivalent</td>
<td>Ambient Conditions</td>
</tr>
<tr>
<td>8 = low level fitting pick-ups</td>
<td>Temperature in operation 0 to +60 °C (30 to 105 °F) for storage -40 °C to + 85 °C (-18 to 30 °F).</td>
</tr>
<tr>
<td></td>
<td>Humidity max 95 % (no condensation)</td>
</tr>
</tbody>
</table>

E16x3

- core versions
- available additions

Mechanical design options
- Surface Mount (A) to place on the rear plate inside a cabinet. Access to terminals from front side. Protection grade IP20 (open).
- 19-inch rack file (E) ready to insert into an existing rack. Access to terminals from rear. Protection grade IP20 (open).
- Outdoor enclosure (G) to mount on a plate or post. Inside a swing open rack file (as under E). Protection grade IP65 (NEMA 4).

Ambient Conditions
- Temperature in operation 0 to +60 °C (30 to 105 °F) for storage -40 °C to + 85 °C (-18 to 30 °F).
- Humidity max 95 % (no condensation)

EMI and CE
- Compliance to Standards 89/336/EWG, EN 61000-6-2, -6-4.

General Specifications applying to all Systems

Trip output of the system
With the 2of3 voting incorporated in the system, the contacts of both safety relays on each monitor are hard wired by the system backplane to two separate and isolated breaking circuits. An optional version has the same safety NO contacts are separately wired to the output terminals.

The power handling facilities as listed for the individual monitor also apply to the system trip output.

Power Supply
Standard 3x24 v DC (18..33 v) separate per channel, common zero. An incorporated diodes network feeds modules not assigned to a specific channel.

Power consumption (without additions) 3x 0.5 A.
Options 2x115 v AC (100..130 v) or 2x230 V AC (200..253 v), feeding a common rail within the system. Power approx. 60 VA.

Insulation and Electric Protection grade I, voltage class I.
E16 - the Safety Concept

Permanently performed Intrinsic checks within the monitors for early failure detection

- Sensor circuit monitoring for interrupt or short circuit, and for the signal lead activity (this feature restricted to BRAUN ASS sensor series),
- Input signal comparison with neighbour channels for their equality in the amount of pulses processed within a programmed period of time,
- Function presence and plausibility check, requiring that measurement must not drop below a programmable low level during operation (to be skipped by the starter function). A very comprehensive check.

Any of these criteria can be included per program into a collective alarm, which is part of the monitor’s trip conditions.

The major criterion certainly is the excess of SP1, the overspeed alarm level.

Another one comes from outside the system. Each channel accepts a contact or electronic signal as a peripheral alarm condition, for instance from a temperature or pressure monitor, or a flame guard.

The user decides per program which of these criteria the channel alarm comprises, in order to release the trip output. And, a similarly programmed selection further actuates a separate warning output of the monitor module.

• Thus, the singular failure will be detected in time. But it does not curtail the speed monitoring process. This remains alert. Indispensable for true safety.

The 2 of 3 voting principle

3 monitoring channels operate in parallel. Each encompasses in its monitoring module the entire function: sensor signal input, measurement, setpoint alarm, peripheral alarm. Its trip alarm or the collective alarm actuates the two monitor incorporated safety relays, each with two contact sets as output and one as response feedback.

The system trip however is not released before 2 of the 3 monitors enter their programmed trip condition. A discrepancy between the 3 monitors will be detected, but does not result in machine tripping.

• This prevents erratic shutdown followed by expensive stops.
• This allows testing of each monitor under duty, for its reaction to an alarm condition.
• This allows replacement of a monitor under full operation.

With the 2of3 voting incorporated in the system, these outputs of the monitors are directly wired on the system backplane. Forming two isolated trip circuits, breaking to trip, if at least two monitors are in trip condition. Only one monitor in trip condition, for whatever reason, cannot release the trip output of the system.

With separate channel trip outputs, the external 2of3 voting (by electric or hydraulic means) must achieve this. However, the E16 thus equipped, provides inputs expecting return signals from the peripheral actuators acknowledging their correct response.

A single channel in error cannot activate the trip, nor can it release an erratic shutdown.

Safety never depends on merely one element or one signal.
Details of the Monitor Modules

**Speed measuring principle**

Utilizing the advantageous principle of quartz controlled pulse distance evaluation, automatically extended over a minimum period of time (5 milliseconds). The ideal combination of fast response and steady measurements, as appropriate for turbine speed monitoring. Programmable relationship between turbine RPM and signal frequency (Hz), thereby all readings and presets in RPM terms.

**Accuracy ± 0.005 % ± 1 in the last of 5 digits.**

**Speed setpoint alarms**

3 programmable alarms on every monitor, each reacting within 15 milliseconds ± measuring period (see above).

Setpoint SP1 is assigned to the overspeed trip alarm, programmable for setpoint and hysteresis bandwidth. Actsuates the safety relays as the trip output of the monitor and participates in its failure signal (see below).

Setpoint SP2 is used for the intrinsic plausibility check: any measurement below this programmable level (during machine operation) registers an obvious function failure of the monitor (check to be disengaged for the turbine start up).

Setpoint SP3 is freely available to set to any other speed level, programmable for its response characteristics, as its hysteresis bandwidth and position, its condition at setpoint excess or not-excess, and start-up state. Output as a NO-contact.

The start-up signal throws SP2 and SP3 to a programmed condition. Following an external contact or pulse signal, the duration of its validity can be extended by program up to 999 s.

The alarm released may be kept memorized for a later analysis.

**Trip output of the monitor**

Both safety relays on every monitor module drop to de-energized state under one of the following conditions:

- Overspeed = SP1 setpoint level exceeded, or
- collective intrinsic failure signal, or
- external trip condition signal.

Both safety relays provide 2 NO-contacts directly to the 2013 wiring on the backplane or to separate terminals. A further contact is used internally by the system to signal correct monitor response to the (optional) test module.

Power handling facility of the trip output contacts:

Standard max 130 v AC/DC, max 2 a AC/DC, max 100 w.

Overload protection must be provided externally.

**Collective intrinsic failure signal**

With programmable selection the monitor assembles these failure signals as its intrinsic collective failure signal acting as one of the trip release conditions (see above):

- sensor circuit failure as supply interrupt, short circuit, or signal lead inactivity (presumes a p/p output as with our ASS.. sensors),
- plausibility check by SP2 (see above) fails,
- sensor signal fails in pulse amount equality compared to its neighbours.

The collective failure signal breaks a relay contact as an externally available alarm.

Each of the above individual failure signals may be memorized or automatically cancelled by programmable selection, once its cause has been eliminated.

**Sensor input**

The standard monitor input fits our recommended ASS.. or equivalent sensors. On/off level >7 / < 3 v, with 3k input impedance.

Optional input for low level magnetic sensors, response 150/300 millivolts and low pass filter selection by program. Input circuit isolated, max signal 60 v, frequency 0…30 kHz.

Sensor supply approx +11 v, max 60 ma, short circuit protected. In the “test” condition, the monitor input is switched by the electronics to the test generator signal.

**Display**

5-digits led 8 mm height. In operation, speed by programmed unit, failures identified by listed code. During the programming phase, the display reads program steps and parameters.

Conditions signalized by single LEDs.

**Data interface**

Output: measurements and alarms on demand. Input to configure the operational parameters (in addition to the front keys).

Standard mode RS232, optional PROFIBUS.

Connection to front socket Sub-D.

**Output repeating the sensor input**

Square wave pulses in same sequence as the input signal, not affected by switching of the monitor to test. Level approx. 22 volts under 1 k load.

Output isolated and without a reaction to the monitor function.

**Analog outputs (option)**

Up to 3 outputs with 20 ma into 500 ohms max load. Each individually programmable for low and high end of its span, with or without live zero.

Programmable response to test condition, level at failure condition, rising or falling output with increasing speed.

Resolution 12 bit, linearity error < 1 %.

Not available for monitors with PROFIBUS interface.

Details of the (optional) Test Generator Module

Continuous testing provides a reliable knowledge of the system's reaction to danger and greatly increases the safety factor. Therefore an appropriate test routine is highly recommended, indispensable for the SIL3 safety level.

The Test Generator Module provides the frequency signals simulating the speed signal to the monitor modules to check their response to different speeds. The Test Module reads the actual test frequency (in terms of RPM) on its display, and indicates which channel is currently under test.

Frequency selection is available in several modes:

- manual tuning over the entire range by narrow steps,
- 4 pre-programmable frequency (speed) levels for automatic application during the course of a test procedure.

The tests may be carried out according to the following options:

- Manual selection of the channel to be tested, by push-button or external signal. The reaction being made apparent by its alarm LED and its monitor collective failure alarm,
- Automatic test procedure, performed in a regular and sequential manner. The monitor response is checked internally by auxiliary contacts of its safety relays, addressing the Test module. A separate system failure alarm is released if one response is not as expected. Further tests are stopped, to prevent any erratic shut down of the machine.

**Intrinsic Self Tests**

The Test Generator module controls the entire test procedures.

The version performing the automatic test routine as approved to SIL3 IEC 61508 has a multiple self test facility, monitoring the correct sequence and timing of all steps, and actuating its own system failure signal, if not as anticipated.
General Functional Diagram

Trip Alarm Safety Contacts in 2of3 technique wired to two isolated breaking trip circuits

Optional Analog Outputs

Test Generator Module

External test control
Optional facilities in conjunction with the A, B, C inputs

- 4 setpoint alarms each individually programmable, outputs as SPNO contacts
- Optional module to vote 4 alarms in 2of3 technique
- Monitor comparing with another drive analog output and set-point alarm contacts
- Acceleration Monitor output as SPNO contact
- Forward/reverse Monitor output as SPNO contact
- Optional 2of3 Voter
- Monitor comparing with another drive analog output and set-point alarm contacts
- Output from Function Modules and Voters as specified
- Speed input to another drive
Specifications of the Optional Facilities

### Additional speed alarms
- **Options:** 4, or 8, in addition to each channel A, B, C.
- **Setpoints individually programmable over the entire range, also their response characteristics, the signal condition at power failure and during the starter phase.**

### Alarm outputs
- **Options:** 1 each separate SPNO relay contact with programmable alarm position.
- **Additional 2of3 voting between channels A, B, C, as breaking circuit.**

### Contacts Capacity
- **Max. 130 Volts AC/ DC, 2 amps AC or DC, max. 100 W.**
- **Higher voltage capacity on request.**
- **Overload protection required for inductive type loads.**

### Response Time
- **1 input signal period at setpoint + 15 milliseconds.**

### Analog outputs
- **1, or 2, or 3 available as optional parts of the Core Monitor, in each channel A, B, C.**
- **Each isolated. Full scale 20 ma into max. 500 ohms load.**
- **High and low end of range, and live zero individually programmable.**
- **Resolution 12 bit (1.4096). Linearity error < 0.1 % of full scale.**
- **Note: the analog output adds 2 milliseconds to the monitor reaction time.**

### Sense of Rotation Monitor
- **Addition to any channel A, B, C with special input to Sensor Series A5S30 …33,**
- **Optional as stand alone addition with own extra input.**
- **2 isolated SPDT contacts reversing with motion signal, as programmed.**
- **One can be converted by program into a RPM setpoint alarm.**
- **Max. 130 Volts AC / DC, 2 amps AC or DC, 100 W.**
- **Overload protection required for inductive type loads.**
- **Signal goes into reverse direction after a programmable amount of pulses, or speed, in reverse direction.**
- **Forward direction will be signalized immediately. By program, the forward or reverse signal can also be assigned to no-motion condition.**
- **Speed by 5-digits readout, reverse direction by LED.**

### Speed/Difference Monitors
- **1, 2, or 3 available as optional addition, with their reference leg attached to A, B, or C.**
- **Speed measurement of own input, 5 digits, scaleable to RPM, measuring principle based on pulse interval with programmable minimum of time > 30 millisec.**
- **Digital comparison to the reference programmable, as difference, percentage difference, or ratio.**
- **Own input with two paths of different level: Path to standard 3-leads sensors 7/6 volts, path to magnetic pick-ups > 50 mV RMS. Sensor supply (not monitored) 12 V / 60 mA.**
- **SPDT contact. Programmable to refer to either the own input speed measurement, or to one of the difference quantities.**
- **Resolution 12 bit (1.4096). Linearity error < 0.1 % of full scale.**
- **4 digits and - sign for deceleration.**

### Acceleration Monitor
- **Available as additional module in channel A, or in each A, B, C.**
- **Each provides 2 setpoint alarms, analog output, and display of the acceleration.**
- **Signal input internally tied to the corresponding channel input.**
- **The rotational speed, as the basis of determining the acceleration, is measured in the proven way of pulse distance extended over a minimum period of time. The acceleration then determines - according to its definition – from the difference between subsequent results and the time interval between them. Parameters are programmable to achieve stable and reliable measurements.**
- **The acceleration module does not participate in the test procedure.**
- **SPNO contact, with programmable setpoint and response characteristics.**
- **0/4-20 mA isolated circuit into max. 500 ohms load, with programmable span.**
- **Resolution 12 bit (1.4096). Linearity error < 0.1 % of full scale.**
- **4 digits and - sign for deceleration.**

### Dimensions sheets on request.