

# RS

## Data Sheet

## Fluke 40/41 Power Harmonics Analysers

This data sheet refers to the Fluke 40 and Fluke 41 Power Harmonics Analysers.

RS stock no.	Description
215-9621	Fluke 41B power harmonics analyser
408-8751	801-1000s 1000A current probe

Worldwide there is an increasing concern about the effects of power harmonics on electrical systems. Using their knowledge of hand held test equipment and digital signal processing techniques Fluke developed these affordable, practical tools to diagnose power harmonics problems.

### What are power harmonics?

Power harmonics are caused by non-linear loads such as inverters (drives) and switch mode power supplies, even electronic ballasts for fluorescent lighting.

Linear loads draw current in sine-waves at the supply frequency, non-linear loads do not, these electronically controlled loads tend to draw current in short pulses causing a distorted current waveform to be drawn from the supply.



ac theory demonstrates that non-linear current consumption actually consists of a sum of current at the supply frequency and at multiples of the supply frequency. These multiples are the harmonics. For example if the supply frequency is 50Hz then the second harmonic is 100Hz and the third harmonic is 150Hz, and so on. Because the electrical distribution system has a source impedance greater than  $0\Omega$ , large harmonic currents will cause harmonics to appear on the supply voltage. When this rises to significant levels it may cause additional problems.

### Why are power harmonics a problem?

Symptoms of harmonics usually show up in the power distribution equipment that support the non-linear loads. There are two basic types of non-linear loads - single-phase and three-phase. Single-phase non-linear loads are prevalent in offices, while three-phase loads are widespread in industrial plants.

Figure 1 Typical non-linear load current waveform (single phase)

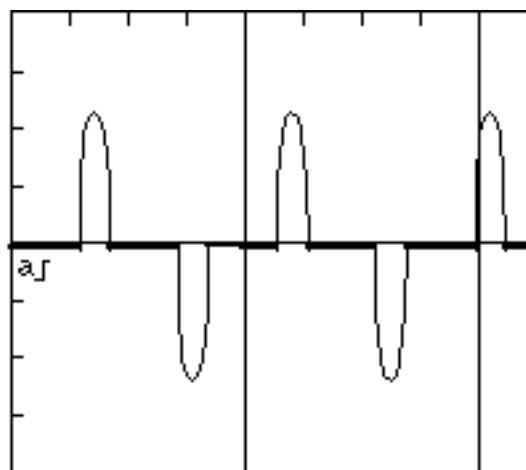
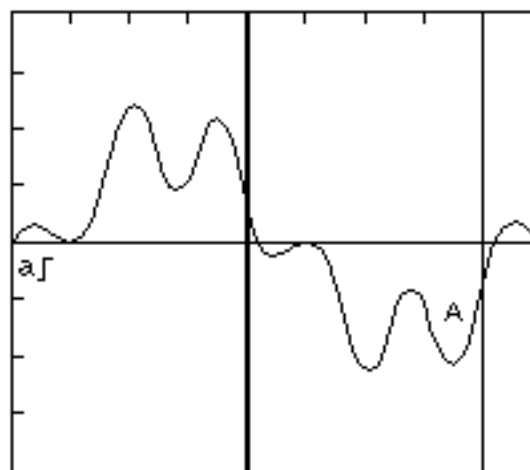


Figure 2 Typical non-linear load current from a three-phase application



Each component of the power distribution system manifests the effects of harmonics a little differently. Yet all are subject to damage and inefficient performance.

Neutral conductors

In a 3-phase, 4-wire system, neutral conductors can be severely affected by non-linear loads connected to single-phase branch circuits. Under normal conditions for a balanced linear load, the fundamental 50Hz portion of the phase currents will cancel in the neutral conductor.

In a 4-wire system with single-phase non-linear loads, certain odd numbered harmonics called triplens (odd multiples of the third harmonic: 3rd, 9th, 15th etc.) do not cancel, but rather add together in the neutral conductor. In systems with many single-phase non-linear loads, the neutral current can actually exceed the phase current. The danger here is excessive overheating because there is no circuit breaker in the neutral conductor to limit the current as there are in the phase conductors.

Excessive current in the neutral conductor can also cause higher than normal voltage drops between the neutral conductor and ground at the 240V mains sockets.

Circuit breakers

Common thermal-magnetic circuit breakers use a bi-metallic trip mechanism which responds to the heating effect of the circuit current. It is designed to respond to the true rms value of the current waveform and therefore will trip when it gets too hot. This type of breaker has a better chance of protecting against harmonic current overloads.

A peak sensing electronic trip circuit breaker responds to the peak of current waveform. As a result it won't always respond properly to harmonic currents. Since the peak of the harmonic current is usually higher than normal, this type of circuit breaker may trip prematurely at a low current. If the peak is lower than normal the breaker may fail to trip when it should.

Bus bars and connecting lugs

Neutral bus bars and connecting lugs are sized to carry the full value of the rated phase current. They can become overloaded when the neutral conductors are overloaded with the additional sum of the triplen harmonics.

Electrical panels

Harmonics can occasionally effect electrical panels. Panels that are designed for use with 50Hz current may become resonant to the magnetic field generated by higher frequency harmonic currents. If this happens a panel can vibrate and emit a buzzing sound at the harmonic frequency.

Transformers

Where a substation has a delta-why transformer, there are two potential problems caused by harmonics. Firstly, single phase non-linear loads produce triplen harmonics which algebraically add up in the neutral. When this neutral current reaches the transformer it is reflected into the delta primary winding where it circulates and causes overheating which may lead to transformer failures.

Secondly, since transformers are rated for 50Hz use harmonic currents can cause core losses and copper

losses. Higher frequency harmonics cause increased core loss due to eddy currents and hysteresis, resulting in more heating than would occur at the same 50Hz current. These heating effects mean that transformers need to be derated for harmonic loads or replaced with specially designed transformers.

Generators

Standby generators are subject to the same kind of overheating problems as transformers. Because they provide emergency back-up for harmonic producing loads such as data processing equipment they are often even more vulnerable. In addition to overheating, certain types of harmonics produce distortion at the zero crossing of the current waveform which causes interference and instability for the generators control circuits.

Motors

Where there is a significant harmonic voltage present on the supply to a motor, certain harmonics can cause a rotating field that opposes the rotation of the motor. Although this may have little apparent effect on the rotation of the motor, it can cause overheating and subsequent damage to the motor.

Power factor

Harmonics is not only a major contributor to adverse power factor, but can also cause overheating of power factor correction capacitors.

Classification of harmonics

Each harmonic has a name, frequency and sequence. The sequence refers to phasor rotation with respect to the fundamental (F), i.e. in an induction motor, a positive sequence harmonic would generate a magnetic field that rotated in the same direction as the fundamental. A negative sequence harmonic would rotate in the reverse direction. The first nine harmonics along with their effects are listed below.

Name	F	2nd*	3rd	4th*	5th	6th*	7th	8th*	9th
Frequency	60	120	180	240	300	360	420	480	540
Sequence	+	-	0	+	-	0	+	-	0

\* Even harmonics disappear when waves are symmetrical (typical for electrical circuits)

Sequence	Rotation	Effects from skin effect, eddy currents, etc.)
Positive	Forward	Heating of conductors, circuit breakers, etc.
Negative	Reverse	Heating as above + motor problems
Zero**	None	Heating, + add in neutral of 3-phase, 4-wire system

\*\* Zero sequence harmonics (odd multiples of the 3rd) are called "Triplens" (3rd, 9th, 15th, 21st, etc.)

## Fluke 40 and 41 power harmonic meters

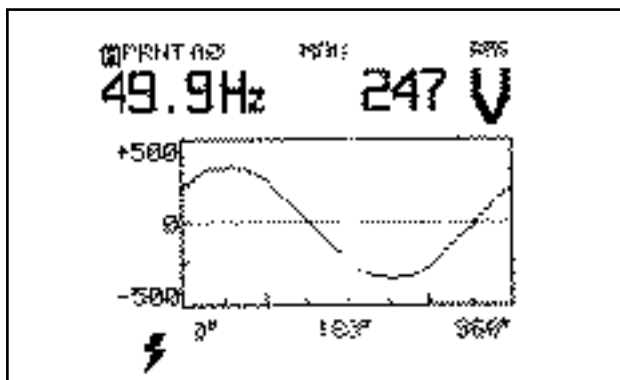
The Fluke 40 and 41 measure the voltage and current (via the 500A current transformer supplied) of the circuit under test. It can then display the voltage, current or power as a waveform, a bargraph of the harmonics or as a digital display.

Fluke have designed these harmonics analysers to be simple to use, all functions and displays are easily accessed via the fewest possible key presses, so there are no menus to work through.

The tester uses a set of nine multi-purpose screens to present each type of measurement (Volts, Amps or Watts) as a waveform, a relational bar chart of harmonics, or a series of digital (text) readouts. One key selects between Volts, Amps and Watts, whilst another selects the display type. With multiple values and computations on each screen it becomes simple to access all the information about the power, voltage or current at the test point.

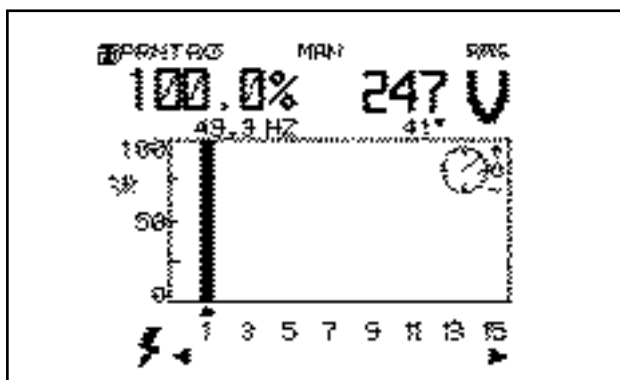
When selected a "Record function stores Max, Min, and Average readings that can be easily accessed with the cursor keys when on a text screen.

### Voltage measurements



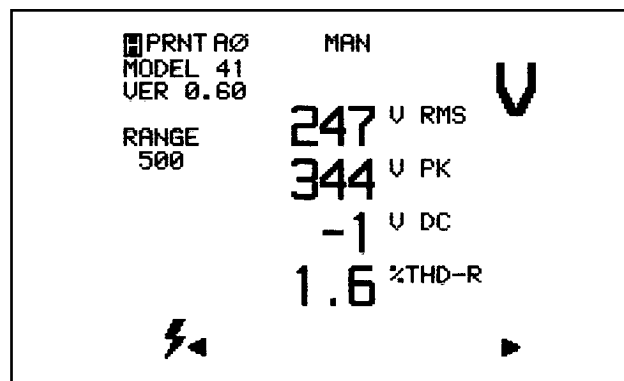
**Display:** One cycle of the fundamental waveform and its frequency. Instantaneous voltage at cursor position.

**Application:** Detecting flat-topped voltage caused by current harmonics, and notching caused by SCR switching.



**Display:** Bar graph of dc voltage, fundamental voltage, and harmonics (up to 31st). Using cursor, view percent of fundamental (%F), percent of total rms (%R), rms value, frequency and phase angle of harmonic voltage.

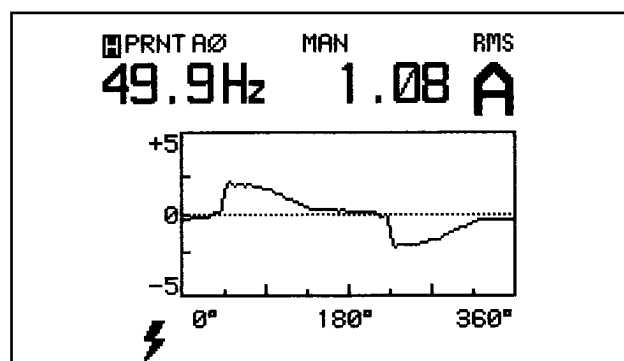
**Application:** Quickly identifying patterns of harmonic distortion, and likely sources of voltage harmonics.



**Display:** Rms, peak, and dc components of measured voltage. The %THD of voltage referenced to either fundamental (%THD-F) or total rms value (%THD-R).

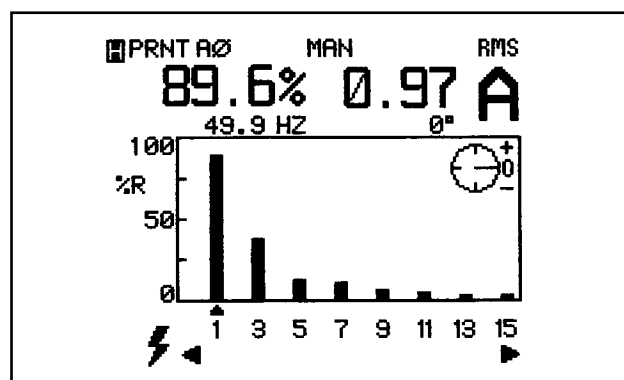
**Application:** Summarising measured quantities.

### Current measurement



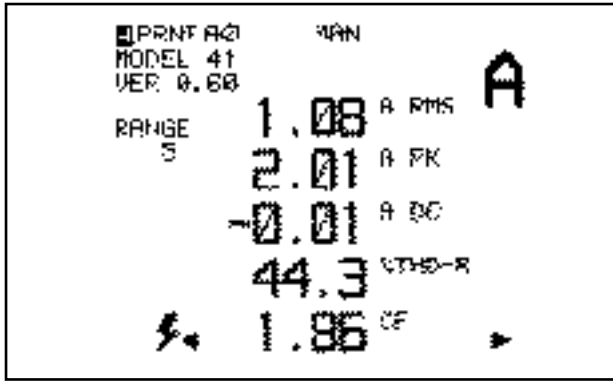
**Display:** One cycle of current and readings of true-rms current and fundamental frequency. Instantaneous current at cursor position.

**Application:** Quickly recognising dominant load types in the circuit. Quickly identifying linear, mixed linear and non-linear loads, and phase-shifted motor loads.



**Display:** %-fundamental or %-rms, rms value, frequency, and phase angle of fundamental or harmonic currents (up to 31st), as selected by cursor from bar graph.

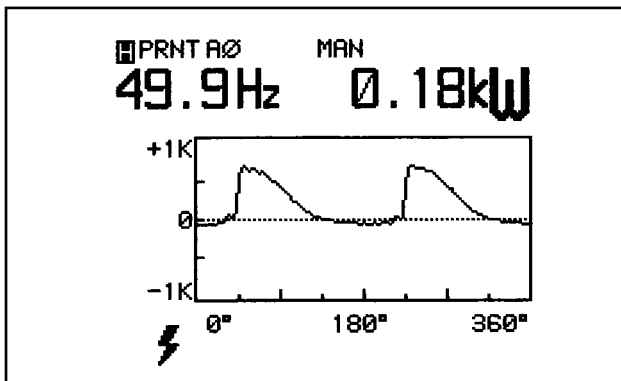
**Application:** Identifying sources of harmonic currents. Obtaining data for designing, specifying or sizing transformers, filters, etc.



**Display:** Rms, peak and dc components of measured current. Crest factor, peak/rms value, %THD of current referenced to fundamental (%THD-F), or total rms (%THD-R) of current.

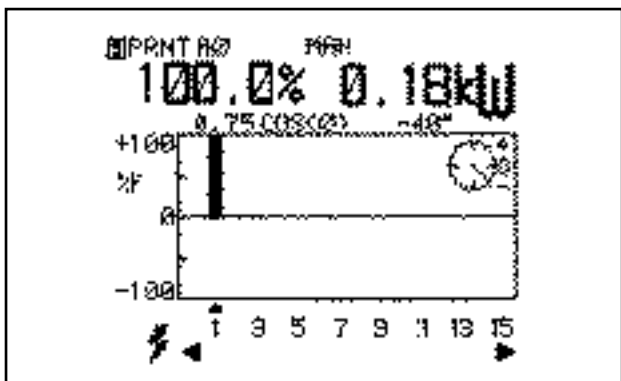
**Application:** Derating transformers. Checking SCR firing balance.

#### Power measurement



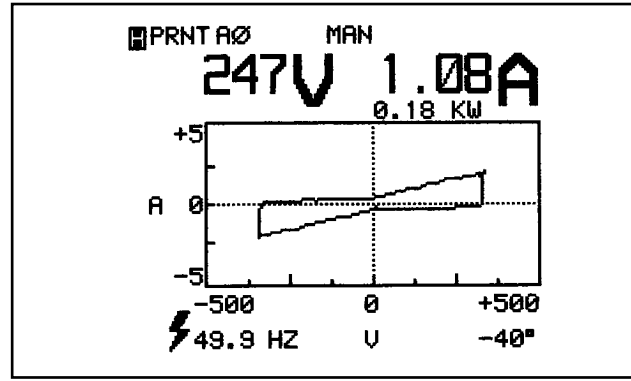
**Display:** Fundamental frequency and active power. Instantaneous value of power over one cycle of voltage or current. Instantaneous power at cursor position.

**Application:** Identifying peak power and positive-versus-negative power components.



**Display:** %fundamental of active power, active power,  $\cos(\phi)$ , and phase angle between voltage and current at harmonic selected by cursor. Magnitude and polarity of power at each harmonic frequency.

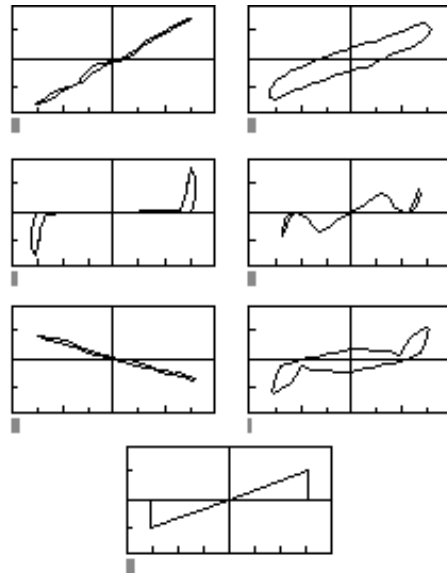
**Application:** Identifying direction of harmonic current flow.



**Display:** Watts, Volt-Amps, power factor (total) and displacement power factor of fundamental of single-phase power.

**Application:** Identifying displacement versus distortion power factor. Determining proper power-factor correction methods.

Figure 3 A/V signatures



Current voltage signatures can be viewed by use of the A/V button. This enables a quick diagnosis of the type of harmonic distortion and the power factor, for instance the typical signatures in Figure 3 are interpreted as follows:

1. A linear load with no phase shift.
2. A linear load with phase shift. A narrow ellipsoid in this pattern usually does not mean there is a problem. For wider ellipsoids, check power factor (PF). If the ellipsoid is backwards (upper left to lower right), check that you have pointed the current probe in the right direction.
3. A non-linear load, usually resulting from pulse-type (switch mode) power supplies.
4. A non-linear load resulting from a 3-phase (six pulse) rectifier power supply.
5. A linear load that is  $180^\circ$  out of phase. A current probe pointed in the wrong direction or reversed polarity voltage leads can cause this indication. This incorrect alignment will also cause negative power readings.
6. A combination of harmonic content and phase shift of the fundamental frequency.
7. A pattern indicative of a phase controlled silicon-controlled rectifier (SCR) power supply.

## Extra features of the Fluke 41B

The Fluke 41B has three additional text screens one each for voltage, current and power. These screens show the following additional data:

- Total harmonic voltage  $V_{HM}$
- Voltage crest factor
- Total harmonic voltage distortion (as % of the fundamental voltage)
- Total harmonic current  $A_{HM}$
- K factor, a transformer rating calculation for harmonics tolerance
- Total harmonic current distortion (as % of the fundamental voltage)
- kVA reactive
- The phase angle by which current lags the voltage ( $^{\circ}A$  lag).

The Fluke 41B is also able to store up to eight complete sets of measurements in memory.

Using the supplied opto-isolated RS-232 link the present screen can be sent to a printer (Epson FX of HP Thinkjet compatible).

The Fluke 41B is also supplied with FlukeView™ software, which enables information from the model 41B to be input to a PC into a Windows™ environment. This enables reading to be archived, further analysis of the measurements and incorporation of survey information into documentation.

## Specifications

**Minimum input levels** \_\_\_\_\_ 5V rms (using VØ reference)  
or 1A rms (using AØ reference)

### Voltage (true rms)

Input range \_\_\_\_\_ 0.0 to 600.0V rms (ac + dc)  
0.0V to  $\pm 933$  peak

Basic accuracy (fundamental, 5-65Hz):

rms \_\_\_\_\_  $\pm(0.3\% + 2 \text{ digits})$

peak, dc \_\_\_\_\_  $\pm(2\% + 3 \text{ digits})$

Input impedance \_\_\_\_\_  $1M\Omega$ , balanced

Crest factor \_\_\_\_\_  $>3.0$  below 300V, 1.56 at 600V

### Current with mV/A input (true rms)

Input range \_\_\_\_\_ 1.00 to 1000A rms (ac + dc)  
1.0 to  $\pm 2000A$  peak

Basic accuracy (fundamental, 5-65Hz):

rms \_\_\_\_\_  $\pm(0.3\% + 3 \text{ digits}) + \text{probe specs}$

Crest factor \_\_\_\_\_  $>3.0$  below 600A, 2.0 @ 1000A

80i-500s current probe (supplied)

1 to 20A ac \_\_\_\_\_  $\pm(5\% + 0.3A)$

20 to 100A ac \_\_\_\_\_  $\pm 5\%$

100 to 500A ac \_\_\_\_\_  $\pm 2\%$

### Power (watts and volt-amps) with 1mV/A input

Range \_\_\_\_\_ 0 to 600kW (kVA) average  
0 to 2000 kW (kVA) peak

Basic accuracy (fundamental, 5Hz-65Hz):

Active power \_\_\_\_\_  $\pm(1\% + 4 \text{ digits}) + \text{probe specs}$

### Harmonics accuracy (cursor data)

Volts:

Fundamental to 15th harmonic:

Volts \_\_\_\_\_  $\pm (1\% + 2 \text{ digits})$

Phase \_\_\_\_\_  $\pm 2^{\circ}$

16th to 31st harmonic:

Volts \_\_\_\_\_  $\pm(2\% + 3 \text{ digits})$

Phase \_\_\_\_\_  $\pm 10^{\circ}$

Amps and Watts:

Fundamental to 15th harmonic:

Amps or Watts \_\_\_\_\_  $\pm (2\% + 3 \text{ digits}) + \text{probe specs}$

16th to 31st harmonic:

Amps or Watts \_\_\_\_\_  $\pm (3\% + 4 \text{ digits}) + \text{probe specs}$

### Other measurement specifications

Frequency \_\_\_\_\_ 5.00Hz-99.9Hz  $\pm 0.3\text{Hz}$

Input bandwidth (-0.5dB) \_\_\_\_\_ dc 5Hz to 2.1 KHz

Crest factor (CF range) \_\_\_\_\_ 1.00 to 5.00

Power factor (PF) \_\_\_\_\_ 0.00 to 1.00

Displacement power factor \_\_\_\_\_ 0.00 to 1.00

Phase measurement range \_\_\_\_\_  $-179$  to  $180^{\circ}$

K-factor (KF) range (Model 41) \_\_\_\_\_ 1.00 to 30.00

**General specifications**

Size \_\_\_\_\_ 9.2 × 3.9 × 2.5 inches (234 × 100 × 64mm)

Weight \_\_\_\_\_ 2.0 lb(1kg)

Battery:

Type \_\_\_\_\_ 4 alkaline "C" cells ANSI/NEDA-14A  
IEC-LR14 (supplied)

Life \_\_\_\_\_ 24 hours minimum (continuous)

Temperature:

Operating \_\_\_\_\_ 32° to 122°F (0 to 50°C)

Storage \_\_\_\_\_ -4° to 140°F (20 to 60°C)

Temperature coefficient \_\_\_\_ 0.1 × specified accuracy per °C  
(0 to 18°C, 28 to 50°C)

Humidity:

Operating \_\_\_\_\_ 32 to 86°F (0 to 30°C) 90%

86 to 104°F (30 to 40°C) 75%

104 to 122°F (40 to 50°C) 45%

Storage \_\_\_\_\_ 90%

Altitude:

Operating \_\_\_\_\_ 15,000 feet (4.6km)

Storage \_\_\_\_\_ 40,000 feet (12km)

Shock and vibration \_\_\_\_\_ Per MIL-T-28800, class 3

**Electromagnetic compatibility**

RF emissions \_\_\_\_\_ EN 50081-1 commercial limits  
FCC Part 15 Class B

VFG 243-1991

RF susceptibility \_\_\_\_\_ EN 50082-2 Industrial limits

Case \_\_\_\_\_ Drip-proof and dust-proof

**Display**

Type \_\_\_\_\_ Super twisted liquid crystal

Contrast \_\_\_\_\_ User-adjustable

Backlight \_\_\_\_\_ Yes

**Safety**

Designed for 600V measurements on industrial power  
distribution circuits

Overload protection:

Voltage or current probe input \_\_\_\_\_ 600V maximum

Surge protection \_\_\_\_\_ 6kV per IEC 1010-1

Max. voltage isolation to earth \_\_ 600V from any terminal

Protection levels \_\_\_\_\_ IEC 1010-1, Pollution Degree 2  
Installation Category III,  
Material Group II, 600V

Protection class \_\_\_\_\_ Protection Class II as  
described in IEC 1010-1, Annex H

**Waveform memory (Model 41B only)**

Eight nonvolatile memories each store waveform data for  
both voltage and current inputs for later recall or sending to  
a computer.

**EIA-232-E (RS-232) Interface (Model 41B only)**


Optically isolated, 1.2, 9.6 or 19.2 k baud rate. Printer output  
in either Epson FX-80™ of HP Thinkjet format. FlukeView  
Windows™ and DOS® software provided.

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