FLUKE.

6100A Electrical Power Standard
Extended Specifications

Introduction

The Fluke 6100A Electrical Power Standard is a unique product designed to address the needs of measurement verification and calibration for those people engaged in the demanding task of making measurements on electrical power systems. It has been designed to provide comprehensive functionality, together with superior accuracy for the widest range of power measurements possible. The 6100A is a configurable system and may be configured by the user to operate with one, two, three or four independent phases by the addition of 6101A auxiliary units.

A fully configured 4-phase Electrical Power Standard system

This document provides detailed specifications for all modes and all ranges of operation, it is intended to support the product brochure which provides further information on product features, applications and ordering information.

Voltage specifications

Voltage range limits						
Full range (FR)	**16 V**	**33 V**	**78 V**	**168 V**	**336 V**	**1008 V**
Max peak [1][2]	22.6 V	46.6 V	110 V	237 V	475 V	1425 V
Minimum amplitude	1.1 V	2.3 V	5.6 V	11 V	23 V	70 V

[1] These values apply to sinusoidal, distorted and modulated waveshapes.
[2] Voltage harmonic phase angle significantly affects the peak value of a non–sinusoidal waveform.

These specifications are applicable to all individual components in a waveform. Harmonic components in a composite waveform can be less than the range lower limit, but the RMS value of the combined output waveform must be greater than the range minimum.

Voltage amplitude specifications

Range	Frequency	Output component [5]	1 yr accuracy, TCal [6] ± 5 °C ± (ppm of output + mV) [1]		Stability ± (ppm of output + mV)/hour [2]		Maximum burden [7]
1.1 V to 16 V	16 Hz – 450 Hz	0 V – 6.4 V [4]	122	2.0	40	0.8	800 mA
		6.4 V – 16 V	112	1.5	40	0.4	800 mA
		0 V – 16 V [3]	122	2.0	200	0.8	800 mA
	450 Hz – 6 kHz	0 V – 4.8 V	512	2.0	60	0.8	800 mA
		0 V – 16 V [3]	512	2.0	400	0.8	800 mA
2.3 V to 33 V	16 Hz – 450 Hz	0 V – 13.2 V [4]	122	2.0	40	0.8	800 mA
		13.2 V – 33 V	112	1.5	40	0.6	800 mA
		0 V – 33 V [3]	122	2.0	200	0.8	800 mA
	450 Hz – 6 kHz	0 V – 9.9 V	512	2.0	60	0.8	800 mA
		0 V – 33 V [3]	512	2.0	400	0.8	800 mA
5.6 V to 78 V	16 Hz – 450 Hz	0 V – 31 V [4]	122	2.0	40	0.8	500 mA
		31 V – 78 V	112	2.0	40	0.8	500 mA
		0 V – 78 V [3]	122	2.0	200	0.8	500 mA
	450 Hz – 6 kHz	0 V – 23 V	512	2.0	60	0.8	500 mA
		0 V – 78 V [3]	512	2.0	400	0.8	500 mA
11 V to 168 V	16 Hz – 450 Hz	0 V – 67 V [4]	122	4.4	40	1.5	220 mA
		67 V – 168 V	112	4.4	40	1.5	220 mA
		0 V – 168 V [3]	122	4.4	200	1.5	220 mA
	450 Hz – 6 kHz	0 V – 50 V	512	4.4	60	1.5	220 mA
		0 V – 168 V [3]	512	4.4	400	1.5	220 mA
23 V to 336 V	16 Hz – 450 Hz	0 V – 134 V [4]	122	12.0	40	3.0	100 mA
		134 V – 336 V	112	8.8	40	3.0	100 mA
		0 V – 336 V [3]	122	8.8	200	3.0	100 mA
	450 Hz – 6 kHz	0 V – 100 V	512	12.0	60	3.0	100 mA
		0 V – 336 V [3]	512	12.0	400	3.0	100 mA
70 V to 1008 V	16 Hz – 450 Hz	0 V – 330 V [4]	166	33	100	10	50 mA
		330 V – 1008 V	158	26	100	10	50 mA
		0 V – 1008 V [3]	158	26	200	10	50 mA
	450 Hz – 6 kHz	0 V – 302 V	524	33	150	10	50 mA
		0 V – 1008 V [3]	524	33	450	10	50 mA

[1] Four wire sense only, for two wire operation, add an additional voltage = 0.3 Ω x maximum burden current to the accuracy specification.
[2] For ± 1 °C and constant load and connection conditions.
[3] Specification when any of: Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied
[4] See 'Voltage range limits' table for fundamental minimum value.
[5] The maximum value for a single harmonic (2nd to 100th); < 2850 Hz is 30 % of range. This maximum value then falls linearly with the log of frequency from 30 % of range at 2850 Hz, to 20 % of range at 6 kHz, remaining at 20 % above 6 kHz.
[6] TCal = temperature of last calibration.
[7] To achieve specifications in 4–wire sense, resistance in the sense lead must be less than 1 Ω and resistance in the power leads less than 1.5 Ω.

Voltage specifications (continued)

Voltage Distortion and Noise specifications			
Full range (FR)	**Frequency**	**Harmonic Distortion (dB relative to FR) [1]**	**Non-harmonic noise floor 16 Hz to 4 MHz (dB relative to FR)**
16 V	16 Hz – 450 Hz	–76	–66
	450 Hz – 6 kHz	–52	–66
33 V	16 Hz – 450 Hz	–76	–70
	450 Hz – 6 kHz	–52	–70
78 V	16 Hz – 450 Hz	–76	–72
	450 Hz – 6 kHz	–52	–72
168 V	16 Hz – 450 Hz	–76	–76
	450 Hz – 6 kHz	–52	–76
336 V	16 Hz – 450 Hz	–76	–66
	450 Hz – 6 kHz	–52	–66
1008 V	16 Hz – 450 Hz	–76	–60
	450 Hz – 6 kHz	–52	–60

[1] The dB harmonic distortion increases linearly between 450 Hz and 6 kHz.

DC Voltage offset	
Full range (FR)	**Maximum DCV offset**
16 V	2 mV
33 V	2 mV
78 V	5 mV
168 V	10 mV
336 V	20 mV
1008 V	60 mV

Current specifications

Current range limits							
Full range (FR)	**0.25 A**	**0.5 A**	**1 A**	**2 A**	**5 A**	**10 A**	**20 A**
Max peak [1][2]	0.353 A	0.707 A	1.414 A	2.828 A	7.07 A	14.14 A	28.28 A
Minimum amplitude	0.05 A	0.05 A	0.1 A	0.2 A	0.5 A	1 A	2 A

[1] These values apply to sinusoidal, distorted and modulated waveshapes.
[2] Voltage harmonic phase angle significantly affects the peak value of a non-sinusoidal waveform.

Voltage from Current terminals – range limits			
Full range (FR)	**0.25 V**	**1.5 V**	**10 V**
Max peak [1][2]	0.353 V	2.121 V	14.14 V
Minimum amplitude	0.05 V	0.15 V	1 V

[1] These values apply to sinusoidal, distorted and modulated waveshapes.
[2] Harmonic phase angle significantly affects the peak value of a non-sinusoidal waveform.

Current specifications (continued)

These specifications are applicable to all individual components in a waveform. Harmonic components in a composite waveform can be less than the range lower limit, but the RMS value of the combined output waveform must be greater than the range minimum.

Current amplitude specifications

Range	Frequency	Output component [4]	1 yr accuracy, TCal [5] ± 5 °C ± (ppm of output + µA)		Stability ± (ppm of output + µA)/hour [1]		Maximum compliance voltage (Vpk)
0.05 A – 0.25 A	16 Hz – 450 Hz	0 A – 0.1 A [3]	139	6	50	3	14 V
		0.1 A – 0.25 A	130	6	50	3	14 V
		0 A – 0.25 A [2]	130	6	240	3	14 V
	450 Hz – 6 kHz	0 A – 0.075 A	505	6	100	3	14 V
		0 A – 0.25 A [2]	505	6	1000	3	14 V
0.05 A – 0.5 A	16 Hz – 450 Hz	0 A – 0.2 A [3]	139	12	50	5	14 V
		0.2 A – 0.5 A	130	12	50	5	14 V
		0 A – 0.5 A [2]	130	12	240	5	14 V
	450 Hz – 6 kHz	0 A – 0.5 A	505	12	100	5	14 V
		0 A – 0.5 A [2]	505	12	1000	5	14 V
0.1 A –1 A	16 Hz – 450 Hz	0 A – 0.4 A [3]	139	24	50	10	14 V
		0.4 A – 1 A	130	24	50	10	14 V
		0 A – 1 A [2]	130	24	240	10	14 V
	450 Hz – 6 kHz	0 A – 1 A	505	24	100	10	14 V
		0 A – 1 A [2]	505	24	1000	10	14 V
0.2 A – 2 A	16 Hz – 450 Hz	0 A – 0.8 A [3]	139	48	50	20	14 V
		0.8 A – 2 A	130	48	50	20	14 V
		0 A – 2 A [2]	130	48	240	20	14 V
	450 Hz – 6 kHz	0 A – 2 A	505	48	100	20	14 V
		0 A – 2 A [2]	505	48	1000	20	14 V
0.5 A – 5 A	16 Hz – 450 Hz	0 A – 2 A [3]	139	120	50	50	14 V
		2 A – 5 A	130	120	50	50	14 V
		0 A – 5 A [2]	130	120	240	50	14 V
	450 Hz – 6 kHz	0 A – 5 A	505	120	100	50	14 V
		0 A – 5 A [2]	505	120	1000	50	14 V
1 A – 10 A	16 Hz – 450 Hz	0 A – 4 A [3]	191	240	70	100	14 V
		4 A – 10 A	164	240	70	100	14 V
		0 A – 10 A [2]	164	240	280	100	14 V
	450 Hz – 6 kHz	0 A – 10 A	519	240	110	100	14 V
		0 A – 10 A [2]	519	240	1100	100	14 V
2 A – 20 A	16 Hz – 450 Hz	0 A – 8 A [3]	213	720	90	300	13 V
		8 A – 20 A	189	720	90	300	13 V
		0 A – 20 A [2]	189	720	320	300	13 V
	450 Hz – 6 kHz	0 A – 20 A	665	720	120	300	13 V
		0 A – 20 A [2]	665	720	1300	300	13 V

[1] For ± 1 °C and constant load and connection conditions.
[2] Specification when any of: Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied.
[3] See 'Current range limits' table for minimum fundamental value.
[4] The maximum value for a single harmonic, (2nd to 100th); < 2850 Hz is 30 % of range. This maximum value then falls linearly with the log of frequency from 30 % of range at 2850 Hz, to 20 % of range at 6 kHz, remaining at 20 % above 6 kHz.
[5] TCal = temperature of last calibration.

Maximum inductive loading for output stability

Full range (FR) Maximum inductive load [1]	**0.25 A** 300 µH	**0.5 A** 300 µH	**1 A** 300 µH	**2 A** 300 µH	**5 A** 300 µH	**10 A** 45 µH	**20 A** 100 µH

[1] The current output will remain stable with the inductive loads shown but may not be able to drive that inductance at all current/frequency/harmonic combinations due to voltage burden limitations.

Current specifications (continued)

Voltage from Current terminals specifications							
Range	**Frequency**	**Output component [4]**	**1 yr accuracy, TCal [6] ± 5 °C ± (ppm of output + μV) [7]**		**Stability ± (ppm of output + μV) for 1 hour [1]**		**Minimum load impedance to maintain spec. [5]**
0.05 V – 0.25 V (Source impedance = 1 Ω)	16 Hz – 450 Hz	0 V – 0.1 V [3]	200	30	50	15	25 kΩ
		0.1 V – 0.25 V	200	30	50	15	22 kΩ
		0 V – 0.25 V [2]	300	30	240	15	25 kΩ
	450 Hz – 6 kHz	0 V – 0.075 V	1000	30	100	15	25 kΩ
		0 V – 0.25 V [2]	350	30	1000	15	25 kΩ
0.15 V – 1.5 V (Source impedance = 6.67 Ω)	16 Hz – 450 Hz	0 V – 0.6 V [3]	200	50	50	25	170 kΩ
		0.6 V – 1.5 V	200	40	50	20	170 kΩ
		0 V – 1.5 V [2]	300	50	240	25	170 kΩ
	450 Hz – 6 kHz	0 V – 1.5 V	1000	50	100	25	170 kΩ
		0 V – 1.5 V [2]	350	50	1000	25	170 kΩ
1 V –10 V (Source impedance = 40.02 Ω)	16 Hz – 450 Hz	0 V – 4 V [3]	200	300	50	150	1 MΩ
		4 V – 10 V	200	240	50	120	1 MΩ
		0 V – 10 V [2]	300	300	240	150	1 MΩ
	450 Hz – 6 kHz	0 V – 10 V	1000	300	100	150	1 MΩ
		0 V – 10 V [2]	350	300	1000	150	1 MΩ

[1] For ±1 °C and constant load and connection conditions.
[2] Specification when any of: Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied.
[3] See 'Voltage from Current terminal – range limits' table for minimum fundamental value.
[4] The max. value for a single harmonic, (2nd to 100th); < 2850 Hz is 30 % of range. This max value then falls linearly with the log of frequency, from 30 % of range at 2850 Hz, to 20 % of range at 6 kHz, remaining at 20 % > 6 kHz.
[5] For load less than specified, calculate error from parallel combination of source and load impedance.
[6] TCal = temperature of last calibration.
[7] These specifications assume a measuring instrument bandwidth of < 100 kHz. Some RMS sensing instruments have voltage input bandwidths of several MHz, so the 6100A specification should be expanded by the non–harmonic noise floor in the 'Distortion and Noise specifications from Current terminals' table.

Flicker, Fluctuating harmonics, Dip/Swell and Interharmonics on Voltage and Current
Full accuracy for pure sine or sine plus harmonics is achieved by using analogue and digital feedback systems. When any of the Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics are applied, the digital system is automatically uncoupled. Initial performance is as specified in both the Voltage and Current amplitude specification tables, 1 year accuracy columns, but performance degrades with time, as described in the stability columns. Full accuracy can be restored by momentarily disabling which ever of the Flicker, Fluctuating harmonics, Dip/Swell or Interharmonics functions are enabled, or by changing the value of the sine wave or any harmonic for that channel.

Distortion and Noise specifications from Current terminals			
Range	**Frequency**	**Harmonic distortion (dB relative to FR) [1]**	**Non-harmonic noise floor 16 Hz to 4 MHz (dB relative to FR)**
0.25 A and 0.25 V	16 Hz – 450 Hz	–70	–50
	450 Hz – 6 kHz	–50	–50
0.5 A and 1.5 V	16 Hz – 450 Hz	–70	–60
	450 Hz – 6 kHz	–50	–60
1 A and 10 V	16 Hz – 450 Hz	–70	–60
	450 Hz – 6 kHz	–50	–60
2 A	16 Hz – 450 Hz	–70	–65
	450 Hz – 6 kHz	–50	–65
5 A	16 Hz – 450 Hz	–70	–65
	450 Hz – 6 kHz	–50	–65
10 A	16 Hz – 450 Hz	–70	–50
	450 Hz – 6 kHz	–50	–50
20 A	16 Hz – 450 Hz	–70	–50
	450 Hz – 6 kHz	–50	–50

[1] The dB harmonic distortion increases linearly between 450 Hz and 6 kHz.

DC Current offset	
Full range (FR)	**Maximum DCI offset**
0.25 A	25 μA
0.5 A	50 μA
1 A	100 μA
2 A	200 μA
5 A	500 μA
10 A	2 mA
20 A	4 mA
0.25 V [1]	50 μV
1.5 V [1]	150 μV
10 V [1]	1 mV

[1] Figures apply to Voltage from Current terminals.

Apparent Power and Phase specifications

Sinusoidal VA specifications [1]						
Current range	**Voltage range**					
	16 V (6.4 V – 16 V)	**33 V** (13.2 V – 33 V)	**78 V** (31 V – 78 V)	**168 V** (67 V – 168 V)	**336 V** (134 V – 336 V)	**1008 V** (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	257 – 395	220 – 295	206 – 259	207 – 260	207 – 260	240 – 304
0.5 A (0.2 A – 0.5 A)	257 – 395	220 – 295	206 – 259	207 – 260	207 – 260	240 – 304
1 A (0.4 A – 1 A)	257 – 395	220 – 295	206 – 259	207 – 260	207 – 260	240 – 304
2 A (0.8 A – 2 A)	257 – 395	220 – 295	206 – 259	207 – 260	207 – 260	240 – 304
5 A (2 A – 5 A)	257 – 395	220 – 295	206 – 259	207 – 260	207 – 260	240 – 304
10 A (4 A –10 A)	279 – 412	245 – 318	233 – 285	233 – 286	233 – 286	263 – 326
20 A (8 A – 20 A)	305 – 444	274 – 358	263 – 330	264 – 330	264 – 330	290 – 366

[1] This table shows in parts per million the minimum to maximum Apparent Power accuracy for specific voltage and current bands under sinusoidal conditions.

Current to Voltage Phase specifications					
For all Voltage ranges (16 V to 1008 V)		**Voltage and Current components > 40 % of range**		**Voltage and Current components 0.5 % to 40 % of range [5]**	
Current range	Frequency	1 yr accuracy, TCal [4] ± 5 °C [1] [2]	Stability per hour [2] [3]	1 yr accuracy, TCal [4] ± 5 °C [1] [2]	Stability per hour [2] [3]
0.25 A to 5 A	16 Hz – 69 Hz	0.003 °	0.0002 °	0.010 °	0.001 °
	69 Hz – 180 Hz	0.005 °	0.0002 °	0.017 °	0.002 °
	180 Hz – 450 Hz	0.015 °	0.0002 °	0.050 °	0.005 °
	450 Hz – 3 kHz	0.150 °	0.0010 °	0.200 °	0.100 °
	3 kHz – 6 kHz	0.300 °	0.0010 °	0.450 °	0.100 °
5 A to 20 A	16 Hz – 69 Hz	0.004 °	0.0003 °	0.013 °	0.002 °
	69 Hz – 180 Hz	0.007 °	0.0003 °	0.023 °	0.004 °
	180 Hz – 450 Hz	0.020 °	0.0003 °	0.065 °	0.010 °
	450 Hz – 3 kHz	0.200 °	0.0010 °	0.250 °	0.100 °
	3 kHz – 6 kHz	0.400 °	0.0010 °	0.600 °	0.150 °

[1] Phase errors relative to L1 Voltage.
[2] Phase angle contribution to power accuracy varies with set phase angle.
[3] For constant load and connection conditions.
[4] TCal = temperature of last calibration.
[5] Phase performance at less than 0.5 % of full range degrades as output components approach the resolution limit of the digital feedback system.

Voltage channel to Voltage channel Phase specifications				
For all Voltage ranges (16 V to 1008 V)	**Voltage components > 40 % of range**		**Voltage components 0.5 % to 40 % of range [4]**	
Frequency	1 yr accuracy, TCal [3] ± 5 °C [1]	Stability per hour [2]	1 yr accuracy, TCal [3] ± 5 °C [1]	Stability per hour [2]
16 Hz – 69 Hz	0.005 °	0.0002 °	0.010 °	0.001 °
69 Hz – 180 Hz	0.007 °	0.0005 °	0.020 °	0.002 °
180 Hz – 450 Hz	0.020 °	0.0010 °	0.050 °	0.005 °
450 Hz to 2 kHz	0.100 °	0.0100 °	0.150 °	0.015 °
2 kHz to 6 kHz	0.200 °	0.0200 °	0.300 °	0.030 °

[1] Phase errors relative to L1 Voltage.
[2] For constant load and connection conditions.
[3] TCal = temperature of last calibration.
[4] Phase performance at less than 0.5 % of full range degrades as output components approach the resolution limit of the digital feedback system.

Sinusoidal Power specifications

16 Hz to 69 Hz, 1.0 > Power Factor > 0.75 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	33 V (13.2 V – 33 V)	78 V (31 V – 78 V)	168 V (67 V – 168 V)	336 V (134 V – 336 V)	1008 V (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	261 – 398	225 – 298	212 – 263	212 – 264	212 – 264	244 – 307
0.5 A (0.2 A – 0.5 A)	261 – 398	225 – 298	212 – 263	212 – 264	212 – 264	244 – 307
1 A (0.4 A – 1 A)	261 – 398	225 – 298	212 – 263	212 – 264	212 – 264	244 – 307
2 A (0.8 A – 2 A)	261 – 398	225 – 298	212 – 263	212 – 264	212 – 264	244 – 307
5 A (2 A – 5 A)	264 – 400	229 – 301	215 – 266	216 – 267	216 – 267	248 – 310
10 A (4 A –10 A)	285 – 417	253 – 324	241 – 292	241 – 292	241 – 292	270 – 332
20 A (8 A – 20 A)	311 – 449	281 – 364	270 – 335	271 – 336	271 – 336	297 – 371

16 Hz to 69 Hz, 0.75 > Power Factor > 0.5 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	33 V (13.2 V – 33 V)	78 V (31 V – 78 V)	168 V (67 V – 168 V)	336 V (134 V – 336 V)	1008 V (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	272 – 405	238 – 308	225 – 275	226 – 275	226 – 275	257 – 317
0.5 A (0.2 A – 0.5 A)	272 – 405	238 – 308	225 – 275	226 – 275	226 – 275	257 – 317
1 A (0.4 A – 1 A)	272 – 405	238 – 308	225 – 275	226 – 275	226 – 275	257 – 317
2 A (0.8 A – 2 A)	272 – 405	238 – 308	225 – 275	226 – 275	226 – 275	257 – 317
5 A (2 A – 5 A)	284 – 413	251 – 319	239 – 286	240 – 287	240 – 287	269 – 327
10 A (4 A –10 A)	304 – 430	273 – 340	262 – 310	263 – 310	263 – 310	290 – 348
20 A (8 A – 20 A)	328 – 461	300 – 378	290 – 351	290 – 352	290 – 352	315 – 385

16 Hz to 69 Hz, 0.5 > Power Factor > 0.25 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	33 V (13.2 V – 33 V)	78 V (31 V – 78 V)	168 V (67 V – 168 V)	336 V (134 V – 336 V)	1008 V (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	327 – 444	299 – 358	289 – 329	290 – 330	290 – 330	314 – 365
0.5 A (0.2 A – 0.5 A)	327 – 444	299 – 358	289 – 329	290 – 330	290 – 330	314 – 365
1 A (0.4 A – 1 A)	327 – 444	299 – 358	289 – 329	290 – 330	290 – 330	314 – 365
2 A (0.8 A – 2 A)	327 – 444	299 – 358	289 – 329	290 – 330	290 – 330	314 – 365
5 A (2 A – 5 A)	373 – 479	349 – 400	340 – 375	340 – 375	340 – 375	362 – 407
10 A (4 A –10 A)	388 – 493	365 – 417	357 – 393	357 – 393	357 – 393	377 – 424
20 A (8 A – 20 A)	407 – 520	385 – 449	377 – 426	378 – 427	378 – 427	397 – 455

69 Hz to 180 Hz, 1.0 > Power Factor > 0.75 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	33 V (13.2 V – 33 V)	78 V (31 V – 78 V)	168 V (67 V – 168 V)	336 V (134 V – 336 V)	1008 V (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	268 – 402	233 – 305	220 – 270	221 – 271	221 – 271	252 – 313
0.5 A (0.2 A – 0.5 A)	268 – 402	233 – 305	220 – 270	221 – 271	221 – 271	252 – 313
1 A (0.4 A – 1 A)	268 – 402	233 – 305	220 – 270	221 – 271	221 – 271	252 – 313
2 A (0.8 A – 2 A)	268 – 402	233 – 305	220 – 270	221 – 271	221 – 271	252 – 313
5 A (2 A – 5 A)	279 – 409	245 – 314	233 – 281	233 – 281	233 – 281	263 – 322
10 A (4 A –10 A)	299 – 426	268 – 336	257 – 305	257 – 305	257 – 305	284 – 343
20 A (8 A – 20 A)	323 – 457	295 – 374	285 – 347	285 – 348	285 – 348	310 – 381

69 Hz to 180 Hz, 0.75 > Power Factor > 0.5 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	33 V (13.2 V – 33 V)	78 V (31 V – 78 V)	168 V (67 V – 168 V)	336 V (134 V – 336 V)	1008 V (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	298 – 423	267 – 331	256 – 300	256 – 301	256 – 301	284 – 339
0.5 A (0.2 A – 0.5 A)	298 – 423	267 – 331	256 – 300	256 – 301	256 – 301	284 – 339
1 A (0.4 A – 1 A)	298 – 423	267 – 331	256 – 300	256 – 301	256 – 301	284 – 339
2 A (0.8 A – 2 A)	298 – 423	267 – 331	256 – 300	256 – 301	256 – 301	284 – 339
5 A (2 A – 5 A)	333 – 448	305 – 363	296 – 335	296 – 335	296 – 335	320 – 370
10 A (4 A –10 A)	350 – 463	324 – 382	315 – 355	315 – 356	315 – 356	338 – 389
20 A (8 A – 20 A)	371 – 492	346 – 416	338 – 392	338 – 392	338 – 392	359 – 423

Sinusoidal Power specifications (continued)

69 Hz to 180 Hz, 0.5 > Power Factor > 0.25 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	**33 V** (13.2 V – 33 V)	**78 V** (31 V – 78 V)	**168 V** (67 V – 168 V)	**336 V** (134 V – 336 V)	**1008 V** (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	425 – 520	403 – 449	396 – 426	396 – 426	396 – 426	415 – 454
0.5 A (0.2 A – 0.5 A)	425 – 520	403 – 449	396 – 426	396 – 426	396 – 426	415 – 454
1 A (0.4 A – 1 A)	425 – 520	403 – 449	396 – 426	396 – 426	396 – 426	415 – 454
2 A (0.8 A – 2 A)	425 – 520	403 – 449	396 – 426	396 – 426	396 – 426	415 – 454
5 A (2 A – 5 A)	538 – 616	522 – 558	516 – 540	516 – 540	516 – 540	531 – 562
10 A (4 A –10 A)	549 – 628	533 – 570	527 – 552	528 – 553	528 – 553	541 – 575
20 A (8 A – 20 A)	563 – 649	547 – 594	542 – 577	542 – 577	542 – 577	555 – 598

180 Hz to 450 Hz, 1.0 > Power Factor > 0.75 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	**33 V** (13.2 V – 33 V)	**78 V** (31 V – 78 V)	**168 V** (67 V – 168 V)	**336 V** (134 V – 336 V)	**1008 V** (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	345 – 457	319 – 374	310 – 347	310 – 348	310 – 348	333 – 382
0.5 A (0.2 A – 0.5 A)	345 – 457	319 – 374	310 – 347	310 – 348	310 – 348	333 – 382
1 A (0.4 A – 1 A)	345 – 457	319 – 374	310 – 347	310 – 348	310 – 348	333 – 382
2 A (0.8 A – 2 A)	345 – 457	319 – 374	310 – 347	310 – 348	310 – 348	333 – 382
5 A (2 A – 5 A)	401 – 501	378 – 426	371 – 402	371 – 403	371 – 403	390 – 432
10 A (4 A –10 A)	415 – 515	394 – 443	386 – 420	386 – 420	386 – 420	405 – 448
20 A (8 A – 20 A)	433 – 541	412 – 473	405 – 451	405 – 452	405 – 452	423 – 478

180 Hz to 450 Hz, 0.75 > Power Factor > 0.5 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	**33 V** (13.2 V – 33 V)	**78 V** (31 V – 78 V)	**168 V** (67 V – 168 V)	**336 V** (134 V – 336 V)	**1008 V** (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	521 – 601	504 – 541	498 – 522	498 – 523	498 – 523	513 – 546
0.5 A (0.2 A – 0.5 A)	521 – 601	504 – 541	498 – 522	498 – 523	498 – 523	513 – 546
1 A (0.4 A – 1 A)	521 – 601	504 – 541	498 – 522	498 – 523	498 – 523	513 – 546
2 A (0.8 A – 2 A)	521 – 601	504 – 541	498 – 522	498 – 523	498 – 523	513 – 546
5 A (2 A – 5 A)	657 – 722	643 – 673	639 – 658	639 – 658	639 – 658	651 – 677
10 A (4 A –10 A)	666 – 732	652 – 683	648 – 668	648 – 669	648 – 669	659 – 687
20 A (8 A – 20 A)	677 – 750	664 – 703	660 – 689	660 – 689	660 – 689	671 – 707

180 Hz to 450 Hz, 0.5 > Power Factor > 0.25 [1]

Current range	Voltage range					
	16 V (6.4 V – 16 V)	**33 V** (13.2 V – 33 V)	**78 V** (31 V – 78 V)	**168 V** (67 V – 168 V)	**336 V** (134 V – 336 V)	**1008 V** (330 V – 1008 V)
0.25A (0.1 A – 0.3 A)	1046 – 1088	1038 – 1056	1035 – 1047	1035 – 1047	1035 – 1047	1042 – 1058
0.5 A (0.2 A – 0.5 A)	1046 – 1088	1038 – 1056	1035 – 1047	1035 – 1047	1035 – 1047	1042 – 1058
1 A (0.4 A – 1 A)	1046 – 1088	1038 – 1056	1035 – 1047	1035 – 1047	1035 – 1047	1042 – 1058
2 A (0.8 A – 2 A)	1046 – 1088	1038 – 1056	1035 – 1047	1035 – 1047	1035 – 1047	1042 – 1058
5 A (2 A – 5 A)	1376 – 1408	1370 – 1384	1368 – 1377	1368 – 1377	1368 – 1377	1373 – 1386
10 A (4 A –10 A)	1380 – 1413	1374 – 1389	1372 – 1382	1372 – 1382	1372 – 1382	1377 – 1391
20 A (8 A – 20 A)	1386 – 1423	1380 – 1399	1377 – 1392	1377 – 1392	1377 – 1392	1383 – 1401

[1] These tables show in parts per million the minimum to maximum Power accuracy for specific voltage and current bands under sinusoidal conditions. Refer to the 'Power (P) accuracy calculations' on page 14 to calculate exact Power accuracy.

Flicker, Harmonic, Interharmonic and Dips/Swells specifications

Voltage and Current Flicker specifications	
Setting range	±30 % of set voltage or current within range values (60 % ΔV/V)
Flicker modulation depth accuracy	0.025 %
Modulation depth setting resolution	0.001 %
Shape	Rectangular or Sinusoidal
Duty cycle (shape = rectangular)	0.01 % to 99.99 %
Modulating Frequency range	0.0008 Hz to 40 Hz
Sine Modulating Frequency accuracy	50 ppm ±10 µHz
Square Modulating Frequency accuracy	< 1300 ppm [1]
Modulating Frequency setting resolution	0.0001 Hz
Pst indication accuracy	0.25 % – Voltage setting only valid between 220 V and 240 V, and at a frequency of 50 Hz

[1] Accuracy is (50 + 31 x modulating frequency) ppm ±10 µHz

Fluctuating harmonics specifications	
Number of harmonics to fluctuate	Any number from 0 to all set harmonics can fluctuate
Setting range	±30 % of nominal harmonic voltage
Fluctuation accuracy	0.025 %
Modulation depth setting resolution	0.001 %
Shape	Rectangular or Sinusoidal
Duty cycle (shape = rectangular)	0.1 % to 99.9 %
Modulating Frequency range	0.008 Hz to 30 Hz
Sine Modulating Frequency accuracy	50 ppm ±10 µHz
Rectangular Modulating Frequency accuracy	< 1300 ppm [1]
Modulating Frequency setting resolution	0.001 Hz

[1] Accuracy is (50 + 31 x modulating frequency) ppm ±10 µHz

Interharmonics specifications	
Frequency accuracy	500 ppm
Amplitude accuracy 16 Hz to < 6 kHz	1 %
Amplitude accuracy > 6 kHz	4 %
Maximum value of a single interharmonic	The maximum value for an interharmonic < 2850 Hz is 30 % of range. This maximum value then falls linearly with the log of frequency from 30 % of range at 2850 Hz, to 20 % of range at 6 kHz, remaining at 20 % above 6 kHz
Frequency range of interharmonic	16 Hz to 9 kHz

Dip/Swell specifications	
Trigger in requirement	TTL falling edge remaining low for 10 µs
Either:	
Trigger in delay	0 to 60 seconds ±31 µs
OR	
Phase angle synchronization with respect to channel fundamental frequency zero crossing	±180 ° ±31 µs
Dip/Swell Min duration	1 ms
Dip/Swell Max duration	1 minute
Dip Min amplitude	10 % of the nominal output
Swell Max amplitude	The least of full range value and 140 % of the nominal output
Ramp up/down period	Settable 100 µs to 30 seconds
Optional repeat with delay	0 to 60 seconds ±31 µs
Starting level amplitude accuracy	±0.25 % of level
Dip/Swell level amplitude accuracy	±0.25 % of level
Trigger out delay	0 to 60 seconds ±31 µs from start of Dip/Swell event
Trigger out	TTL falling edge co-incident with end of trigger out delay, remaining low for 10 µs to 31 µs

General specifications

General parametric specifications	
Voltage/Current amplitude setting resolution	6 digits
Range of fundamental frequencies	16 Hz to 450 Hz
Line frequency locking	45 Hz to 66 Hz at users discretion
Frequency accuracy	50 ppm
Frequency setting resolution	0.1 Hz
Warm up time to full accuracy	1 hour or twice the time since last warmed up
Settling time following change to the output	1.4 seconds
Nominal angle between voltage phases	120 °
Nominal angle between voltage and current of a phase	0 °
Phase angle setting	±180 °, ±π radians [1]
Phase angle setting resolution	0.001 °, 0.00001 radians [1]
Maximum number of voltage harmonics	100 including the 1st (fundamental frequency)
Maximum number of current harmonics	100 including the 1st (fundamental frequency)

[1] Switching between phase set in degrees, phase set in radians and back may not be consistent because of calculation rounding errors.

Input power	
Voltage	100 V to 240 V with up to ±10 % fluctuations
Transient overvoltages	Impulse withstand (overvoltage) category II of IEC 60364-4-443
Frequency	47 Hz to 63 Hz
Max. Consumption	1250 VA Max. (1000 VA for 115 V nominal)

Dimensions	
Height	233 mm (9.17 inches)
Width	432 mm (17 inches)
Depth	630 mm (24.8 inches)
Weight	23 kg (51 lb)

Environment	
Operating temperature	5 °C to 35 °C
Calibration temperature (TCal) range	16 °C to 30 °C
Storage temperature	0 °C to 50 °C
Transit temperature	-20 °C to 60 °C < 100 hours
Warm up time	1 hour
Safe Operating Max. Relative Humidity (non-condensing)	< 80 % 5 °C to 31 °C ramping linearly to 50 % at 35 °C
Storage Max Relative Humidity (non-condensing)	<95 % 0 °C to 50 °C
Operating altitude	0 m to 2,000 m
Non operating altitude	0 m to 12,000 m
Shock	MIL-PRF-28800F class 3
Vibration	MIL-PRF-28800F class 3
Enclosure	MIL-PRF-28800F class 3

Calculating Power and Power phenomena

An example to help determine the amplitude specification for a non-sinusoidal voltage waveform

The RMS value of the combination of voltage components is $V_{RMS}^2 = \sum_{i=1}^{N} V_i^2$ and, assuming symmetrical uncertainties, $u(V)_i$, for each of V_i.

Note that the uncertainties of the components of a 6100A nonsinusoidal voltage (or current) waveform are correlated so must be combined by linear addition.

$$(V_{RMS} + u(V_{RMS}))^2 = \sum_{i=1}^{N} (V_i + u(V_i))^2$$

$$V_{RMS}^2 + 2V_{RMS}u(V_{RMS}) + u^2(V_{RMS}) =$$

$$V_1^2 + 2V_1\,u(V_1) + u^2(V)_1 + V_2^2 + 2V_2\,u(V_2) + u^2(V_2) \ldots V_n^2 + 2V_n\,u(V_n)u^2V_n$$

But $V_{RMS}^2 = \sum_{i=1}^{N} V_i^2$

and, where uncertainties are relatively small (as in the 6100A), components become negligible. The uncertainty of the combined waveform becomes:

$$2V_{RMS}uV_{RMS} = 2V_1\,u(V_1) + 2V_2\,u(V_2) \ldots 2V_n\,u(V_n)$$

which simplifies to give u_c as the combined uncertainty:

$$u_c(V_{RMS}) = \sum_{i=1}^{N} c_i u(V_i)$$

where $c_i = \frac{V_i}{V_{RMS}}$ and is known as the sensitivity coefficient.

An example of a nonsinusoidal voltage amplitude calculation

The wave form is a 60 Hz, 110 V RMS waveform, from the 168 V range, comprising 10 % 95th harmonic, 30 % 3rd harmonic with the remainder contributed by the fundamental frequency. Using the voltage uncertainty values given in the 'Voltage amplitude specifications' table, determine the 1 year accuracy.

3rd Harmonic RMS voltage = 0.3 x 110 = 33 V

95th Harmonic RMS voltage = 0.1 x 110 = 11 V

Fundamental RMS voltage = $\sqrt{(110^2 - 33^2 - 11^2)}$ = 104.3552 V

Accuracy contribution from the fundamental:
112 ppm of output + 4.4 mV = (104.3552 x 0.000112) + 0.0044 = 0.011688 + 0.0044 = 0.016088 V
Modified by the sensitivity coefficient = 0.016088 x 104.3552 ÷ 110 = 0.015262 V

Accuracy contribution from the 3rd Harmonic:
122 ppm of 3rd harmonic value + 4.4 mV = (0.000122 x 33) + 0.0044 = 0.008426 V
Modified by the sensitivity coefficient = 0.008426 x 33 ÷ 110 = 0.002528 V

Accuracy contribution from the 95th Harmonic:
512 ppm of 95th harmonic value + 4.4 mV = (0.000512 x 11) + 0.0044 = 0.010032 V
Modified by the sensitivity coefficient = 0. 010032 x 11 ÷ 110 = 0. 001003 V

Combining the uncertainties
total amplitude uncertainty = 0.015262 + 0.002528 + 0. 010032 = 0.018793 V

$$Voltage\ Accuracy = 110 \pm 018793\ \ V$$

Calculating Power and Power phenomena

Apparent Power (S) accuracy calculations
For the purpose of calculation of apparent power (S) for nonsinusoidal outputs the following equations are used:

$$S = \sqrt{\sum_n V_n^2 \sum_n I_n^2} \text{ VA}$$

To calculate the accuracy of apparent power (S), the amplitude accuracy specifications of voltage harmonic components must be combined as in the example on page 12. Current components are combined using the same method. As apparent power is the product of two different quantities, uncertainties are conveniently combined using relative values. Note that 6100A voltage and current components are generated independently and are therefore largely uncorrelated.

As $S^2 = V_{RMS}^2 . I_{RMS}^2$;

$$\frac{u_c^2(S)}{S^2} = [\frac{u(V_{RMS})}{V_{RMS}}]^2 + [\frac{u(I_{RMS})}{I_{RMS}}]^2$$

where $u_c(S)$ is the combined uncertainty of the apparent Power, $u(V_{RMS})$ is the uncertainty of the RMS voltage and $u(I_{RMS})$ is the uncertainty of the RMS current.

An example of an Apparent Power calculation
The Voltage channel fundamental frequency output is 109 V on the 168 V range, at 60 Hz. A 15 V 3rd harmonic has been added. The current channel output is 7 A at 60 Hz on the 10 A range with 3rd and 5th harmonics at 0.7 A and 0.3 A respectively. Phase angles are not relevant to the calculation of apparent power. Voltage uncertainty values are given in the 'Voltage amplitude specifications' table on page 3, Current uncertainty values are given in the 'Current amplitude specifications' table on page 5.

The voltage RMS value is $\sqrt{109^2 + 15^2} = 110.02727\ V$

Accuracy contribution from the voltage fundamental:
112 ppm of 109 V + 4.4 mV = (109 x 0.000112) + 0.0044 = 0.012208 + 0.0044 = 0.016608 V
Modified by the sensitivity coefficient = 0.016608 x 109 ÷ 110.02727 = 0.016453 V

Accuracy contribution from the voltage 3rd harmonic:
122 ppm of 15 V + 4.4 mV = (15 x 0.000112) + 0.0044 = 0.01830 + 0.0044 = 0.006230 V
Modified by the sensitivity coefficient = 0.006230 x 15 ÷ 110.02727 = 0.000849 V

Combined voltage uncertainty:

$$\frac{u(V_{RMS})}{V_{RMS}} = \frac{0.016453 + 0.000849}{110.02727} = 0.000157$$

(or 157 ppm).

The current RMS value is $\sqrt{7^2 + 0.7^2 + 0.3^2} = 7.041307$

Accuracy contribution from the current fundamental:
164 ppm of 7 A + 240 µA = (7 x 0.000164) + 0.000240 = 0.001148 + 0.000240 = 0.001388
Modified by the sensitivity coefficient = 0.001388 x 7 ÷ 7.041307 = 0.001380 A

Accuracy contribution from the current 3rd harmonic:
191 ppm of 0.7 A + 240 µA = (0.7 x 0.000191) + 0. 000240 = 0.000134 + 0.000240 = 0.000374
Modified by the sensitivity coefficient = 0. 000374 x 0.7 ÷ 7.041307 = 0.000037 A

Accuracy contribution from the current 5th harmonic:
191ppm of 0.3 A + 240 µA = (0.3 x 0.000191) + 0. 000240 = 0.000058 + 0.000240 = 0.000297
Modified by the sensitivity coefficient = 0. 000297 x 0.3 ÷ 7.041307 = 0.000013 A

Calculating Power and Power phenomena

Combined current uncertainty:

$$\frac{u(I_{RMS})}{I_{RMS}} = \frac{0.001388 + 0.000037 + 0.000013}{7.041307} = 0.000204$$

(or 204 ppm).

Now, $S^2 = V_{RMS}^2 I_{RMS}^2 = 110.02727 \times 7.041307 = 774.7358 \ VA$

Apparent Power uncertainty:

$$\frac{u(S)}{S} = \sqrt{[\frac{u(V_{RMS})}{V_{RMS}}]^2 + [\frac{u(I_{RMS})}{I_{RMS}}]^2} = \sqrt{0.000157^2 + 0.000204^2} = 0.0002574$$

giving: $u_c^{\ 2}(S) = 0.0002574 \times 774.735748 = 0.1994 \ VA$

$Apparent\ Power\ Accuracy = 774.7358 \pm 0.1994 \ VA$

Power (P) accuracy calculations

Real power is the sum of the products of volt/current/phase accuracy at each harmonic frequency.

$P = \sum V_n I_n \cos\Phi_n$ Watts, where n is the harmonic order of the components.

Calculation of power accuracy uses the same techniques shown previously. The uncorrelated uncertainty components of voltage, current and phase are combined using root sum of squares for each frequency.

$$\frac{u^2(P_f)}{P_f^{\ 2}} = [\frac{u(V_f)}{V_f}]^2 + [\frac{u(I_f)}{I_f}]^2 + [\frac{u(phase_f)}{phase_f}]^2$$

where $u(x)$ is the uncertainty of the component x and $phase$ is the phase angle between the current and voltage at frequency f. It is easiest to express each of these contributions as ppm.

The contribution of phase angle accuracy varies with the set phase angle as shown below.

$$u(phase) = 1 - \frac{\cos(\Phi + u(\text{Æ}))}{\cos\Phi}$$

where Φ is the set phase angle and $u(\text{Æ})$ is the phase accuracy.

The power uncertainties for each frequency, modified by the appropriate sensitivity coefficient *ci*, are then linearly summed to give the combined uncertainty *uc* (linearly summed because voltage components are correlated, as are those of current and phase).

$$u_c(P) = \sum_{i=1}^{N} c_i u(P_i)$$

A Power calculation example

Voltage channel output is 109 V on the 168 V range at 60 Hz with 3rd harmonic at 15 V. The voltage 3rd harmonic has 0 ° phase angle relative to the voltage fundamental.

The current channel output is 7 A on the 10 A range at 60 Hz with 3rd and 5th harmonics at 0.7 A and 0.3 A respectively. The current fundamental phase angle is 12 ° relative to the voltage fundamental. The current 3rd harmonic has a phase angle of +25 ° relative to the current fundamental, i.e. the phase angle between the 3rd current harmonic and the 3rd voltage harmonic is 25 ° + (3 x 12 °) = 61 °. As the current 5th harmonic is not matched by a voltage 5th harmonic, there is no 5th harmonic power contribution.

Voltage uncertainty values are given in the 'Voltage amplitude specifications' table on page 3, Current uncertainty values are given in in the 'Current amplitude specifications' table on page 5 and those for phase are given in the 'Current to Voltage Phase specifications' table on page 7.

Calculating Power and Power phenomena

Converting all values to ppm, accuracy contribution at the fundamental frequency:

$$u(V_1) = 112\ ppm + \frac{0.0044\ \ V \times 10^6}{109\ \ V} = 152\ ppm$$

$$u(I_1) = 164\ ppm + \frac{0.00024\ \ A \times 10^6}{7\ \ A} = 198\ ppm$$

$$u(phase_1) = 1 - \frac{\cos(12 + 0.004)}{\cos(12)} \times 1e6 = 15\ ppm$$

Combined accuracy for the fundamental frequency components:

$$u(P_1) = \sqrt{152^2 + 198^2 + 15^2} = 250\ ppm$$

Power in the fundamental frequency:

$P_1 = V_1 I_1 \cos\Phi_1 = 109 \times 7 \times 0.9781476 = 746.3266$ *Watts* so:

$u(P_1) = 250 \times 10^{-6} \times 746.3266 = 0.1866$ *Watts*

Accuracy contribution for the 3rd harmonic:

$$u(V_3) = 122\ ppm + \frac{0.0044\ \ V \times 10^6}{15\ \ V} = 415\ ppm$$

$$u(I_3) = 191\ ppm + \frac{0.00024\ \ A \times 10^6}{0.7\ \ A} = 534\ ppm$$

$$u(phase_3) = 1 - \frac{\cos(61 + 0.023)}{\cos(61)} \times 1e6 = 724\ ppm$$

Combined accuracy for the 3rd harmonic components:

$$u(P_3) = \sqrt{415^2 + 534^2 + 724^2} = 991\ ppm$$

Power in the 3rd harmonic components:

$P_3 = V_3 I_3 \cos\Phi_3 = 15 \times 0.7 \times 0.484810 = 5.0905$ *Watts* so:

$u(P_3) = 991 \times 10^{-6} \times 5.0905 = 0.005045$ *Watts*

Total $P = P_1 + P_2 = 746.3266 + 5.0905 = 751.4171$ power Watts

From:

$$u_c(P) = \sum_{i=1}^{N} c_i u(P_i)$$

$$u_c(P) = \frac{746.3266}{751.4171} \times 0.1866 + \frac{5.0905}{751.4171} \times 0.005045 = 0.1854\ \ Watts$$

Power Accuracy $= 751.4171 \pm 0.1854$ *Watts*

Ordering information

Model

6100A Electrical Power Standard Master comprises:

- One phase, (one voltage channel to 1000 V, one current channel to 20 A)
- User controls and display system
- Interfacing via GPIB/RS232
- Interfacing to Auxiliary Unit
- Line cord
- Lead kit
- User manual

6101A Auxiliary Power Standard comprises:

- One phase, (one voltage channel to 1000 V, one current channel to 20 A)
- Cable and interfacing to connect to Master
- Line cord
- Lead kit
- User manual

Accessories

6100-CASE
6100A/6101A Transit case

Y6100
6100A/6101A Rack Mount Kit

Complete systems

6120A complete 2-phase system comprises:

- One 6100A
- One 6101A

6130A complete 3-phase system comprises:

- One 6100A
- Two 6101As

6140A complete 4-phase system comprises:

- One 6100A
- Three 6101As

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