

Welcome!

Device Characterization with the Keithley Model 4200-SCS Characterization System

Speed and Timing Considerations



Factors Affecting Measurement Time

Internal to 4200:

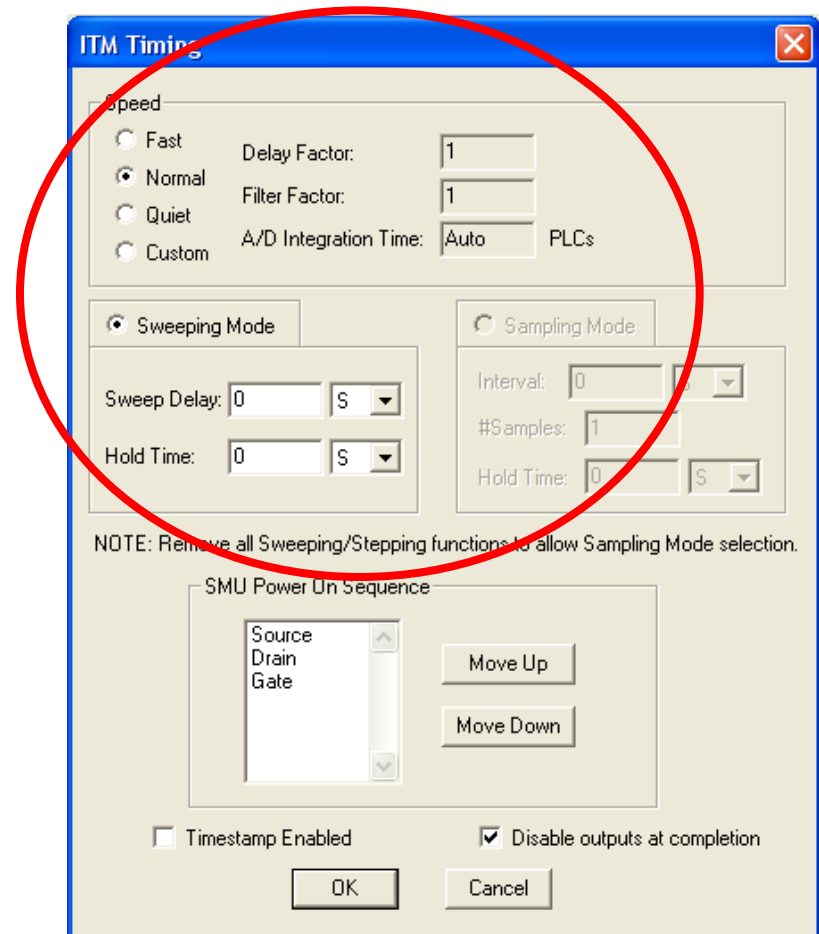
- Settings in the Timing Window: speed mode, A/D time, filter factor, delay factor
- Current measurement and source range
- Number of data points in the sweep
- Number of SMUs in taking measurements in a test

External to 4200:

- Resistance of DUT
- Cables: guarded vs. unguarded
- Test Fixturing: probers, switch matrix

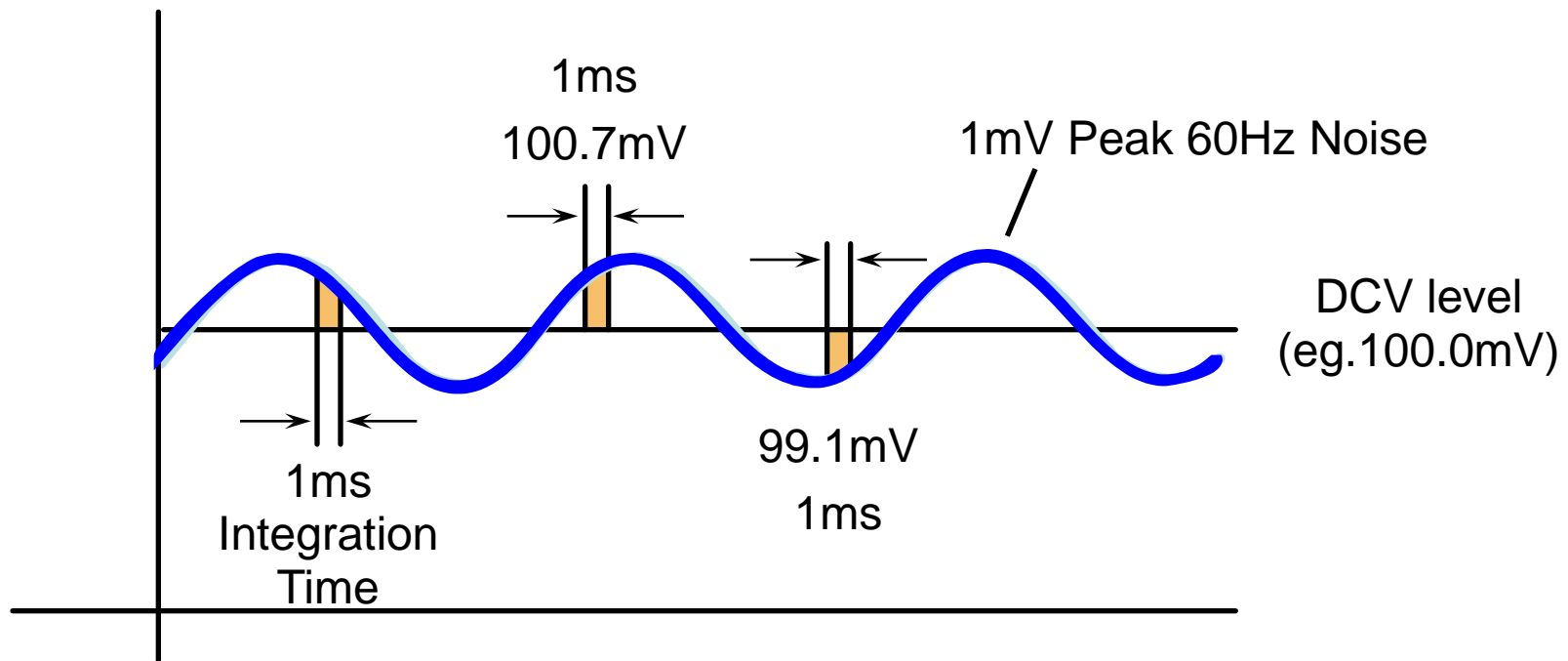
Settings in the Timing Window

- **Fast Speed:** Optimizes measurements for speed at the expense of noise performance.
- **Quiet Speed:** Optimizes for low noise measurements at the expense of speed.
- **Delay Factor:** enables longer settling times for low current measurements. The higher the number, the longer the measurement time.
- **Filter Factor:** Reduces measurement noise by averaging multiple readings. The higher the setting, the longer the measurement time.
- **Hold Time, Sweep Delay, and Interval:** User inputs delay to allow for sufficient settling time.
- **A/D Integration Time:** The larger the A/D time, the lower the noise, the increase in measurement time.



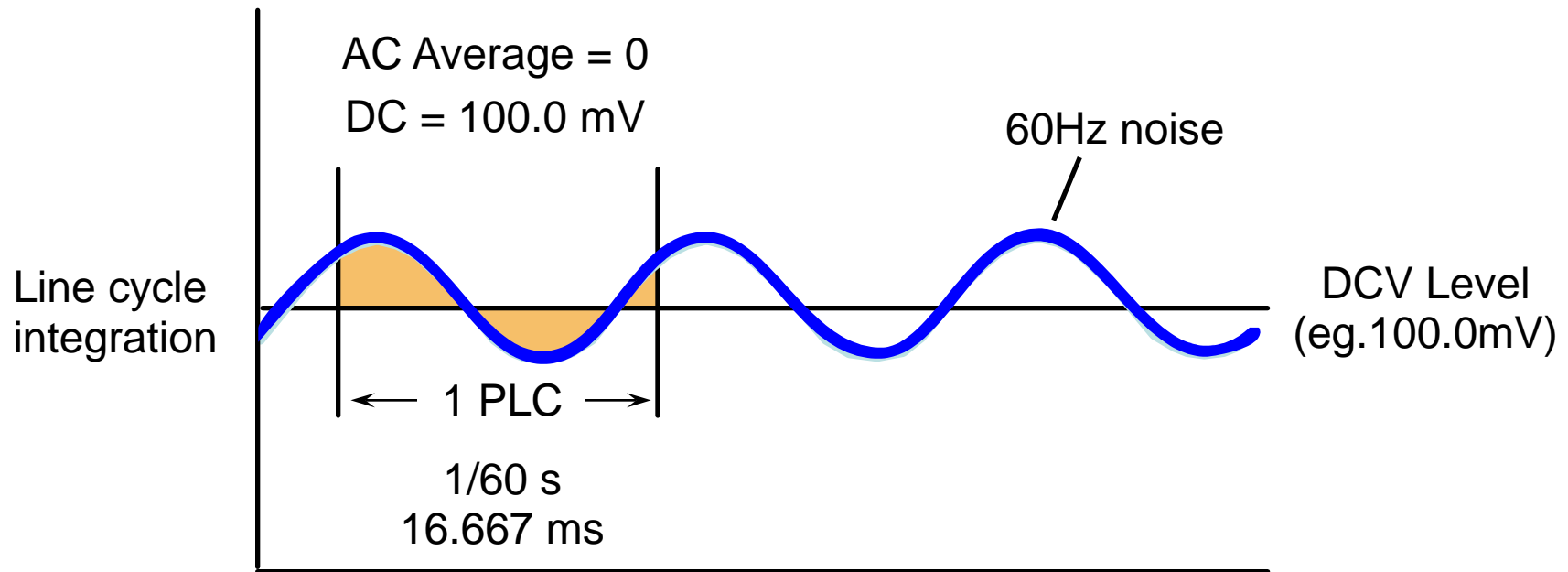
How Does External Noise “Pick-up” Affect a Measurement?

Noise signal superimposed on DC signal being measured may result in highly inaccurate and fluctuating measurements

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Line-Cycle Integration



**Power lines are principal sources of noise.
Integration of power line noise over precisely
one or more full cycles cancels this noise.**

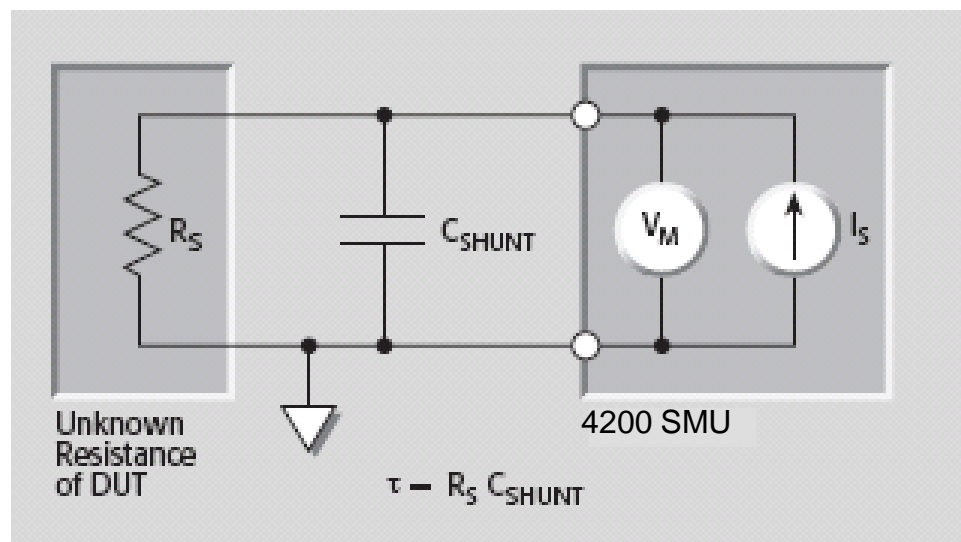
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Settling Time

Settling Time is the time that a measurement takes to stabilize after the current or voltage is applied or changed.

Factors affecting the settling time include:

- **Instrument (4200)** – varies mainly with current range, the lower the current range, the longer the settling time.
- **Cables, Test fixtures, Switches and Probers** – the higher the shunt capacitance (C_{SHUNT}), the longer the settling time
- **DUT** – the higher the source resistance (R_S), the longer the settling time



Settling Time

The settling time is the result of the RC time constant, or τ .

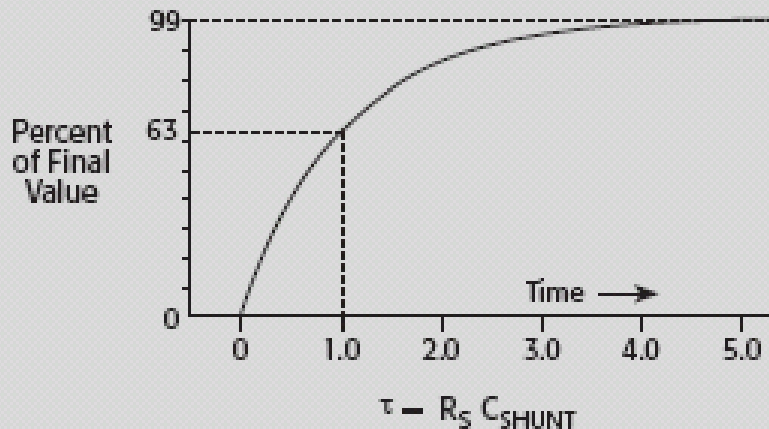
$$\tau = R_S C_{SHUNT}$$

Example, if $C_{SHUNT} = 10 \text{ pF}$

$$R_S = 1 \text{ T}\Omega$$

Then, $\tau = 10 \text{ pF} \times 1 \text{ T}\Omega = 10 \text{ seconds}$.

Therefore, a settling time of 50 seconds would be required for the reading to settle with 1% of final value!



NOTE: Using triax cables and guarding will reduce the shunt capacitance of the test circuit.

Ways to Reduce Test Time

- Used a fixed measurement range, if possible.
- If autoranging is unavoidable, use limited auto feature.
- Use less points in the sweep.
- Turn off all unnecessary measurements.
- Optimize the speed settings.
- Reduce (or set to 0 seconds) the Hold Time, Delay Time, and Interval Time settings.
- Use triax cables and guarding.

Definition Tab

Timing

Action

Click on Timing button

The timing window is used to configure ITM timing settings for the SMU:

- 1) Select **Speed Mode Settings**: Fast, Normal, Quiet, or Custom
- 2) Configure custom **Delay Factor**, **Filter Factor**, and **A/D Integration Time** (in Custom Speed Mode only)
- 3) Add delays for **Sweeping Mode** and **Sampling Mode**.
- 4) Set the SMU power-on sequence when a test is started.
- 5) Enable a timestamp to be recorded for each measurement.

ITM Timing

Speed

☐ Fast
☒ Normal
☐ Quiet
☐ Custom

Delay Factor:
 Filter Factor:
 A/D Integration Time: PLCs

☒ **Sweeping Mode**
☐ **Sampling Mode**

Sweep Delay: S
 Hold Time: S

Interval: S
 #Samples:
 Hold Time: S

NOTE: Remove all Sweeping/Stepping functions to allow Sampling Mode selection.

SMU Power On Sequence

☐ Timestamp Enabled
☒ Disable outputs at completion

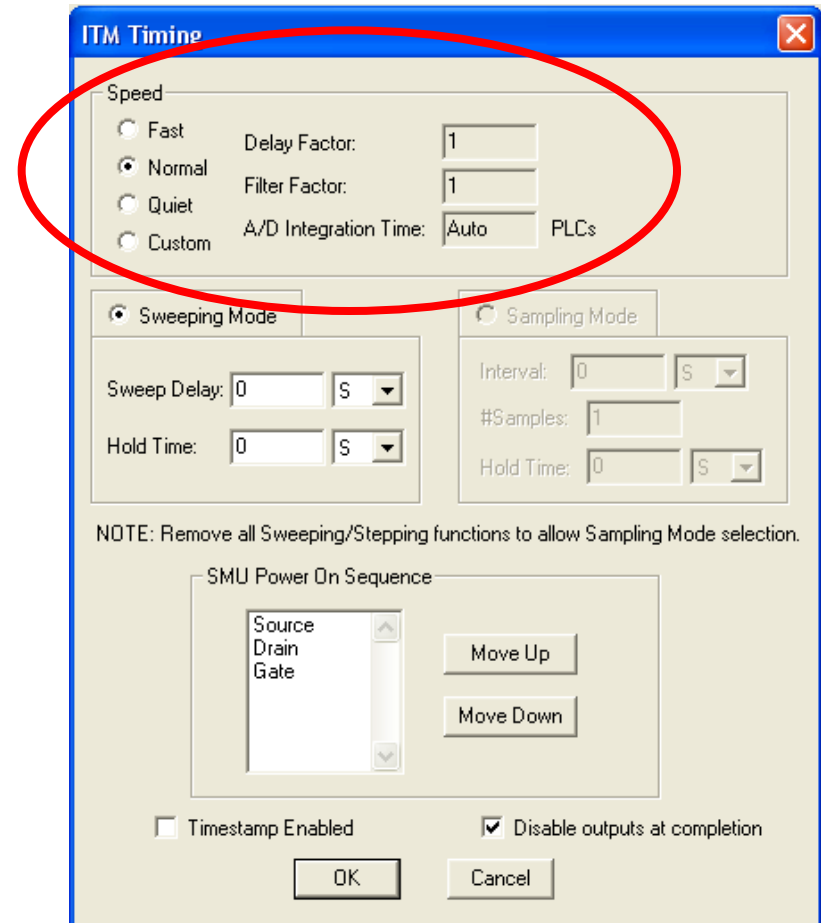
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Definition Tab

Timing – Speed Settings

Speed Settings:

- 1) **Fast:** Optimizes the 4200 for speed at the expense of noise. Good choice if noise and settling times are not concerns.
- 2) **Normal:** The default and most commonly used setting. Provides good combination of speed and low noise and is the best setting for best cases.
- 3) **Quiet:** Optimizes for low noise measurements at the expense of speed.
- 4) **Custom:** Enables fine tuning of timing parameters to meet a particular need. With custom you can configure the A/D integration time and delay and filter factors.



Definition Tab

Timing – Speed Settings – Delay Factor Setting

Delay Factor Setting:

- After an applied current or voltage, the SMU waits for a delay time before making a measurement. The delay time allows for source settling.
- The default delay time is pre-programmed and range-dependent.
- The Applied Delay Time = (Default Delay Time) x (Delay Factor)
- For Custom measurement Speed, you can enter a custom delay factor from 0 to 100.

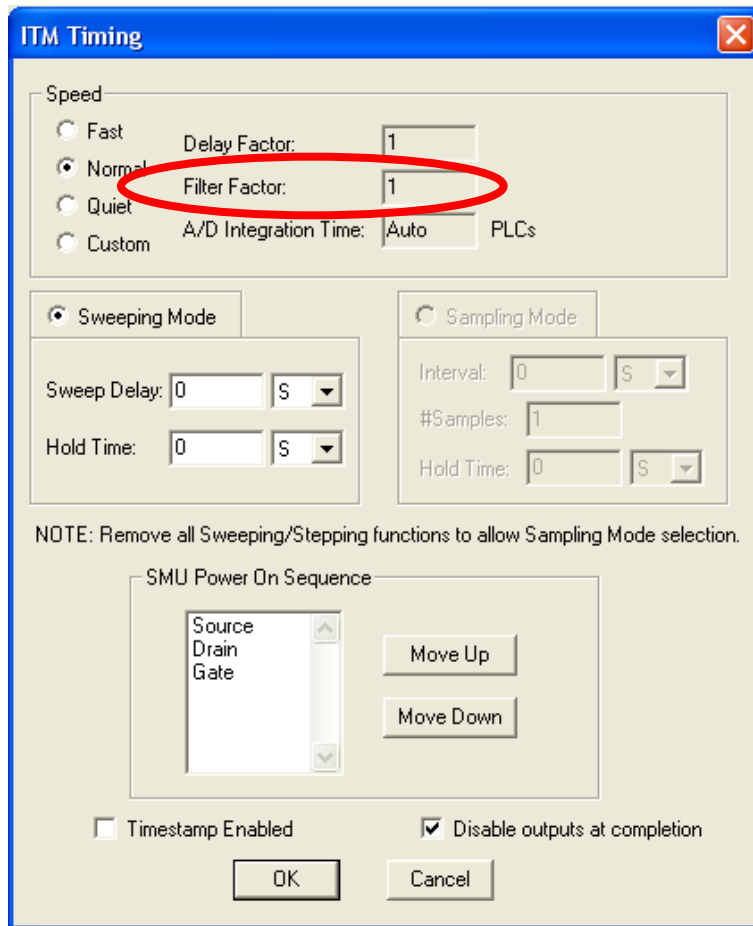
Summary of allowed Delay Factor settings

Speed Mode	Delay Factor Settings
Fast	0.7
Normal	1.0
Quiet	1.3
Custom	0 to 100

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Definition Tab

Timing – Speed Settings – Filter Factor Setting



- To reduce measurement noise, the 4200 SMU applies filtering which may include averaging of multiple readings to make one measurement.
- The SMU adjusts the filtering according to the measurement range.
- Filter Factor is a White Noise Reduction factor. If it is set to 2, it reduces the noise by a factor of 2.

Summary of allowed Filter Factor settings

Speed Mode	Filter Factor Settings
Fast	0.2
Normal	1
Quiet	3
Custom	0 to 100

Definition Tab

Timing – Speed Settings – A/D Integration Time

The A/D Integration time box controls the A/D converter integration time used to measure a signal.

- A short integration time results in a relatively fast measurement speed at the expense of noise.
- A long integration time results in a relatively low noise reading at the expense of speed.
- Integration time setting is based on the number of power line cycles (NPLCs). For 60Hz line power, 1.0 PLC = 16.67msec (1/60)

Summary of allowed A/D Integration Time settings

Speed Mode	A/D Integration Time Setting
Fast	Auto
Normal	Auto
Quiet	Auto
Custom	0.01 to 10 PLC

Definition Tab

Timing - Sweep Mode and Sampling Mode

Normal Sweeping

ITM Timing

Speed

☐ Fast
☒ Normal
☐ Quiet
☐ Custom

Delay Factor:
 Filter Factor:
 A/D Integration Time: PLCs

☒ Sweeping Mode
☐ Sampling Mode

Sweep Delay: S
 Hold Time: S

Interval: S
 #Samples:
 Hold Time: S

NOTE: Remove all Sweeping/Stepping functions to allow Sampling Mode selection.

☒ Timestamp Enabled

OK Cancel

Custom Sampling

ITM Timing

Speed

☐ Fast
☐ Normal
☐ Quiet
☒ Custom

Delay Factor:
 Filter Factor:
 A/D Integration Time: ☒ Customize PLCs

☐ Sweeping Mode
☒ Sampling Mode

Sweep Delay: S
 Hold Time: S

Interval: S
 #Samples:
 Hold Time: S

NOTE: Remove all Sweeping/Stepping functions to allow Sampling Mode selection.

☒ Timestamp Enabled

OK Cancel

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SMU Test Modes

Sweeping and Sampling

- The **Sweeping** test mode applies to any ITM in which one or more forced voltages/currents vary with time.
 - Example – **Sweeping** mode would be used to increment a series of voltage values to the drain of a FET, while measuring and recording current at each voltage point.
- The **Sampling** test mode applies to any ITM in which all forced voltages or currents are static, with measurements typically being made at timed intervals.
 - Example – **Sampling** mode would be used to record a few static measurements or to time profile the charging voltage of a capacitor while forcing a constant current.

Definition Tab

Timing - Sweep Mode and Sampling Settings

Sweep Mode:

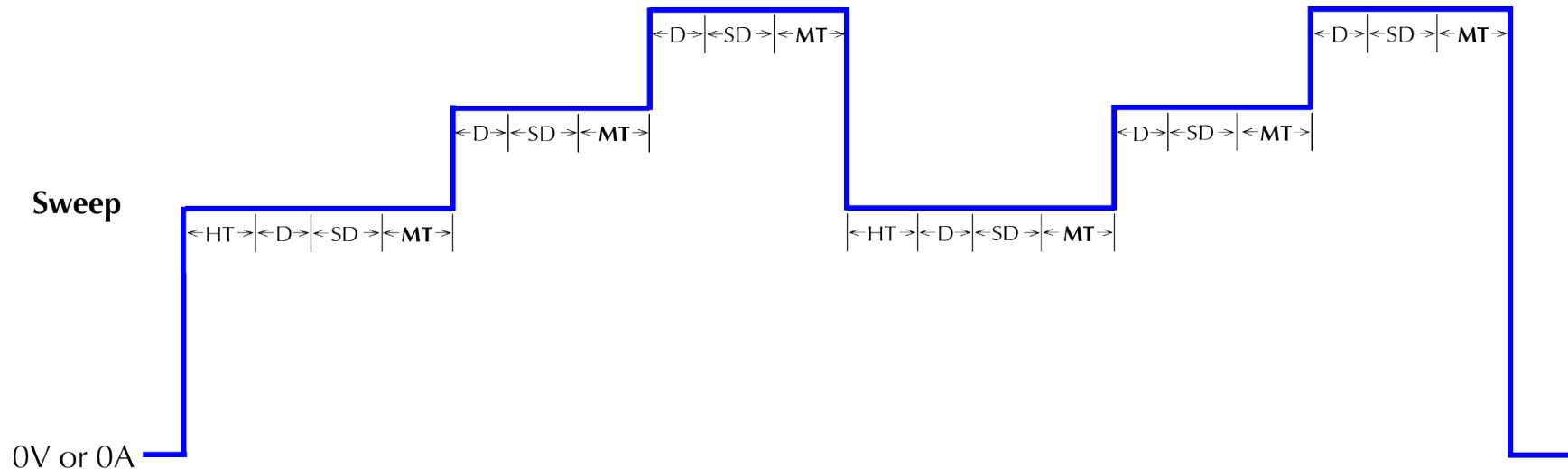
- **Sweep Delay:** Extra time added before each measurement.
- **Hold Time:** Time added at the beginning of each sweep. Allows for additional settling time prior to measurements being taken in the sweep.

Sampling Mode:

- **Interval:** Specifies the time between measurements (data points). The Interval time can be set from 0 to 1000sec.
- **#Samples:** Specifies the number of data points to be acquired. #Samples can be set from 1 to 4096.
- **Hold Time:** Delay time added before making the first measurement.

Definition Tab

Timing - Sweep Mode Timing Diagram



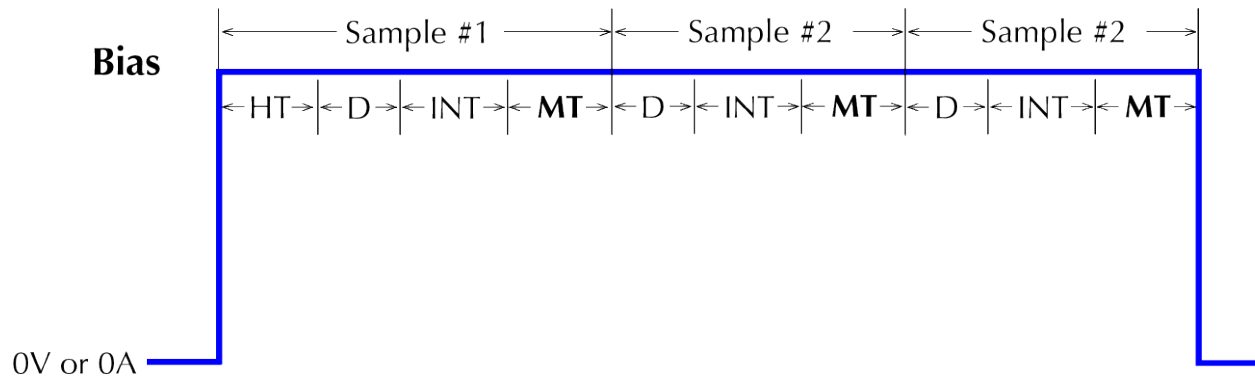
HT = Hold Time
 D = Delay (default delay x delay factor)
 SD = Sweep Delay
 MT = Measure Time

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Definition Tab

Timing - Sample Mode Timing Diagram



HT = Hold Time
 D = Delay (default delay x delay factor)
 INT = Interval
 MT = Measure Time

Definition Tab

Timing – Power On Sequence

- When an ITM test is run, the SMUs power-on in a specific sequence.
- The power on sequence is identified by device terminals.
- The power-on sequence can be changed by selecting a terminal and using the Move Up and/or Move Down buttons to change its position in the sequence.

ITM Timing

Speed

☐ Fast Delay Factor: 1

☒ Normal Filter Factor: 1

☐ Quiet A/D Integration Time: Auto PLCs

☐ Custom

☒ Sweeping Mode

Sweep Delay: 0 S

Hold Time: 0 S

☐ Sampling Mode

Interval: 0 S

#Samples: 1

Hold Time: 0 S

NOTE: Remove all Sweeping/Stopping functions to allow Sampling Mode selection.

SMU Power On Sequence

Source
Drain
Gate

Move Up

Move Down

☐ Timestamp Enabled ☒ Disable outputs at completion

OK Cancel

Action

Click on OK to exit
Timing window.

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