DEC
STANDARD
122 SEC. 1
REV. A

MEASUREMENTS OF AC POWER PARAMETERS

DEC STD 122-1 - AC POWER LINE STANDARD - MEASUREMENT OF AC POWER PARAMETERS

DOCUMENT IDENTIFIER: A-DS-EL00122-01-0, Rev A, 17-Mar-83

ABSTRACT: Describes how to measure ac power parameters for power supplies, power control equipment, and other devices that operate from primary ac power sources.

APPLICABILITY: Mandatory for all new computer products marketed by Digital that use any of the following types of equipment and components requiring ac power: Power supplies; power control equipment; rotating equipment such as blowers, fans, and motors; distribution components such as ac power cables, line filters, contactors, circuit breakers, and connectors.

This document can be distributed to vendors.

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1 INTRODUCTION

This section describes the methods to be used when measuring ac power parameters of Digital hardware products and systems that require interfacing with ac power sources. Characteristics of measuring devices are given, as well as suggested instruments that are available and suitable for use.

1.1 PURPOSE

The purpose of this section is to assure uniformity of testing methods among the product engineering design groups and test groups, and to achieve an acceptable level of accuracy. Some of the results obtained using test methods specified herein may be used by Digital employees to fulfill requirements of the ac power specifications (subhead 4) of DEC STD 009 Section 1.

As with any measurements taken requiring accuracy, certain general guidelines must be adhered to for reliable and repeatable results.

a. Use instruments at 25°C ± 5°C.

b. Ascertain that the instrument is within the calibration period and that the calibration is done against standards traceable to National Bureau of Standards.

c. Apply correction factors after determining the amount of instrument error.

d. Do not use average sensing instruments for measuring power parameters covered in this section. Data taken with these types of instruments will not be considered valid.

e. Always check the test circuit and hook-up to assure connections are correct, properly torqued, and safe.

f. Measurements must be permanently recorded in the DEC Engineering Notebook, signed and dated by the person conducting the tests. In addition, test schematics, test conditions, wire sizes and lengths, the model, serial number, and calibration information of measuring instruments used, and all other pertinent information that may affect test data shall be recorded.

1.2 RESPONSIBILITIES

It is the responsibility of hardware design engineers to use the methods described in this section when conducting tests where the data is used to determine compliance to engineering specifications.

2 AC VOLTAGE

Unless otherwise specified in the product specification, input voltages to equipment are to be measured at the plug end of the equipment's power cord. In all cases, when measuring ac voltage, a meter that indicates true rms values shall be used. A measurement accuracy within 2% is required when conducting tests where the data is used to determine compliance to engineering specifications.

2.1 METER CHARACTERISTICS (defined in DEC STD 122)

Meter accuracy: ± 0.5% or better, over the frequency range of 40 Hz to 2500 Hz
Crest Factor: 2:1 at specified input range.

2.2 SUGGESTED TRUE RMS METERS

a. Fluke Model 8520A
b. Yokogawa Model 2504
c. Yokogawa Model 2505
d. Analogic Model PI-4461
e. RFL Model 620
f. RFL Model 636
g. Magtrol Model 4612
h. Weston (Solartron) Model 7150

3 AC CURRENT

The ac current will be measured in all phase conductors of the equipment's input power cord. In multiphase equipment where the neutral is used, the neutral current shall also be measured. A measurement accuracy within 2% is required when conducting tests where the data is used to determine compliance with engineering specifications.

Current transformers provide isolation from the line voltage and are the recommended method to be used.

If no internal termination is provided by the current transformer device, its secondary shall be properly terminated with a standard burden, as specified by the National Bureau of Standards.

If a current shunt is used as the transformer burden, the calibration factor must be determined. For example, if a 5 A, 50 mV shunt is used with a current transformer with a ratio of 6:1 (30 A primary, 5 A secondary) current, the calibration factor is 0.6 A per mV.

CAUTION

> When the current transformer is connected in an energized circuit and an external burden is used, such as an ammeter, current shunt, or burden resistor, NEVER OPEN THE SECONDARY because high induced voltages are generated.

A current transformer that is internally terminated, such as the Pearson Model 110A, can be disconnected from the measuring instrument without causing high induced voltages.

3.1 CURRENT TRANSFORMER CHARACTERISTICS

The current transformer used shall provide ± 0.5% accuracy over the frequency range of 40 Hz to 2500 Hz.

3.2 SUGGESTED CURRENT TRANSFORMERS

a. Pearson Current Transformer Model 110A
   Current transformer calibration factor = 0.01 A/mV (internally-terminated).

Note

> The output receptacle of the current transformer is calibrated to match the oscilloscope or true rms voltmeter load.

b. Yokogawa 2241 Current Transformer

c. Weston Model 461 Type 2

3.3 METER CHARACTERISTICS

Meter accuracy: ± 0.5% or better, over the frequency range of 40 Hz to 2500 Hz
Crest Factor: 3:1 at specified input range.

3.4 SUGGESTED TRUE RMS METER

a. Yokogawa Model 2504
b. Yokogawa Model 2505
c. RFL Model 620
d. RFL Model 636
e. Magtrol Model 4612

4 PEAK VALUE, VOLTAGE, AND CURRENT

The peak value may be obtained from a peak reading meter or oscilloscope that will assure the desired accuracy. An accuracy within 5% is considered acceptable for peak value measurements.

4.1 CHARACTERISTICS OF PEAK-READING INSTRUMENTS

Function: Measures and holds peak amplitude of repetitive pulses.

Response: 40 to 2500 Hz

4.2 SUGGESTED PEAK-READING INSTRUMENTS

a. Micro Instrument Co., Model 5203B (digital peak-reading memory voltmeter)

b. Tektronix 7854 Oscilloscope

c. Nicolet Explorer III Oscilloscope

5 CREST FACTOR

Crest factor shall be determined for both the voltage and current by dividing the peak value by the rms value.

6 POWER

Power may be measured with an electrodynamometer or digital wattmeter. As with any instrument, care must be taken not to exceed the voltage and current ratings, as well as the voltage and current crest factors and peak limitations.

A measurement accuracy within 5% is required when conducting tests where the data is used to determine compliance to engineering specifications.

Where current and potential transformers are used to extend the meter ranges or for isolation purposes, verify that the instrument transformers are designed for use with the wattmeter, because both the phase angle displacement and ratio are important to obtain the required accuracy.

Care must be taken when connecting wattmeters to account for loading effects of the wattmeter on the indicated readings. In general, when using an electrodynamometer type meter, the potential coil is connected to the source side, as shown in Figure 1-1, because the potential coil losses are significantly higher than the current coil losses. In this case, the meter reads the sum of the current coil power plus the load power. If greater accuracy is required, subtract the power consumed by the current coil from the meter reading.

When using an electronic type wattmeter, the current coil is connected to the source side, as shown in Figure 1-1, because the current coil losses are generally higher than the potential coil losses. Most electronic type wattmeters compensate for this burden and need not be considered unless the highest degree of accuracy is required.

6.1 AC, SINGLE-PHASE REAL POWER

Figure 1-1 (A and B) shows the connection for power measurement for a single-phase load. The current transformer shown in Figure 1-1B is used to increase the current capability of the wattmeter. In this case, the wattmeter reading must be multiplied by the transformer ratio used. Observe polarity!

6.2 THREE-PHASE REAL POWER

With a wye-connected load, either balanced or unbalanced, it is always possible to measure the total power to the load by using a wattmeter in each phase and adding the readings algebraically. This is true whether there is a return conductor (neutral) or not. A multiphase wattmeter may also be used, as shown in Figure 1-2.

Whether three separate wattmeters or a multiphase wattmeter is used, it is important to observe that the proper polarity of the wattmeter(s) connections is correct. In most cases, the readings should be positive, but with an unbalanced load, power may be "pumped back" in one or two phases, particularly when there is a mutual inductance between phases.

Use three single-phase wattmeters and add the three results algebraically. For 3-phase, 4-wire wattmeter connection, use the diagram shown in Figure 1-2.

6.3 CHARACTERISTICS OF WATTMETER

Function: Electrodynamometer type wattmeter or digital wattmeter.

Meter Accuracy: ± 0.5% over the frequency range of 40 Hz to 500 Hz.

Voltage Crest Factor: 2:1

Current Crest Factor: 3:1

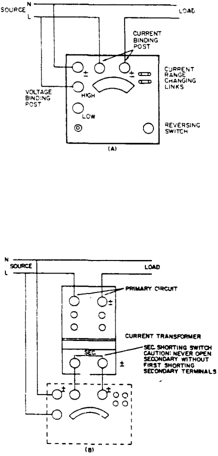


Figure 1-1. Power Measurement for a Single-Phase Load

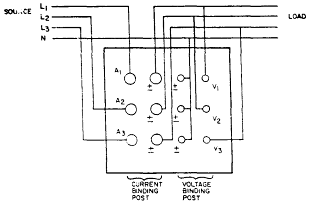


Figure 1-2. Three-Phase, 4-Wire Wattmeter Connection Diagram

6.4 SUGGESTED WATTMETERS

a. RFL Model 636 (three phase, three wire)
b. Yokogawa Type 2505 (three phase)
c. Weston Model 432 (single phase)
d. Yokogawa Type 2504 (single phase)
e. RFL Model 620 (single phase)
f. RFL Model 636 (single phase)
g. Magtrol Model (single phase)

7 APPARENT POWER

The apparent power is the product of the true rms voltage and the true rms current measured as described under subheads 1 and 2.

Since the real power is a scalar quantity and is algebraically summed, the apparent power is a vector quantity and must be vectorially summed to obtain the total apparent power.

In non-linear loads, the relationship between real power and apparent power is more complex than that for sinusoidal voltage and current waveforms due to the presence of harmonic (distorted) power. Because it is difficult to obtain displacement and distortion phase angles, the total apparent power shall be determined by arithmetic summation of the individual apparent powers. It is recognized that this is not absolutely correct. However, within the desired limits, the total 3-phase power obtained in this manner is acceptable.

This method shall be used when obtaining the total power of several single-phase loads that are connected to a single-phase source or of several single-phase loads connected to a 3-phase source.

8 TOTAL POWER FACTOR

The total power factor is calculated from the measured watts divided by the apparent power. For non-linear loads, the power factor will be considered as an absolute value and will not be specified as lagging or leading power factor. For linear loads, the power factor may be defined as lagging or leading power factor.

Note

> For multiphase loads consisting of unlike single-phase equipment, the total power factor for each phase shall be calculated and specified.

9 MEASUREMENT OF HARMONICS

Measurements of harmonic currents and voltages are made to determine total harmonic distortion, which is used as a figure of merit to describe the effect of the non-linear loads on the distribution system. Measurements of the individual harmonics are desirable to aid in selecting suppression techniques because the amplitudes actually generated frequently differ considerably from those indicated by simplified theory.

Harmonic distortion produced by a given source is directly related to the impedance of the mains, which in turn depends on the complexity of the mains network. Moreover, the mains impedance is generally frequency dependent in all but the simplest network, so that a knowledge of this dependence is essential for assessing the effects of harmonic distortion in a real system.

For the purpose of rationalization of maximum permitted harmonic content, this standard has assumed a typical main impedance as follows: Provisionally, for the purposes of calculating the voltage distortion factor, the source impedance will be assumed to be resistance and pure inductance in series. Values for the fundamental frequency impedances given below apply to utility distribution networks. Distribution networks sourced from motor-generators or other auxiliary power sources may exhibit impedances higher than the following:

a. For loads up to 1.4 kVA per phase, use Z1 = (0.40 + jw0.79E-3)

b. For loads up to 4 kVA per phase, use Z1 = (0.20 + jw0.31E-3)

c. For loads greater than 4 kVA per phase, use Z1 = (0.10 + jw0.16E-3)

In modern networks, however, the impedance will be lower than these.

A primary consideration in measuring harmonics is the provision of suitable wide band sensors and instruments. Frequencies up to 6 kHz are usually of interest, and in some cases, even higher harmonics may be of some concern. The bandwidth of interest in a given case depends upon the susceptibility of apparatus in the specific distribution system. Generally, the commonly available line frequency sensors and instruments, such as those used for system operation, are not suitably broad band.

To measure the fundamental and each of the harmonics, a spectrum analyzer, such as the Hewlett-Packard Model 3582A, can be used. The total harmonic distortion can then be calculated. To use the spectrum analyzer, system voltages and currents must be divided or transformed to be compatible with the instrument. Wide band current transformers, such as the Pearson Model 301X, and voltage dividers, such as the ITT Jennings Model JP-200, may be used for this purpose. Normally, harmonic distortion is measured on either voltage or current.

No special voltage or current couplers are required for harmonic distortion measurements. Good practice would include the use of either coaxial cable or shielded twisted-pair conductors between voltage and current sensors and instruments. Current transformers will require suitable non-inductive resistor burdens as recommended by the transformer manufacturer. (This subject will be addressed in further detail later.)

10 MEASUREMENT OF INRUSH CURRENT AND START-UP CURRENTS

The significance of specifying inrush and start-up currents is to coordinate overload characteristics of protective devices (circuit breakers, fuses, etc.) and of back-up power sources, such as uninterruptable power sources (UPS), motor-generator (MG) sets, ferro-resonant transformers, etc., with the turn-on transient characteristics of the load to prevent tripping or excessive voltage depression.

Turn-on currents may take on various waveforms and duration, depending on the type of load. Figure 1-3 shows a typical waveform that could be encountered with electronic loads (with or without front end power line frequency transformers), lighting loads, and some small motor loads. This waveform is characterized by the initial inrush current followed by an exponential decay until steady state conditions are reached. The duration of the decay may vary between 50 milliseconds to several hundred milliseconds.

Figure 1-4 shows a typical waveform of loads using a soft start or step start circuit such as those used in some power supplies or where loads may be sequenced on for the purpose of limiting the initial turn-on current.

The waveform shown in Figure 1-5 is characterized by two or more major peaks, each followed by an exponential decay of varying duration.

Duration until steady state is reached may vary from a few hundred milliseconds for a load with step-start to several seconds for sequenced loads.

For some types of step-start circuits, the recovery time of current limiting devices is time/temperature dependent. In these cases, under rapid on/off cycling or restarts due to short power outages, abnormally high inrush currents may occur. The design engineer must be cognizant of this and design the circuit to prevent damage to circuit components, such as welded contacts or power switches, circuit breakers, semiconductors, etc. These restart inrushes should be measured, recorded, and specified in the product engineering specifications.

Figure 1-4 shows a typical waveform usually encountered with disk or tape drives and large motors. This waveform is characterized by the initial inrush current, followed by a relatively constant amplitude, followed by an exponentially decaying period until steady state condition is reached.

In some loads, the duration of the relatively constant amplitude portion and the decaying portion may be approximately the same. The duration for the total turn-on transient will usually be several seconds and typically 10-15 seconds.

In measuring inrush and start-up currents, good engineering practice dictates that certain basic requirements be met for results to be valid and meaningful. These are stated in the following:

a. Turn-on currents shall be photographed and included in the engineering notebook as part of the permanent record. The purpose is to show the typical waveform of the start-up current.

b. Record sufficient points and durations to be able to describe in words the waveform (magnitudes and duration) envelope.

c. Currents are to be measured using a current transformer with a peak current rating above the expected peak current value. This is to assure that the output current of the current transformer secondary is not limited by any saturation effects of the transformer.

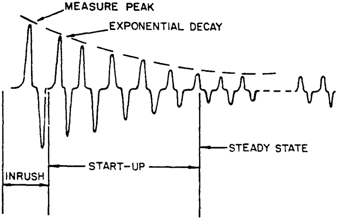


Figure 1-3. Typical Waveform That May Be Encountered With Electronic Loads

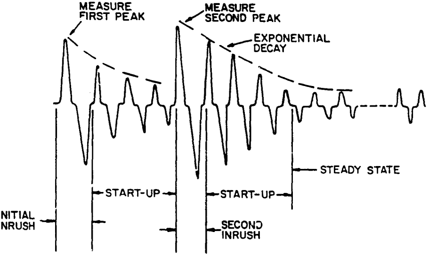


Figure 1-4. Typical Waveform of Loads Using a Soft Start or Step Start Circuit

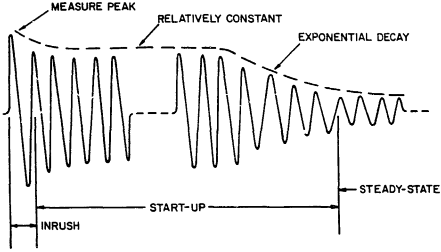


Figure 1-5. Typical Waveform of Loads Usually Encountered With AC Motors

d. For multi-phase loads, the turn-on current in all lines, excluding neutrals, shall be measured and recorded. The maximum observed current in each phase shall be recorded.

e. The line impedance must be kept at a minimum to assure test conditions provide the maximum current. To meet this requirement, the source capacity shall be at least six times the load rating. It is recommended that the unit under test be connected as near to the lab power source as possible using the lab distribution bus system. Do not use conventional wall outlets or bench outlets, as these add significant impedances.

f. No variable auto transformer shall be used for the purpose of setting the line voltage.

g. The ampacity of the wire used in test circuits shall be consistent with the level of current being drawn; lead lengths shall be minimized and good quality connections should be assured.

h. Measurements are to be taken with the temperature of the unit stabilized at the testing ambient.

10.1 INRUSH CURRENT MEASUREMENT

The inrush is measured and recorded as a peak current. Typically, the maximum inrush will occur during the first half cycle after the application of power; but can also occur during the second half cycle. In either case, the duration of the inrush is specified in half cycle terms. In cases where the first and second half cycle have equal magnitude of inrush current, it shall be so stated in the product specification.

The inrush current is a function of where on the voltage waveform the power is applied, the prior history of the magnetic material, and the temperature of the unit. Where on/off cycling is accomplished using SCRs, and where the turn-on points on the sine wave can be preselected, it is sufficient to cycle only six times in 30-degree intervals, starting at 0 degrees. However, always be sure that the turn-on is accomplished when the input voltage waveform is going the same direction as when the unit was turned off. This assures that the transformer core magnetic flux is set on the portion of the hysteresis loop that will result in miminum flux change and therefore the largest inrush current. When on-off cycling is accomplished by means other than SCRs, the ac input line should be cycled a minimum of 35 times to ensure obtaining the maximum inrush current.

Before each test, assure that the equipment electrical circuits contain no stored electrostatic or electromagnetic energy. Power cycling must be accomplished by a method that will insure random turn-on points. Such methods as the manual operation of a power switch or the use of a dc contactor/relay are acceptable. Do not use an ac contactor/relay because the ac coil provides timing factors related to the cycling of the power line, thus negating the random effect.

Inrush currents can be expected to be greatest at high input line condition, low temperature, and when the source impedance is low. Because these test conditions are not always fully realized, it is necessary to modify the actual recorded readings with multipliers.

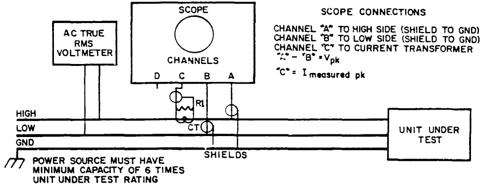
The value of the inrush peak current to be specified in the product specification shall be determined using the following expression:

$$I_{inrush} = T1 \times \frac{V_{max}}{V_{Test}} \times \frac{V_{Test\ PK}}{V_{pk}} \times I_{Meas}$$

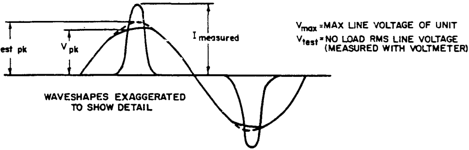
$$I_{inrush} = 1.414 \times T1 \times \frac{V_{max}}{V_{pk}} \times I_{Meas}$$

Where

V_{max} = highest input rms voltage specified in the product specification (that is, 128 V)



A. Equipment Connections



B. Displayed Waveforms

Figure 1-6. Inrush Current Measurement

V_{Test} = the rms voltage of the source just prior to applying power to the unit

$V_{Test\ PK}$ = the peak voltage of V_{Test} (1.414 x V_{Test})

V_{pk} = the peak of the voltage waveform during the inrush current period as measured with an oscilloscope

I_{Meas} = actual measured peak current

T1 = 1.02 when tests are conducted in ambients 10°C to 20°C
= 1.06 when tests are conducted in ambients 20°C to 30°C
= 1.10 when tests are conducted in ambients 30°C to 40°C
= 1.14 when tests are conducted in ambients 40°C to 50°C

To accurately measure Vpk at the point where the inrush current is maximum, the oscilloscope must be connected to the input of the product (see Figure 1-6). The oscilloscope must be used in the differential input mode so that the high side of the ac line is connected to one input of the scope and the low side (neutral) is connected to the other input of the scope. This connection will then assure that the actual line voltage at the input is accurately measured. It is not adequate, or safe, to only measure the high side with the scope, since there is additional voltage drop in the neutral lead of the power source that must be considered.

CAUTION

Do not "float" or isolate the scope to provide this measurement.

10.2 START-UP CURRENT MEASUREMENT

Start-up currents are measured using an oscilloscope. The preferred method is to use a storage scope from which readings of amplitudes and durations can be obtained and recorded.

The test is an extension of the inrush current measurement using the same guidelines presented in subhead 10. However, it is not necessary to cycle the load as in the case when measuring the inrush.

10.3 RECORDING OF DATA

For waveforms similar to Figure 1-3, measure the initial inrush peak current as described in subhead 10.1 and the duration, in cycles, measured from the initial rise of the current to steady state condition.

For waveforms similar to Figure 1-4, measure the duration, in cycles, from the initial rise of current to the occurrence of the second maximum peak and the duration, in cycles, from the second peak to steady state conditions.

For waveforms similar to Figure 1-5, measure the duration from the initial rise of current to the approximate point where the exponential decay begins and the duration of the exponential decaying portion to steady state condition. For the relatively constant peak amplitude portion following the initial inrush, measure the peak current at approximately the 50% duration point and the peak current just prior to the decay indicating the time, in seconds, of the occurrence.

11 PHASE ROTATION

Phase rotation is the order in which the voltages or currents of a polyphase circuit successively reach their positive maximum values. Phase rotation may be measured with phase rotation meters, detectors, or by means of an oscilloscope.

Phase rotation measurements are only required on polyphase equipment sensitive to phase rotation. The rotation is specified as ABC (positive) or CBA (negative).

11.1 SUGGESTED PHASE ROTATION DETECTOR

a. Associated Research Model 46 Phase Sequence Indicator

b. A.W. Sperry Instrument Inc. Model PSI-8031

11.2 SUGGESTED OSCILLOSCOPE

Tektronix Model 7803 or equivalent

Four Tektronic P6009 100X Probes may be needed for line to line readings.

11.3 TEST METHOD

- Connect the phase sequence indicator to the appropriately labeled phase. The indicator will display phase sequence ABC or CBA.

The method can be used for either voltages measured line to neutral, or for line to line voltages. This data should be recorded. Phase rotation tests using the oscilloscope are as follows:

- For line to line voltages, the oscilloscope should be used differentially across the line to line voltages.

- Set the oscilloscope to display in the "chop" mode. The "alternate" mode does not guarantee correct phase relationships between different signals.

- Observe the first waveform on the oscilloscope (Phase A or line L1).

If maximum value of the waveform is delayed in time from the maximum value of the first waveform, then phase A leads phase B.

- Observe the second waveform on the oscilloscope (Phase B or line L2).

- Measure the time difference between the positive going zero crossing of each waveform.
- Record the period of the waveforms. Phase Angle is:

$$\text{Phase Angle} = \frac{\text{Time Difference}}{\text{Period}} \times 360 \text{ (deg)}$$

If phase A leads phase B and the phase angle between them is 120 degrees, then the phase rotation is ABC. If phase A leads phase B and the phase angle between them is 240 degrees, then the phase rotation is CBA.

- Observe the third waveform on the oscilloscope (Phase C or line L3).

If the maximum value of the waveform is delayed in time from the maximum value of the first waveform, then phase A leads phase C.

If phase A leads phase C, and the phase angle between them is 120 degrees, then the phase rotation is CBA. If phase A leads phase C and the phase angle between them is 240 degrees, then the phase rotation is ABC.

The phase rotation may be recorded as positive or negative. By convention, positive rotation is the same as phase rotation ABC. Negative rotation is the same as phase rotation CBA.

12 DC CURRENT COMPONENT

Generally, equipment connected to ac power sources is not permitted to contain dc current components.

DC components arise whenever waveforms are asymetrical (where the average value is non-zero). In most cases, asymetrical ac current waveforms will contain both odd and even harmonic components, but may also contain only even harmonic components. Power conversion devices and techniques using asymmetrical rectifiers or switching circuits contain dc components in their supply currents and should not be used. In some specific cases when it is necessary to have equipment that produces a dc component, the equipment shall be limited to a rating of 100 watts or less.

Note

> This test is not required if the supply current waveform is symmetrical, since symmetrical wave forms do not contain dc components.

The dc component may be measured by a current nulling technique with either an oscilloscope, or with a true rms meter. The overall accuracy of this method is within 10 percent. Particular attention must be paid to accurately determine the balancing current as measured on either the oscilloscope or on the meter. Refer to Figure 1-7 for suggested test circuit. DC components under 10 milliamperes cannot be reliably measured.

12.1 SUGGESTED TRUE RMS METER

a. Hewlett-Packard 3403C
b. Fluke 8010A, 8012A, 8030A or 8860A

12.2 SUGGESTED OSCILLOSCOPE

Tektronix Model 7803

12.3 SUGGESTED DC CURRENT PROBE

Tektronix A6302 or A6303 Current Probe
Tektronix AM503 Current Probe Amplifier

Note

> The A6302 will handle up to 20 A (peak ac plus dc). The Tektronix A6303 Current Probe will handle currents up to 100 A (peak ac plus dc).

12.4 SUGGESTED POWER SUPPLY

Hewlett-Packard 6110A, 6112A, 6113A, 6116A Precision Power Supply

12.5 TEST METHOD

- Measure and observe the current waveform with the current probe.

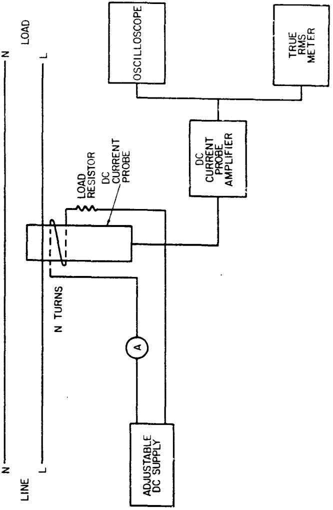


Figure 12. DC Component Test Circuit

- Insure that probe has been carefully dc balanced.
- Apply a counterbalancing dc current by means of a loop of wire through the current probe jaw (using the power supply as the current source).
- Measure the output of the current probe amplifier on the meter. If the counterbalancing dc current causes a higher current, reverse the direction of current flow.
- Increase the value of the current until the meter reading reaches a minimum point. The dc component of the current waveform is the value of the current from the power supply.

If the dc component is larger than can be supplied by the power supply, it may be necessary to add more turns through the current probe jaw to minimize the reading. Then the dc component of the current is the value of the current from the power supply times the number of turns.

The oscilloscope may be used to indicate the balance of the dc component and the externally applied dc current. As the externally applied dc current is increased, one of the waveform peaks (positive or negative) will decrease. This will continue until the dc component is balanced by the externally applied dc current. Then the peak of the waveform will start to increase. At the minimum point, the dc component is balanced by the external dc current. Measure this current. The dc component is the value of the current from the power supply (times the number of turns if necessary).

13 RIDE-THROUGH TIME MEASUREMENT

Ride-through time is the maximum duration of a specified magnitude of a line voltage sag during which the equipment will not initiate power-down sequence routine. Because the ride-through time is a function of the magnitude and duration of line voltage sags, it is a variable quantity and may be represented graphically. A ride-through curve may be generated by measurements or calculations taking into account worse case conditions of loading, storage component tolerances, operating frequency, operating temperature, and with the line voltage to the equipment at the nominal value just prior to the voltage sag at the nominal rated value.

Ride-through time is a function of many parameters, including the following:

a. Peak and/or rms line voltage
b. Design of the ac line detection circuitry
c. Energy storage devices used in the product or system

d. Design of the power conversion section of the product or system
e. Loading of the system
f. Operating temperature of product or system

Each of these parameters will influence the results of measurements of ride-through time, so care must be taken to ensure that testing is performed under conditions that are accurately set to meet the product or system specification. In particular, care should be taken in setting the peak line voltage, the operating temperature, and the total system.

13.1 TEST CIRCUIT DESCRIPTION

Refer to Figure 1-

The equipment/circuitry used to perform this test is as follows:

a. Circuit/device for removing ac power for the unit under test (UUT). This device can be a triac, back-to-back SCRs, solid state relay, or a mechanical switch.

   Depending upon the device used, the ride-through time measured may have to be modified mathematically to correct for the point in the ac cycle where power is actually removed from the input.

   If a mechanical switch is used, the test at each required data point should be run 35 times to find the shortest time. This is because the opening of the mechanical switch is random and a "worst case" value is desired in the data gathering. Do not use an ac contract/relay because the ac coil provides timing factors related to the cycling of the power line, thus negating the random effect.

   The design of the circuitry for use with this device is left up to the user.

b. Peak reading voltmeter for measuring the peak of the ac line.

   This device is important for accurate data, and should yield a measurement accuracy within 5%. If a device with less accuracy is used, the error in the data could be very high.

   If a peak reading voltmeter of the required accuracy is not available, use an rms reading ac meter and observe the voltage waveform on an oscilloscope; if no clipping of the input waveform is evident by observation, use the setting as found on the rms reading meter.

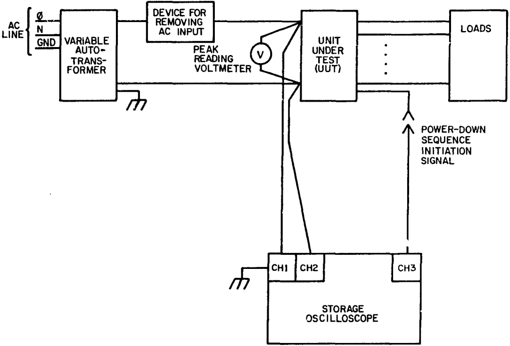


Figure 13. Sample Test Setup for Ride-Through Time

c. Variable autotransformer

This device is needed to adjust the input voltage for the required test points.

This device should provide a sufficiently "stiff" source that it does not cause clipping of the ac input waveform. As a good rule of thumb, size this device to be at least 6 times the rated current for the UUT.

d. Storage oscilloscope

The oscilloscope should be a four-channel storage device to allow observation of the ac line in a "differential" mode, and the signal that initiates the power-down sequence of the system. The oscilloscope does not need a wide bandwidth since times in the order of milliseconds will be monitored.

13.2 TEST PROCEDURE

The procedure for measuring ride-through time is as follows:

1. Have the unit under test (UUT) operating at an ambient temperature that represents worst case.
2. Adjust the peak input line voltage to the required value for the data point being taken. Use peak voltage, not rms voltage. In the event that only rms voltages are specified in the product or system specification, use 1.414 X V rms for peak voltage values.
3. Ensure that the load on the power conversion section is the highest load expected for the system.
4. Monitor the ac line and the signal that initiates the power-down sequence of the system with the oscilliscope.
5. Interrupt the ac line while observing the ac line on the oscilloscope.
6. Measure the time on the oscilloscope as the time from the loss of ac to the point where the power-down initiation signal changes state.

Note

> If a mechanical switch is used, repeat the test 35 times. Record the shortest time observed. If a triac or similiar device is used, the test need only to be made once.

7. Muliply the value found in step 6 by 0.65 to correct for tolerance variations on input storage capacitors.

Note

> The factor 0.65 is based upon the assumption that the "typical" capacitor is 1.2 times rated capacitance and the lowest tolerance is 0.8 times rated capacitance. If it is known that the capacitors in the UUT are different from the assumption, use actual ratios.

8. If a mechanical switch is used, subtract 5.0 milliseconds from the value found in step 7.

   If a triac or similar device is used, subtract 10.0 milliseconds from the value found in step 7.

9. The final value found in step 8 represents the minimum ride-through time and is the value that is to be used in product engineering specifications.

13.3 TEST CONDITIONS-VOLTAGE

Since it is desired to generate a curve of ride-through time versus ac line be performed at a sufficient number of line voltage settings to generate a curve. As a minimum, the following should be used:

a. Lowest value of recommended operating range per subhead 4.1.

b. Nominal line voltage - if 100 - 120 Vac and 200 - 240 Vac are specified nominal ranges, use 100 and 200, respectively, for this data point.

c. Lowest value of design range per subhead 4.1.

d. Highest value of recommended operating range per subhead 4.1.

Note

> The ride-through time test procedure generates a curve for only a 100% sag and, as such, represents the shortest ride-through time. When equipment is identified to allow testing at sags of less than 100%, this procedure will be revised.

14 HOLD-UP TIME MEASUREMENT

Hold-up time is that duration of time measured from the instant of power outage occuring at the point on the input ac voltage waveform where the stored energy in the storage element is at its lowest value to that time when the output voltage has decayed to its lower specified regulation limit.

Hold-up time, as defined in subhead 2, is determined by completely removing the ac power input from the UUT and measuring the time between this loss of input power and the loss of regulation on the power supply output.

14.1 TEST CIRCUIT DESCRIPTION

Refer to Figure 1-9.

The equipment/circuitry used to perform this test is as follows:

a. Circuit/device for removing ac power from the UUT.

   This device can be a triac, back-to-back SCRs, solid state relay, or a mechanical switch.

   Depending upon the device used, the hold-up time measured may have to be modified mathematically to correct for the point in the ac cycle where power is actually removed from the input.

   If a mechanical switch is used, the tests at each required data point should be run 35 times to find the shortest time. This is because the opening of the mechanical switch is random and a "worst case" value is desired in the data gathering. Do not use an ac contractor/relay because the ac coil provides timing factors related to the cycling of the power line, thus negating their random effect.

   The design of the circuitry for use with this device is left up to the user.

b. Comparator circuits, with a reference, for each output.

   This comparator is used to indicate that a given output has passed through its lower regulation threshold. One comparator is required for each output of the UUT power supply; the outputs of the comparators should be ORed to yield a composite signal that changes state when any output drops out of regulation.

   The design of this circuitry is left up to the user.

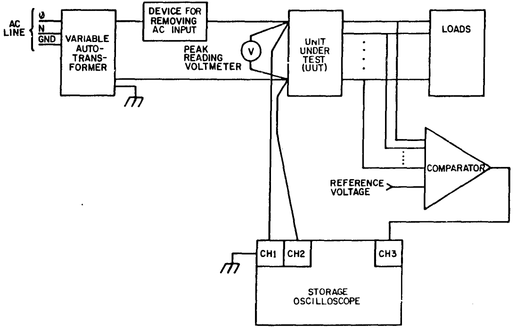


Figure 14. Sample Test Setup for Hold-Up Time

c. Peak reading voltmeter for measuring the peak of the ac line.

   This device is important for accurate data and should yield a measurement accuracy within 5%. If a device with less accuracy is used, the error in the data could be very high.

   If a peak reading voltmeter of the required accuracy is not available, use a rms reading ac meter and observe the voltage waveform on an oscilloscope. If no clipping of the input waveform is evident by observation, use the setting as found on the rms reading meter.

d. Variable autotransformer.

   This device should provide a sufficiently "stiff" source that it does not cause clipping of the ac input waveform. As a good rule of thumb, size this device to be at least 6 times the rated current for the UUT.

e. Storage oscilloscope.

   The oscilloscope should be a four-channel storage device to allow observation of the ac line in a "differential" mode, and the output of the comparator. The oscilloscope does not need a wide bandwidth since times in the order of milliseconds will be monitored.

14.2 TEST PROCEDURE

The procedure measuring hold-up time is as follows:

1. Adjust the input voltage to the peak value for the data point being taken; peak values should be 1.414 X V rms for the data point being taken.
2. Interrupt the ac line while observing the ac line on the oscilloscope.
3. From the oscilloscope trace, measure the time from the point of loss of ac to the point of change of state of the comparator output.

Note

> If a mechanical switch is used, repeat the test 35 times and record the shortest time observed.
>
> If a triac or similar device is used, this test need only be made once, subtract 5.0 milliseconds from the time found in step 3. This will yield the shortest time that could occur.

4. Multiply the value found in step 3 by 0.65 to correct for tolerance variations on input storage capacitors:

Note

> The factor 0.65 is based upon the assumption that the "typical" capacitor is 1.2 times rated capacitance and the lowest tolerance is 0.8 times rated capacitance. If it is known that the capacitors in the UUT are different from the assumption, use actual ratios.

14.3 TEST CONDITIONS-VOLTAGE

Values of hold-up time should be determined using the test procedure for three values of line voltage, as follows:

1. Lowest value of recommended operating range per subhead 4.1.

2. Nominal line voltage if 100 - 120 Vac and 220 -240 Vac are specified nominal ranges, use 100 and 220, respectively, for this data point.

3. Lowest value of design range per subhead 4.1.