White Paper on AC/DC Dual Purpose Power Supply Application

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➢ Foreword

In the past, the purpose of using the AC power supply was to provide the voltage and frequency of the utility power in various countries and to simulate various phenomena of abnormal power quality. With the development of new energy sources, in addition to using AC power as input, communications and server power supplies can also directly input DC power (HVDC or LVDC) from UPS or energy storage devices to save power consumption from AC to DC conversion. In addition, the DC mode of the AC power supply has a faster voltage change response time (compared to the DC power supply), this characteristics can meet the testing needs of vehicle-mounted electrical equipment, and this White Paper will comprehensively describe these applications.

The bounden duty of testing instruments: Exploring the unknown with the known

Test instruments are output-type instruments. The output provided has two purposes. The first purpose is to provide an output with a known error to stimulate (Stimulate) the input of the DUT so that the DUT can operate; the second purpose is to simulate possible fault phenomena by the input to the DUT to observe the fault tolerance of the DUT or to reproduce the fault for circuit debugging.

Why can't the functional test be done directly by utility power?

Take the charger specifications of a notebook computer as an example, the specifications of the input terminals are：

- Rated input voltage AC 100~240V
- Operating voltage range AC 90~264V
- Rated frequency 50/60Hz±3Hz

The utility power cannot provide the rated input voltage range of 100~240V for the global universal charger, and must also provide a stable voltage tolerance range of ±10%, so it must be able to provide an operating voltage of 90~264V as the input excitation source.

The autotransformer is cheaper than the AC power supply and can provide a voltage of 90~264V. Why can't the autotransformer replace the AC power supply?

There are five reasons why autotransformer cannot replace AC power：

1. It has no electrical isolation function
2. In addition to controlling the variable factor in experiments or product verification, it is necessary to observe the unknown from the known. The voltage of the utility power itself is unstable. Even if you use an electricity meter to confirm that the output of the autotransformer is 90V, it is difficult to guarantee the next second the output of the autotransformer to become 88V due to the change of the neighbor's load. The experimental purpose cannot be achieved by using the unknown to observe the unknown.
3. The autotransformer cannot provide the frequency range of rated frequency 50/60Hz±3Hz.

4. The output impedance of the autotransformer will distort the output sine wave, causing the PFC (Power Factor Compensation) circuit of the power supply circuit to track a problematic waveform.
5. It will produce 50Hz or 60Hz low-frequency electromagnetic radiation to interfere peripheral circuits

Electricity quality related standards

ITI[1] (CBEMA[2]) Information Technology Industry Committee (Computer and Business Equipment Manufacturers Association): Founded in 1916, the committee was formerly abbreviated as CBEMA[2] in 1973, and changed to its current name ITI[1] in 1994. The purpose of the committee is to encourage innovation. Almost all the giants in the information technology industry are members. This Paper will use the power quality curve updated by the ITI committee in 2000 as an explanatory case.

Note 1: ITI is the abbreviation of Information Technology Industry Council

Note 2: CBEMA is the abbreviation of Computer and Business Equipment Manufacturers Association.

In addition to ITI, related standards for power quality include IEEE 1159 Recommended Practice for Monitoring Electric Power Quality; IEC 61000-4-11; IEC 61000-4-34; Semi47: Specifications for processing voltage sag immunity).

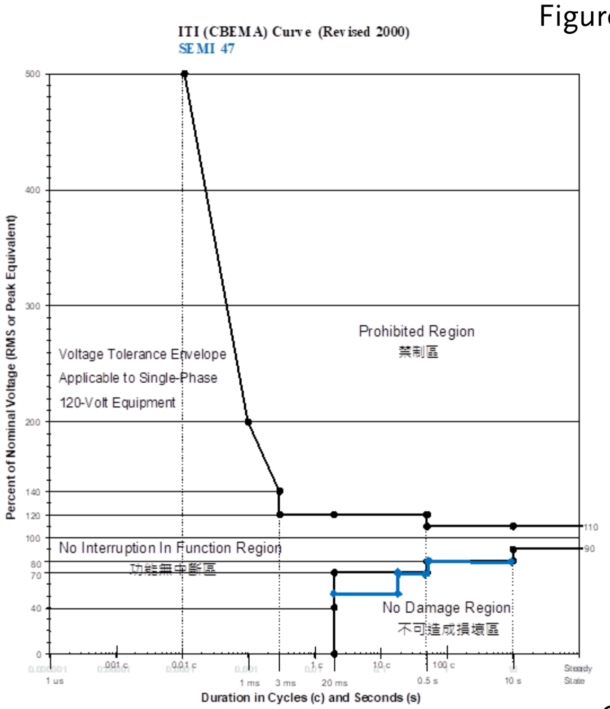


Figure 1 is the ITI Curve, the Voltage Tolerances envelope curve of this figure is suitable for single-phase 120V equipment. There are three areas in the figure, the first area is the No interruption in function region; the second area is the Prohibited region; the third region is the No damage region)

Design countermeasures for the power circuit：

- No interruption in function region: Hold-up capacitor; feedforward; feedback control; surge absorption.
- Prohibited region: Overvoltage protection (OVP[3])
- No damage region: low voltage protection (UVLO[4])

Figure 1: ITI Curve (this figure refers to the ITI application article and adds Chinese notes and SEMI47 specifications)

Note 3: OVP Over Voltage Protection

Note 4: UVLO Under Voltage Lockout

The power converter control mechanism includes: voltage feedback; current feedback; input voltage feedforward; input current feedforward; temperature feedforward; load change feedforward, etc.

Power quality issues of no interruption in function region

From the voltage tolerances envelope curve of the no interruption in function region of the ITI curve function, it can be subdivided into several areas. These areas have their own power quality issues and countermeasures. These subdivision areas include：

1. ±10% steady-state allowable area: Take 100V as the rated value in Figure 1, and 90~110V as the steady-state allowable area. In this interval, the equipment must always be able to operate normally.
2. Voltage sag: The causes of voltage sag include motor startup period, line failure or affected interference (short circuit, damage, lightning strike), power supply equipment failure, transient load changes, etc. Possible effects include illumination flickering, voltage-sensitive equipment tripping (such as electromagnetic contactor MC or electromagnetic relay), and equipment not functioning properly (programmable logic controller PLC, high intensity discharge lamp HID). Products that meet the Semi47 specification for voltage sag tolerances are better than ITI and IEC-61000-4-11 specifications. ITI's specification is that voltage sags to 70% of rated value must maintain normal operation of equipment for 0.5 seconds; and that voltage sags to 80% of rated value must maintain normal operation of equipment for 10 seconds. The Semi47 additionally requires that voltage sags to 50% of the rated value must maintain the normal operation of the device for 0.2 seconds and the rest of the specifications are the same as that of the ITI.
3. Voltage Interruptions: for short-term voltage interruptions, the ITI specification requires that the equipment must tolerate interruptions within 20ms and the equipment must still operate normally
4. Voltage swell: The causes of voltage swell include transient large load trips and system failures. Possible effects include illumination flickering, tripping of voltage-sensitive equipment, and equipment not functioning properly. The ITI specification states that 120% of the rated value must maintain normal operation of the device for 0.5 seconds.
5. Low-Frequency Decaying Ring wave: Ringing caused by power factor correction (PFC) capacitors in AC power distribution systems. This capacitor-equipped device is called STATCOM or SV in Taiwan Power Company, and its resonant frequency can range from 200Hz to 5kHz. To simulate this phenomenon, the AC power supply must have an output capability of 5kHz. The maximum ringing peak value is the percentage of the peak value of the rated voltage, 140% of the peak value; the frequency starts from 200Hz to 200% of the peak value; the frequency is 5kHz, and the peak value changes and the frequency changes are set in a linear increment. The ASR-3400HF launched by GW Instek in 2022 provides an output frequency of 5kHz, which can simulate the low frequency attenuation ring wave of ITI.

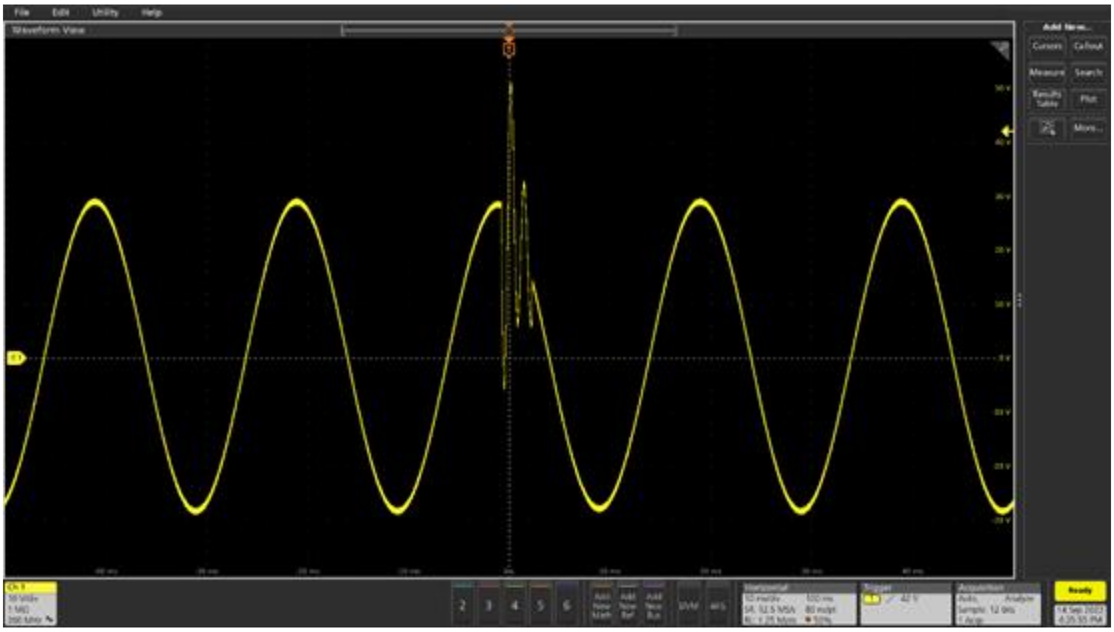


Figure 2 Example of low frequency attenuated ring wave

6. High-Frequency Decaying Ring Wave is the transient state of lightning strike. The AC power supply cannot directly correspond to this test. It is achieved by adding a "Lightning Surge Simulator". Please refer to ANSI/IEEE C62.41-1991 for the test conditions and methods. The countermeasure of the circuit is to use a surge absorber (TVSS[5]). The information in the ITI application document mentions that the equipment must have a transient surge withstand capability of at least 80 joules.

Figure 3 Schematic diagram of power quality issues of no interruption in function region

Note 5: TVSS Transient Voltage Surge Suppressor

Other applications of AC power when testing power supplies

Inrush current

From the results, when the power supply is turned on at any point of the AC input sine wave, the inrush current must not damage the power supply or cause the fuse to blow. The power supply should allow AC switches, bridge rectifier circuits, fuses, and EMI filter components to withstand the surge level. In the past, the random switching method of confirming the maximum inrush current was very time-consuming. The maximum inrush current usually occurs when the maximum voltage is turned on. Now this test and measurement task can be quickly completed using the designated phase switching function of the AC power supply.

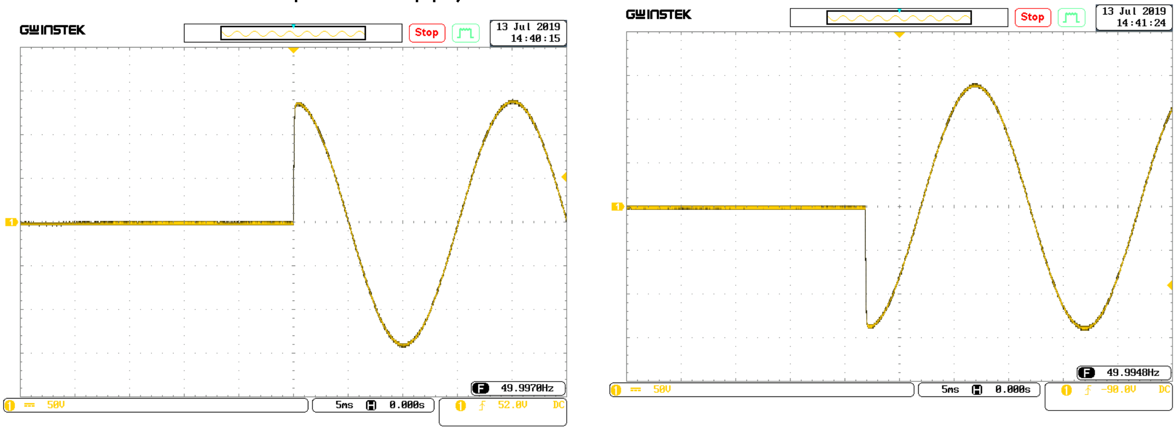


Figure (4) The left picture sets the AC power output to start at 90 degrees, and the right picture sets the output to start at 270 degrees

The measurement of inrush current requires an oscilloscope and a current probe. The upper left of Figure 5 is an enlarged screenshot of the measurement results of the current probe. The maximum current measured is 34A. The lower left of Figure 5 shows the measurement result of the AC power supply through the Ipeak measurement function, which is 33.39A. Although there is still a slight difference with the current probe, AC power supply with this measurement function can still be used as a simple judgment when there is no current probe at hand.

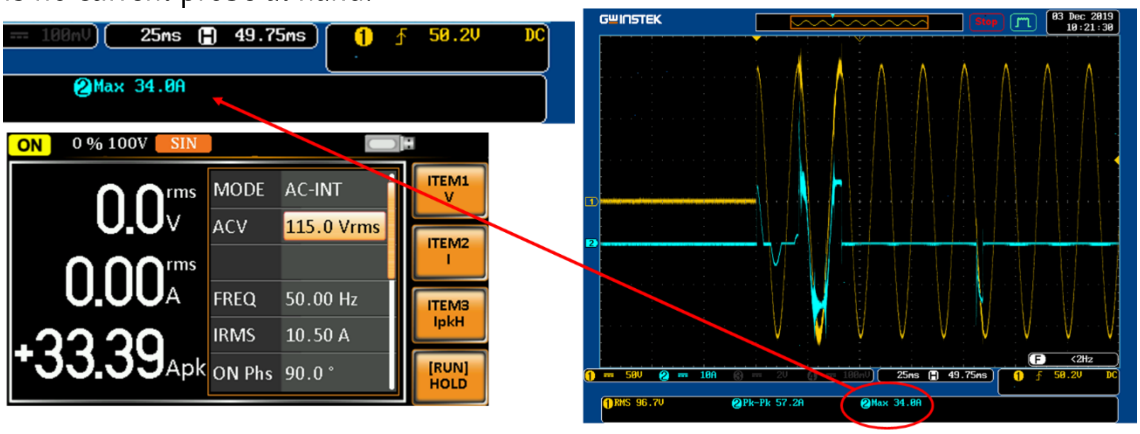


Figure (5) Comparison of AC power Ipeak measurement function and oscilloscope current probe to catch inrush current

DC Mode Applications for AC Power: Testing LVDC, HVDC Power Supplies

The power supplies used in the telecommunications room or the server power supplies of the data center, in addition to the conventional AC power supply as the input, the renewable energy or the DC power supply of the uninterruptible power system can also be used as the input. These types of power supplies are divided into LVDC or HVDC, LVDC is used in the telecommunications room, the voltage is 48V required by the computer room, and the voltage of HVDC is 180V~400V or 336V. GW Instek ASR-2000/3000 series AC/DC dual-purpose power supply can meet the applications of these voltages and for the rated power in the specifications, the rated power of DC is equal to the rated power of AC. For similar designs on the market, most of the DC rated power are only between 0.5 and 0.8 of the AC rated power. At this time, in order to meet the power demand, for 3kVA DC rated power requirement, if it is a 0.5 design, an AC 6kVA model is required to have 3kVA DC capability, so the cost of procurement will increase, while the design of full power will not have this problem. In addition, when converting AC to DC, most designs are to stop the AC output first and then switch to the DC output mode. Such conversion may cause the DUT to be shut down and then restarted. GW Instek ASR-2000/3000 series adopts seamless transition design and there will be no such issue. Figure 6 is a schematic diagram of the two conversion designs.

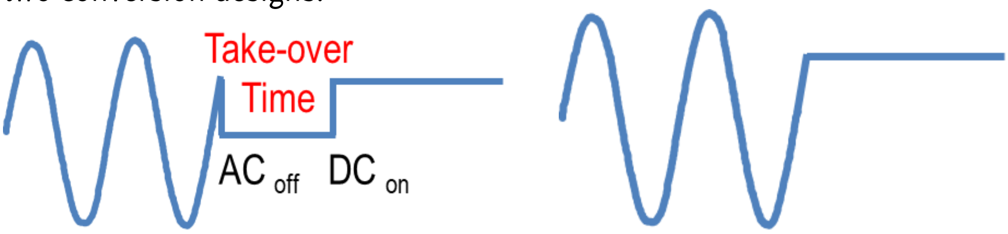


Figure (6) The left picture is the transition mode that may cause downtime; the right picture is the seamless transition mode

DC mode application of AC power supply: Make up for applications where the response speed of DC power supply is not fast enough

Take GW Instek ASR-2000/3000 series specifications as an example：

Time Mode: Time mode, the rise time is less than or equal to 100us (Figure 7)

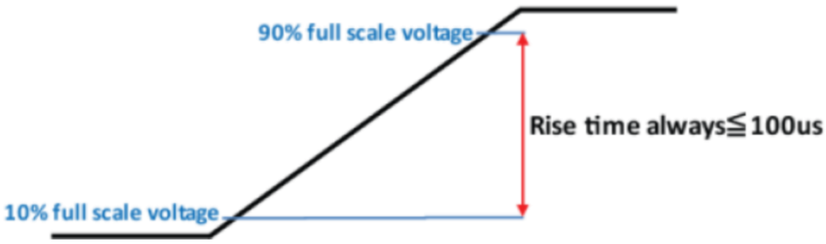


Figure (7) Time mode response speed

Slope Mode: Rising with a fixed slope, 1.5V every 1us (Figure 8)

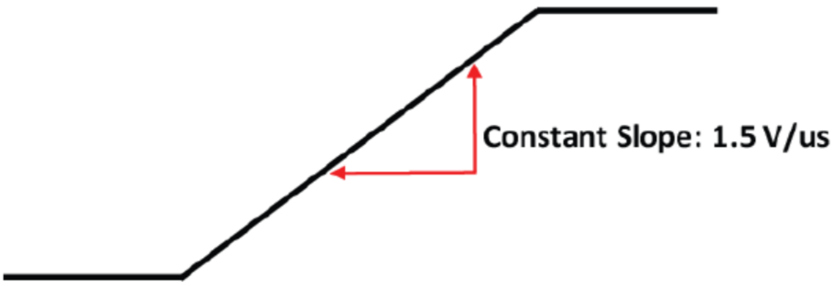


Figure (8) Response speed of slope mode

For automated tests that require fast response, the DC mode of the AC power supply can compensate insufficient DC power supply. Such capability can verify the feedforward control mechanism or verify the power-on response.

However, the ripple and noise of the DC mode of the AC power supply are larger than those of the DC power supply, and there is no constant current mode of the DC power supply.

➢ Other Applications for AC Power

Taking automotive electronic testing as an example, it is necessary to use a DC power supply (such as GW Instek PSW and PSU series) to perform tests such as Overvoltage, Slow decrease and increase, discontinuous, etc. When corresponding to relatively complex test items such as Reverse Voltage, Ground reference off-set , Superimposed alternating voltage or special waveforms (Load Dump pulse 5a, 5b, Voltage Drop pulse 4) etc., it is required to precisely control arbitrary waveforms by using AC/DC power supply.

Arbitrary Wave Application of AC Power Supply: ISO16750-2/2003 Vehicle Motor Electronic Environmental Test/Power Load Test Standards

SEQ6 (4.5.1): Momentary drop in supply voltage:
Simulate the effects of fuse failure in other circuits
SEQ7 (4.5.2): Reset behavior at voltage drop:
Demonstrate the effect of the device's reset behavior on the product at different pressure drops
SEQ8(4.5.3): Starting profile
Evaluate the effect of different voltage changes on the product
SEQ9: Load dump without centralized load dump suppression

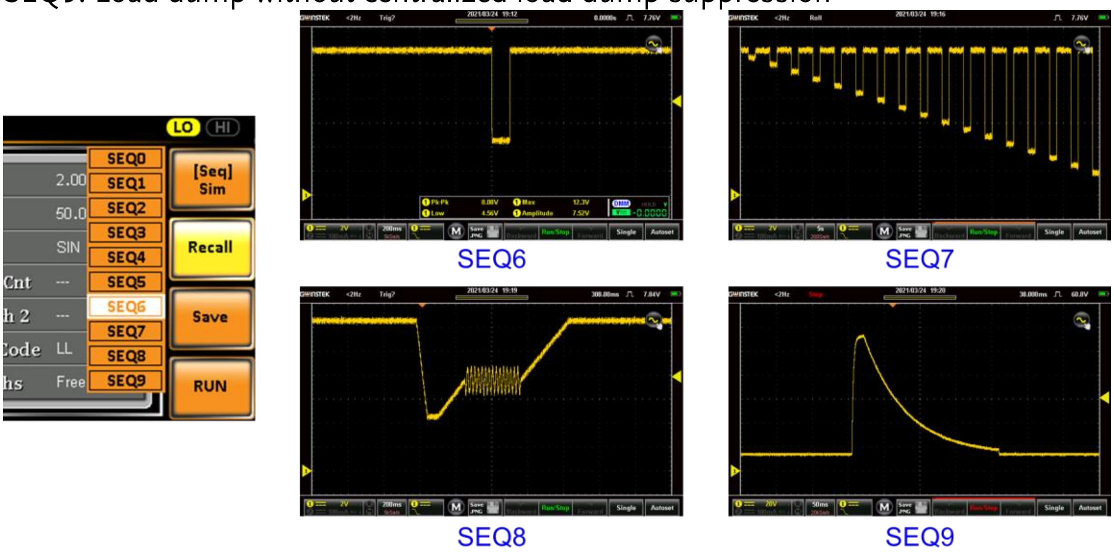


Figure (9) An example of the built-in arbitrary waveform of GW Instek ASR series AC power supply

AC power measurement function

For high-accuracy power analysis, a power meter or power analyzer is required. But for production line tests that require less accuracy, the AC power measurement function is an economical choice for multiple purposes.

- Basic measurement includes: AC and DC output voltage, current and power
- Common measurements (Useful) include: output voltage and current true root mean square (true RMS), peak value and average value (DC)
- Advanced measurement includes: apparent power (VA), reactive power (VAR), power factor (PF), crest factor (CF) and peak hold current)

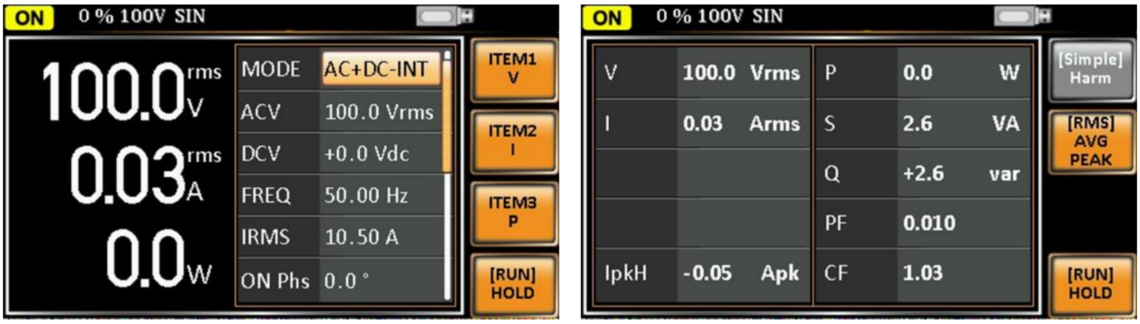


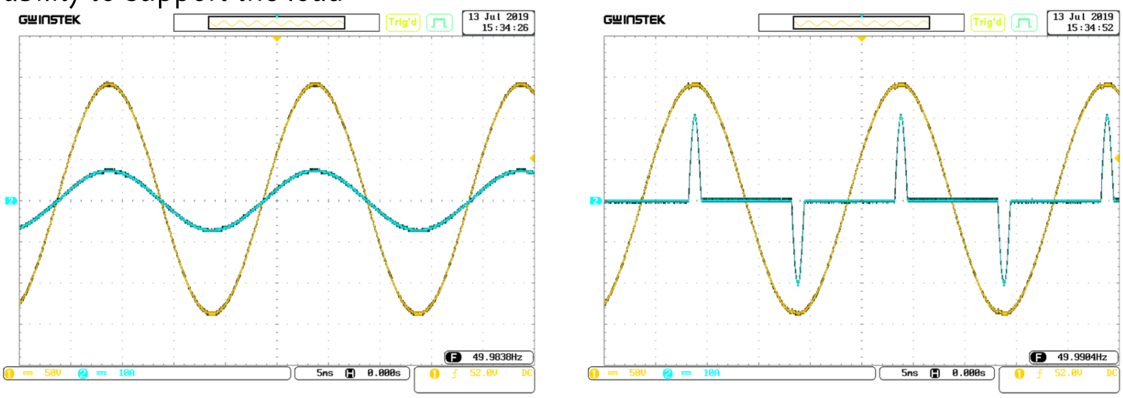
Figure (10) Example of measurement results of AC source

In addition to the above measurements, GW Instek ASR-2000/3000 series also has built-in voltage and current harmonic analysis functions.

Figure (11) Example of measurement results of AC source

Current Crest Factor CF (Crest Factor) of AC Power Supply

The power supply serves the load, the higher the current crest factor, the stronger the ability to support the load



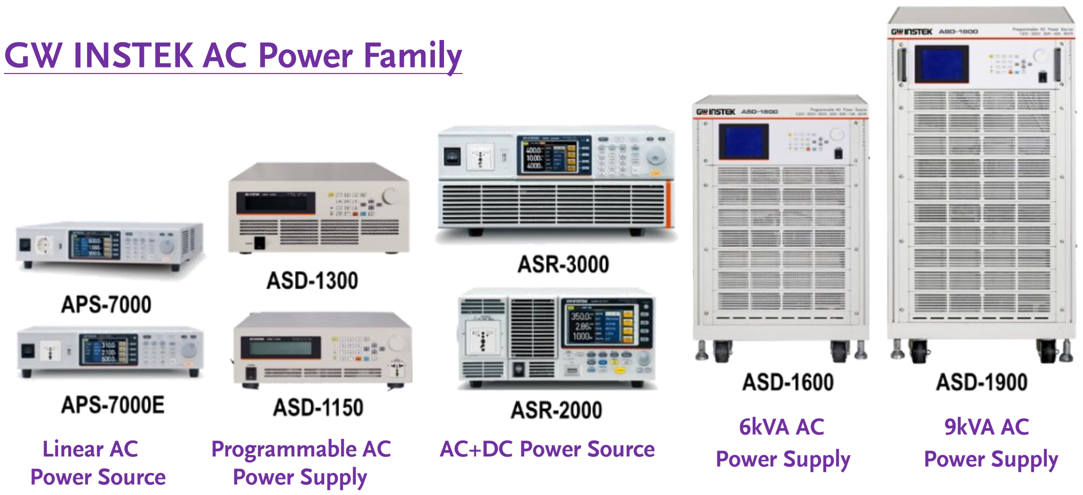
100VAC, 5A, PF=1, CF=1.414 **100VAC, 5A, PF=1, CF=4**

Figure (12) Waveform example of current crest factor

Under the same rated power, the higher-order AC source current crest factor is larger, the current crest factor CF of GW Instek ASD-1300, 1600, 1900 is 3, and the current crest factor CF of ASD-1150 and ASR-2000 series is 4. , ASR-3000 series current crest factor CF is 6.

Conclusion

Mencius once used three sentences to describe a man of character: Neither riches nor honors can corrupt him; neither poverty nor humbleness can make him swerve from principle; and neither threats nor forces can subdue him. We can make an analogy. A good power supply has the same characteristics as the man described by Mencius. Neither riches nor honors can corrupt him and neither poverty nor humbleness can make him swerve from principle are just like the line voltage regulation rate of the power supply, we expect that no matter how the quality of the input power changes, it will not affecting the output of the power supply. Neither threats nor forces can subdue him is just like the load regulation rate. We expect that the change of the load will not affect the output of the power supply. This Paper covers the characteristics of the input end of the test power supply. We will discuss the application of electronic loads in a special article in the near future.



Note: The ASD-1000 series: Only available in Southeast Asia, Taiwan and Korea

Figure (13) GW Instek AC Power Supply Family

Table 1: Application Segmentation of GW Instek AC Source Family

APS-7000 series	ASD-1000 series	ASR-2000 series	ASR-3000 series
Output capacity: **APS-7050** (500VA) 310Vrms、4.2Arms **APS-7100** (1000VA) 310Vrms、8.4Arms **APS-7200** (2000VA) 310Vrms、16.8Arms **APS-7300** (3000VA) 310Vrms、25.2Arms Options 600Vrms/1000Vrms/45~1000Hz Models New energy grid-connected application (APS-7000 can withstand reverse current conditionally)	Output capacity: **ASD-1150** (1500VA、150/300Vrms、15/7.5 Arms) with DC mode，CF=4 1.0~1000.0Hz (AC+DC Mode) **ASD-1300** (3000VA、150/300Vrms、30/15 Arms) **ASD-1600** (6000VA、150/300/600Vrms、60/30/15 Arms) can be connected in series to expand the output range to 600V (480Vrms applications are available in North America) **ASD-1900** (9000VA、150/300Vrms、90/45 Arms single-phase, 30/15 Arms three-phase) can output single-phase or three-phase 30~1000.0Hz (AC Mode)	Output capacity: **ASR-2050** (500VA) 175/350Vrms、5/2.5 Arms) **ASR-2100** (1000VA) 175/350Vrms、10/5 Arms) 40~999.9Hz (AC Mode) 1.0~999.9Hz (AC+DC Mode)	Output capacity: **ASR-3200** (2000VA) 200/400Vrms、20/10 Arms) **ASR-3300** (3000VA) 200/400Vrms、30/15 Arms) **ASR-3400** (4000VA) 200/400Vrms、40/20 Arms) 40~999.9Hz (AC Mode) 1.0~999.9Hz (AC+DC Mode)

Support low current measurement 2mA ~ 35A, minimum resolution 0.01mA (APS-7050& APS-7100)	CF=3 for other models except ASD-1150	With DC mode (editable fast arbitrary waveform), CF=4	With DC mode (editable fast arbitrary waveform), CF=6
APS-7000E economic model is available	Blue indicates the special functions of each model, and other models of the same series do not have the functions		Note: Due to the great difference in the environment of each customer's input terminal wiring, the standard accessories of the ASR-3000 series do not include the input terminal power cord and load line

References：

1. ITI (CBEMA) CURVE APPLICATION NOTE
   http://www.itic.org/resources/Oct2000Curve-UPDATED.doc
2. Taiwan Electric Research & Testing Center（TERTEC）online seminar speech on July 27, 2022, an invitation by GW Instek.
3. Master's Thesis, Department of Electrical Engineering, National Sun Yat-Sen University: Analysis of Sensitive Equipment Affected by Voltage Sag, written by Chen Zhiqiang, July 1994
4. Figure 14 Original graph in ITI (CBEMA) CURVE APPLICATION NOTE document

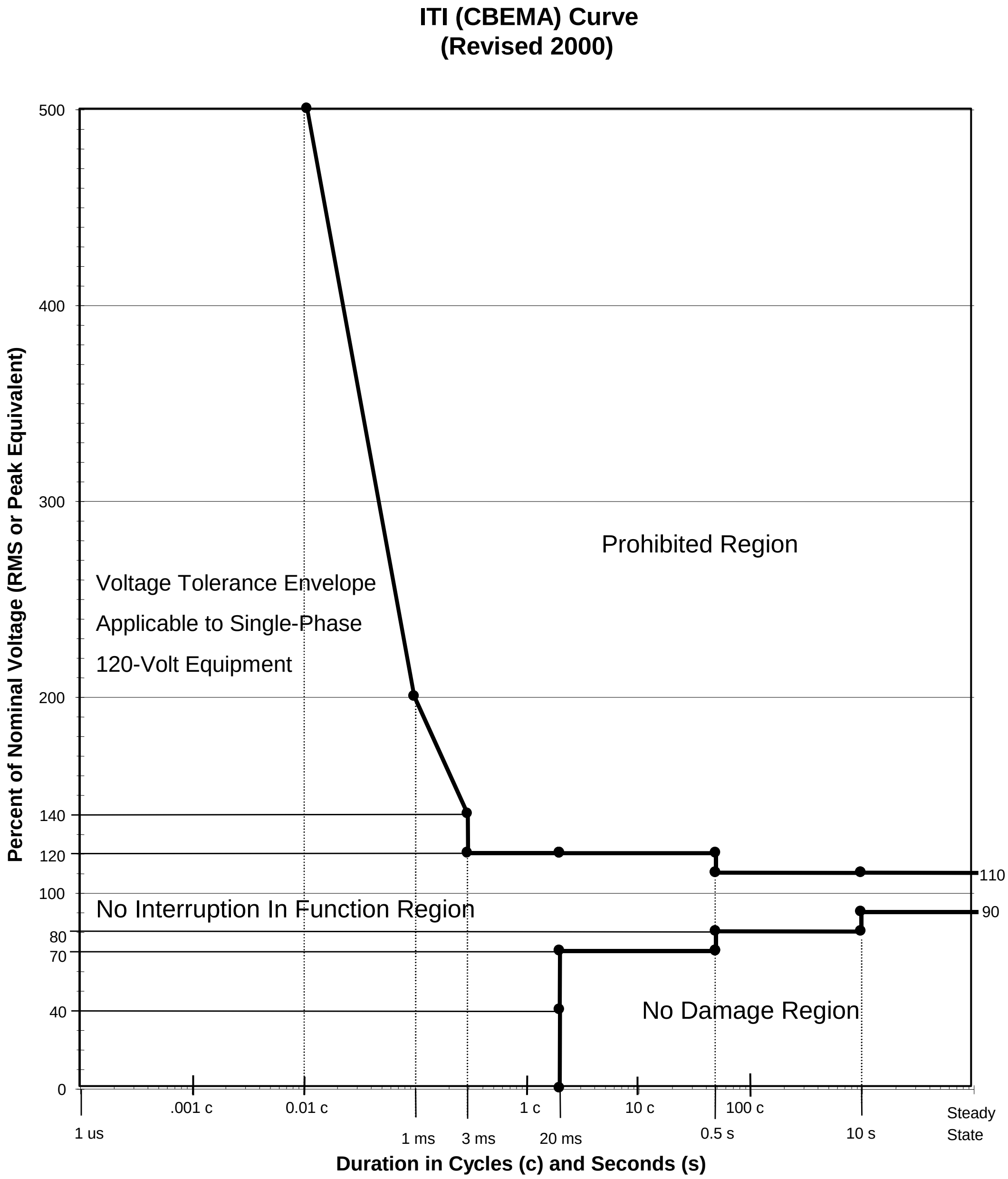


Figure 14 Original graph in ITI (CBEMA) CURVE APPLICATION NOTE document

ITI (CBEMA) Curve (Revised 2000)
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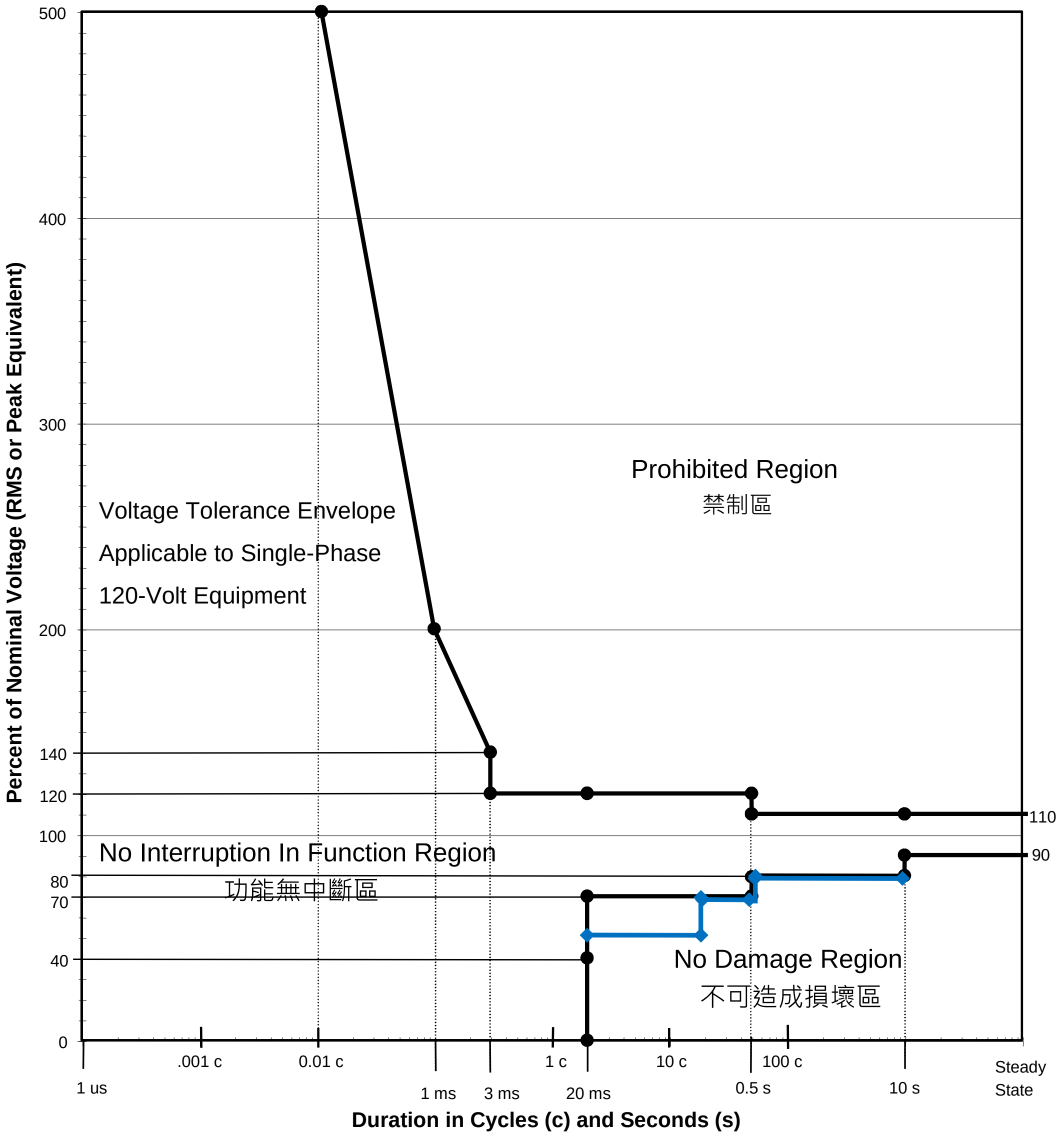

Global Headquarters
GOOD WILL INSTRUMENT CO., LTD.
No.7-1, Jhongsing Road., Tucheng Dist., New Taipei City 236, Taiwan
T +886-2-2268-0389
F +886-2-2268-0639
Email: marketing@goodwill.com.tw

U.S.A. Subsidiary
INSTEK AMERICA CORP.
5198 Brooks Street, Montclair, CA. 91763, U.S.A.
T +1-909-399-3535
F +1-909-399-0819
Email: sales@instekamerica.com

Europe Subsidiary
GOOD WILL INSTRUMENT EURO B.V.
De Run 5427A, 5504DG Veldhoven, THE NETHERLANDS
T +31(0)40-2557790
F +31(0)40-2541194
Email: sales@gw-instek.eu

India Subsidiary
GW INSTEK INDIA LLP
No. 2707/B&C, 1st Floor, UNNATHI Building, E-Block, Sahakara Nagar, Bengaluru 560 092, India
T +91-80-68110600
F +91-80-68110626
Email: sesha_shahi@goodwill.com.tw

South East Asia Subsidiary
GOOD WILL INSTRUMENT (SEA) SDN. BHD.
No.1-3-18, Elit Avenue, Jalan Mayang Pasir 3, 11950 Bayan Baru, Penang, Malaysia
T +604-6111122
F +604-6115225
Email: sales@goodwill.com.my

China Subsidiary
GOOD WILL INSTRUMENT (SUZHOU) CO., LTD.
No. 521, Zhujiang Road, Snd, Suzhou Jiangsu 215011 China
T +86-512- 6661-7177
F +86-512-6661-7277
Email: marketing@instek.com.cn

Japan Subsidiary
TEXIO TECHNOLOGY CORP.
7F Towa Fudosan Shin Yokohama Bldg, 2-18-13 Shin Yokohama, Kohoku-ku, Yokohama, Kanagawa, 222-0033 JAPAN
T +81-45-620-2305
F +81-45-534-7181
Email: info@texio.co.jp

Korea Subsidiary
GOOD WILL INSTRUMENT KOREA CO., LTD.
Room No.503, Gyeonginro 775 (Mullae-Dong 3Ga, Ace Hightech-City B/D 1Dong), Yeongduengpo-Gu, Seoul 07299, Korea.
T +82-2-3439-2205
F +82-2-3439-2207
Email: gwinstek@gwinstek.co.kr

Website Facebook LinkedIn