Understanding Potentiostat Specifications

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GAMRY INSTRUMENTS

Goals for today

- Leave here knowing how to read specifications and what they mean for your results.
- Understand what specifications are important

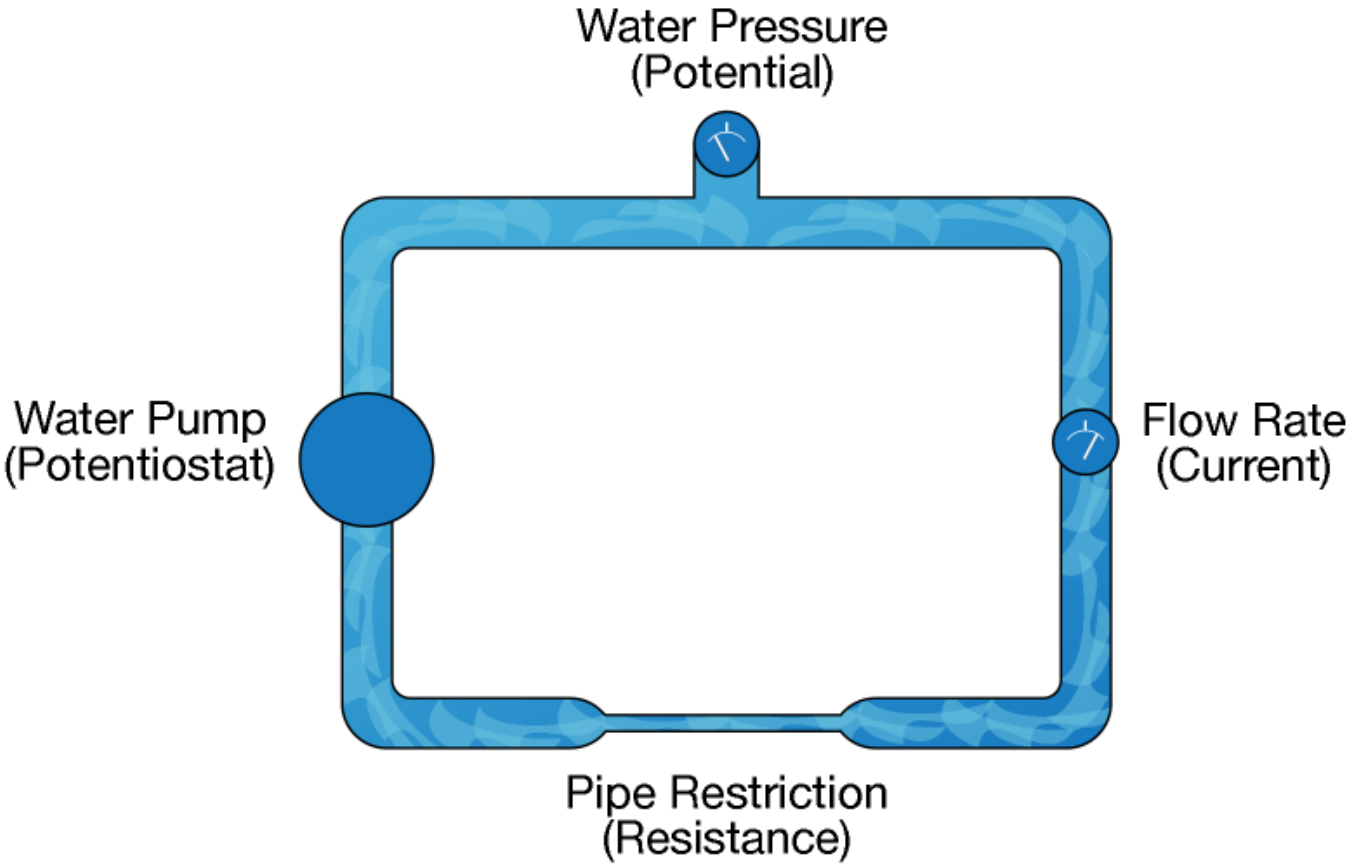
POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

	Reference 3000/3000AE	Reference 600+	Interface 5000	Interface 1010
SYSTEM				
Cell Connections	2, 3, 4, 5 or 21*	2, 3, 4, or 5	2, 3, 4, or 5	2, 3, 4, or 5
Maximum Current	± 3A @ 15 V or ± 1.5 A @32 V	±600 mA	± 5 A	±1 A
Current Ranges	11 (300 pA–3 A)	11 (60 pA–600 mA)	6 (50 µA–5 A)	9 (10 nA–1 A)
Current Ranges (Including Internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum Timebase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms
CONTROL AMPLIFIER				
Compliance	±32 V @ 1.5 A	±22 V	±8.5 / ±2.5 V	±22 V
Output Current	> ±3 A	> ±600 mA	> ±5 A	> ±1 A
Speed Settings	5	5	5	5
Unity Gain Bandwidth	1100, 330, 50, 5.0, 0.5 kHz	2500, 1100, 335, 50, 5.2, 0.5 kHz	1050, 250, 43, 4.4, 0.5 kHz	1100, 320, 39, 4, 0.4 kHz
EIS MEASUREMENT				
EIS	10 µHz–1 MHz	10 µHz–5 MHz	10 µHz–1 MHz	10 µHz–2 MHz
Voltage AC amplitude	3 V max	3 V max	3 V max	3 V max
Current AC amplitude	3 A max	600 mA max	5 A max	1 A max
Accuracy	1% @ 0.5 mΩ	1% @ 1 mΩ	1% @ 0.5 mΩ	1% @ 0.8 mΩ
ELECTROMETER				
Input Impedance	> 10^{14} Ω ‖ < 0.2 pF	> 10^{14} Ω ‖ < 0.2 pF	> 10^{12} Ω ‖ < 2 pF	> 2 × 10^{12} Ω ‖ < 0.3 pF
Input Current (typical)	< 6 pA	< 10 pA	< 25 pA	< 25 pA
Bandwidth	> 15 MHz at –3 dB	> 15 MHz at –3 dB	> 12 MHz at –3 dB	> 15 MHz at –3 dB
Common Mode Rejection Ratio (CMRR)	> 80 dB (100 kHz), > 60 dB (1 MHz)	> 65 dB (1 MHz)	> 98 dB (10 kHz), > 88 dB (100 kHz)	> 86 dB (10 kHz), > 60 dB (1 MHz)
POTENTIAL				
Applied Accuracy	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting
Applied Resolution	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit
Measured Accuracy	±1 mV ± 0.2% of reading	±1 mV ± 0.2% of reading	±0.5 mV ± 0.2% of reading	±1 mV ± 0.3% of reading
Measured Resolution	High-resolution Electrometer: 400 µV, 100 µV, 10 µV, 1 µV/bit High-voltage Electrometer: 1.6 mV, 400 µV, 40 µV, 4 µV/bit	400 µV, 100 µV, 10 µV, 1 µV/bit	200 µV, 20 µV, 2 µV/bit	400 µV, 100 µV, 10 µV, 1 µV/ bit
CURRENT				
Applied/Measured Accuracy	±5 pA ± 0.05% of range ± 0.2% of value (3 A–3 nA) or 0.5% of value (300 pA)	±10 pA ± 0.05% of range ± 0.2% of value (600 mA–6 nA) or 0.75% of value (600 pA) or 1.5% of value (60 pA)	±25 pA ± 0.05% of range ± 0.2% of value	±10 pA ± 0.05% of range ± 0.3% of value
Applied/Measured Resolution	0.003% full-scale/bit	0.003% full-scale/bit	0.003% full-scale/bit	0.003% full-scale/bit
Bandwidth	> 10 MHz (3 A–3 mA), > 0.15 MHz (30 µA)	> 10 MHz (600 mA–600 µA), > 0.15 MHz (6 µA)	> 5 MHz (5 mA)	> 1.5 MHz (10 µA), > 0.15 MHz (1 µA)

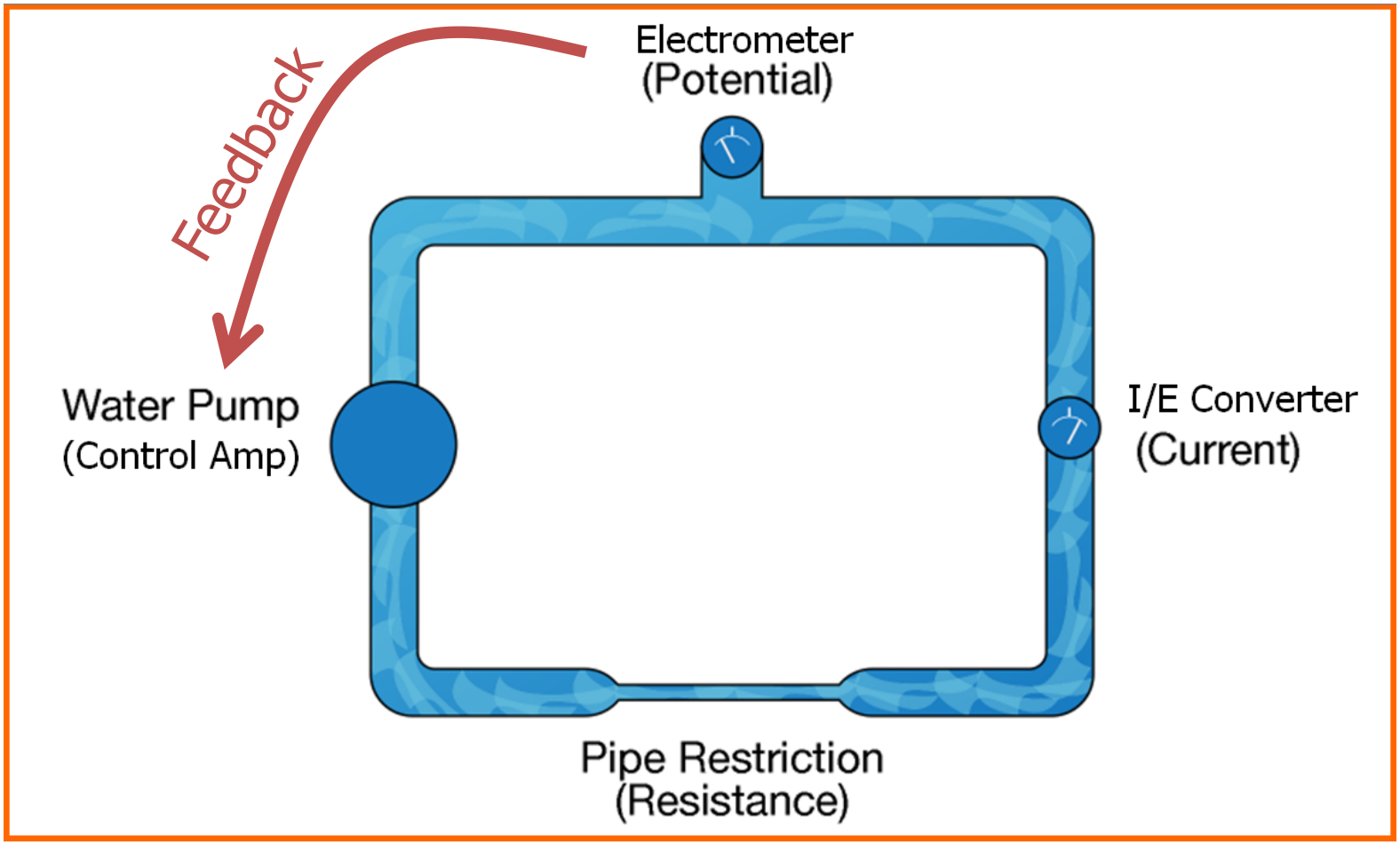
What is a Potentiostat?

- A potentiostat is an instrument that measures and controls the potential difference between a Working Electrode and a Reference Electrode.
- Measures the current flow between the Working and Counter Electrodes.

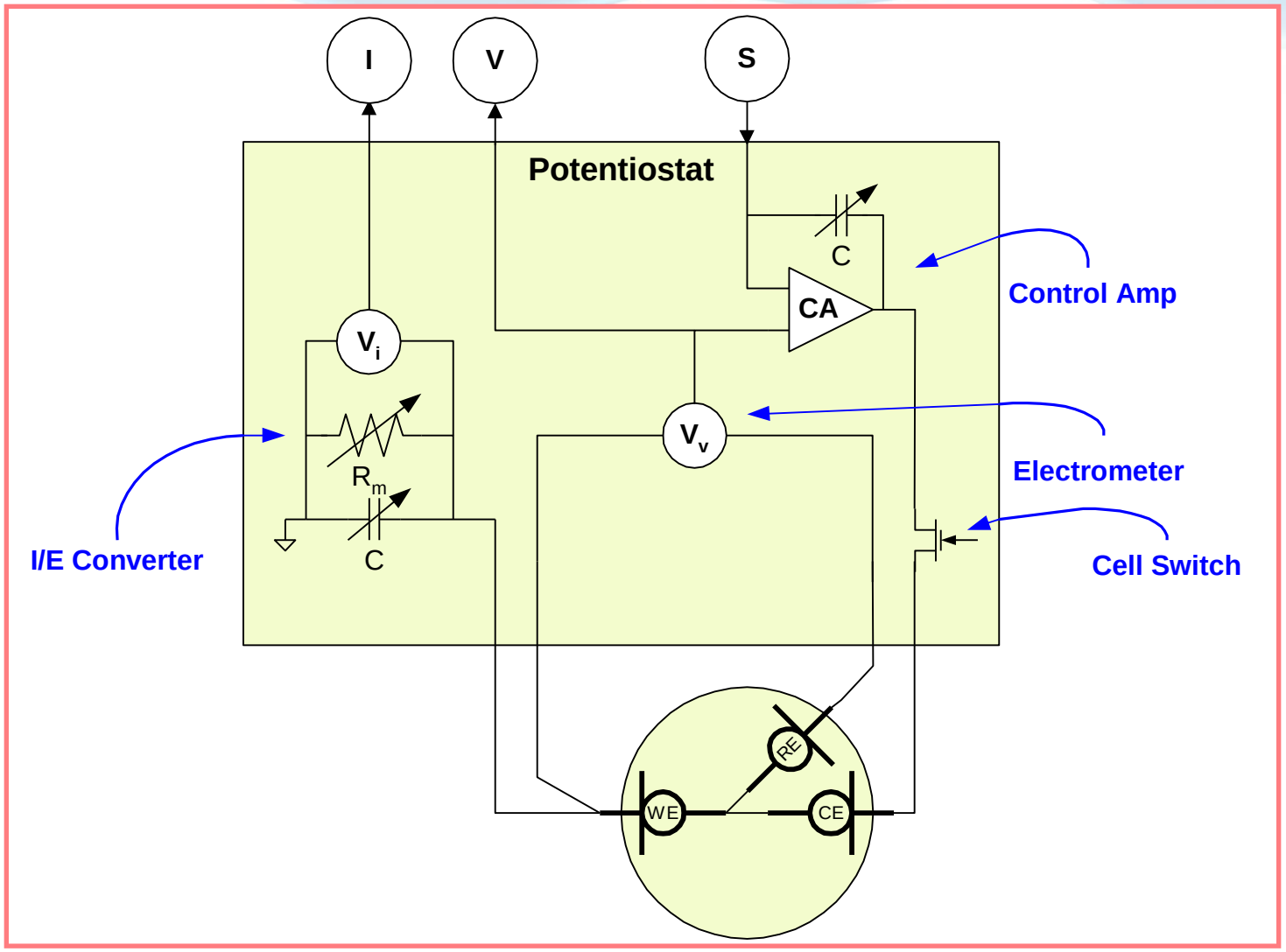
Potentiostat as a Water Circuit



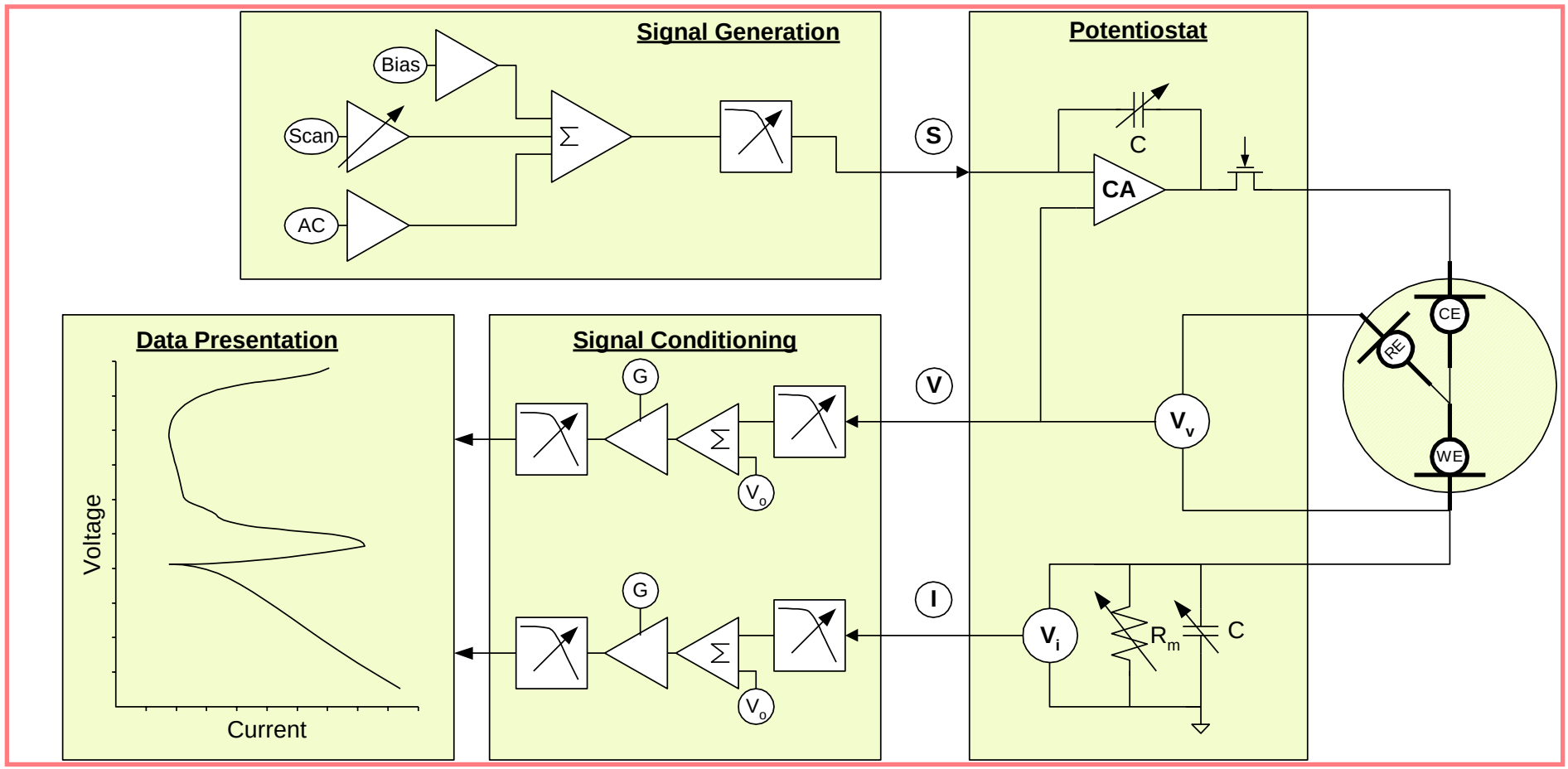
Water Circuit with Feedback



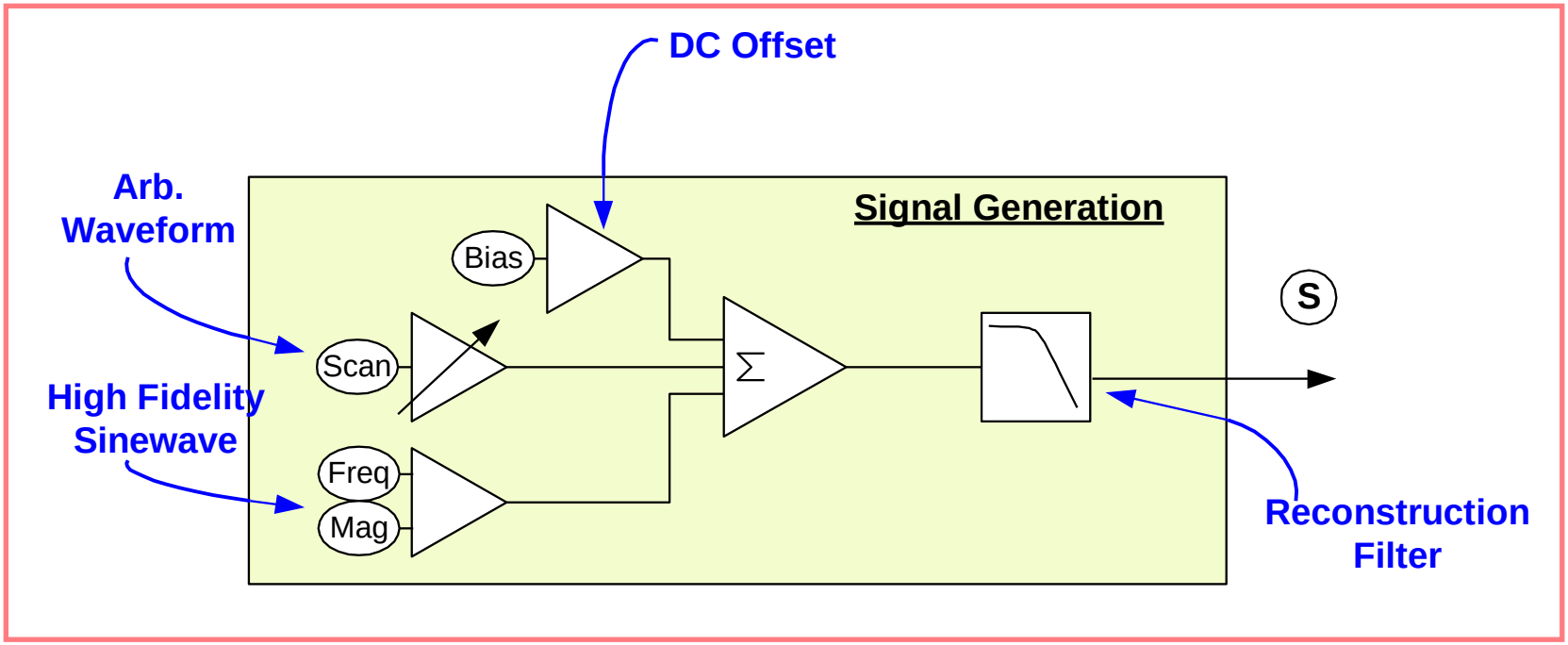
The Analog Potentiostat



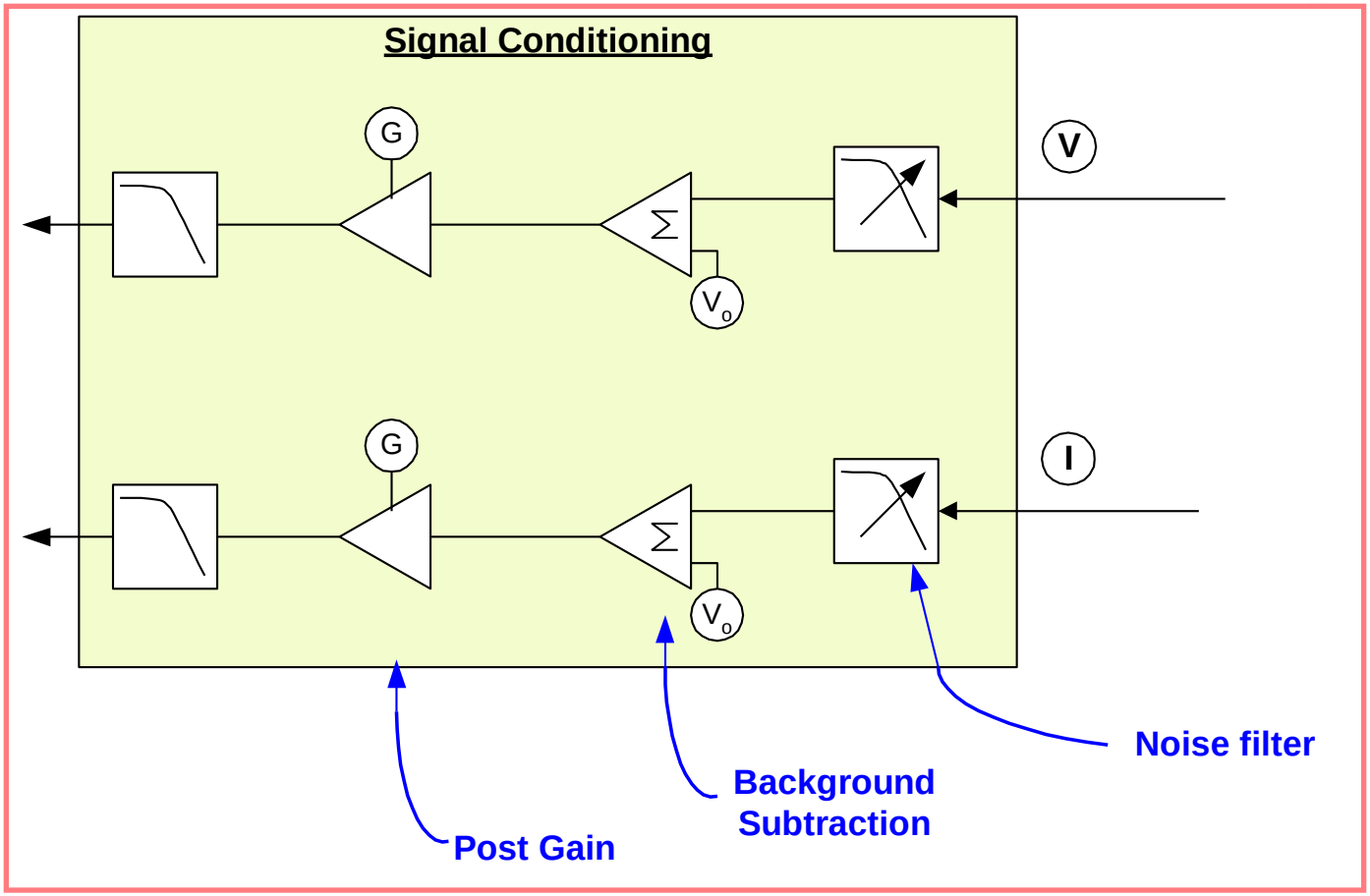
Need to have signal input and measurement output



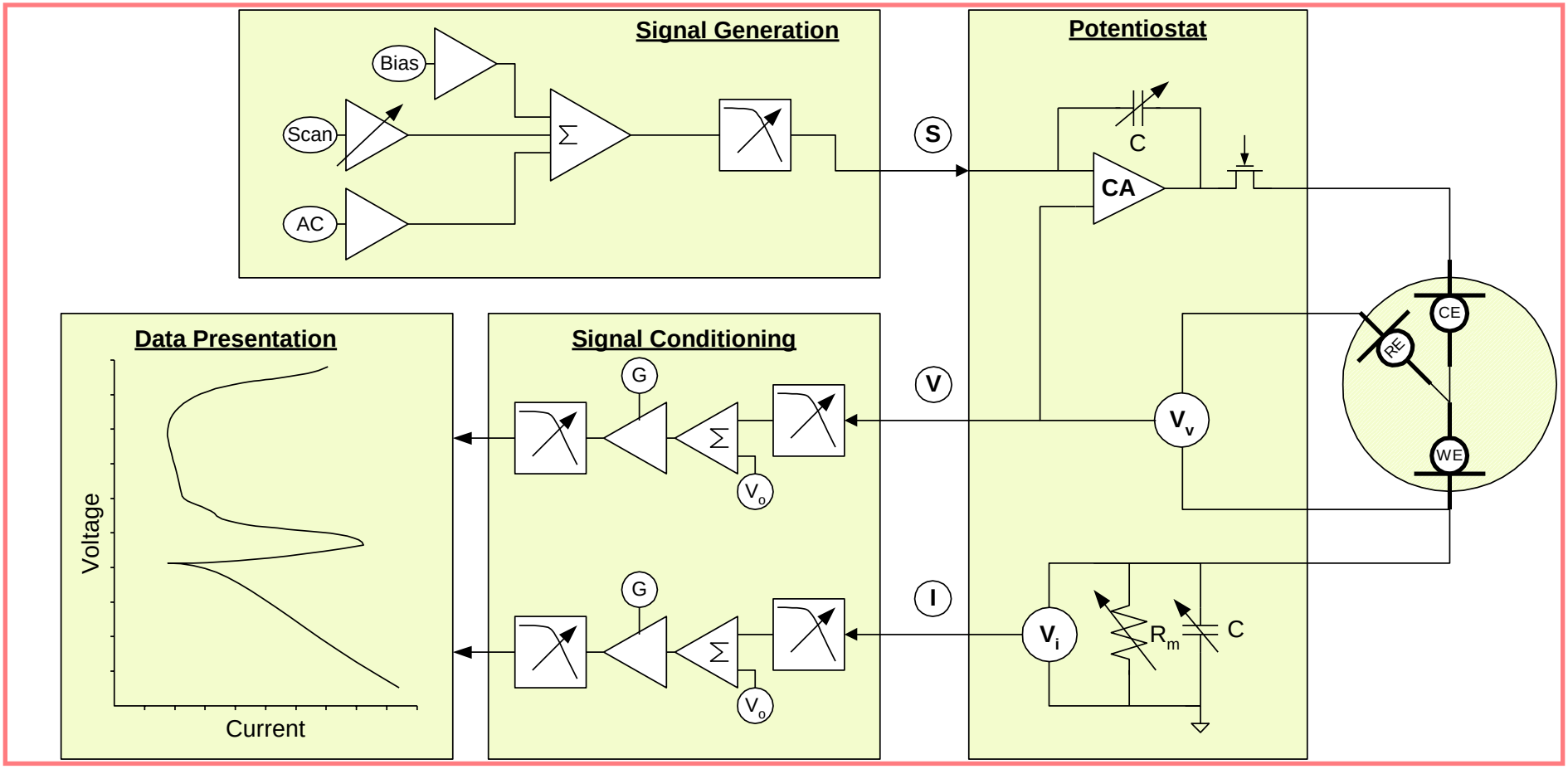
Signal Generation



Signal Conditioning



Putting It Back Together



Reading Specifications

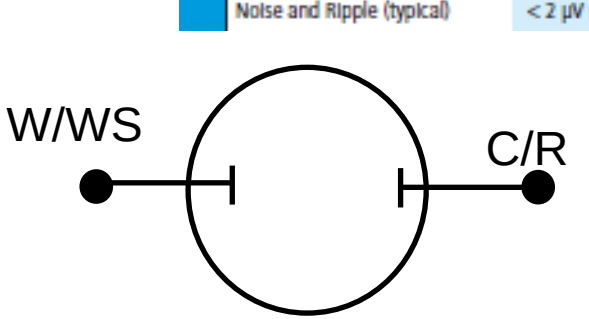
POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

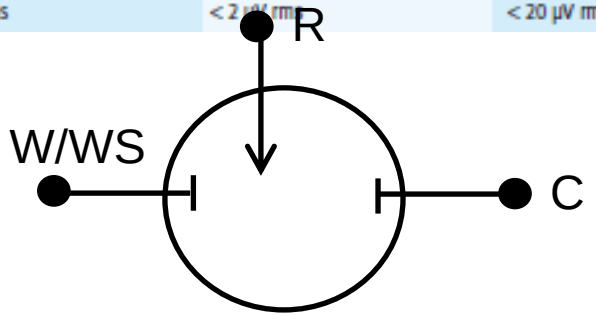
	Reference 3000/3000AE	Reference 600+	Interface 5000	Interface 1010
SYSTEM				
Cell Connections	2, 3, 4, 5 or 21*	2, 3, 4, or 5	2, 3, 4, or 5	2, 3, 4, or 5
Maximum Current	± 3A @ 15 V or ± 1.5 A @32 V	±600 mA	± 5 A	±1 A
Current Ranges	11 (300 pA–3 A)	11 (60 pA–600 mA)	6 (50 µA–5 A)	9 (10 nA–1 A)
Current Ranges (Including Internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum Timebase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms
CONTROL AMPLIFIER				
Compliance	±32 V @ 1.5 A	±22 V	±8.5 / ±2.5 V	±22 V
Output Current	> ±3 A	> ±600 mA	> ±5 A	> ±1 A
Speed Settings	5	5	5	5
Unity Gain Bandwidth	1100, 330, 50, 5.0, 0.5 kHz	2500, 1100, 335, 50, 5.2, 0.5 kHz	1050, 250, 43, 4.4, 0.5 kHz	1100, 320, 39, 4, 0.4 kHz
EIS MEASUREMENT				
EIS	10 µHz–1 MHz	10 µHz–5 MHz	10 µHz–1 MHz	10 µHz–2 MHz
Voltage AC amplitude	3 V max	3 V max	3 V max	3 V max
Current AC amplitude	3 A max	600 mA max	5 A max	1 A max
Accuracy	1% @ 0.5 mΩ	1% @ 1 mΩ	1% @ 0.5 mΩ	1% @ 0.8 mΩ
ELECTROMETER				
Input Impedance	$> 10^{14}$ Ω ‖ < 0.2 pF	$> 10^{14}$ Ω ‖ < 0.2 pF	$> 10^{12}$ Ω ‖ < 2 pF	$> 2 \times 10^{13}$ Ω ‖ < 0.3 pF
Input Current (typical)	< 6 pA	< 10 pA	< 25 pA	< 25 pA
Bandwidth	> 15 MHz at –3 dB	> 15 MHz at –3 dB	> 12 MHz at –3 dB	> 15 MHz at –3 dB
Common Mode Rejection Ratio (CMRR)	> 80 dB (100 kHz), > 60 dB (1 MHz)	> 65 dB (1 MHz)	> 98 dB (10 kHz), > 88 dB (100 kHz)	> 86 dB (10 kHz), > 60 dB (1 MHz)
POTENTIAL				
Applied Accuracy	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting
Applied Resolution	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit
Measured Accuracy	±1 mV ± 0.2% of reading	±1 mV ± 0.2% of reading	±0.5 mV ± 0.2% of reading	±1 mV ± 0.3% of reading
Measured Resolution	High-resolution Electrometer: 400 µV, 100 µV, 10 µV, 1 µV/bit High-voltage Electrometer: 1.6 mV, 400 µV, 40 µV, 4 µV/bit	400 µV, 100 µV, 10 µV, 1 µV/bit	200 µV, 20 µV, 2 µV/bit	400 µV, 100 µV, 10 µV, 1 µV/ bit
CURRENT				
Applied/Measured Accuracy	±5 pA ± 0.05% of range ± 0.2% of value (3 A–3 nA) or 0.5% of value (300 pA)	±10 pA ± 0.05% of range ± 0.2% of value (600 mA–6 nA) or 0.75% of value (600 pA) or 1.5% of value (60 pA)	±25 pA ± 0.05% of range ± 0.2% of value	±10 pA ± 0.05% of range ± 0.3% of value
Applied/Measured Resolution	0.003% full-scale/bit	0.003% full-scale/bit	0.003% full-scale/bit	0.003% full-scale/bit
Bandwidth	> 10 MHz (3 A–3 mA), > 0.15 MHz (30 µA)	> 10 MHz (600 mA–600 µA), > 0.15 MHz (6 µA)	> 5 MHz (5 mA)	> 1.5 MHz (10 µA), > 0.15 MHz (1 µA)

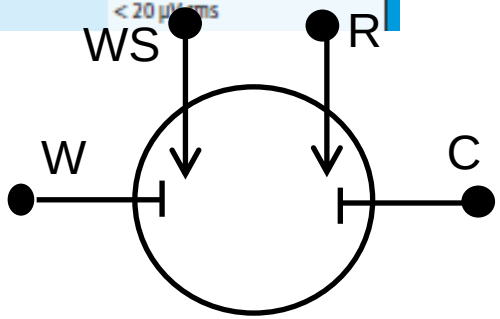
Cell Connections

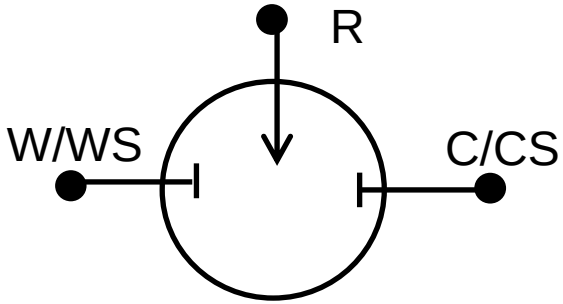
POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

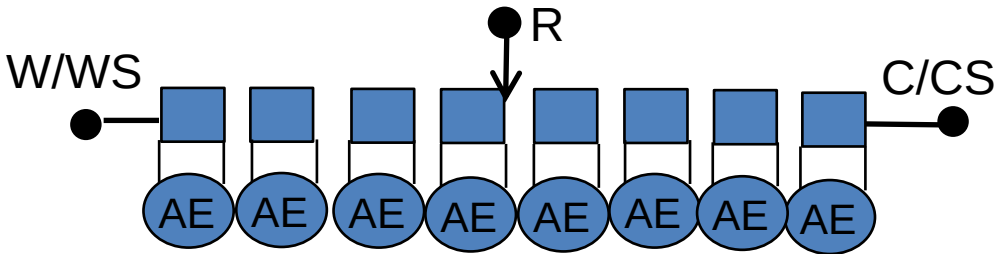
	Reference 3000/3000AE	Reference 600+	Interface 5000	Interface 1010
SYSTEM				
Cell Connections	2, 3, 4, 5 or 21+	2, 3, 4, or 5	2, 3, 4, or 5	2, 3, 4, or 5
Maximum Current	± 3A @ 15 V or ± 1.5 A @32 V	±600 mA	± 5 A	±1 A
Current Ranges	11 (300 pA–3 A)	11 (60 pA–600 mA)	6 (50 µA–5 A)	9 (10 nA–1 A)
Current Ranges (Including Internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum Timebase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms











Broad System Specifications

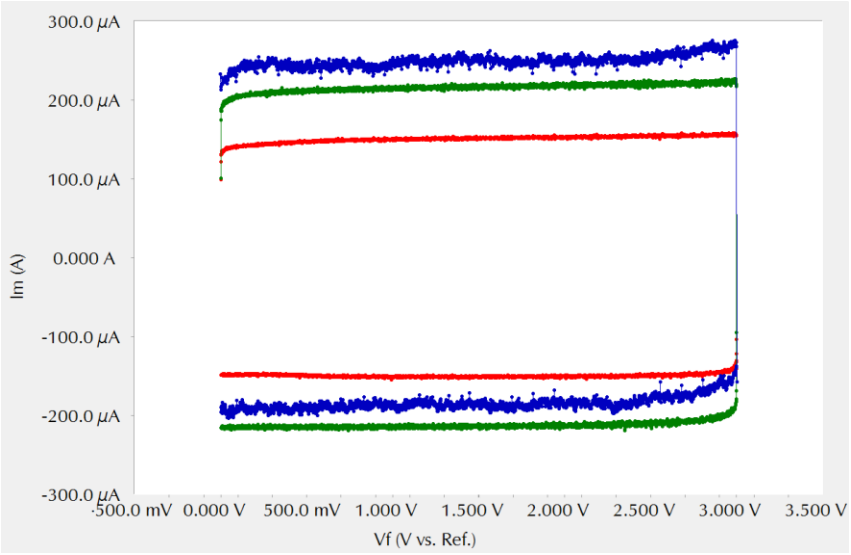
POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

	Reference 3000/3000AE	Reference 600+	Interface 5000	Interface 1010
SYSTEM				
Cell Connections	2, 3, 4, 5 or 21*	2, 3, 4, or 5	2, 3, 4, or 5	2, 3, 4, or 5
Maximum Current	± 3A @ 15 V or ± 1.5 A @32 V	±600 mA	± 5 A	±1 A
Current Ranges	11 (300 pA–3 A)	11 (60 pA–600 mA)	6 (50 µA–5 A)	9 (10 nA–1 A)
Current Ranges (including internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum Timebase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms

- Maximum Current – What is the maximum applied or measured current?
- Current Ranges – How many current ranges (I/E converters) are there?
  - Important for scanning experiments where currents can vary span magnitudes during a scan. Usually most important during corrosion experiments
  - Internal Gain – Some signals can be gained to increase signal. Increases noise but this can be somewhat offset with oversampling
- Minimum Current Resolution – Minimum current range divided by number of bits. This number is well below the noise level of the instrument

Understanding Current Ranges

- More real current ranges is better.
- Ex - cyclic voltammetry of a supercapacitor using different current ranges. Blue – less sensitive range, green – correct range, red – too sensitive (overloads)
- Gained ranges can be useful but you're also gaining noise.

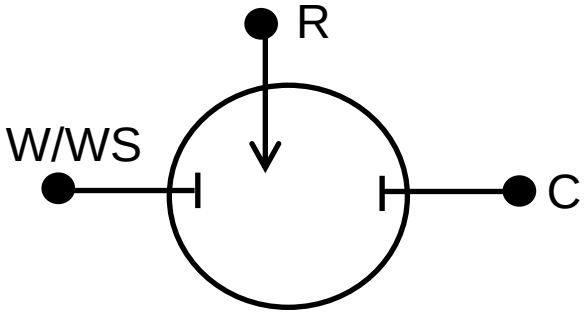


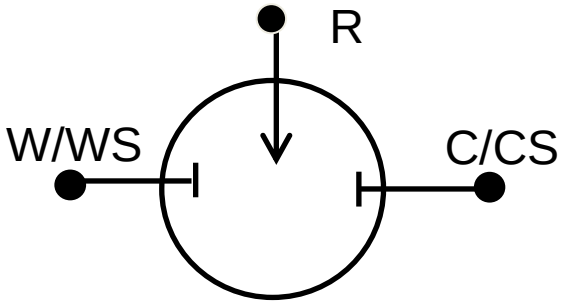
Maximum Applied Potential

POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

	Reference 3000/3000AE	Reference 600+	Interface 5000	Interface 1010
SYSTEM				
Cell Connections	2, 3, 4, 5 or 21*	2, 3, 4, or 5	2, 3, 4, or 5	2, 3, 4, or 5
Maximum Current	± 3A @ 15 V or ± 1.5 A @32 V	±600 mA	± 5 A	±1 A
Current Ranges	11 (300 pA–3 A)	11 (60 pA–600 mA)	6 (50 µA–5 A)	9 (10 nA–1 A)
Current Ranges (Including Internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum Timebase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms

- Maximum Applied Potential – What is the largest voltage that the potentiostat can apply. For a typical three-electrode setup, it is the potential between the working and reference.



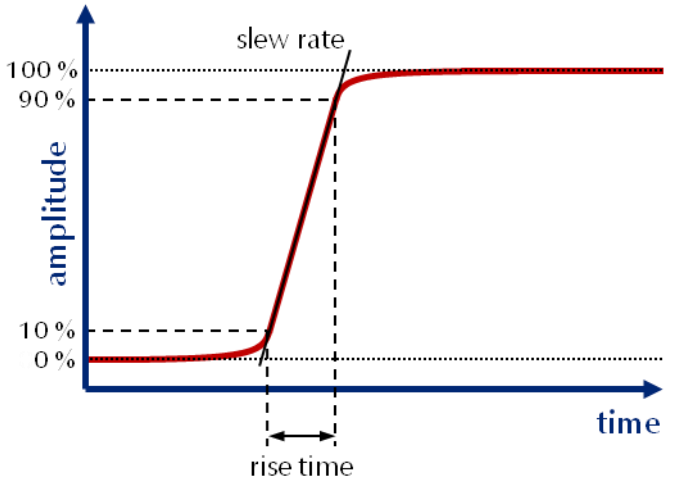


Rise time

POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

	Reference 3000/3000AE	Reference 600+	Interface 5000	Interface 1010
SYSTEM				
Cell Connections	2, 3, 4, 5 or 21+	2, 3, 4, or 5	2, 3, 4, or 5	2, 3, 4, or 5
Maximum Current	± 3A @ 15 V or ± 1.5 A @32 V	±600 mA	± 5 A	±1 A
Current Ranges	11 (300 pA–3 A)	11 (60 pA–600 mA)	6 (50 µA–5 A)	9 (10 nA–1 A)
Current Ranges (Including Internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum TimeBase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms

- Rise Time – How fast does the applied signal rise or fall between 10 and 90% of the signal's amplitude.
- Especially important in rapid pulsing or EIS experiments



Noise and Ripple

POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

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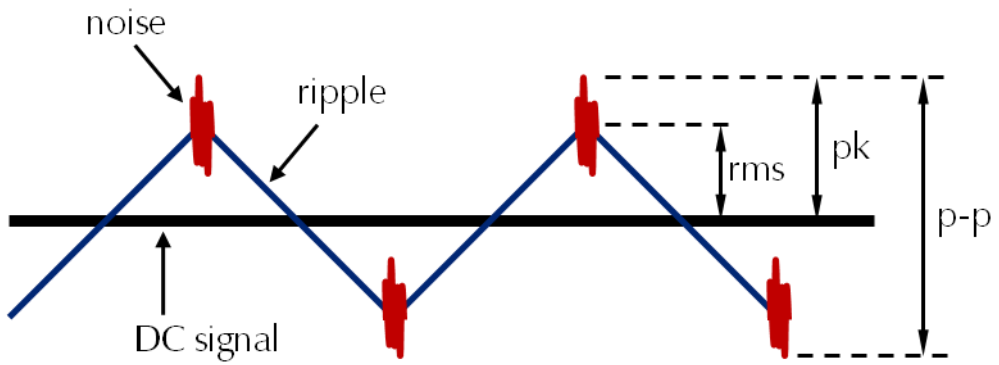
Current Ranges (Including Internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum Timebase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms

- Noise and Ripple – Noise of CA output signal. DC signals applied by the CA are always superimposed by a very small AC signal.



Data acquisition rates

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Maximum Current	± 3A @ 15 V or ± 1.5 A @32 V	±600 mA	± 5 A	±1 A
Current Ranges	11 (300 pA–3 A)	11 (60 pA–600 mA)	6 (50 µA–5 A)	9 (10 nA–1 A)
Current Ranges (Including Internal gain)	13	13	8	11
Minimum Current Resolution	92 aA	20 aA	150 pA	3.3 fA
Maximum Applied Potential	±32 V	±11 V	±6 V	±12 V
Rise Time	< 250 ns	< 250 ns	< 1 µs	< 1 µs
Minimum Timebase	3.333 µs	3.333 µs	10 µs	10 µs
Noise and Ripple (typical)	< 2 µV rms	< 2 µV rms	< 20 µV rms	< 20 µV rms

- Minimum Timebase/Acquisition Time – Typically this is how fast an instrument can sample
- Can be used to calculate a maximum scan rate for CV

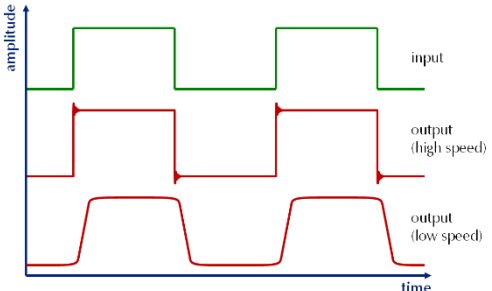
$$Scan\ rate = \frac{step\ size}{minimum\ timebase}$$

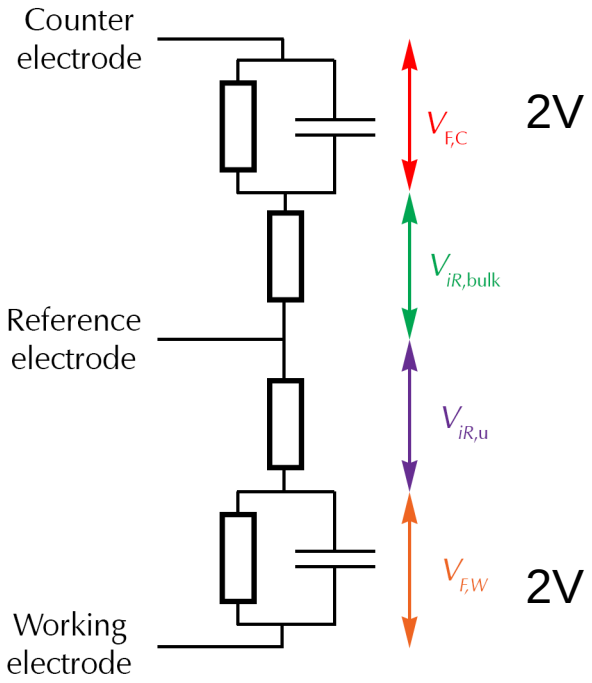
Ref600+ SR $SR = \frac{10\ mV}{3.333us} = 3000V/s$

Control Amplifier

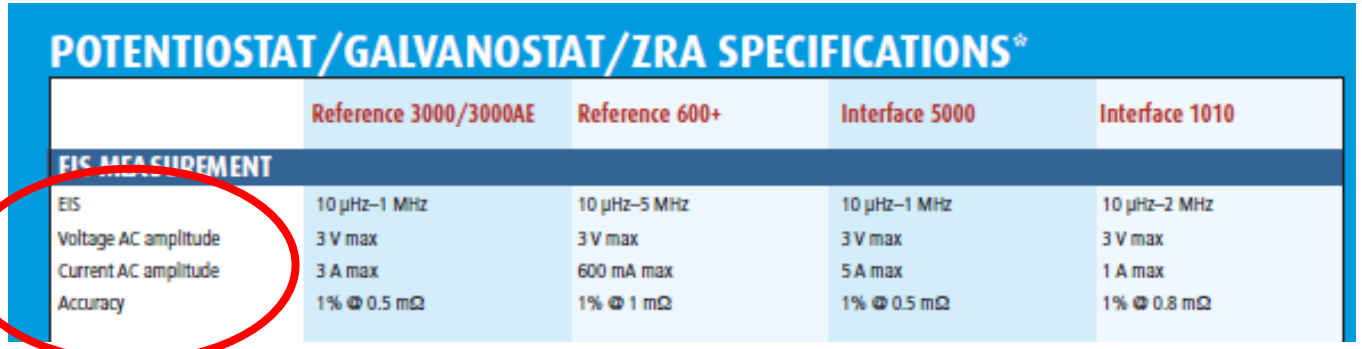
CONTROL AMPLIFIER				
Compliance	± 32 V	± 22 V	± 8.5 / ± 2.5 V	± 22 V
Output Current	> ±3 A	> ± 600 mA	> ± 5 A	> ± 1 A
Speed Settings	5	5	5	5
Unity Gain Bandwidth	1100, 330, 50, 5.0, 0.5 kHz	980, 260, 40, 4, 0.4 kHz	1050, 250, 43, 4.4, 0.5 kHz	1100, 320, 39, 4, 0.4 kHz
EIS MEASUREMENT				
EIS	10 µHz - 1 MHz	10 µHz - 5 MHz	10 µHz - 1 MHz	10 µHz - 1 MHz
Voltage AC amplitude	3 V max	3 V max	3 V max	3 V max

- Compliance Voltage – Maximum voltage that can be applied by CA between counter and working electrodes. Put another way, this is the maximum voltage the counter electrode can apply to obtain the desired voltage at the working.
  - Specifications in manual should specify current and load at which voltage is measured
- Speed settings – allows you to speed up or slow down the CA response





EIS Measurements

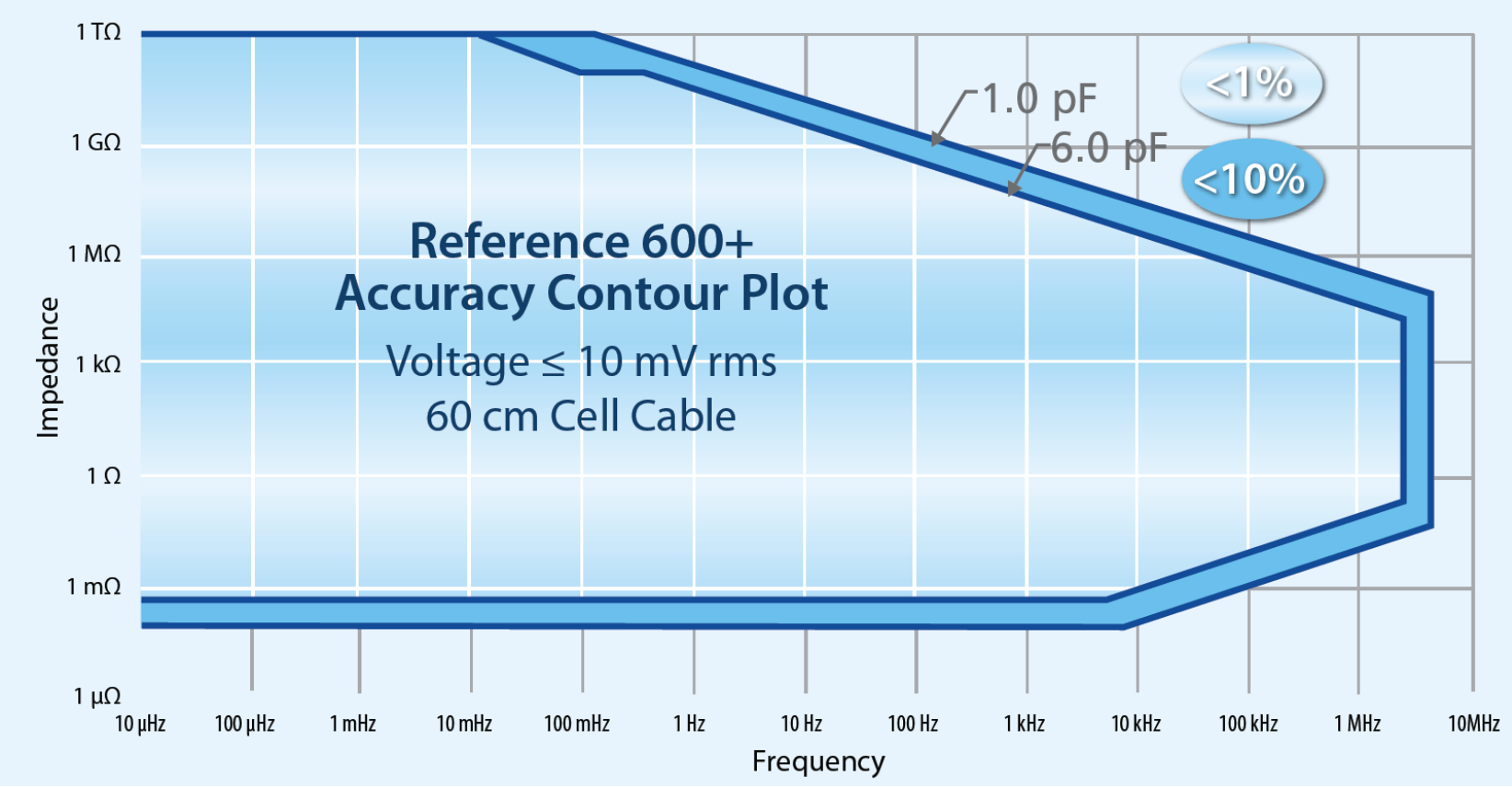


POTENTIOSTAT/GALVANOSTAT/ZRA SPECIFICATIONS*

	Reference 3000/3000AE	Reference 600+	Interface 5000	Interface 1010
EIS MEASUREMENT				
EIS	10 µHz–1 MHz	10 µHz–5 MHz	10 µHz–1 MHz	10 µHz–2 MHz
Voltage AC amplitude	3 V max	3 V max	3 V max	3 V max
Current AC amplitude	3 A max	600 mA max	5 A max	1 A max
Accuracy	1% @ 0.5 mΩ	1% @ 1 mΩ	1% @ 0.5 mΩ	1% @ 0.8 mΩ

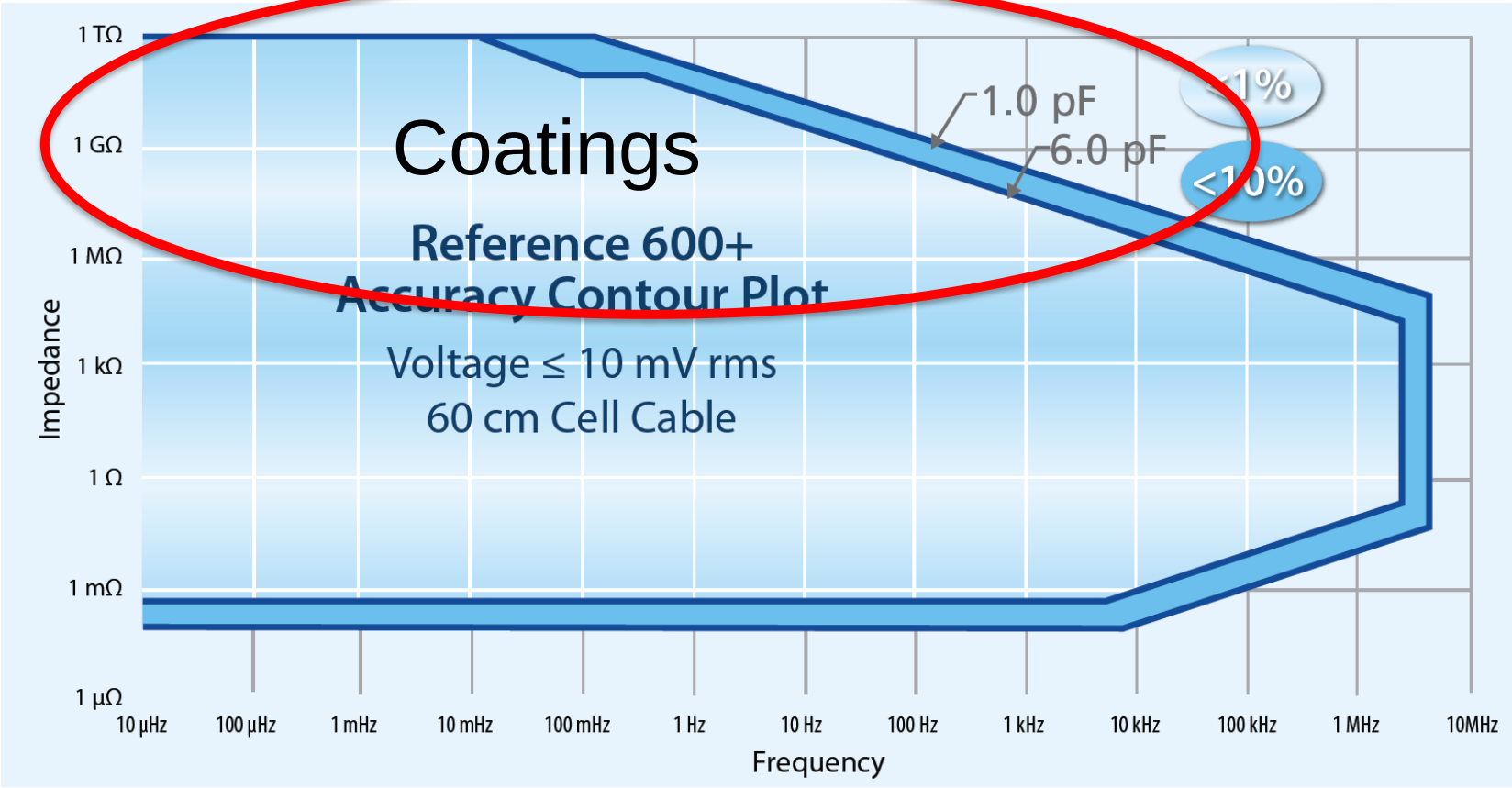
- EIS – Frequency range for that instrument
- Voltage AC amplitude – the largest AC signal that can be applied. Sometimes these are specified as Peak-to-Peak (P-P) or max
- Accuracy – how accurate an instrument is. Usually these specify the lowest impedance and at what percent error.
- For full Accuracy Specifications, look at the Accuracy Contour Plot.

EIS Measurements



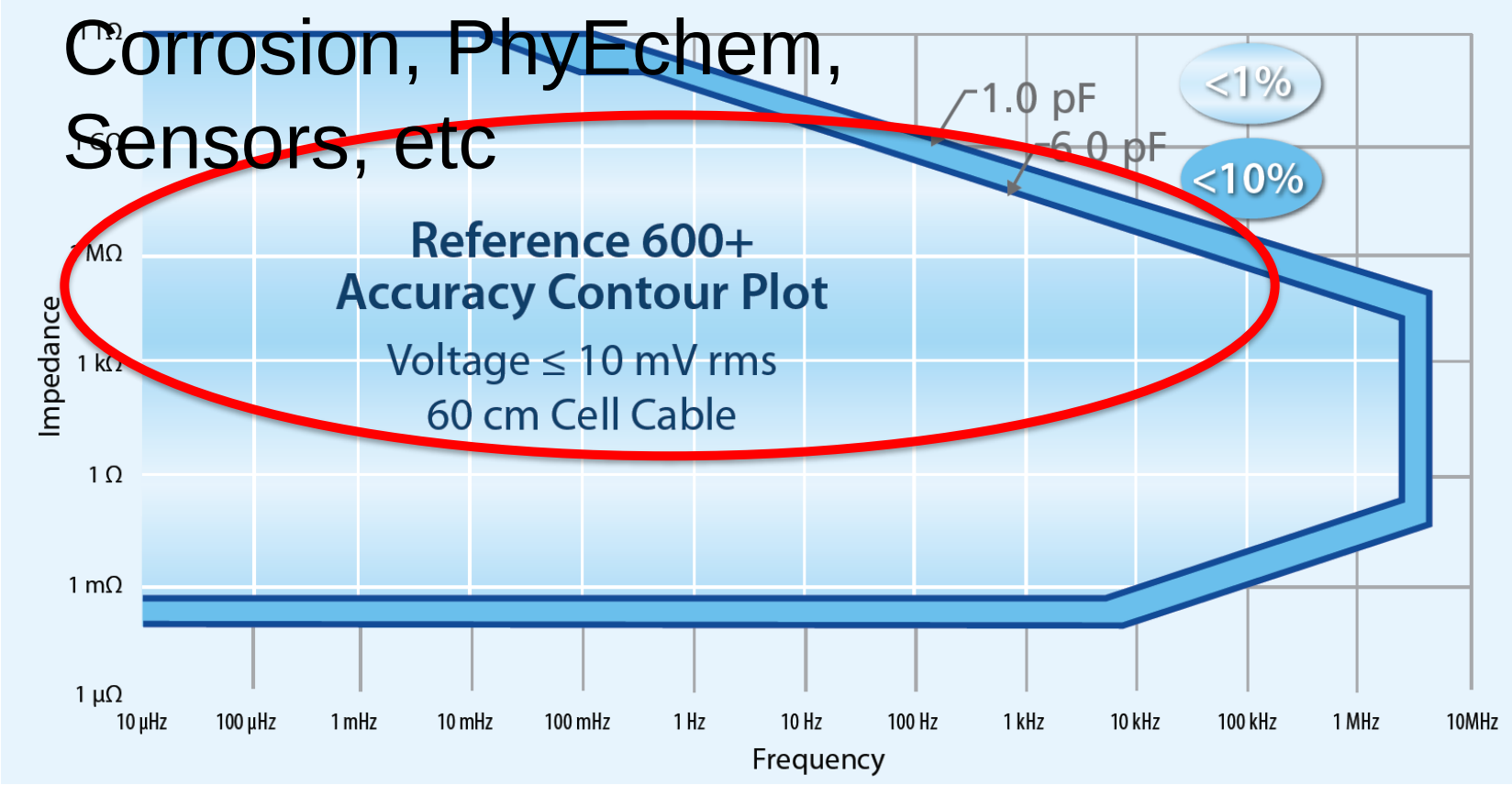
- Accuracy Contour Plots show you the range of impedance values that you can measure using a particular instrument under a particular set of conditions.

EIS Measurements



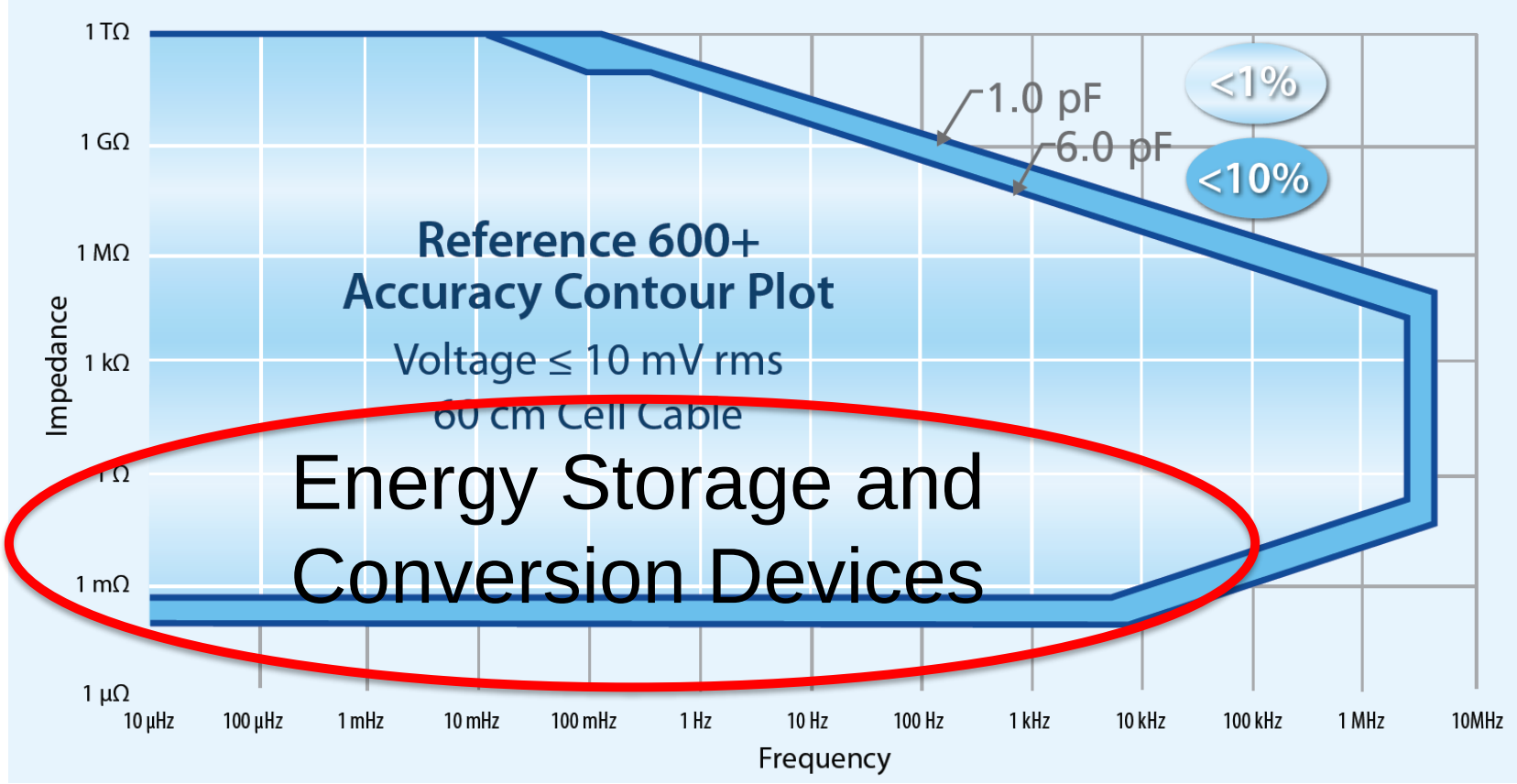
- Accuracy Contour Plots show you the range of impedance values that you can measure using a particular instrument under a particular set of conditions.

EIS Measurements



- Accuracy Contour Plots show you the range of impedance values that you can measure using a particular instrument under a particular set of conditions.

EIS Measurements

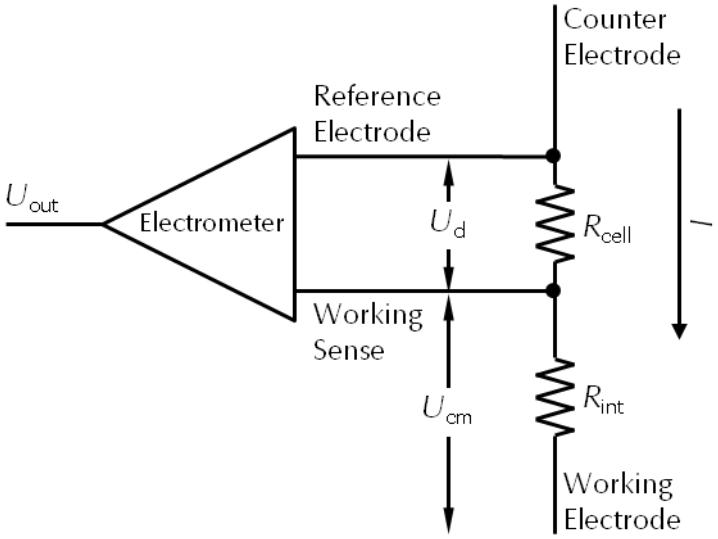


- Accuracy Contour Plots show you the range of impedance values that you can measure using a particular instrument under a particular set of conditions.

Electrometer

Input Impedance	$> 10^{14}\ \Omega \parallel < 0.2$ pF	$> 10^{14}\ \Omega \parallel < 0.2$ pF	$> 10^{12}\ \Omega \parallel < 2$ pF	$> 2 \times 10^{13}\ \Omega \parallel < 0.3$ pF
Input Current (typical)	< 6 pA	< 10 pA	< 25 pA	< 25 pA
Bandwidth	> 15 MHz at –3 dB	> 15 MHz at –3 dB	> 12 MHz at –3 dB	> 15 MHz at –3 dB
Common Mode Rejection Ratio (CMRR)	> 80 dB (100 kHz), > 60 dB (1 MHz)	> 65 dB (1 MHz)	> 98 dB (10 kHz), > 88 dB (100 kHz)	> 86 dB (10 kHz), > 60 dB (1 MHz)

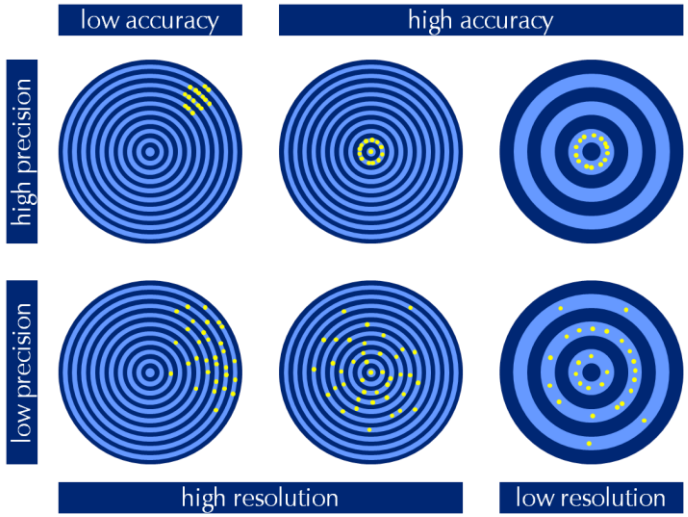
- Input current – typical current flow through the electrometer. Want it to be small to minimize current flow through the reference electrode.
- Input impedance – want this to be high so input current is low. Also the theoretical maximum impedance limit for an EIS measurement.
- Bandwidth – how fast the electrometer can measure signal changes. Often higher than practical frequency range of the potentiostat
- Common Mode Rejection Ratio (CMRR) – shows how good a differential amplifier (electrometer here) can suppress unwanted signals caused by non-idealities of components and design limitations. The higher the better. Also frequency dependent.



Accuracy, Resolution, and Precision

POTENTIAL				
Applied Accuracy	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting	±1 mV ± 0.2% of setting
Applied Resolution	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit	200 µV, 50 µV, 12.5 µV/bit
Measured Accuracy	±1 mV ± 0.2% of reading	±1 mV ± 0.2% of reading	±0.5 mV ± 0.2% of reading	±1 mV ± 0.3% of reading
Measured Resolution	High-resolution Electrometer: 400 µV, 100 µV, 10 µV, 1 µV/bit High-voltage Electrometer: 1.6 mV, 400 µV, 40 µV, 4 µV/bit	400 µV, 100 µV, 10 µV, 1 µV/bit	200 µV, 20 µV, 2 µV/bit	400 µV, 100 µV, 10 µV, 1 µV/ bit
CURRENT				
Applied/Measured Accuracy	±5 pA ± 0.05% of range ± 0.2% of value (3 A–3 nA) or 0.5% of value (300 pA)	±10 pA ± 0.05% of range ± 0.2% of value (600 mA–6 nA) or 0.75% of value (600 pA) or 1.5% of value (60 pA)	±25 pA ± 0.05% of range ± 0.2% of value	±10 pA ± 0.05% of range ± 0.3% of value
Applied/Measured Resolution	0.003% full-scale/bit	0.003% full-scale/bit	0.003% full-scale/bit	0.003% full-scale/bit
Bandwidth	> 10 MHz (3 A–3 mA), > 0.15 MHz (30 µA)	> 10 MHz (600 mA–600 µA), > 0.15 MHz (6 µA)	> 5 MHz (5 mA)	> 1.5 MHz (10 µA), > 0.15 MHz (1 µA)

- Accuracy – how correct a measurement is
- Resolution – describes the degree of fineness for an instrument. Range / # bits
- Precision – how repeatable a measurement is.



What is Floating

	Interface 1010T	Interface 1010B	Interface 1010E
Cell Connections		2, 3, 4	
Floating		Yes	
System			
Maximum Current	±100 mA		±1 A
Current Ranges	6		9
Current Ranges (with Gain)	8		11
Minimum Current Resolution	0.3 pA		3.3 fA
Minimum Voltage Resolution		1 µV	
Maximum Applied Potential	±5 V		± 12 V
Rise Time		1 µs	
Noise and Ripple		<20 µV rms	
Minimum Timebase	1 ms		10 µs

- Floating – this means isolation from Earth. Having this capability allows you to make measurements in grounded cells or grounded electrodes. It could be measurements in the field or measurements in an autoclave or measurements with a coupled technique such as TEM, AFM or in conjunction with a load or power supply. Example – doing EIS on top of an electronic load driving a fuel cell test stand.
- All Gamry potentiostats are floating.

Lastly, how do we generate these specifications?

- Check the back of a potentiostat manual.
- Additional specs are listed plus notes about how we generate specs.

Current-to-Voltage Converter

Maximum Full-Scale Range		3000	mA	Note 12
Minimum Full-Scale Range		300 3 (after ×100 gain)	pA pA	Note 12
Voltage across Rm	Typ.	150	mV at full scale	Note 13
Output Voltage (at BNC and ADC in)	Typ.	3.0	V at full scale	
Input Offset Current	Max. Typ.	5 2	pA	Note 14
Range Zero Offset	Max.	0.05	% of range	Note 14
Gain Tolerance 3000 mA to 3 nA ranges 300 pA range	Max.	 0.2 0.5	% of reading	Note 14
Zero drift	Typ.	0.03	% FS/°C	Note 15
Bandwidth 3000 mA to 300 µA ranges 30 µA range 3 µA range	Typ.	 >10 >1.5 >0.15	MHz	Note 16

13. The voltage across the current-measurement resistor, Rm, is as shown. Slightly higher voltages may be seen at the working-electrode terminal on the cell cable, because the cable has both resistive and inductive impedance.
14. The total error in a current measurement is:

    Error = Input Current Offset + Range Zero Offset × FS Current + Gain Tolerance × Measured Current

    For small currents (pA) the first term is usually dominant.
    For large currents (µA), the first term can usually be ignored.
    The units for the error are amperes.
15. Drift can be approximated by simple drift in the Range Zero Error. In reality all three terms in the equation above can have drift.
16. The Current-to-Voltage converter bandwidth is a function of the current range, the cell cable, and the IEStability setting. The bandwidth can be very low on very sensitive ranges. Longer cell cables add capacitance and slow the current measurement.

Thank you for your time.

Questions?