

BEN 6000

Extreme digital fault recorder



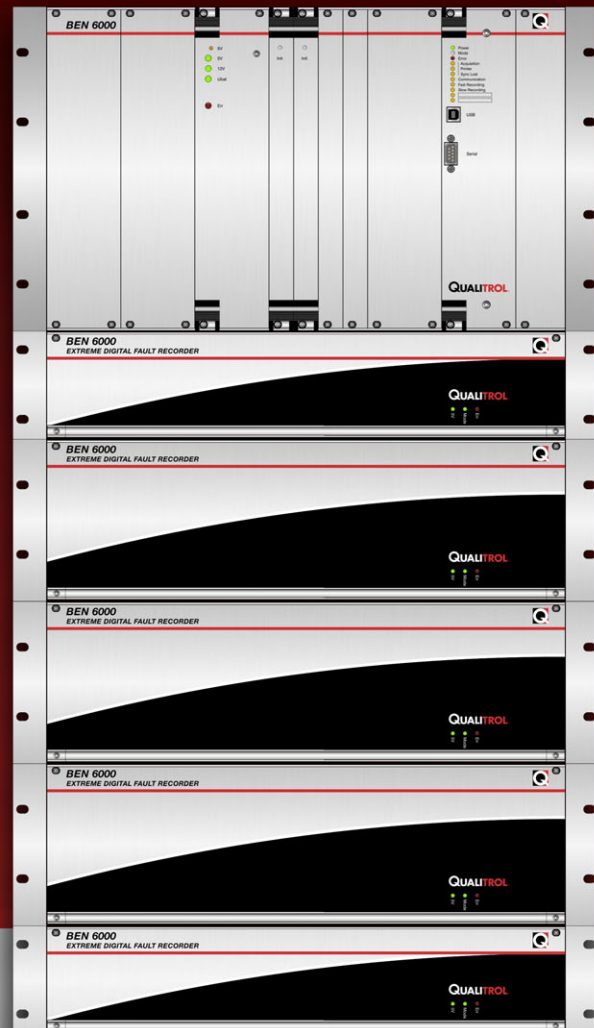
Continues to record no matter what!

- Leverages investment with many critical functions built into one device
- Achieve cost effective, integrated, automated substation via IEC 61850
- Utilizes the most accurate and highly flexible system acquisition topology
- Option for Class A power quality profiling

Product Summary

Description Extreme digital fault recorder and power generation monitor with multifunctional capabilities contained in one device

Application Functions as digital fault recorder, disturbance system monitor, power generation dynamic monitor, continuous fault recorder, synchrophasor measurement unit and/or class A power quality monitor



QUALITROL[®]
Defining Reliability

BEN 6000 Extreme digital fault recorder

Continues to record no matter what!

- The only digital fault recorder with the IEC 61000-6-5 Criteria 1 certification - indicating it has the highest immunity and reliability available
- Continues to record during the very harshest events (lightning strikes, power surges, swells and sags, persistent faults) and environmental conditions
- Other digital fault recorders will reset during such harsh events and often miss vital records
- Advanced optical isolation, current input isolation and hardware shielding techniques enables system to deliver the highest immunity available
- Special components unique to the BEN product family ensure highest robustness in the industry and also provide high EMC compliance
- Increased distances are achieved between electrical inputs to avoid 'domino' failure effect
- Totally isolated from the effects of electrical surges, etc (inputs are at the back and signal processing at the front)
- Each digital input has common return to ensure other channels are isolated on grounding fault
- Exceeds IEEE, IEC and ANSI standards
- Ultimately, never miss a record!

Leverages investment with many critical functions built into one device

- One flexible, upgradeable device for multiple uses
- Digital fault recorder (DFR), Dynamic system monitor (DSM)
- Dynamic Monitoring Equipment (DME), Dynamic Disturbance Recorder (DDR)
- Continuous recorder (CR), Class A power quality meter (PQ)
- Phasor measurement unit (PMU), Impedance-based fault location (FL)
- Sequence of events type display (SOE) and sequential of events integration with Qualitrol SER 4100 alarm and events monitor
- Full NERC compliance

Achieve cost effective, integrated, automated substation via IEC 61850

- Complies with IEC 61850 protocol
- Can monitor substation equipment in real time
- Scalable architecture
- Provides utility-wide common communication infrastructure, from the control center to the switchyard
- Peer-to-peer communication reduces wiring costs and provides higher flexibility than hard wired system
- Designed specifically for LANs to lower life cycle cost to use a device (from installation to product life maintenance)
- Master - slave control available (GOOSE messaging)

Utilizes the most accurate and highly flexible system acquisition topology

- Extremely high accuracy on inputs - 0.1% on voltage and 0.2% on current
- For systems below 96 analog channels, provides up to 384 digital channels (i.e., 4:1 ratio)
- For systems below 128 analog channels, provides up to 384 digital channels (i.e., 3:1 ratio)
- Optical link module combined with remote acquisition units provides unique de-centralized acquisition topology. Utility can monitor large number of lines across a 3km radius (1.86 miles) from a centralized control unit
- The acquisition data is synchronous on all system channels offering single device convenience
- Enables the spreading of the acquisition units close to the landing of the CT/PTs wiring, eliminating need and risk for expensive wiring



Class A power quality profiling (IEC 61000-4-30)

- Optional Class A IEC 61000-4-30 power quality
- Detection, capture and restitution of power quality events and trends in standardized fashion
- Power quality profiling at an interface between distribution and load, or between utilities at the transmission level
- Class A devices used primarily for contractual applications, verification with standards and resolving questions/disputes with utility customers. (Note, Class B devices used mostly for statistical surveys and trouble shooting where uncertainty is less important)

Monitor large networks from one, single high-channel capacity system

- Up to 192 analog inputs and up to 384 digital inputs
- Up to 200 triggerable derived quantities (virtual channels)

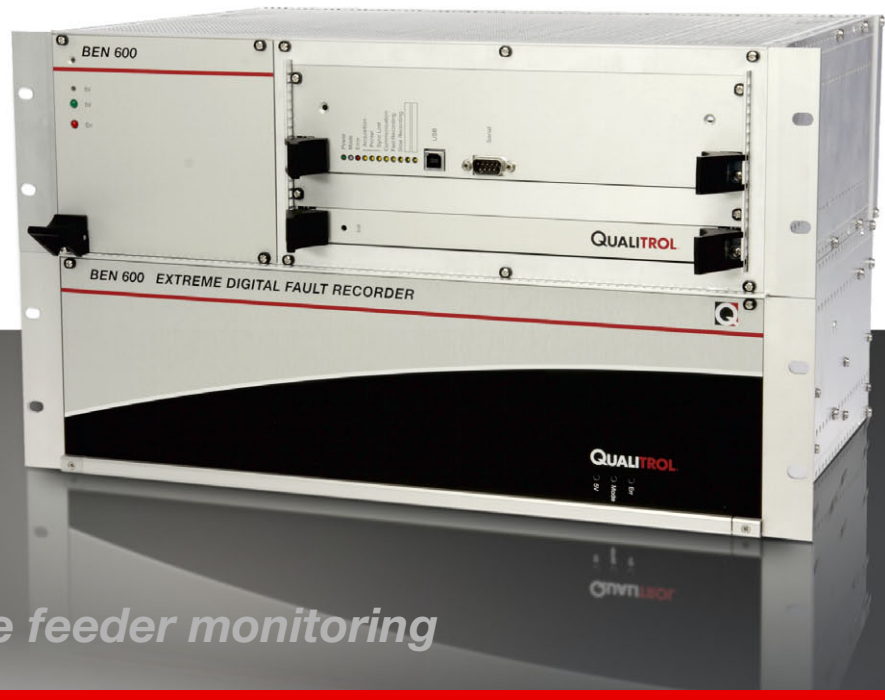
Other key features

- 16 bit analog to digital resolution and up to 12kHz sampling rate
- Shunts for current measurement to obtain high accuracy 0.2% on current
- One analog to digital converter per channel
- Ability to monitor frequency on every voltage channel
- Flash disk mass storage as standard (hard disk optional)
- Triggered recordings (3 speeds)
- Contains continuous recorder - can provide more than one month of recording independently of eventual triggering conditions
- Centralized OR decentralized architecture
- Real time embedded operating system
- Remote acquisition units for 8 analog channels and 16 digitals as small as 89mm (3.5 inches) high
- Dynamic swing monitor enables combination of any inputs to create derived quantities to trigger long duration records
- Cross triggering capability for improved fault identification - allows fast digital fault recording and/or slow signals
- High synchronization (<math><5\mu\text{s}</math>) on any channel

Other BEN 6000 versions

BEN 6000 portable version available for temporary or emergency power investigations or for testing performance of relays

BEN 600 version also available - a limited input device (i.e., 32 analog and 64 digital) for single feeder monitoring



BEN 600 for single feeder monitoring

BEN 6000 Extreme digital fault recorder

BEN 6000 - an intelligent electronic device

General Description

- The BEN 6000 is a high resolution, extreme digital fault recorder designed to monitor electrical signals in generation, transmission, and distribution networks and in industrial electrical energy installations.
- Unlike all other fault recorders, the BEN 6000 falls within the **Extreme** class, that is, it is designed to operate in the harshest of conditions. It has the unique benefit of providing the highest immunity levels in the world. As a result, a utility or power generation facility will never miss a record.
- Revolving around a powerful multi-task and real time operating system, easily distributed architecture enables the complete overview of a high voltage environment from a single, extremely dependable and accurate, focal point.

Input and sampling signals

- The BEN 6000 system continuously records all the input signals in a pre-fault memory in order to keep a record of their development.
- Three different, adjustable and simultaneous acquisition speeds with automatic, digitally controlled antialiasing filters (to eliminate the undesirable frequencies), provide the highest accuracy of sampling of the input signals.
- All of the input signals are sampled synchronously at a programmable frequency. Frequencies range among:
 - 1kHz and 10kHz –12kHz (fast)
 - 1 - 120Hz (slow)
 - 1 - 1kHz* or 5/6 kHz (continuous - requires additional flash memory)
- The time skew between channels is less than 5 μ s as standard before GPS synchronization improvements.
- Each analog input is converted into binary values by its own dedicated 16-bit analog to digital converter. To make full use of the 16 bit conversion range, four different input ranges can be selected (from 5V to 300V and one for converters type 4 to 20 mA).
- Each analog input has its own anti-aliasing filter to eliminate undesirable frequencies. The bandwidth of the input circuit automatically adapts to the sampling frequency of this channel.

* limitations on number of channels apply

Triggers and virtual channels

- A specialized user defined detection logic for each channel, monitors permanently the criteria defining a fault and the status triggering the record of an incident.
- The triggering logic of the BEN 6000 Extreme digital fault recorder is built around a dedicated digital signal processor (DSP). This processor analyses the analog and digital values sampled by the extreme digital fault recorder and executes detection algorithms (triggers) according to the user defined/ configured criteria.
- The BEN 6000 Extreme digital fault recorder contains a whole library of triggers, each one having its own detection algorithm. The user can choose whichever combination of triggers best suits his needs. For each of these, the triggering levels are remotely programmable.
- Examples of available triggers include:
 - over/under voltage level
 - over current level
 - imbalance of phases
 - dU/dt
 - frequency variation or active transition of a logic input
- Virtual channels (up to 200 real time calculated quantities) and logical equations can be defined by the user, in order to determine more complex starting conditions. The following virtual channels can be calculated:
 - single-phase active power and tri-phase active power
 - single-phase, reactive power and tri-phase reactive power
 - frequency
 - zero sequence, negative sequence and positive sequence
 - unbalance factor and phase angle

Recording

- As soon as a triggering condition is encountered, the recording cycle contained in the pre-fault memory is stored in memory with the post-fault recording. In this way a file containing the pre-fault, fault and post-fault is created in the memory. The system parameters defining the pre-fault and post-fault recording time and the maximum size of the recording are all programmable.



- The BEN 6000 system has the capability to record data at different acquisition speeds. This allows the user to monitor and record the changes in voltage, current or many other parameters over a longer time period centered around the fault, itself sampled at several kilohertz, without having to use a large amount of memory.
- An optionally available continuous recording function for disturbance monitoring provides more than one months worth of data, recording independently from eventual triggering conditions.

Control unit

- An extremely powerful and reliable control unit allows the concentration and monitoring of a large array of quantities from different sources and its dispatch to the user interfaces.
- There are two control units available:
 - Compact 3U - for small systems (less than 64 channels) and no need for system extension in future or some key features
 - Standard 6U - for medium to large systems (greater than 64 channels) or systems with maximized functionality

Acquisition unit

- Acquisition units perform the following functions:
 - connection to the input signal with shunts for current measurement
 - pre-filtering and isolation
 - anti-aliasing filter for the analog channels
 - analog/digital conversion
 - synchronized sampling for all channels (analog and digital)
- There are 5 types of acquisition units:
 - 8 analog and 16 digital channels (all voltage acquisition unit – 2U in height or current acquisition unit with built-in shunts for currents – 3U in height)
 - 16 analog and 0 digital channels (heights as above)
 - 0 analog and 16 digital channels (2U height)
 - 0 analog and 32 digital channels (2U height)
 - Remote acquisition units with built-in fiber optic connectors to allow measurement up to 3km from the control unit

6U control unit and six acquisition units (48 analog channels and 96 digital channels)



BEN 6000 Extreme digital fault recorder

BEN 6000 - options and packages

Class A power quality (IEC 61000-4-30)

- The BEN 6000 power quality cards primary function is to measure, integrate and store electrical quantities related to power quality in MV and HV networks, eg, flicker, harmonics dips and swells, etc.
- The module is installed on an extension card inside the control unit (up to two modules per card). The module computes and stores the power quality data. It uses the communication functions of the BEN 6000 extreme digital fault recorder to transfer data to the SQL database of the Qualitrol QIS software (for further analysis). Up to 4 power quality cards may operate in parallel in order to meet the monitoring capacity/requirements.
- The BEN 6000 can assess power quality according to the IEC 61000-4-30 Class A and IEC 61000-3-6..7, elaborating and compiling the power quality profile of the connected signals.
- The BEN 6000 cross triggering capability allows fast (DFR) and/or slow (DSM) signals/ recordings of a power quality event, significantly easing identification of its origin.

- Class A power quality is traditionally used for contractual applications (verification with standards and resolving disputes between utility and customer).

Phasor Measurement Unit - PMU (IEEE C37.118 - 2005)

- In addition to recording power system quantities, the BEN 6000 extreme digital fault recorder has the capability to provide real-time phasor information to remote locations.
- The ability to transfer real time synchronized phasor information from a number of locations on a power network to a central point is expected to ultimately:
 - provide early warnings of instability (blackout aversion)
 - improve power system (security) monitoring
 - improve state estimation
 - identify fault location in compensated networks
- Due to the high performance of the BEN 6000 acquisition chain the PMU sensor card surpasses the C37.118 standard.
- The PMU option can be supplied as part of a new system order or can be retrofitted to existing BEN 6000 systems in the field.*

* Note: The BEN 6000 PMU system requires IRIG-J synchronization.



BEN portable and



- The following is the high level functionality of the BEN PMU card:
 - Up to 3 three-phase circuit measurements
 - Up to 32 digital channels.
 - Sensors: frequency low, frequency high, df/dt, magnitude max and magnitude min for each voltage or current calculated quantities.
 - One of the voltage inputs, chose by the user, allows the frequency measurement.
 - Reporting rates available for a 60Hz network: 5, 6, 10, 12, 15,20, 30, 60. 50Hz reporting rates are: 10, 25 and 50.
 - TVE measured in the different settings < 1%.
 - Phase angle accuracy : better than 0.05° (with no out-of-band frequency).
 - Delay between input and output less than 85ms.
- Some of the many specialized areas where the BEN portable can provide value to a user include:
 - Temporary investigations, targeted at special areas of interest or emergency situations on transmission or distribution lines.
 - Temporary or emergency investigations, targeted at special areas of interest within nuclear or thermal generation plants, wind farms, solar generation farms or hydro electric plants.
 - Testing of third party protection system devices prior to installation or as part of type / conformance testing.
 - Testing of repaired protection devices (eg, relays) to ensure they will provide all the necessary protection functionality when put back in use.
 - Monitoring of power quality from the grid into large industrial plants.
 - Monitoring of an industrial plants own internal generators or fault diagnosis at the plant / grid connection.

BEN 6000 portable unit

- The BEN 6000 portable extreme digital fault recorder is a portable high resolution unit. It provides central processing control, as well as all inputs (i.e., 16 analog and 16 digital channels) inside one rugged enclosure.
- The analogue and digital inputs are provided as standard by means of banana plug connectors at the front of the unit, for ease of use and quick connection in any situation. Optional Phoenix terminal blocks can be provided. They are short-circuitable and interruptible in order to keep the current loop closed while disconnecting the inputs.
- This portable device can also be expanded to monitor more inputs via the connection of up to 3 remote acquisition units to the device via fibre optic cables, thus providing ability to monitor up to 40A and 64D.
- The portable BEN device is designed to maximize the mobility, with no compromise on critical features. Therefore the compact device can incorporate DFR, DSM/DME, Class A PQ, PMU, IEC 61850 just as with the standard BEN 6000 system.
- It is packed in a 19 inch, 6U high case with handle.
- All inputs are voltage. Current inputs can be optionally chosen on any or all of the 16 analog inputs, by adding a 19 inch, 3U high, portable shunt box.

BEN 600 Extreme digital fault recorder

- A BEN 600 extreme digital fault recorder is available. It is limited to 32 analog and 64 digital channels for more customized single feeder monitoring.

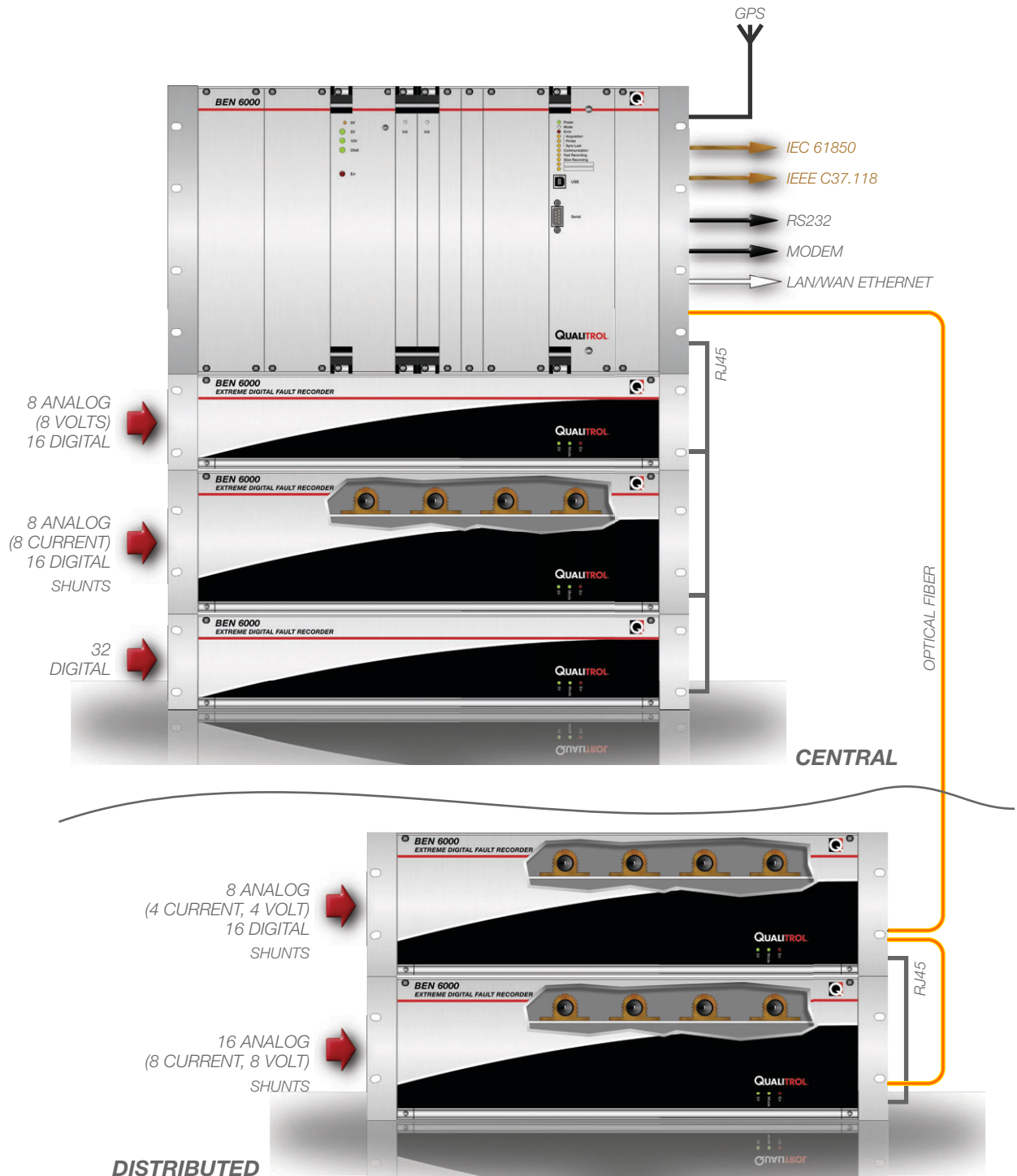
BEN Extreme service package

- The BEN extreme service package provides the ultimate peace of mind by best-in-class service support. The extreme service package includes:
 - 5 year warranty
 - 5 year remote service / support contract, on customer site classroom training for up to 6 personnel
 - Commissioning of the unit
 - Full *BENPro*[™] software and licences (up to 15 users)
 - Provision of all future upgrades of software
- A tailored managed service is also available including the option of leasing the BEN system over an agreed time frame and consultancy support in post fault diagnosis. This option has the added benefit of minimizing the capital equipment on the utilities balance sheet, whilst also ensuring that any loss of highly skilled protection system resource does not hinder any future fault investigations.

BEN PMU... more functions for the ultimate multifunction device

BEN 6000 Extreme digital fault recorder

BEN 6000 - flexible architecture



Example 40 analog 80 digital configuration, including remote acquisition (20 current, 20 volt)



TECHNICAL SPECIFICATIONS

| | | |
|----------------------|-----------------------------|---|
| General | Sampling speed | Fast: 1 to 12kHz; slow:1 to 120Hz |
| | Accuracy | 0.1% on voltage - 0.2% on current |
| | Resolution | 16 bits optimized per input ranges |
| | Memory capacity | Standard 64Mb per 64 channels Partitioned for both fast and slow recording |
| | Mass storage (optional) | Hard Disk: 8GB or flashdisk |
| | Time resolution | Records tagged to 0.1 ms |
| | Skew between different BENs | <40µs with IRIG-B/J+1pps pulse |
| | Absolute time precision | <100µs with IRIG-B/J+1pps pulse. 5 ms (typical) if external pulse or IRIG-B only |
| | Absolute time drift | 20 ppm maximum without external synchro |
| Power supply | Model | Vin |
| | SENS 941-04 | 48 - 60 VDC |
| | SENS 941-01 | 110 - 220 VDC or 125 - 220 VAC |
| | Tolerance on input voltage | ±20% |
| | Isolation resistance | >100MΩ |
| | Common mode isolation | IEC 255-5, 2.5kV RMS |
| | Oscillatory waves | IEC61000-4-12, 2.5kV crit A |
| | Conducted disturbances | IEC 61000-4-6, 10V/m crit A |
| | Surges withstand capability | IEC 61000-4-5, CM 4kV crit A, DM 2kV crit A |
| | Fast transient capability | IEC 61000-4-4, CM 4kV crit A, DM 2kV crit A |
| | Electromagnetic emissions | EN 55011 class A |
| Input/outputs | Input | Real time clock synchro; modulated IRIG-B/J, pulse; serial IRIG-J + 1pps; synch pulse input |
| | Input/output | PC direct, EIA-232, USB, modem, 24 volt, Ethernet, 10Base-FL, 100Base-FX |
| | Output | Printer, Centronics |
| | Isolation resistance | >100MΩ |
| | Common mode isolation | 1kV RMS |
| | Fast transient capability | IEC 61000-4-4, CM 2kV |
| | Ethernet | 10Base-FL or 100-BaseFX, effective throughput: 100KB/s |
| | Synch pulse input | Vih: 15 or 80V, Twidth: 5ms min; period: 1, 5 or 15 min, 1 or 24 h |
| | Calibration | 1 x EIA-232 per acquisition controller. |
| | Relays | 8 potential free contacts (optional 8 additional) |
| | Contacts | Rated (NO/NC): 250VRMS - 5A (resistive load), 110V - 0.5A DC |
| | Delay from start bus | 15ms |
| | Minimum alarm duration | 100ms |
| | Isolation resistance | >100MW |
| | Common mode isolation | IEC 255-5, 2.5kV RMS |
| | Oscillatory waves | IEC 61000-4-12, 2.5kV |
| | Surges withstand capability | IEC 61000-4-4, CM 4kV |
| | Fast transient capability | IEC 61000-4-4, CM 2kV |

BEN 6000 Extreme digital fault recorder

TECHNICAL SPECIFICATIONS

| | | | | | |
|---------------------|-----------------------------|--|--|--|--|
| Analog input | Voltages | 5, 20, 140 and 300 Vrms; 50, 200 Arms on 0.1Ω shunt 3 (100A*1s std) | | | |
| | Currents | Special 4-20mA range | | | |
| | Bandwidth | ±0.5dB, DC to 0.38 x Fs (Fs ≥ 10kHz); DC to 0.3 x Fs (Fs = 5 or 6 kHz) | | | |
| | Cut-off frequency | -3dB; 0.49 x Fs (Fs ≥ 10kHz); 0.32 x Fs (Fs = 5 or 6kHz) | | | |
| | Attenuation | 90dB min above 0.54xFs | | | |
| | Common mode rejection | 74dB min (140V range) | | | |
| | Signal/noise ratio | 82dB min | | | |
| | Time skew between channels | 5μs max | | | |
| | Cross talk between channels | <-84dB | | | |
| | Insulation resistance | >100MΩ | | | |
| | Common mode isolation | IEC 255-5, 2.5kV RMS | | | |
| | Oscillatory waves | IEC 61000-4-12, 2.5kV crit A | | | |
| | Surge withstand capability | IEC 61000-4-5, CM 4kV crit A, DM 1kV crit A | | | |
| | Fast transient capability | IEC 61000-4-4, CM 4kV crit A, DM 2kV crit A | | | |

| | | | | | |
|----------------------|---|--------------------------------|----------------|----------------|----------------|
| Digital input | Vnom | Vil min | Vil max | Vih min | Vih max |
| | 24-36 V | -70 V | 5 V | 17V | 70 V |
| | 48-60 V | -80 V | 10 V | 34 V | 80 V |
| | 110-130 V | -160 V | 25 V | 80 V | 160 V |
| | 220-250 V | -300 V | 45 V | 160 V | 300 V |
| | Time skew between channels | 25μs max | | | |
| | Insulation resistance | >100MΩ | | | |
| | Common mode isolation (IEC255-5) | 2.5kV RMS | | | |
| | Oscillatory waves (IEC61000-4-12) ⁴⁾ | 2.5kV crit A | | | |
| | Surges withstand capability (IEC 61000-4-5) ⁴⁾ | CM 4kV crit A; DM 1kV crit A | | | |
| | Fast transient capability (IEC 61000-4-4) ⁴⁾ | CM 2.5kV crit A; DM 1kV crit A | | | |

| | | |
|---|------------------------------|---|
| Triggers and derived quantities (virtual channels) | Physical analog channels | Level, rate of change, swing, adaptive rate of change |
| | Virtual (derived) quantities | RMS, P, Q, F, angle, sequence components, unbalance |
| | Digital channels | Edge |
| | Threshold resolution | 0.10% |
| | Tpost | 0.02 to 1300s (resolution: 10ms) |
| | Tmax | 0.05 to 3000s (resolution: 10ms) |
| | Tinhibit | 0 to 24h (resolution: 10ms) |
| | Rate of change | Time window: 10 to 1000ms |

| | |
|--------------|-----------------------------------|
| Comms | COMTRADE; IEC 61850; IEEE C37.118 |
|--------------|-----------------------------------|



TECHNICAL SPECIFICATIONS

| | | |
|---|--------------------------------|---|
| Standard compliance | Immunity | IEC 61000-4-4, 4-5, 4-6, 4-12 compliant |
| Environmental | Operating | 5 to 55 °C (41° to 131 °F) without disk 5° to 45 °C (41° to 113 °F) with disk 5° to 40 °C (41° to 104°F) with battery option |
| | Storage | -10 to 65 °C (14° to 149°F) |
| | Humidity | 10 to 90% non-condensing |
| | Vibration | IEC 68-2-6, 4.9m/s ² |
| | | IEC 61000-4-2; class 4 |
| | Radiated electromagnetic field | IEC 61000-4-3; class 4 |
| Human interface | LEDs | Front panel LEDs for feedback on status, synchronization, triggering |
| Control unit configurations | | Built on an industrial compact PCI bus and one 250 MIPS CPU card |
| | BEN 6000 standard | Up to 192 analog/384 digital with 6 extension slots |
| | BEN 6000 compact | Up to 64 analog/128 digital with one extension slot |
| Data acquisition unit configurations | | Depending on the type of control unit, up to 8 or 24 data acquisition units can be assembled |
| | All voltage acquisition unit | For 8 analog voltages and 16 digital inputs |
| | Current acquisition unit | For up to 8 analog currents (the remaining channels are voltages) and 16 digital inputs |
| | All digital acquisition unit | For 32 digital inputs |
| | Remote acquisition unit | An assembly of all voltage acquisition units and/or current acquisition units and/or all digital acquisition units remotely located from the control unit. Includes its own power supply and optical fibre interfaces for the connection to the control unit. |



BEN 6000... the choice of generation



What is an Extreme digital fault recorder?



- **The highest class of digital fault recorders available**
- **Must meet IEC 60000 6-5 Criteria 1 certification**
- **Can NOT miss vital records**
- **Does NOT reset during extreme events**
- **MUST continue to record and function normally during the worst conditions**

QUALITROL® Field Services

QUALITROL® provides on-site commissioning/start-up and comprehensive maintenance contracts to all customers worldwide. To further improve reliability, an extended warranty is available on selected products commissioned by QUALITROL®.

QUALITROL® Educational Services

QUALITROL® professional training (designed to achieve hands-on performance based objectives) prepares operations, maintenance, and engineering personnel to install, test, configure, operate and maintain QUALITROL® products.

QUALITROL® Accelerated Delivery

QUALITROL® provides accelerated delivery on many products and services including replacements, spare parts and repairs.

About QUALITROL®

QUALITROL® manufactures substation and transformer monitoring and protection devices used by electric utilities and manufacturing companies. It is the global leader in sales and installations of transformer asset protection equipment, fault recorders and fault locators. Established in 1945, QUALITROL® produces thousands of different types of products on demand, each customized to customers' unique requirements.

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