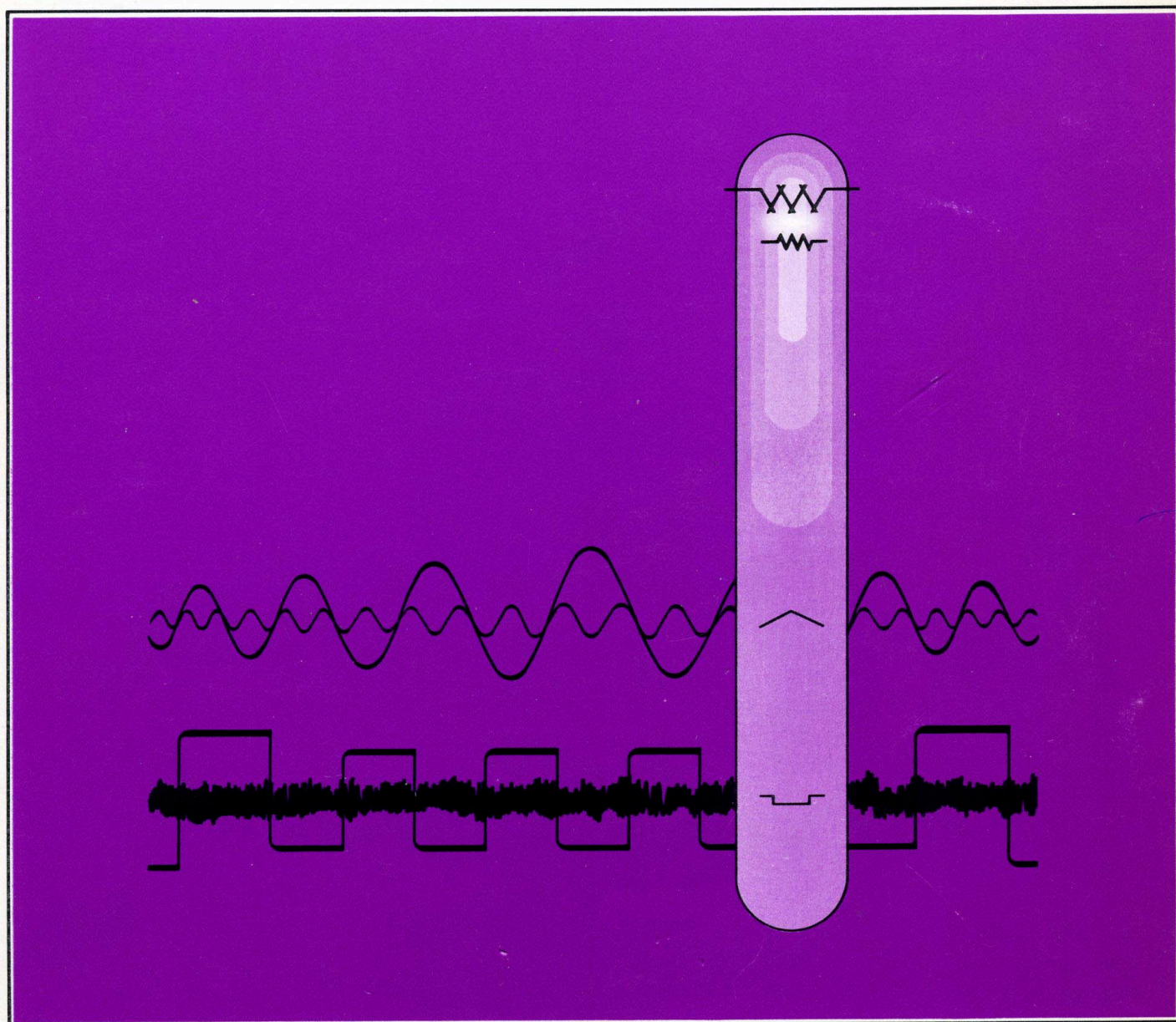


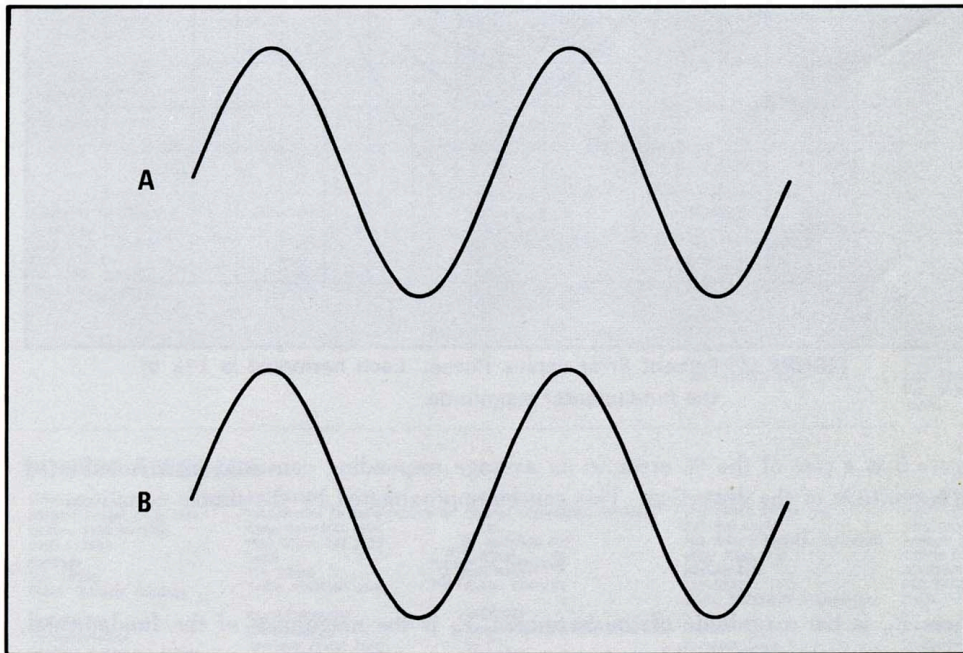
# True RMS Measurements



# True RMS Measurements

Copyright 1970 by **HEWLETT-PACKARD COMPANY**

June 5, 1970

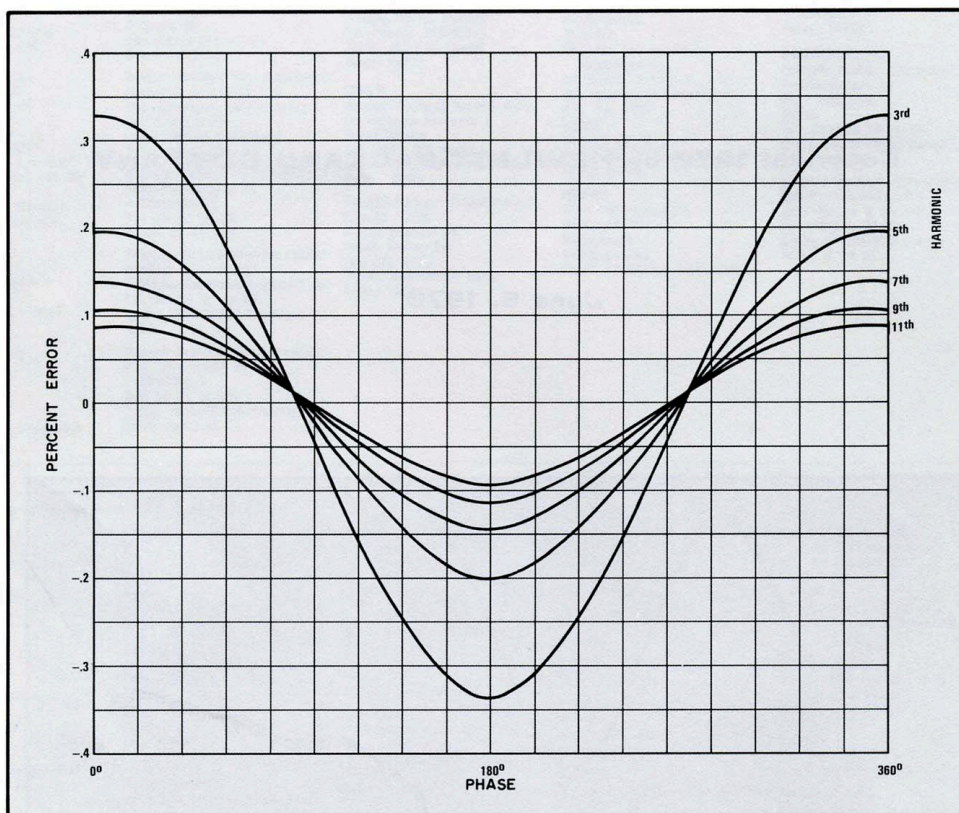


**FIGURE 1.**

Can you see any difference in the waveforms shown in Figure 1? Both waveforms were computer generated. One waveform is distorted by 1% 3rd harmonic in phase with the fundamental. The other waveform is a pure sine wave. 1% distortion is a typical specification for many good oscillators and is present in almost every sine wave used today. Would you be able to determine that waveform A in Figure 1 is distorted? Do you realize that if you measure the voltage level of this 1% distorted waveform with an average responding 4 digit DVM, only 3 digits are accurate, or with a 5 digit DVM, still only 3 digits are accurate? This AN will show that many measurements being made today are not "good enough".

## EFFECTS ON MEASUREMENTS

The two major types of converters used with DVM's today are average responding and true rms responding. The average responding converter responds to the average value of the rectified waveform times a constant (constant  $\cong 1.11$  for a pure sine wave). If the waveform contains harmonics of the fundamental, the average value will vary depending on the amplitude and phase of the harmonics. Multiplying this varying average by a constant has to give a varying rms indication. Figure 2 is a plot of the error caused by the common 1% distorted waveform in Figure 1. Each harmonic was held to 1% of the fundamental and the phase of the harmonic varied from  $0^\circ$  to  $360^\circ$ .



**FIGURE 2.** Percent Error versus Phase. Each harmonic is 1% of the fundamental magnitude.

Figure 3 is a plot of the % error in an average responding converter as a function of the magnitude of the distortion. This can be approximated by the simple equation:

$$\text{Error} \cong \frac{E_h}{NE_f}$$

where  $E_h$  is the magnitude of the harmonic,  $E_f$  is the magnitude of the fundamental, and  $N$  is the order of the odd harmonic.

Table 1 gives the equations for both average responding rms calibrated voltage and true rms voltage. Note that only the average responding equation contains a phase term.

**TABLE 1.**

$F(t) = A + B\sin\omega t + C\sin(3\omega t + \phi) + \dots + Z\sin(n\omega t + \theta)$ $E_{AVG} = \frac{1}{T} \int_0^{t_0} [A + B\sin\omega t + C\sin(3\omega t + \phi) + \dots] dt$ $E_{TRMS} = \frac{1}{\sqrt{2}} \sqrt{A^2 + B^2 + \dots}$
---

The 1% 3rd harmonic can add an additional  $\pm 0.33\%$  error to the basic accuracy of an average responding converter. In a 4 digit DVM, this amounts to an additional 33 counts of error, or the last digit is meaningless. In a 5 digit DVM, 333 counts of error can be added, or the last 2 digits are meaningless. In both cases, only 3 digits are meaningful with the typical 1% distorted waveform.

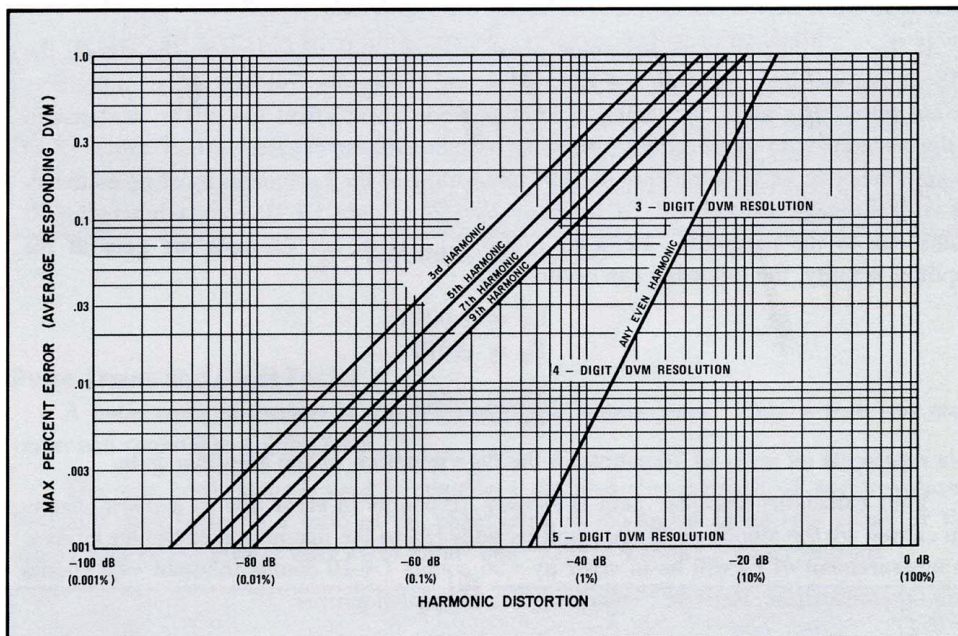


FIGURE 3. Maximum % Error versus Harmonic Magnitude. Harmonic phase is constant.

So far, worst case has been assumed. This need not be done if the magnitude and phase of the harmonics can be determined. Determining the magnitude of the harmonics would not be too difficult, but determining the phase relationship is next to impossible. It would be possible to analyze the signal using the wave analysis technique where each harmonic is isolated and measured by an average responding converter. After the fundamental and all the harmonics have been measured and recorded, they could be summed together by the square root of the sum of the squares method. This process eliminates the phase relationship problem, but requires expensive instrumentation and a great deal of time.

On the other hand, the true rms converter responds to the effective dc heating value of the waveform. The fundamental and each harmonic contribute to the total heating value. The true rms converter in essence takes each component of the waveform and sums them by the square root of the sum of the squares technique. The converter does the job of the wave analysis and computing in a very economical way. Harmonic phase relationships have no effect on the response of the converter. The true rms conversion is a correct indication of the distorted waveform and is usable with 4 and 5 digit DVM's.

The following example is used to exemplify the problems encountered with the average responding converter. The gain of an amplifier is determined by comparing the relative input voltage  $E_1$  to the relative output voltage  $E_2$ .

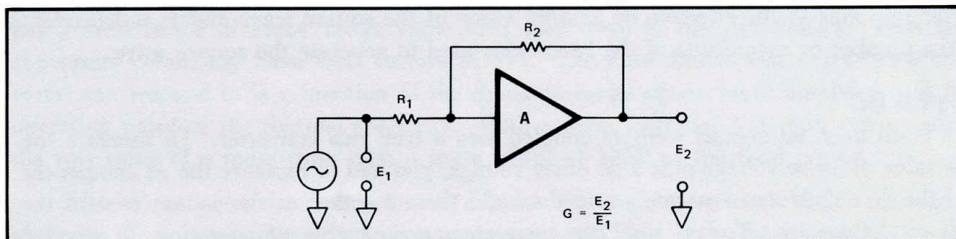


FIGURE 4. Amplifier Example

$E_1$  contains the typical 1% harmonic distortion. Since it is difficult to determine which components are present, assume the worst case in which all of the distortion is contained in the in-phase 3rd harmonic. The total error in an average responding converter will be the converter's inherent error plus the 33 counts of error due to the harmonic content of the waveform. A typical average converter specification is  $\pm 0.1\%$ , or the total worst case error of +43 counts for a 4 digit DVM.

If the amplifier adds no harmonic phase or amplitude distortion to the signal, the +43 counts will be present on the  $E_2$  voltage and the errors will cancel, but amplifiers are not pure. The amplifier, being a reactive device, will affect the phase relationship of the harmonics to some extent. Since it is impossible to determine how much effect the amplifier will have, worst case of  $180^\circ$  phase shift of the harmonics must be assumed. The measurement of  $E_2$  will be in error by -23 counts (+10 counts inherent -33 counts due to the harmonic—Refer to Figure 2). If in our example the gain of the amplifier is unity, the following can occur:

$$\begin{aligned} E_1 &= 1.0043 \\ E_2 &= .9973 \\ \frac{E_2}{E_1} &= .9930 \end{aligned}$$

This represents an error of 70 counts in the determination of the amplifier gain.

Your calculated amplifier gain is already 70 counts in error due to a phase distortion caused by the amplifier. If the amplifier adds 1% to the magnitude of the harmonics, the measurement of  $E_2$  will be in error by -56 counts (+10 counts inherent -66 counts due to the distortion. Refer to Figure 3). The calculated gain is

$$\frac{E_2}{E_1} = \frac{.9944}{1.0043} = .9901$$

or the calculated gain is in error by 89 counts.

By using a true rms converter, you don't have to worry about the errors caused by distortion. All of the digits remain useful and the reading is affected only by the basic accuracy of the instrument. Distortion does not cause errors in true rms converters. Distortion is part of the total power of the waveform and the converter responds to the power, not the average of the waveform. Distortion would have to be less than 0.1% to use all 4 digits of a 4 digit DVM and less than 0.01% to use all 5 digits of a 5 digit DVM. Signals just are not pure enough for you to gamble with average responding measurements.

## TRUE RMS MEASUREMENTS

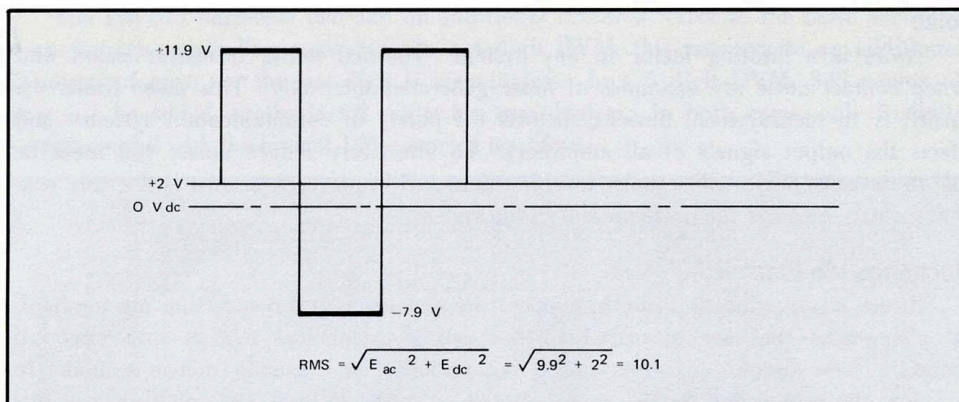
Besides being the only accurate way to make everyday ac voltage measurements, the true rms converter allows you to accurately measure signals containing very high distortion such as square waves, pulse trains, and even noise. This section discusses some of these unique measurement capabilities.

### Square Wave

A square wave can be generated by summing together sine waves of the appropriate frequency and amplitude. The harmonic content of a square wave is so great that the average responding converter calibrated to respond to the rms of a sine wave cannot even make an approximate measurement of the rms value. The true rms converter responds to the effective dc heating value of the square wave and is independent of the number or magnitude of the harmonics used to generate the square wave.

### AC plus DC

Until now, all signals were ac coupled into a true rms converter. To measure the rms value of an ac voltage plus a dc offset voltage, you had to measure the ac component and the dc component separately and then add them together as the square root of the sum of the square. Today, true rms converters are capable of accepting dc coupled signals and measuring the rms value in one step. (Note Figure 5.)

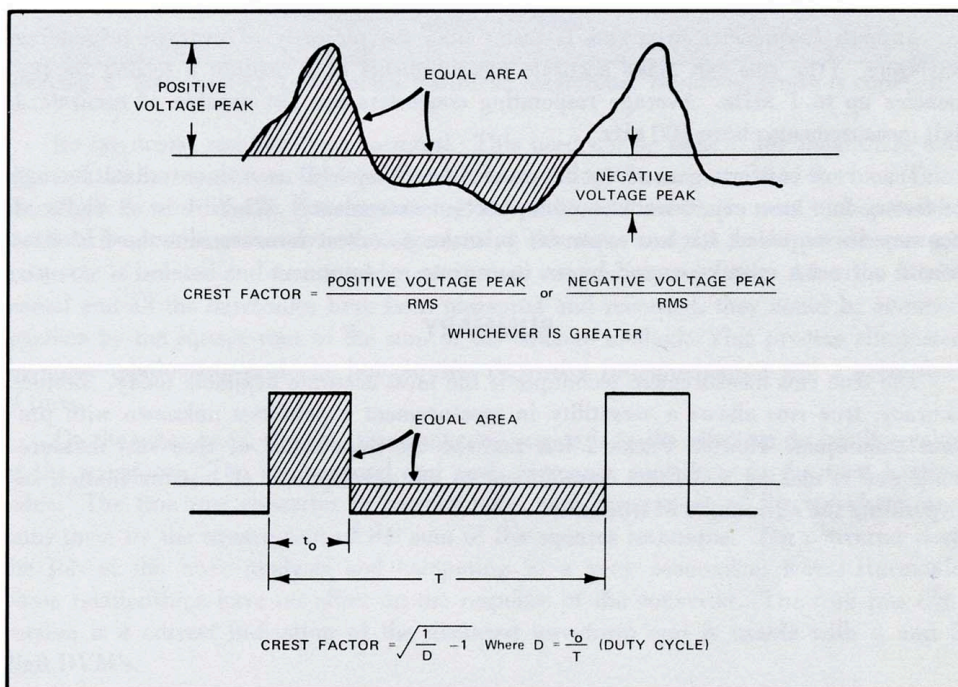


**FIGURE 5.** AC plus DC

### Pulse Trains and Crest Factor

A pulse train in essence is a non-symmetrical square wave. Only a true rms converter can respond to a pulse train.

The term crest factor is used to describe a physical characteristic of any waveform. Basically crest factor is a ratio of the peak value of the signal to its rms value, or the square root of the inverse duty cycle minus one. Figure 6 shows both definitions.



**FIGURE 6.** Definition of Crest Factor

An average responding converter that can measure only pure sine waves accurately has a crest factor of 1.414 (peak value of a sine wave to the rms value). True rms converters commonly have crest factors of 7:1. The crest factor that a true rms converter can respond to is a function of the dynamic range of the input amplifier and the operating point of the thermal converter. With a crest factor of 7:1, you can measure the rms value of a pulse train with a pulse width of 1/50 of the total period.

Also, to measure the rms value of a pulse that originates at 0 V dc, the signal must be dc coupled into the true rms converter. This is a direct application of  $\sqrt{E_{ac}^2 + E_{dc}^2}$ .

## **Noise**

Noise is a limiting factor in any system. Thermal noise, transistor noise, and switch contact noise are examples of noise generated internally. This noise limits the sensitivity in measurement devices, distorts the purity of communication systems, and affects the output signals of all amplifiers. To effectively reduce noise, you must be able to measure noise. Since noise level is referenced to power, true rms is the only way to accurately measure the noise present in the system.

## **Mechanical to Electrical**

Stress, strain, vibration, shock, temperature expansion and contraction are mechanical phenomena that are measured by converting mechanical motion into electrical signals. These signals are often noisy, non-periodic, and usually non-sinusoidal. In addition, the signals are usually superimposed on some dc level, thus making true rms the only way to measure these signals accurately. More importantly, mechanical movement is a form of energy. To measure total mechanical energy, you convert to electrical energy and measure the rms value of the electrical power. Only the thermal converter technique is a direct measurement of power.

## **THE USED-TO-BE'S**

True rms measurements used to be slow. Today, 1 sec response time is possible. At frequencies below 20 Hz, measurement speed must be decreased to allow the converter time to respond to the signal. This is true for both average responding and true rms responding converters.

At high frequencies, true rms is faster than the majority of average responding converters. True rms can make accurate measurements at 1 reading a second on frequencies up to 1 MHz. Average responding converters are not capable of accurate 4 digit measurements above 100 kHz.

True rms converters used to be expensive. They still cost more than average converters but how expensive is an incorrect measurement? When 4 or 5 digits of accuracy are required, it's less expensive to make a correct measurement the first time than to correct a mistake caused by an inaccurate measurement.

## **SUMMARY**

The true rms measurement technique is the most accurate available today. Besides accuracy, true rms allows a versatility in measurement capabilities unknown with previous techniques. Hewlett Packard has realized the importance of true rms measurements and is making a definite commitment to the development of instrumentation incorporating the advantages of true rms.

## SALES & SERVICE OFFICES

### UNITED STATES

**ALABAMA**  
P.O. Box 4207  
2003 Byrd Spring Road S.W.  
Huntsville 35802  
Tel: (205) 881-4561  
TWX: 810-726-2204

**ARIZONA**  
3009 North Scottsdale Road  
Scottsdale 85251  
Tel: (602) 945-7601  
TWX: 910-950-1282

5737 East Broadway  
Tucson 85716  
Tel: (602) 298-2313  
TWX: 910-952-1162

**CALIFORNIA**  
1430 East Orangethorpe Ave.  
Fullerton 92631  
Tel: (714) 870-1000

3939 Lankershim Boulevard  
North Hollywood 91604  
Tel: (213) 877-1282  
TWX: 910-499-2170

1101 Embarcadero Road  
Palo Alto 94303  
Tel: (415) 327-6500  
TWX: 910-373-1280

2220 Watt Ave.  
Sacramento 95825  
Tel: (916) 482-1463  
TWX: 910-367-2092

1055 Shafter Street  
San Diego 92106  
Tel: (714) 223-8103  
TWX: 910-335-2000

**COLORADO**  
7965 East Prentice  
Englewood 80110  
Tel: (303) 771-3455  
TWX: 910-935-0705

**CONNECTICUT**  
508 Tolland Street  
East Hartford 06108  
Tel: (203) 289-9394  
TWX: 710-425-3416

111 East Avenue  
Norwalk 06851  
Tel: (203) 853-1251  
TWX: 710-468-3750

**DELAWARE**  
3941 Kennett Pike  
Wilmington 19807  
Tel: (302) 655-6161  
TWX: 510-956-2214

**FLORIDA**  
P.O. Box 24210  
2806 W. Oakland Park Blvd.  
Ft. Lauderdale 33307  
Tel: (305) 731-2020  
TWX: 510-955-4099

P.O. Box 20007  
Herndon Station 32814  
621 Commonwealth Avenue  
Orlando  
Tel: (305) 841-3970  
TWX: 810-850-0113

P.O. Box 8128  
Madeira Beach 33708  
410 150th Avenue  
St. Petersburg  
Tel: (813) 391-0211  
TWX: 810-863-0366

**GEORGIA**  
P.O. Box 28234  
450 Interstate North  
Atlanta 30328  
Tel: (404) 436-6181  
TWX: 810-766-4890

**ILLINOIS**  
5500 Howard Street  
Skokie 60076  
Tel: (312) 677-0400  
TWX: 910-223-3613

**INDIANA**  
3839 Meadows Drive  
Indianapolis 46205  
Tel: (317) 546-4891  
TWX: 810-341-3263

**LOUISIANA**  
P.O. Box 856  
1942 Williams Boulevard  
Kenner 70062  
Tel: (504) 721-6201  
TWX: 810-955-5524

**MARYLAND**  
6707 Whitestone Road  
Baltimore 21207  
Tel: (301) 944-5400  
TWX: 710-862-0850

P.O. Box 1648  
2 Choce Cherry Road  
Rockville 20850  
Tel: (301) 948-6370  
TWX: 710-828-9684

**MASSACHUSETTS**  
32 Hartwell Ave.  
Lexington 02173  
Tel: (617) 861-8960  
TWX: 710-326-6904

**MICHIGAN**  
24315 Northwestern Highway  
Southfield 48075  
Tel: (313) 353-9100  
TWX: 810-224-4882

**MINNESOTA**  
2459 University Avenue  
St. Paul 55114  
Tel: (612) 645-9461  
TWX: 910-563-3734

**MISSOURI**  
11131 Colorado Ave.  
Kansas City 64137  
Tel: (816) 763-8000  
TWX: 910-771-2087

2812 South Brentwood Blvd.  
St. Louis 63144  
Tel: (314) 962-5000  
TWX: 910-760-1670

**NEW JERSEY**  
W. 120 Century Road  
Paramus 07652  
Tel: (201) 265-5000  
TWX: 710-990-4951

1060 N. Kings Highway  
Cherry Hill 08034  
Tel: (609) 667-4000  
TWX: 710-892-4945

**NEW MEXICO**  
P.O. Box 8366  
Station C  
6501 Lomas Boulevard N.E.  
Albuquerque 87108  
Tel: (505) 265-3713  
TWX: 910-989-1665

156 Wyatt Drive  
Las Cruces 88001  
Tel: (505) 526-2485  
TWX: 910-983-0550

**NEW YORK**  
1702 Central Avenue  
Albany 12205  
Tel: (518) 869-8462  
TWX: 710-441-8270

1219 Campville Road  
Endicott 13760  
Tel: (607) 754-0050  
TWX: 510-252-0890

82 Washington Street  
Poughkeepsie 12601  
Tel: (914) 454-7330  
TWX: 510-248-0012

39 Saginaw Drive  
Rochester 14623  
Tel: (716) 473-9500  
TWX: 510-253-5981

1025 Northern Boulevard  
Roslyn, Long Island 11576  
Tel: (516) 869-8400  
TWX: 510-223-0811

5858 East Molloy Road  
Syracuse 13211  
Tel: (315) 454-2486  
TWX: 710-541-0482

**NORTH CAROLINA**  
P.O. Box 5188  
1923 North Main Street  
High Point 27262  
Tel: (919) 885-8101  
TWX: 510-926-1516

**OHIO**  
25575 Center Ridge Road  
Cleveland 44145  
Tel: (216) 835-0300  
TWX: 810-427-9129

3460 South Dixie Drive  
Dayton 45439  
Tel: (513) 298-0351  
TWX: 810-459-1925

1120 Morse Road  
Columbus 43229  
Tel: (614) 846-1300

**OKLAHOMA**  
2919 United Founders Boulevard  
Oklahoma City 73112  
Tel: (405) 848-2801  
TWX: 910-830-6862

**OREGON**  
Westhills Mall, Suite 158  
4475 S.W. Scholls Ferry Road  
Portland 97225  
Tel: (503) 292-9171  
TWX: 510-464-6103

**PENNSYLVANIA**  
2500 Moss Side Boulevard  
Monroeville 15146  
Tel: (412) 271-0724  
TWX: 710-797-3650

1021 8th Avenue  
King of Prussia Industrial Park  
King of Prussia 19406  
Tel: (215) 265-7000  
TWX: 610-660-2670

**RHODE ISLAND**  
873 Waterman Ave.  
East Providence 02914  
Tel: (401) 434-5535  
TWX: 710-381-7573

**TEXAS**  
P.O. Box 1270  
201 E. Arapaho Rd.  
Richardson 75080  
Tel: (214) 231-6101  
TWX: 910-867-4723

P.O. Box 22813  
6300 Westpark Drive  
Suite 100  
Houston 77027  
Tel: (713) 781-6000  
TWX: 910-881-2645

231 Billy Mitchell Road  
San Antonio 78226  
Tel: (512) 434-4171  
TWX: 910-871-1170

**UTAH**  
2890 South Main Street  
Salt Lake City 84115  
Tel: (801) 487-0715  
TWX: 910-925-5681

**VERMONT**  
P.O. Box 2287  
Kennedy Drive  
South Burlington 05401  
Tel: (802) 658-4455  
TWX: 710-658-4712

**VIRGINIA**  
P.O. Box 6514  
2111 Spencer Road  
Richmond 23230  
Tel: (703) 282-5451  
TWX: 710-956-0157

**WASHINGTON**  
433-108th N.E.  
Bellevue 98004  
Tel: (206) 454-3971  
TWX: 910-443-2303

**\*WEST VIRGINIA**  
Charleston  
Tel: (304) 768-1232

**FOR U.S. AREAS NOT LISTED:**  
Contact the regional office nearest you: Atlanta, Georgia... North Hollywood, California... Paramus, New Jersey... Skokie, Illinois. Their complete addresses are listed above.  
\*Service Only

### CANADA

**ALBERTA**  
Hewlett-Packard (Canada) Ltd.  
11745 Jasper Ave.  
Edmonton  
Tel: (403) 482-5561  
TWX: 610-831-2431

**BRITISH COLUMBIA**  
Hewlett-Packard (Canada) Ltd.  
1037 West Broadway  
Vancouver 12  
Tel: (604) 731-5301  
TWX: 610-922-5059

**MANITOBA**  
Hewlett-Packard (Canada) Ltd.  
511 Bradford Ct.  
St. James  
Tel: (204) 786-7581  
TWX: 610-671-3531

**NOVA SCOTIA**  
Hewlett-Packard (Canada) Ltd.  
2745 Dutch Village Rd.  
Suite 203  
Halifax  
Tel: (902) 455-0511  
TWX: 610-271-4482

**ONTARIO**  
Hewlett-Packard (Canada) Ltd.  
880 Lady Ellen Place  
Ottawa 3  
Tel: (613) 722-4223  
TWX: 610-562-1952

Hewlett-Packard (Canada) Ltd.  
50 Galaxy Blvd.  
Rexdale  
Tel: (416) 677-9611  
TWX: 610-492-4246

**QUEBEC**  
Hewlett-Packard (Canada) Ltd.  
275 Hymus Boulevard  
Pointe Claire  
Tel: (514) 697-4232  
TWX: 610-422-3022  
Telex: 01-20607

**FOR CANADIAN AREAS NOT LISTED:**  
Contact Hewlett-Packard (Canada) Ltd. in Pointe Claire, at the complete address listed above.

### CENTRAL AND SOUTH AMERICA

**ARGENTINA**  
Hewlett-Packard Argentina  
S.A.C.e.I.  
Lavalle 1171 - 3°  
Buenos Aires  
Tel: 35-0436, 35-0627, 35-0431  
Telex: 012-1009  
Cable: HEWPACKARG

**BRAZIL**  
Hewlett-Packard Do Brasil  
I.e.C Ltda.  
Rua Coronel: Oscar Porto, 691  
Sao Paulo - 8, SP  
Tel: 288-7111  
Cable: HEWPACK Sao Paulo

Hewlett-Packard Do Brasil  
I.e.C. Ltda.  
Avenida Franklin Roosevelt 84-  
grupo 203  
Rio de Janeiro, ZC-39, GB  
Tel: 232-9733  
Cable: HEWPACK Rio de Janeiro

**CHILE**  
Héctor Calcagni y Cia, Ltda.  
Bustos, 1932-3er Piso  
Casilla 13942  
Santiago  
Tel: 4-2396  
Cable: Calcagni Santiago

**COLOMBIA**  
Instrumentacion  
Henrik A. Langebaek & Kier  
Ltda.  
Carrera 7 No. 48-59  
Apartado Aereo 6287  
Bogota, 1 D.E.  
Tel: 45-78-06, 45-55-46  
Cable: AARIS Bogota  
Telex: 044-400

**COSTA RICA**  
Lic. Alfredo Gallegos Gurdían  
Apartado 3243  
San José  
Tel: 21-86-13  
Cable: GALGUR San José

**ECUADOR**  
Laboratorios de Radio-Ingenieria  
Calle Guayaquil 1246  
Post Office Box 3199  
Quito  
Tel: 12496  
Cable: HORVATH Quito

**EL SALVADOR**  
Electrónica  
Apartado Postal 1589  
27 Avenida Norte 1133  
San Salvador  
Tel: 25-74-50  
Cable: ELECTRONICA  
San Salvador

**GUATEMALA**  
Olander Associates Latin America  
Apartado Postal 1226  
Ruta 4, 6-53, Zona 4  
Guatemala City  
Tel: 63958  
Cable: OLALA Guatemala City

**JAMAICA**  
General Engineering Services,  
Ltd.  
27 Dunrobin Ave.  
Kingston  
Tel: 42657  
Cable: GENSERV

**MEXICO**  
Hewlett-Packard Mexicana, S.A.  
de C.V.  
Moras 439  
Col. del Valle  
Mexico 12, D.F.  
Tel: 5-75-46-49

**NICARAGUA**  
Roberto Terán G.  
Apartado Postal 689  
Edificio Terán  
Managua  
Tel: 3451, 3452  
Cable: ROTERAN Managua

**PANAMA**  
Electrónica Balboa, S.A.  
P.O. Box 4929  
Ave. Manuel Espinosa No. 13-50  
Bldg. Alina  
Panama City  
Tel: 30833  
Cable: ELECTRON Panama City

**PERU**  
Fernando Ezeta B.  
Avenida Petit Thouars 4719  
Miraflores  
Casilla 3061  
Lima  
Tel: 45-2335  
Cable: FEPERU Lima

**PUERTO RICO**  
San Juan Electronics, Inc.  
P.O. Box 5167  
Ponce de Leon 154  
Pda. 3-Pta. de Tierra  
San Juan 00906  
Tel: (809) 725-3342  
Cable: SATRONICS San Juan  
Telex: SATRON 3450 332

**URUGUAY**  
Pablo Ferrando S.A.  
Comercial e Industrial  
Avenida Italia 2877  
Casilla de Correo 370  
Montevideo  
Tel: 40-3102  
Cable: RADIUM Montevideo

**VENEZUELA**  
Hewlett-Packard De Venezuela  
C.A.  
Apartado 50933  
Caracas  
Tel: 71.88.05, 71.88.69, 71.99.30  
Cable: HEWPACK Caracas

**FOR AREAS NOT LISTED, CONTACT:**  
Hewlett-Packard  
INTERCONTINENTAL  
3200 Hillview Ave.  
Palo Alto, California 94304  
Tel: (415) 326-7000  
TWX: 910-373-1267  
Cable: HEWPACK Palo Alto  
Telex: 034-8461

## EUROPE

### AUSTRIA

Unilabor GmbH  
Wissenschaftliche Instrumente  
Rumlehardtgasse 6/3  
P.O. Box 33  
Vienna A-1095  
Tel: (222) 42 61 81, 43 13 94  
Cable: LABORINSTRUMENT  
Vienna  
Telex: 75 762

### BELGIUM

Hewlett-Packard Benelux S.A.  
348 Boulevard du Souverain  
Brussels 1160  
Tel: 72 22 40  
Cable: PALOEN Brussels  
Telex: 23 494

### DENMARK (May 70)

Hewlett-Packard A/S  
Datavej 38  
DK-3460 Birkerød  
Tel: (01) 81 66 40  
Cable: HEWPACK AS  
Telex: 66 40

### EASTERN EUROPE

Hewlett-Packard S.A. Genf.  
Korrespondenz Büro Für Ost-Europa  
(Czechoslovakia, Hungary,  
Poland, DDR, Rumania,  
Bulgaria)  
Innstrasse 23  
Postfach  
A-1204 Vienna, Austria  
Tel: (222) 33 66 06  
Cable: HEWPACK Vienna

### FINLAND

Hewlett-Packard Oy  
Bulevardi 26  
P.O. Box 12185  
Helsinki 12  
Tel: 13-730  
Cable: HEWPACKOY-Helsinki  
Telex: 12-1563

### FRANCE

Hewlett-Packard France  
Quartier de Courtaboeuf  
Boite Postale No. 6  
91 Orsay  
Tel: 920 88 01  
Cable: HEWPACK Orsay  
Telex: 60048

Hewlett-Packard France  
4 Quai des Etoiles  
69 Lyon 5ème  
Tel: 42 63 45  
Cable: HEWPACK Lyon  
Telex: 31617

### GERMANY

Hewlett-Packard Vertriebs-GmbH  
Lietzenburgerstrasse 30  
1 Berlin 30  
Tel: (0811) 211 60 16  
Telex: 18 34 05

Hewlett-Packard Vertriebs-GmbH  
Herrenbergerstrasse 110  
703 Böblingen, Württemberg  
Tel: 07031-6671  
Cable: HEPAG Böblingen  
Telex: 72 65 739

Hewlett-Packard Vertriebs-GmbH  
Achenbachstrasse 15  
4 Düsseldorf 1  
Tel: 68 52 58/59  
Telex: 85 86 533

Hewlett-Packard Vertriebs-GmbH  
Berliner Strasse 117  
6 Nieder-Eschbach/Frankfurt 56  
Tel: (0611) 50 10 64  
Cable: HEWPACKSA Frankfurt  
Telex: 41 32 49

Hewlett-Packard Vertriebs-GmbH  
Beim Strohhaus 26  
2 Hamburg 1  
Tel: 24 05 51/52  
Cable: HEWPACKSA Hamburg  
Telex: 21 53 32

Hewlett-Packard Vertriebs-GmbH  
Reginiedstrasse 13  
8 München 9  
Tel: 0811 69 59 71/75  
Cable: HEWPACKSA München  
Telex: 52 49 85

### GREECE

Kostas Karayannis  
18, Ermou Street  
Athens 126  
Tel: 230301,3,5  
Cable: RAKAR Athens  
Telex: 21 59 62 RKAR GR

### IRELAND

Hewlett-Packard Ltd.  
224 Bath Road  
Slough, Bucks, England  
Tel: Slough 753-33341  
Cable: HEWPIE Slough  
Telex: 84413

### ITALY

Hewlett-Packard Italiana S.p.A.  
Via Amerigo Vespucci 2  
20124 Milano  
Tel: 6251 (10 lines)  
Cable: HEWPACKIT Milan  
Telex: 32046

Hewlett-Packard Italiana S.p.A.  
Palazzo Italia  
Piazza Marconi 25  
00144 Rome - Eur  
Tel: 591 2544  
Cable: HEWPACKIT Rome  
Telex: 61514

### NETHERLANDS

Hewlett-Packard Benelux, N.V.  
Weerdestein 117  
P.O. Box 7825  
Amsterdam, Z 11  
Tel: 020-42 7777  
Cable: PALOEN Amsterdam  
Telex: 13 216

### NORWAY

Hewlett-Packard Norge A/S  
Box 149  
Nesveien 13  
N-1344 Haslum  
Tel: 53 83 60  
Cable: HEWPACK Oslo  
Telex: 6621

### PORTUGAL

Teletra  
Empresa Tecnica de  
Equipamentos  
Electricos, S.a.r.l.  
Rua Rodrigo da Fonseca 103  
P.O. Box 2531  
Lisbon 1  
Tel: 68 60 72  
Cable: TELETRAL Lisbon  
Telex: 1598

### SPAIN

Ataio Ingenieros SA  
Ganduxer 76  
Barcelona 6  
Tel: 211-44-66  
Cable: TELEATAIO BARCELONA

Ataio Ingenieros SA  
Enrique Larreta 12  
Madrid, 16  
Tel: 215 35 43  
Cable: TELEATAIO Madrid  
Telex: 2749E

### SWEDEN

Hewlett-Packard (Sverige) AB  
Hagakergatan 9C  
S 431 04 Mölndal 4  
Tel: 031 - 27 68 00

Hewlett-Packard (Sverige) AB  
Svetsarvägen 7  
S171 20 Solna 1  
Tel: (08) 98 12 50  
Cable: MEASUREMENTS  
Stockholm  
Telex: 10721

### SWITZERLAND

Hewlett-Packard (Schweiz) AG  
Zürcherstrasse 20  
8952 Schlieren  
Zürich  
Tel: (051) 98 18 21/24  
Cable: HEWPACKAG Zurich  
Telex: 53933

Hewlett-Packard (Schweiz) A.G.  
Rue du Bois-du-Lan 7  
1217 Meyrin 2 Geneva  
Tel: (022) 41 54 00  
Cable: HEWPACKSA Geneva  
Telex: 2 24 86

### TURKEY

Telekom Engineering Bureau  
P.O. Box 376 - Galata  
Istanbul  
Tel: 49 40 40  
Cable: TELEMATIION Istanbul

### UNITED KINGDOM

Hewlett-Packard Ltd.  
224 Bath Road  
Slough, Bucks  
Tel: Slough 33341  
Cable: HEWPIE Slough  
Telex: 84413

Hewlett-Packard Ltd.  
The Graftons  
Stamford New Road  
Altrincham, Cheshire  
Tel: 061 258-8626

### USSR

Please Contact  
Hewlett-Packard S.A.  
Rue du Bois-du-Lan 7  
1217 Meyrin 2 Geneva  
Tel: (022) 41 54 00  
Cable: HEWPACKSA Geneva  
Switzerland  
Telex: 2.24.86

### YUGOSLAVIA

Belram S.A.  
83 avenue des Mimosas  
Brussels 15, Belgium  
Tel: 34 33 32, 34 26 19  
Cable: BELRAMEL Brussels  
Telex: 21790

### FOR AREAS NOT LISTED, CONTACT:

Hewlett-Packard S.A.  
Rue du Bois-du-Lan 7  
1217 Meyrin 2 Geneva  
Switzerland  
Tel: (022) 41 54 00  
Cable: HEWPACKSA Geneva  
Telex: 2.24.86

## AFRICA, ASIA, AUSTRALIA

### ANGOLA

Teletra Empresa Técnica  
de Equipamentos Eléctricos  
SAR  
Rua de Barbosa Rodrigues  
42-1°  
Box 6487  
Luanda  
Cable: TELETRA Luanda

### AUSTRALIA

Hewlett-Packard Australia  
Pty. Ltd.  
22-26 Weir Street  
Glen Iris, 3146  
Victoria  
Tel: 20 1371 (6 lines)  
Cable: HEWPARD Melbourne  
Telex: 31024

### Hewlett-Packard Australia Pty. Ltd.

61 Alexander Street  
Crows Nest 2065  
New South Wales  
Tel: 43.7866  
Cable: HEWPARD Sydney  
Telex: 21561

### Hewlett-Packard Australia Pty. Ltd.

97 Churchill Road  
Prospect 5082  
South Australia  
Tel: 65.2366  
Cable: HEWPARD Adelaide

### Hewlett Packard Australia Pty. Ltd.

Prabhadevi  
Bombay 25DD, India  
Tel: 45 73 01  
Telex: 2396  
Cable: BLUESTAR

### Hewlett-Packard Australia Pty. Ltd.

Blue Star Ltd.  
14/40 Civil Lines  
Kanpur, India  
Tel: 6 88 82  
Cable: BLUESTAR

### Hewlett-Packard Australia Pty. Ltd.

Blue Star, Ltd.  
7 Mare Street  
P.O. Box 506  
Calcutta 1, India  
Tel: 23-0131  
Telex: 655  
Cable: BLUESTAR

### Blue Star Ltd.

Blue Star House,  
34 Ring Road  
Lajpat Nagar  
New Delhi 24, India  
Tel: 62 32 76  
Telex: 463  
Cable: BLUESTAR

### CYPRUS

Kytronics  
19-100 Hommer Avenue  
P.O. Box 752  
Nicosia  
Tel: 6282-75628  
Cable: HE-I-NAMI

### ETHIOPIA

African Salespower & Agency  
Private Ltd., Co.  
P. O. Box 718  
58/59 Cunningham St.  
Addis Ababa  
Tel: 12285  
Cable: ASACO Addisababa

### HONG KONG

Schmidt & Co. (Hong Kong) Ltd.  
P.O. Box 297  
1511, Prince's Building  
10, Chater Road  
Hong Kong  
Tel: 240168, 232735  
Cable: SCHMIDTCO Hong Kong

### INDIA

Blue Star Ltd.  
Kasturi Buildings  
Jamshedji Tata Rd.  
Bombay 20BR, India  
Tel: 29 50 21  
Telex: 2396  
Cable: BLUEFROST

### Blue Star Ltd.

Band Box House  
Prabhadevi  
Bombay 25DD, India  
Tel: 45 73 01  
Telex: 2396  
Cable: BLUESTAR

### Blue Star Ltd.

14/40 Civil Lines  
Kanpur, India  
Tel: 6 88 82  
Cable: BLUESTAR

### Blue Star, Ltd.

7 Mare Street  
P.O. Box 506  
Calcutta 1, India  
Tel: 23-0131  
Telex: 655  
Cable: BLUESTAR

### Blue Star Ltd.

Blue Star House,  
34 Ring Road  
Lajpat Nagar  
New Delhi 24, India  
Tel: 62 32 76  
Telex: 463  
Cable: BLUESTAR

Blue Star, Ltd.  
96 Park Lane  
Secunderabad 3, India  
Tel: 7 63 91  
Cable: BLUEFROST

### Blue Star, Ltd.

23/24 Second Line Beach  
Madras 1, India  
Tel: 2 39 55  
Telex: 379  
Cable: BLUESTAR

### Blue Star, Ltd.

1B Kaiser Bungalow  
Dindli Road  
Jamshedpur, India  
Tel: 38 04  
Cable: BLUESTAR

### INDONESIA

Bah Bolon Trading Coy. N.V.  
Djaloh Merdeka 29  
Bandung  
Tel: 4915 51560  
Cable: ILMU  
Telex: 809

### IRAN

Telecom, Ltd.  
P. O. Box 1812  
240 Kh. Saba Shomali  
Teheran  
Tel: 43850, 48111  
Cable: BASCOM Teheran

### ISRAEL

Electronics & Engineering  
Div. of Motorola Israel Ltd.  
17 Aminadav Street  
Tel-Aviv  
Tel: 36941 (3 lines)  
Cable: BASTEL Tel-Aviv  
Telex: Bastel Tv 033-569

### JAPAN

Yokogawa-Hewlett-Packard Ltd.  
Nisei Ibaragi Bldg.  
2-2-8 Kasuga  
Ibaragi-Shi  
Osaka  
Tel: 23-1641

### Yokogawa-Hewlett-Packard Ltd.

10 Building  
No. 59, Kotori-cho  
Nakamura-Ku, Nagoya City  
Tel: 551-0215

Yokogawa-Hewlett-Packard Ltd.  
Ohashi Building  
59 Yoyogi 1-chrome  
Shibuya-ku, Tokyo  
Tel: 30-2281/7  
Telex: 232-2024YHP  
Cable: YHPMARKET TOK 23-724

### KENYA

R. J. Tilbury Ltd.  
P. O. Box 2754  
Suite 517/518  
Hotel Ambassador  
Nairobi  
Tel: 25670, 68206, 58196  
Cable: ARJAYTEE Nairobi

### KOREA

American Trading Co., Korea, Ltd.  
P.O. Box 1103  
Dae Kyung Bldg.  
107 Sejong Ro  
Chongro Ku  
Seoul  
Tel: 75-5841 (4 lines)  
Cable: AMTRACO Seoul

### LEBANON

Constantin E. Macridis  
Clemenceau Street  
P.O. Box 7213  
Beirut  
Tel: 220846  
Cable: ELECTRONUCLEAR Beirut

### MALAYSIA

MECOMB Malaysia Ltd.  
2 Lorong 13/6A  
Section 13  
Petaling Jaya, Selangor  
Cable: MECOMB Kuala Lumpur

### MOZAMBIQUE

A. N. Goncalves, LDA.  
4.1 Apt. 14 Av. D. BUIS  
P.O. Box 107  
Lourenco Marques  
Cable: NEGON

### NEW ZEALAND

Hewlett-Packard (N.Z.) Ltd.  
32-34 Kent Terrace  
P.O. Box 9443  
Wellington, N.Z.  
Tel: 56-559  
Cable: HEWPACK Wellington

### PAKISTAN (EAST)

Mushko & Company, Ltd.  
Zirat Chambers  
31, Jinnah Avenue  
Dacca  
Tel: 280058  
Cable: NEWDEAL Dacca

### PAKISTAN (WEST)

Mushko & Company, Ltd.  
Osman Chambers  
Victoria Road  
Karachi 3  
Tel: 511027, 512927  
Cable: COOPERATOR Karachi

### PHILIPPINES

Electromex Inc.  
Makati Commercial Center  
2129 Pasong Tamo  
Makati, Rizal D 708  
P.O. Box 1028  
Manila  
Tel: 89-85-01  
Cable: ELEMEX Manila

### SINGAPORE

Mechanical and Combustion  
Engineering Company Ltd.  
9, Jalan Kilang  
Singapore, 3  
Tel: 642361-3  
Cable: MECOMB Singapore

### SOUTH AFRICA

Hewlett Packard South Africa  
(Pty.), Ltd.  
Breeccastle House  
Bree Street  
Cape Town  
Tel: 3-6019, 3-6545  
Cable: HEWPACK Cape Town  
Telex: 5-0006

### Hewlett Packard South Africa (Pty.), Ltd.

P.O. Box 31716  
30 De Beer Street  
Braamfontein, Johannesburg  
Tel: 724-4172 724-4195  
Telex: 0226 JH  
Cable: HEWPACK Johannesburg

### TAIWAN REP. OF CHINA

Hwa Sheng Electronic Co., Ltd.  
P. O. Box 1558  
Room 404  
Chia Hsin Building  
No. 96 Chung Shan  
North Road, Sec. 2

### Taipei

Tel: 555211 Ext. 532-539  
545936, 546076, 548661  
Cable: VICTRONIX Taipei

### TANZANIA

R. J. Tilbury Ltd.  
P.O. Box 2754  
Suite 517/518  
Hotel Ambassador  
Nairobi  
Tel: 25670, 26803, 68206, 58196  
Cable: ARJAYTEE Nairobi

### THAILAND

The International  
Engineering Co., Ltd.  
P. O. Box 39  
614 Sukhumvit Road  
Bangkok  
Tel: 910722 (7 lines)  
Cable: GYSOM  
TLX INTENCOM BK-226 Bangkok

### UGANDA

R. J. Tilbury Ltd.  
P.O. Box 2754  
Suite 517/518  
Hotel Ambassador  
Nairobi  
Tel: 25670, 26803, 68206, 58196  
Cable: ARJAYTEE Nairobi

### VIETNAM

Peninsular Trading Inc.  
P.O. Box H-3  
216 Hien-Vuong  
Saigon  
Tel: 20.805  
Cable: PENINSULA Saigon

### ZAMBIA

R. J. Tilbury (Zambia) Ltd.  
P.O. Box 2792  
Lusaka  
Zambia, Central Africa

### FOR AREAS NOT LISTED, CONTACT:

Hewlett-Packard  
INTERCONTINENTAL  
3200 Hillview Ave.  
Palo Alto, California 94304  
Tel: (415) 326-7000  
TWX: 910-373-1267  
Cable: HEWPACK Palo Alto  
Telex: 034-8461

