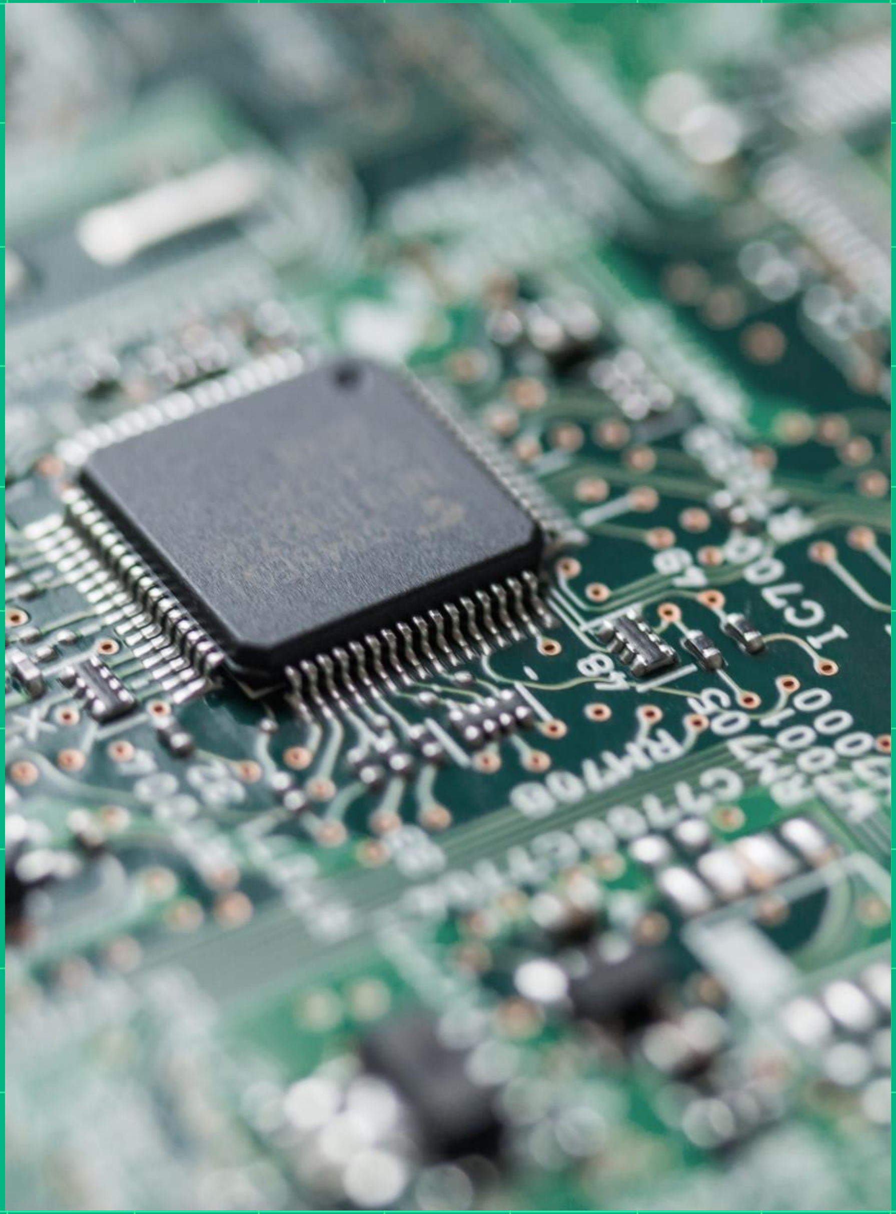
WELCOME TO AUSTIN

5 Tips for Optimizing NI SMUs for High Throughput Test

Craig Hitchman

Principal Applications Engineer



Optimizing Test Execution Is a Competitive Advantage

"Some ASIC manufacturers report that testing time consumes 40-50% of the entire IC product development cycle."

IC Insights

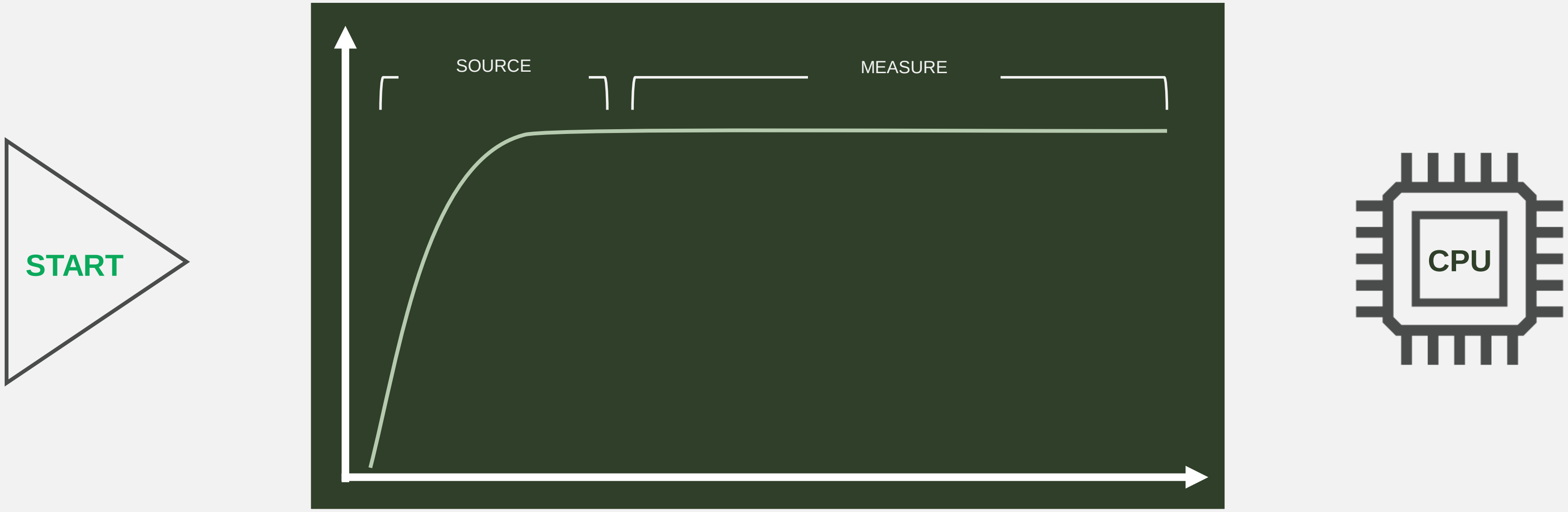
McClean Report 2015

Functionality of Source Measure Units

- DC VOLTAGE SOURCE
- DC CURRENT SOURCE
- PULSE GENERATOR
- WAVEFORM GENERATOR

- VOLTMETER
- AMMETER
- OHMMETER
- ISOLATED DIGITIZER
- PROGRAMMABLE LOAD

SMU Measurement Flow



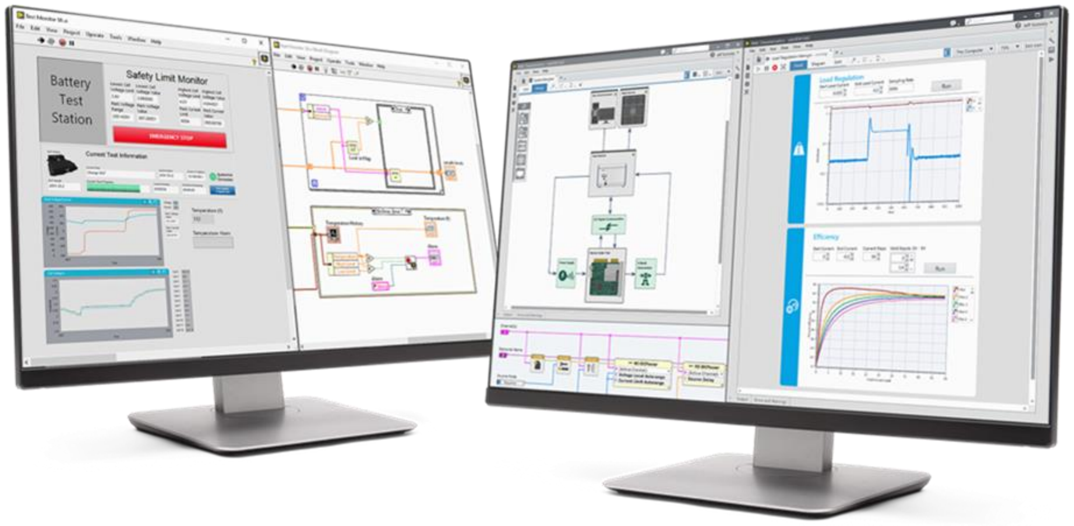
TRIGGER → SOURCE → MEASURE → PROCESS

You can take high-precision measurements quickly.

Removing small inefficiencies in timing can reduce your cost of test.

Programming Support

- NI product portfolio supports a breadth of programming languages: **LabVIEW, C/C++, C# .NET, Python**
- **What you get with NI's best-in-class APIs:**
  - Well Documented API
  - Shipped Examples
  - Help Documentation
- NI ensures **long-term interoperability** of our instrumentation
  - NI instrument class driver APIs are consistent across all past & future product variants
  - Provides built in abstraction layer to prevent unnecessary code revisions when hardware is upgraded/replaced



LabVIEW™

C/C++

```
import nidcpower
# Configure the session.

with nidcpower.Session(resource_name='PXI1Slot2', channels='0') as session:
    session.measure_record_length = 20
    session.measure_record_length_is_finite = True
    session.measure_when = nidcpower.MeasureWhen.AUTOMATICALLY_AFTER_SOURCE_COMPLETE
    session.voltage_level = 5.0

    session.commit()
    print('Effective measurement rate: {0} S/s'.format(session.measure_record_delta_time / 1))

    samples_acquired = 0
    print('  #    Voltage    Current    In Compliance')
    row_format = '{0:3d}:   {1:8.6f}   {2:8.6f}   {3}'
    with session.initiate():
        while samples_acquired < 20:
            measurements = session.fetch_multiple(count=session.fetch_backlog)
            samples_acquired += len(measurements)
            for i in range(len(measurements)):
                print(row_format.format(i, measurements[i].voltage, measurements[i].current, measuremen
```

Instrument Studio™

Application Software for Interactive Instrument Control and Lab Measurements

All your instruments in a single application

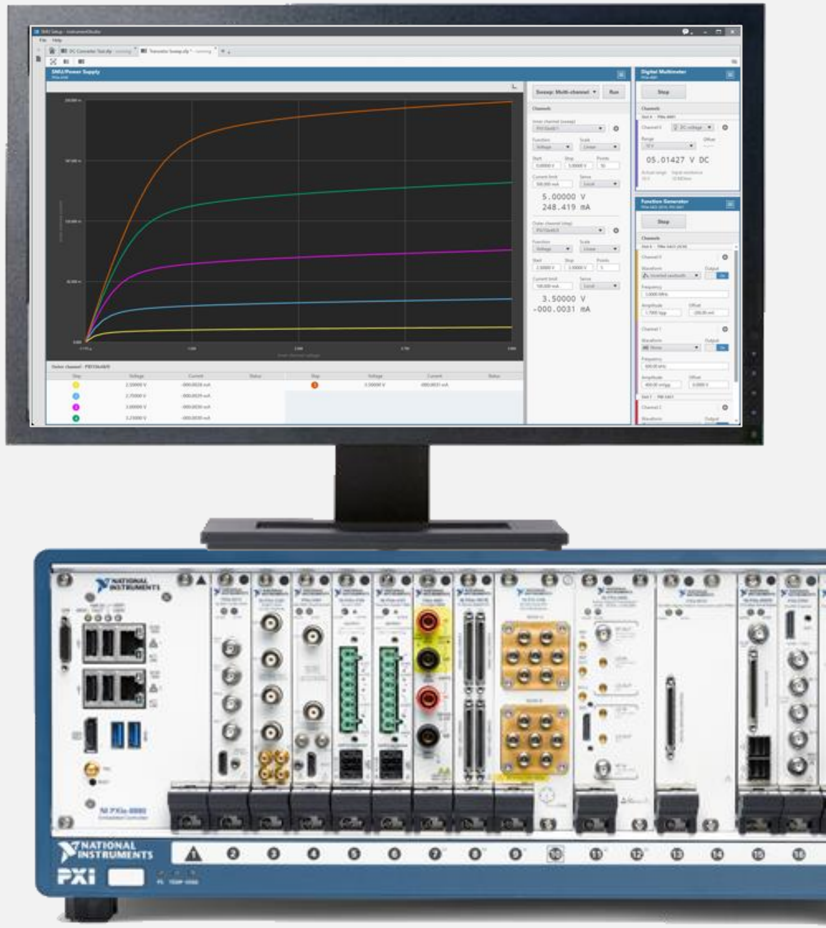
Capture screenshots and export data

Build custom plugins for common measurements or tasks

Share projects with colleagues and between systems

Export configurations for programmatic use

Monitor and debug automated test systems



System SMU Family






PXIe-	4135	4136	4137	4138	4139	4190 LCR
Max Source Power	20W/40W	20W	20W/40W	20W	20W/40W	1W/4W
Max Sink Power	12W/40W	12W	12W/40W	12W	12W/40W	1W/4W
Max Sampling	1.8 MS/s					600 kS/s
Max Update	100 kS/s					
Max Voltage	200 V			60 V		10V/40V
Max DC Current	1 A			3 A		100mA
Max Pulsed Current	3 A	n/a	3 A	n/a	10 A	n/a
Current Sensitivity	10 fA	1 pA	100 fA	1 pA	100 fA	1 fA
SourceAdapt	Yes	No	Yes	No	Yes	Yes
Connectivity	Triaxial	Screw Terminals				BNC

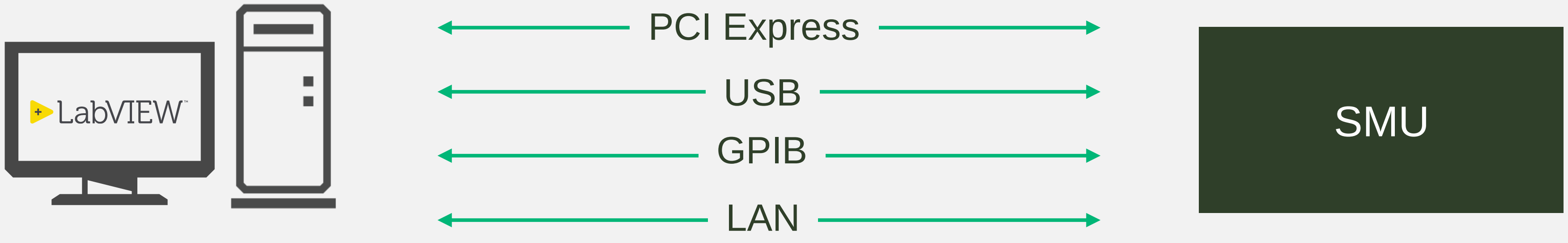
Multi Channel SMU Family

PXIe-	4140/4141	4142/4143	4144/4145	4147	4162	4163
Channels	4				12	24
Max Sampling	600 kS/s			1.8 MS/s	100 kS/s	
Max Update	100 kS/s					
Max Voltage	10 V	24 V	6 V	8 V	24 V	24 V
Max DC Current	100 mA	150 mA	500 mA	3 A	100 mA	50 mA
Current Sensitivity	100pA/10pA	100pA/10pA	150pA/15pA	100 fA	10pA/100pA	10pA/100pA
SourceAdapt	No/Yes	No/Yes	No/Yes	Yes	Yes	Yes

The 5 Tips

1. **Choose the right equipment**
2. Measure in parallel
3. Optimize source delay and aperture time
4. Utilize advanced instrument capabilities
5. Tune transient response with Source Adapt

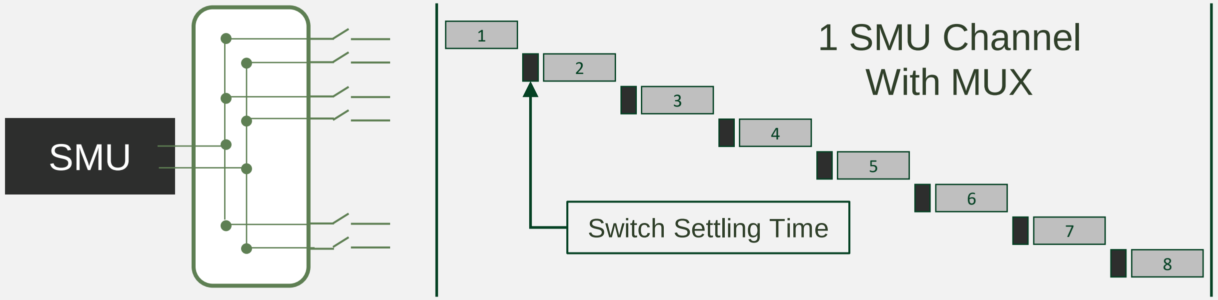
1. Bus Communication

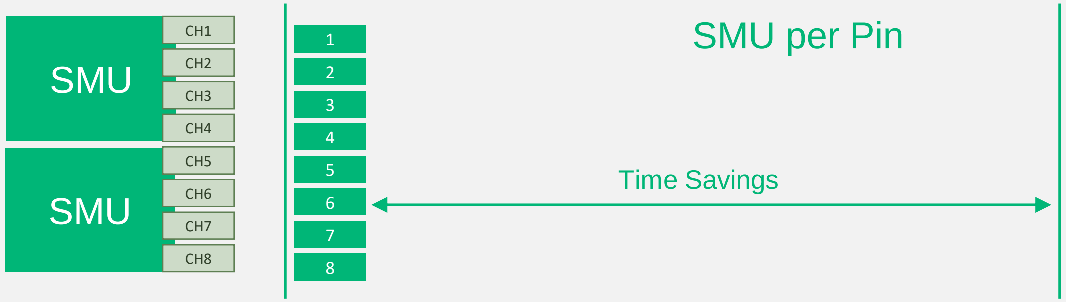


SMU Ranges

Model	SourceAdapt	Voltage Ranges (V)	Current Ranges (A)	Channels
PXIe-4135	Yes	±0.6, ±6, ±20, ±200	±10n, ±1u, ±100u, ±1m, ±10m, ±100m, ±1	1
PXIe-4136	No	±0.6, ±6, ±20, ±200	±1u, ±10u, ±100u, ±1m, ±10m, ±100m, ±1	1
PXIe-4137	Yes	±0.6, ±6, ±20, ±200	±1u, ±10u, ±100u, ±1m, ±10m, ±100m, ±1	1
PXIe-4138	No	±0.6, ±6, ±60	±1u, ±10u, ±100u, ±1m, ±10m, ±100m, ±1, ±3	1
PXIe-4139	Yes	±0.6, ±6, ±60	±1u, ±10u, ±100u, ±1m, ±10m, ±100m, ±1, ±3	1
PXIe-4140	No	±10	±10u, ±100u, ±1m, ±10m, ±100m	4
PXIe-4141	Yes	±10	±10u, ±100u, ±1m, ±10m, ±100m	4
PXIe-4142	No	±24	±10u, ±100u, ±1m, ±10m, ±150m	4
PXIe-4143	Yes	±24	±10u, ±100u, ±1m, ±10m, ±150m	4
PXIe-4144	No	±6	±10u, ±100u, ±1m, ±10m, ±100m, ±500m	4
PXIe-4145	Yes	±6	±10u, ±100u, ±1m, ±10m, ±100m, ±500m	4
PXIe-4147	Yes	±1, ±8	±1u, ±10u, ±100u, ±1m, ±10m, ±100m, ±1, ±3	4
PXIe-4162	Yes	±24	(±1u), ±10u, ±100u, ±1m, ±10m, ±100m	12
PXIe-4163	Yes	±24	(±1u), ±10u, ±100u, ±1m, ±10m, ±50m	24
PXIe-4190	Yes	±1, ±10, ±40	±1n,±100n, ±1u, ±10u, ±100u, ±1m, ±10m, ±100m	1

Parallel Versus Serial SMU Channels





24-Channel SMUs

400+ channels in PXI chassis
Parallel execution in LabVIEW and TestStand

The 5 Tips

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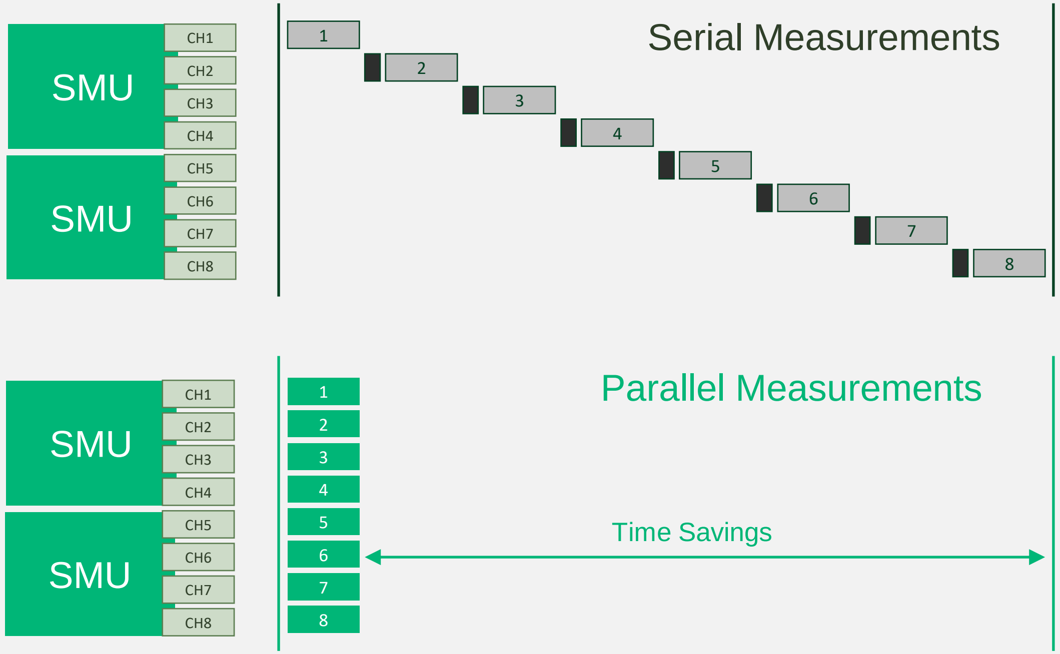
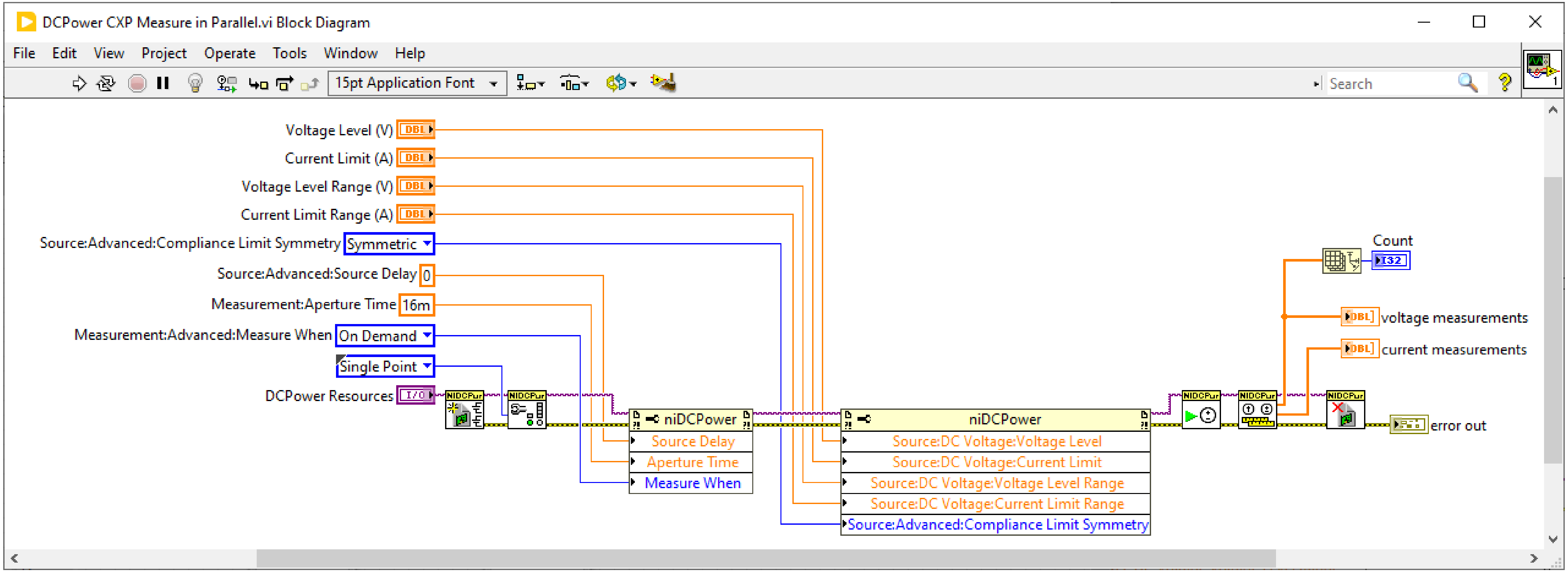
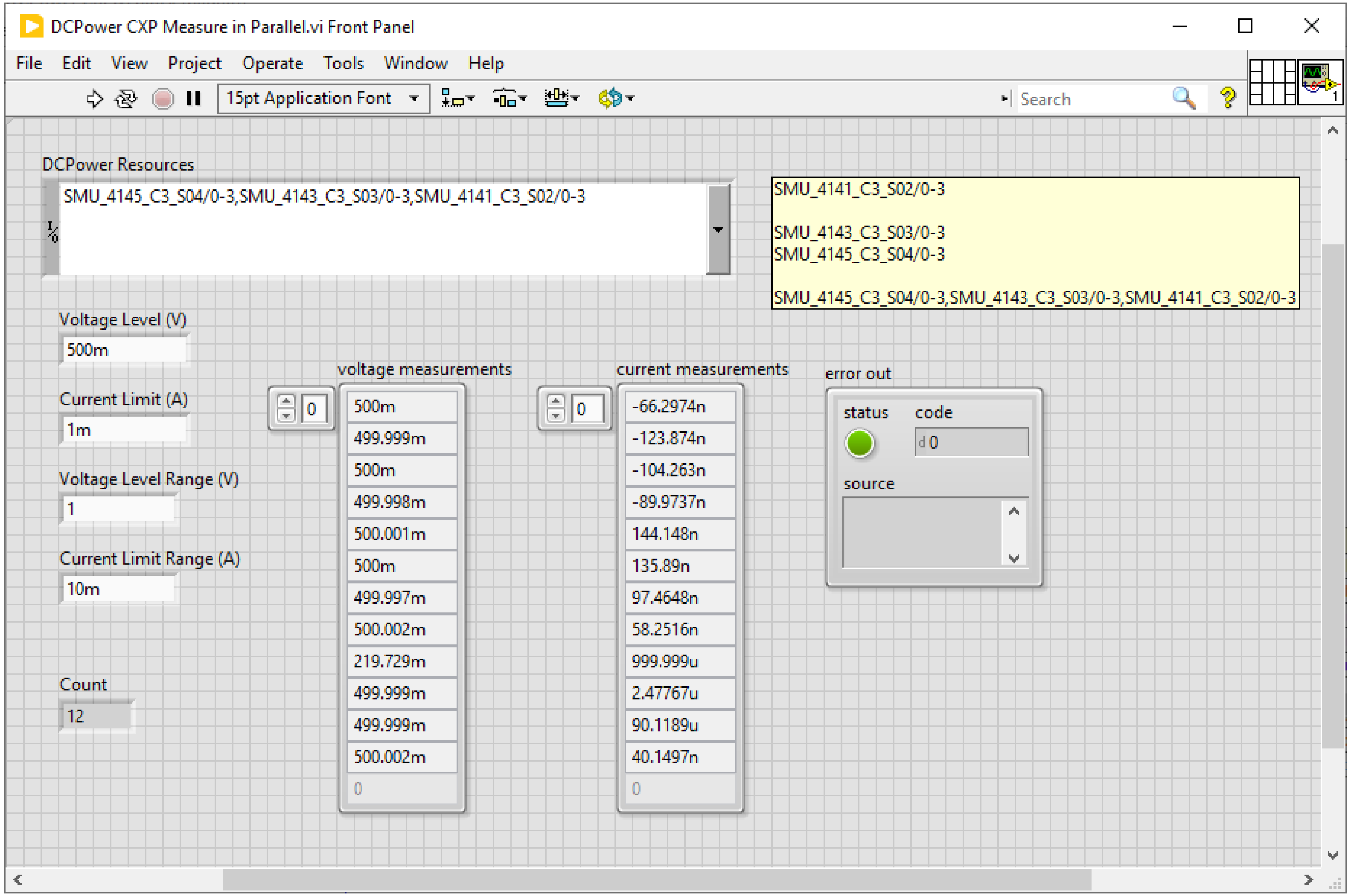
Parallel Versus Serial Measurements



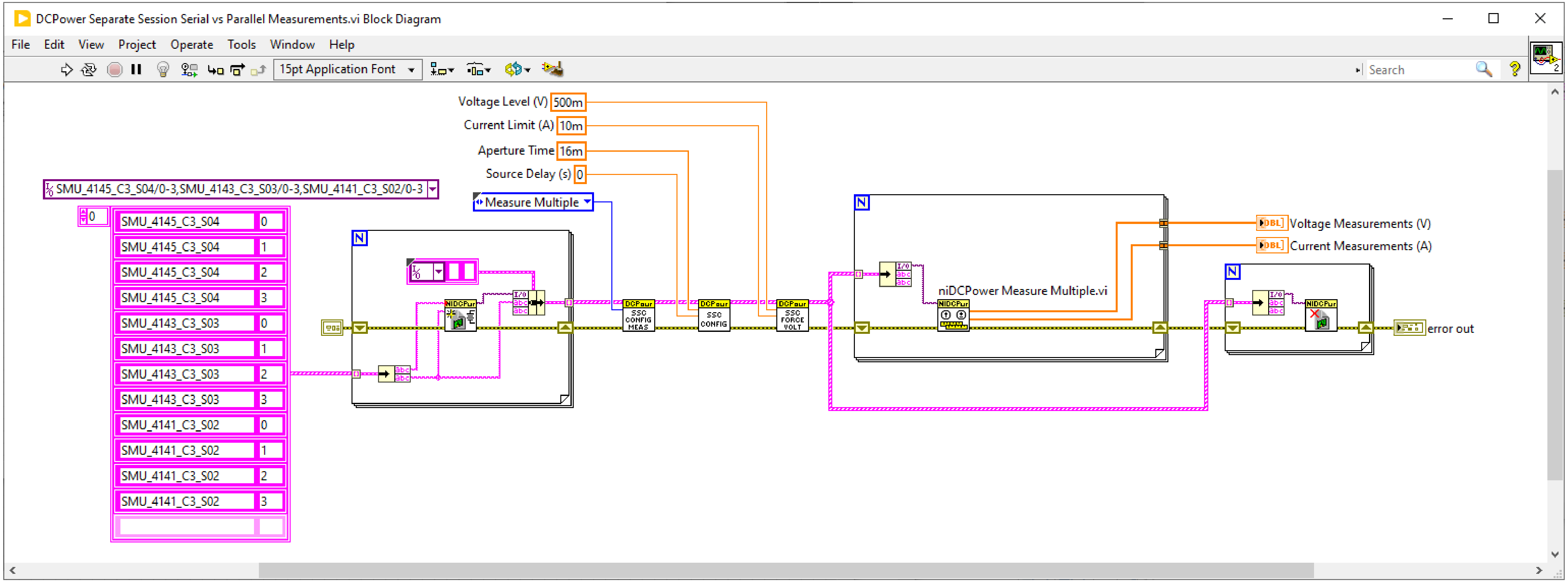
DCPower Parallel Measurements



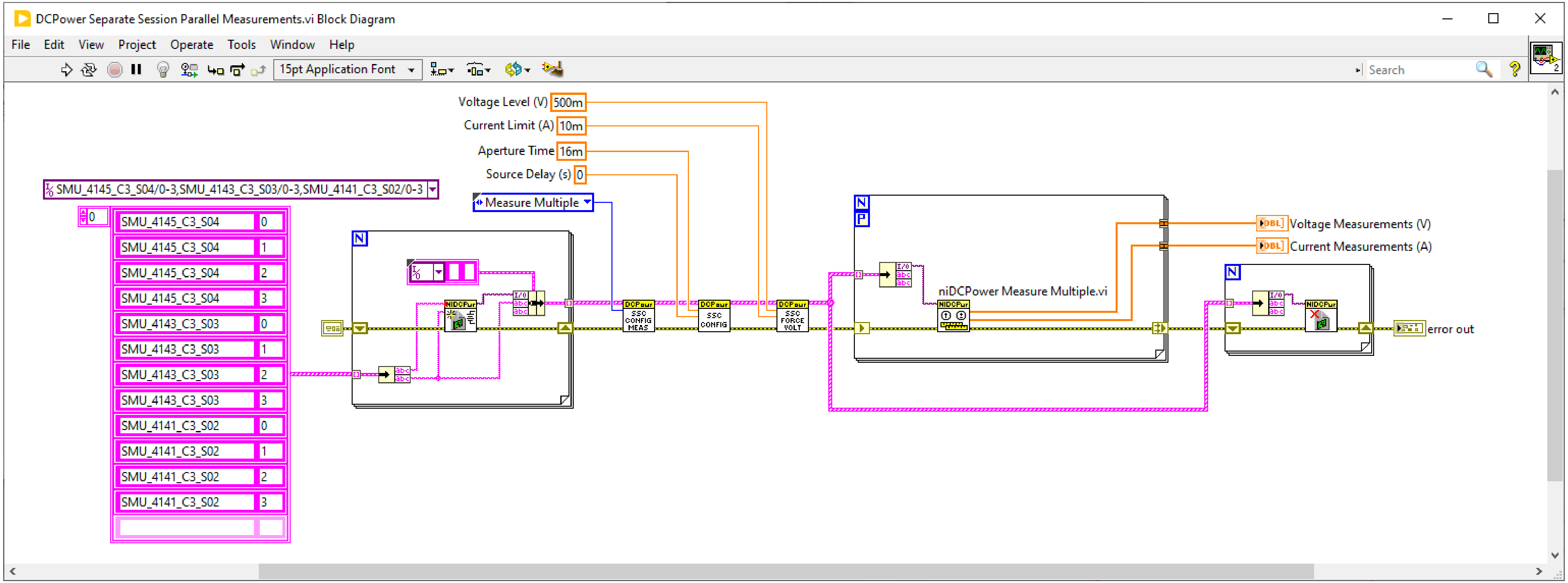
DCPower Parallel Measurements



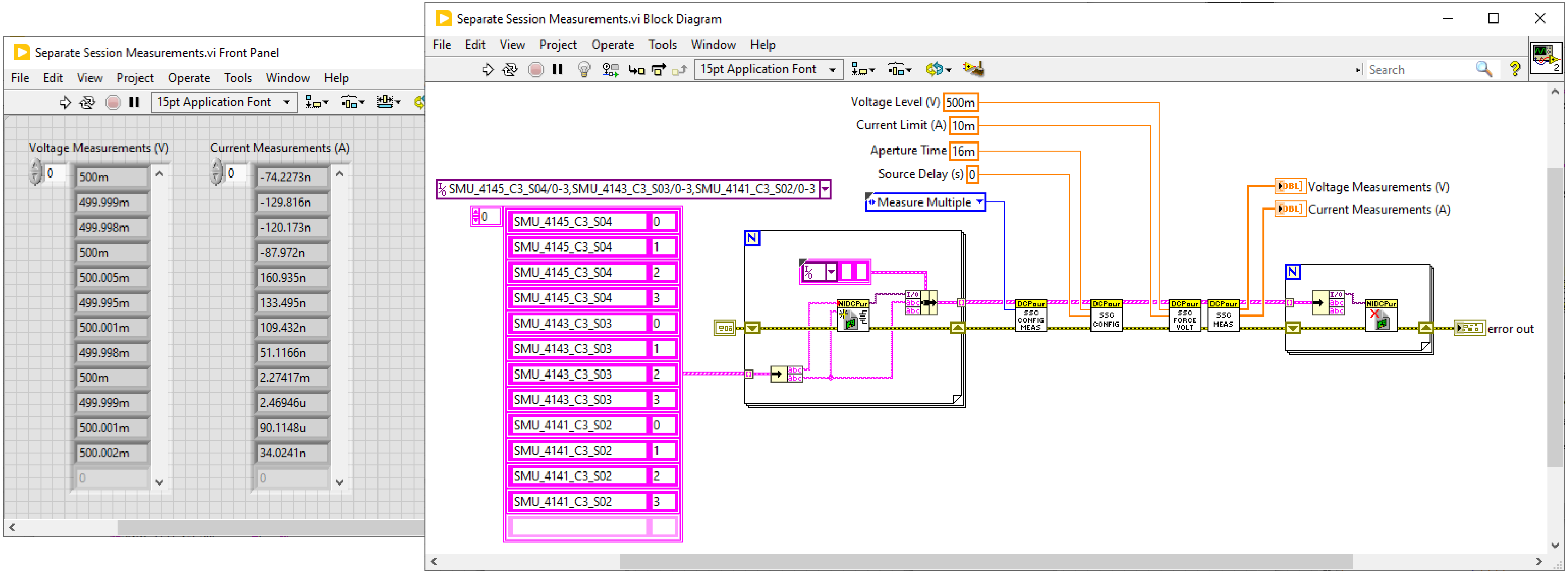
DCPower Separate Session Serial Measurements



DCPower Separate Session Parallel Measurements



DCPower Separate Session Parallel Measurements



DCPower Separate Session Parallel Measurements in C#

```
public void Measure(out double[] voltageMeasurements, out double[] currentMeasurements)
{
    var vMeasurements = new double[SSC.Length];
    var iMeasurements = new double[SSC.Length];

    Parallel.ForEach(SSC, (ssc, state, index) =>
    {
        if (DevTools.UseSoftwareMeasureTriggers && ssc.InstrumentModel != 4110)
        {
            ssc.Session.Triggers.MeasureTrigger.SendSoftwareEdgeTrigger();
            var measurements = ssc.Session.Measurement.Fetch(ssc.DriverChannelList, PrecisionTimeSpan.FromSeconds(5), 1);
            vMeasurements[index] = measurements.VoltageMeasurements[0];
            iMeasurements[index] = measurements.CurrentMeasurements[0];
        }
        else
        {
            var measurements = ssc.Session.Measurement.Measure(ssc.DriverChannelList);
            vMeasurements[index] = measurements.VoltageMeasurements[0];
            iMeasurements[index] = measurements.CurrentMeasurements[0];
        }
    });

    voltageMeasurements = vMeasurements;
    currentMeasurements = iMeasurements;
}
```

The 5 Tips

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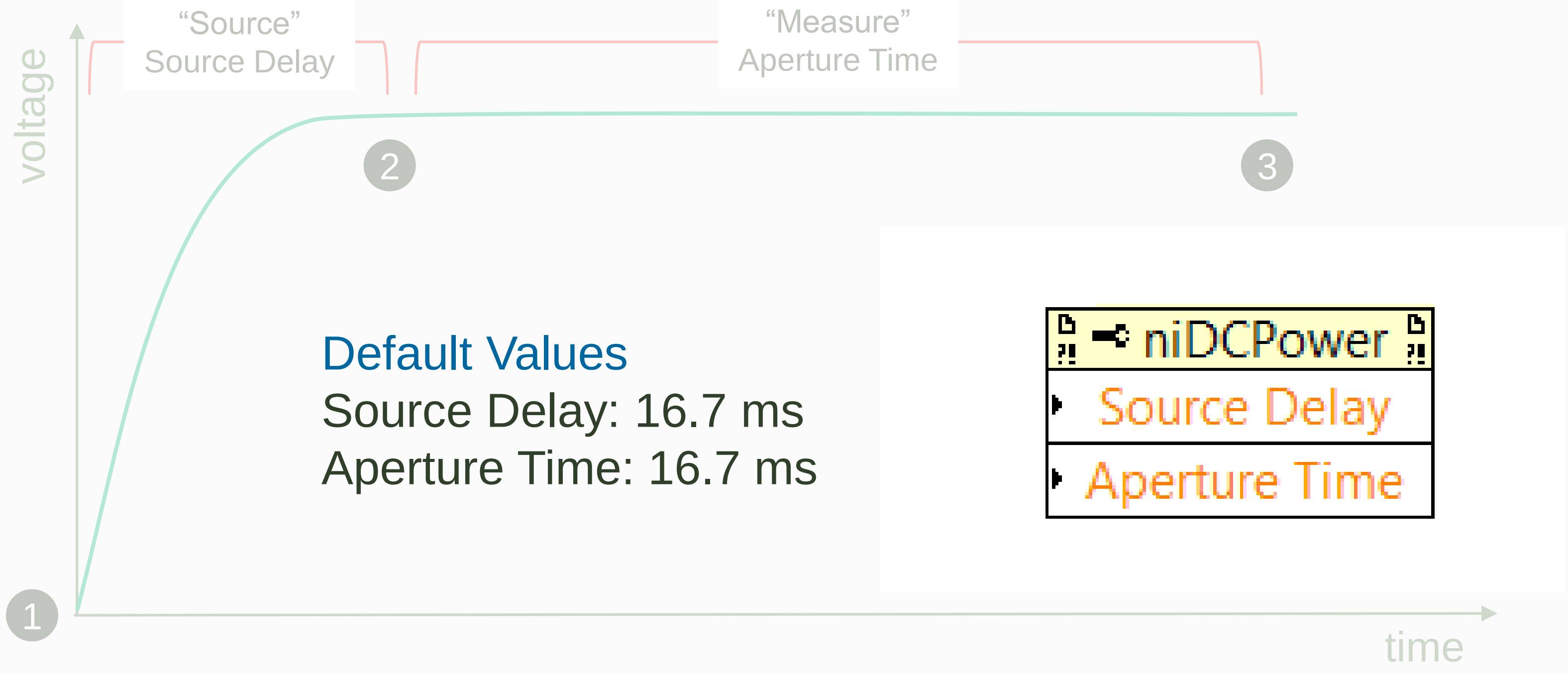
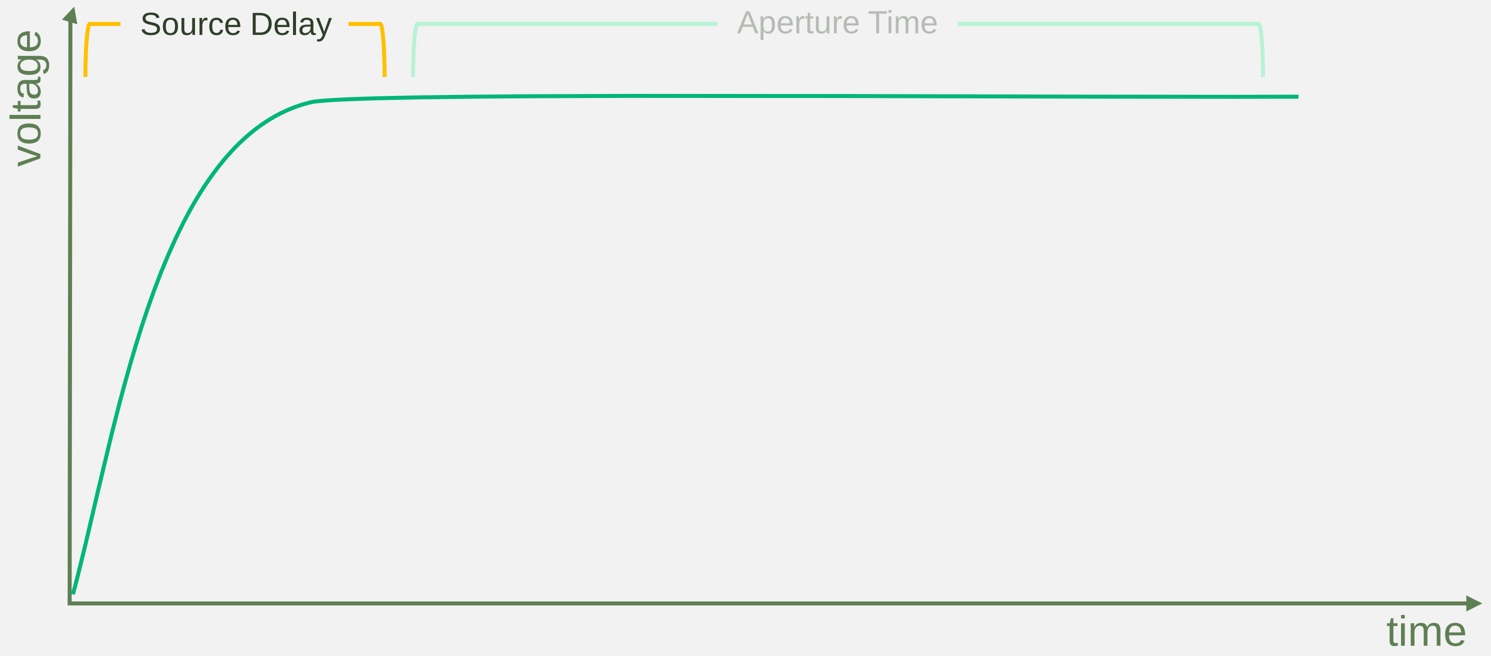
3. Source and Measure Cycle

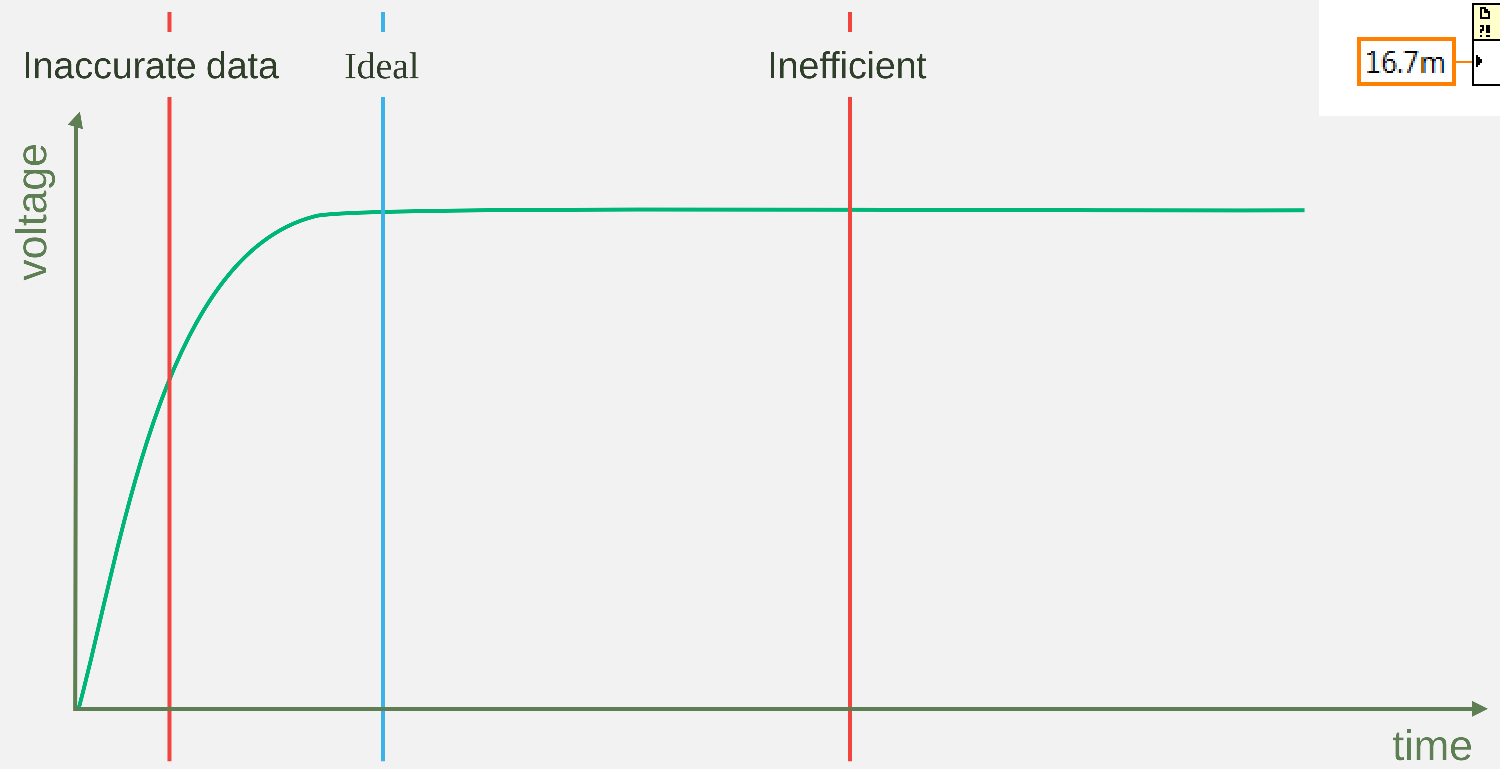


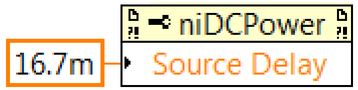
Default Values
Source Delay: 16.7 ms
Aperture Time: 16.7 ms

Source and Measure Cycle



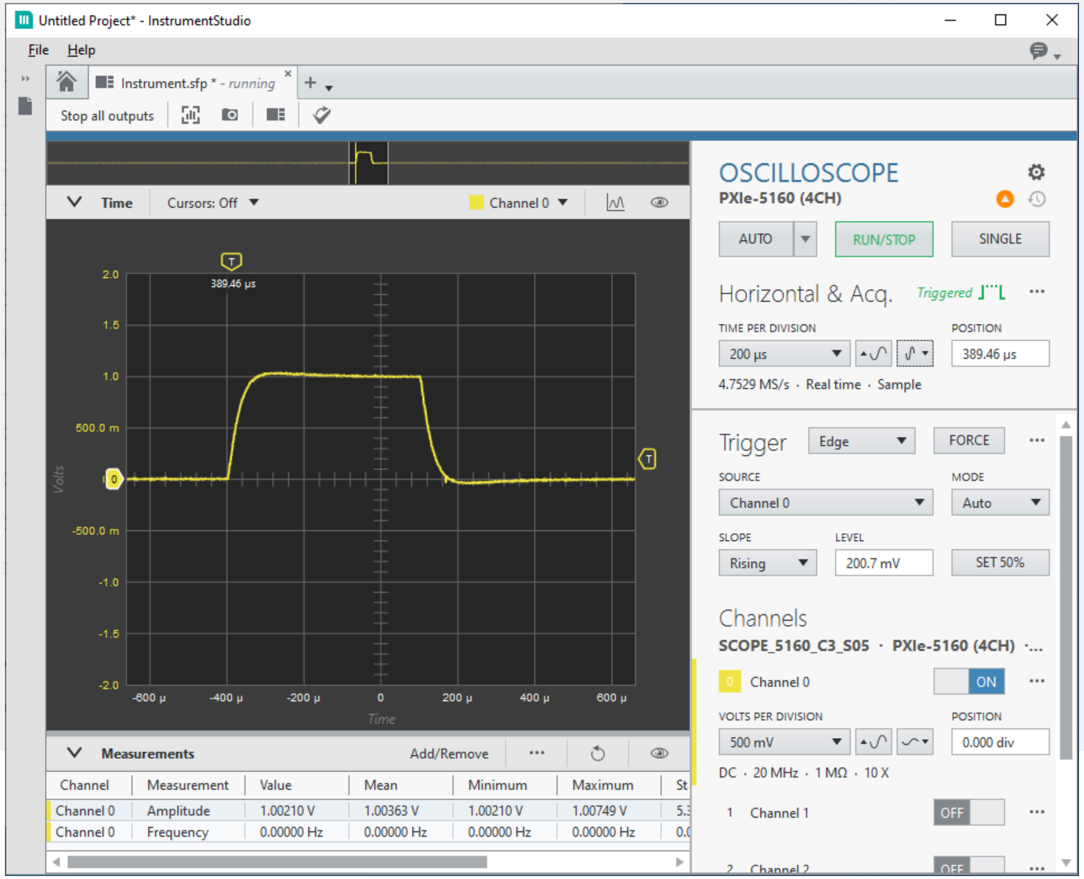
Source Delay



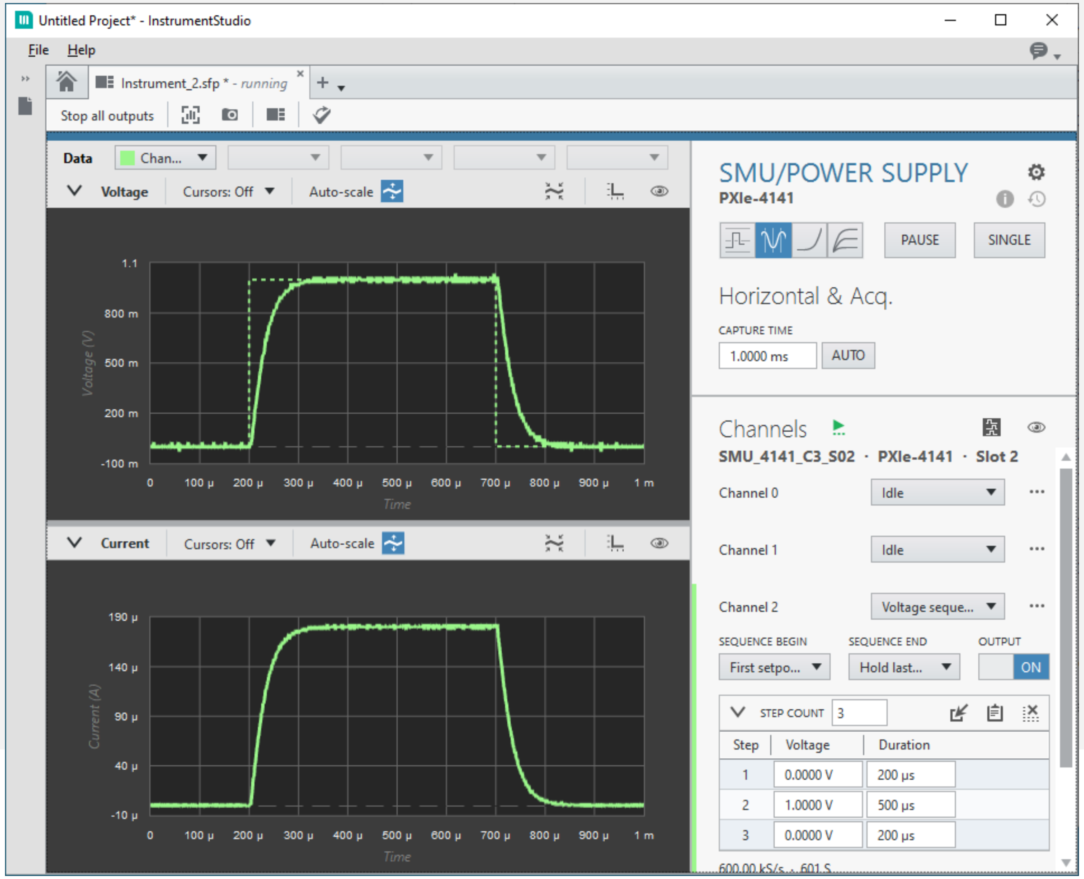


Determining Ideal Source Delay

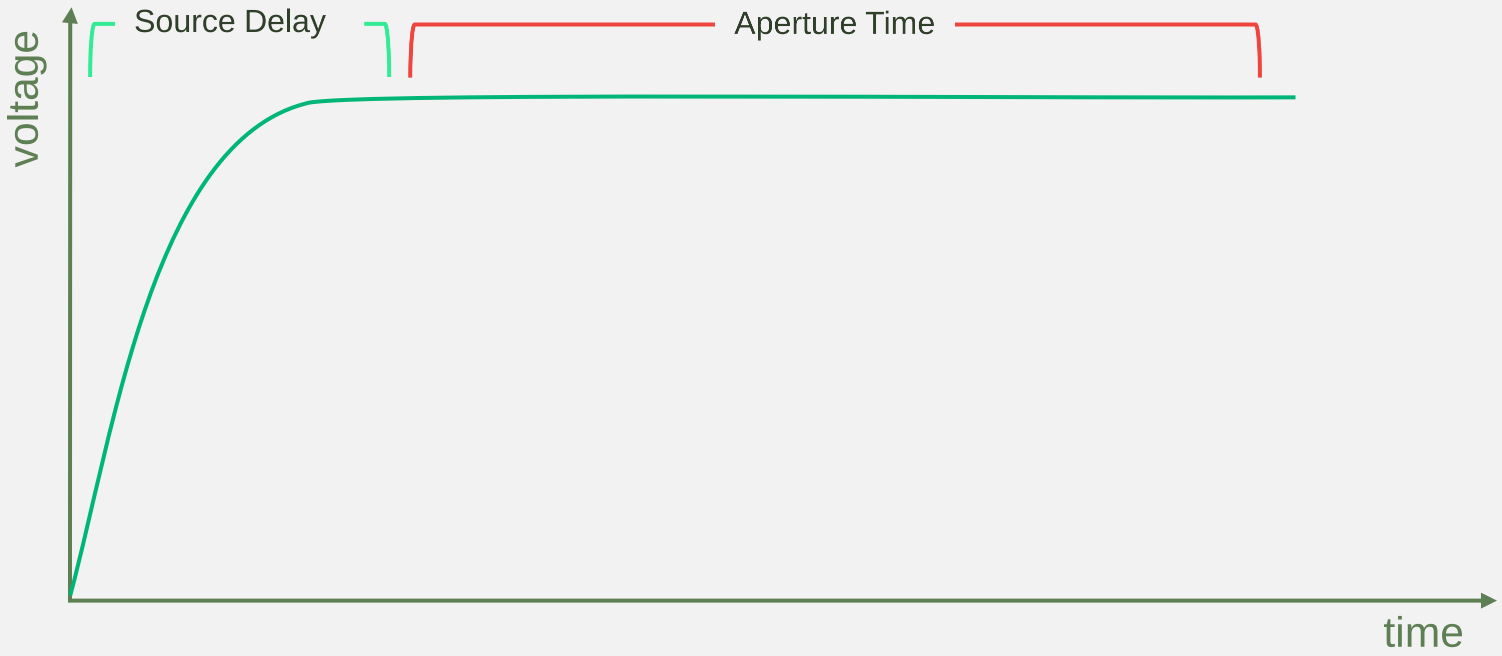
Method 1: Oscilloscope



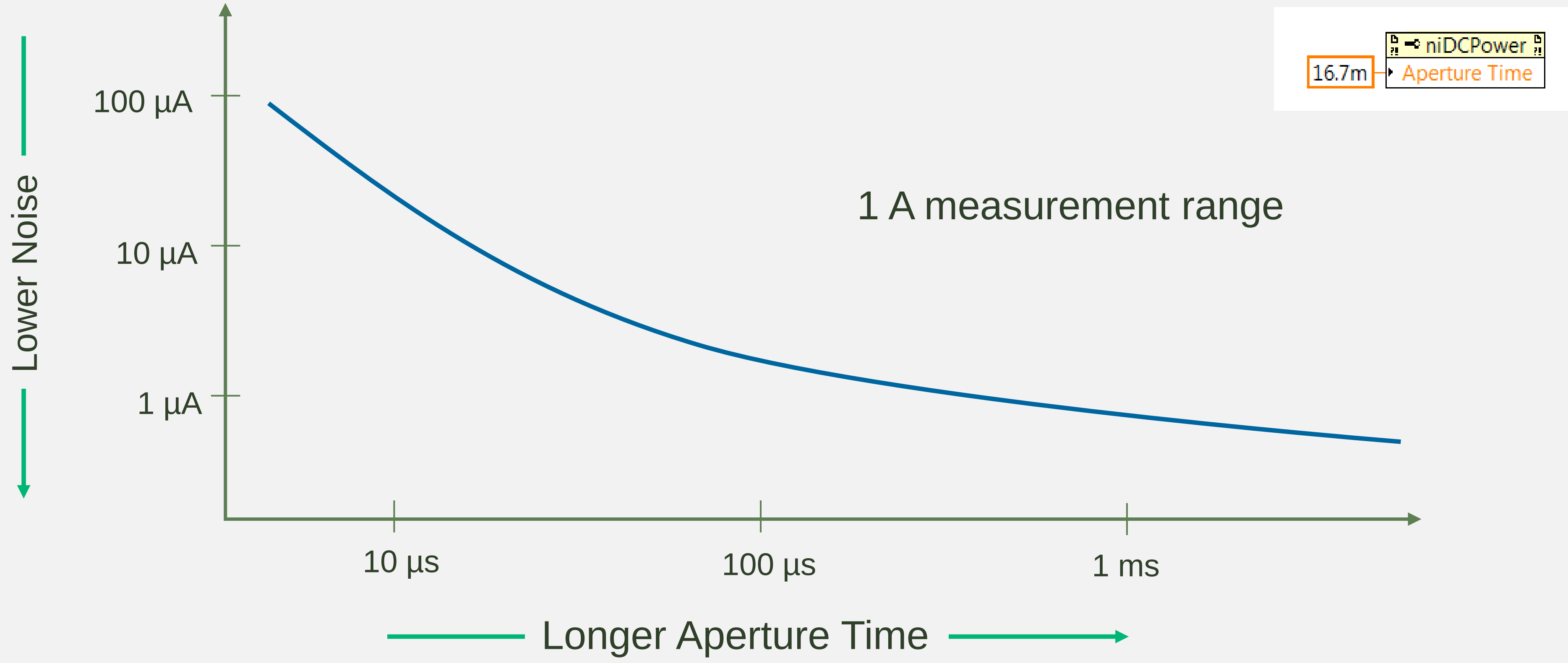
Method 2: SMU built-in digitizer



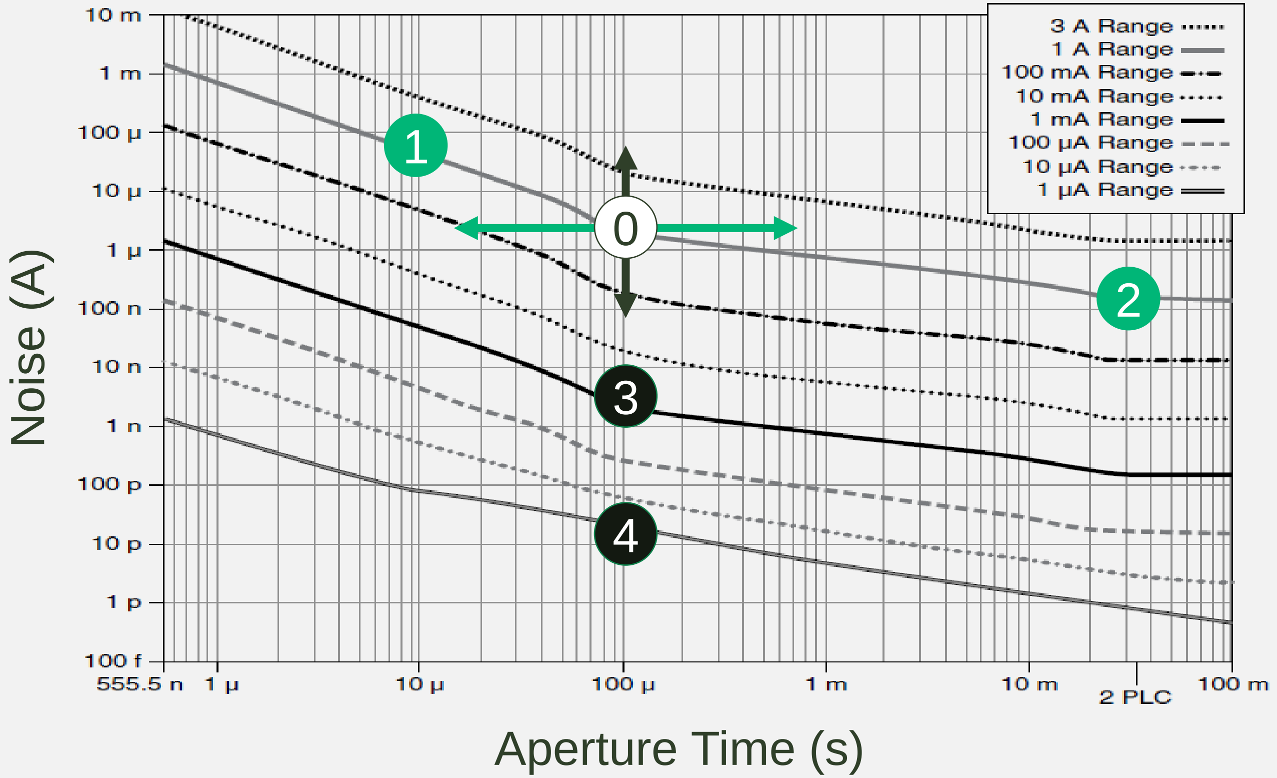
Source and Measure Cycle



Property: Aperture Time



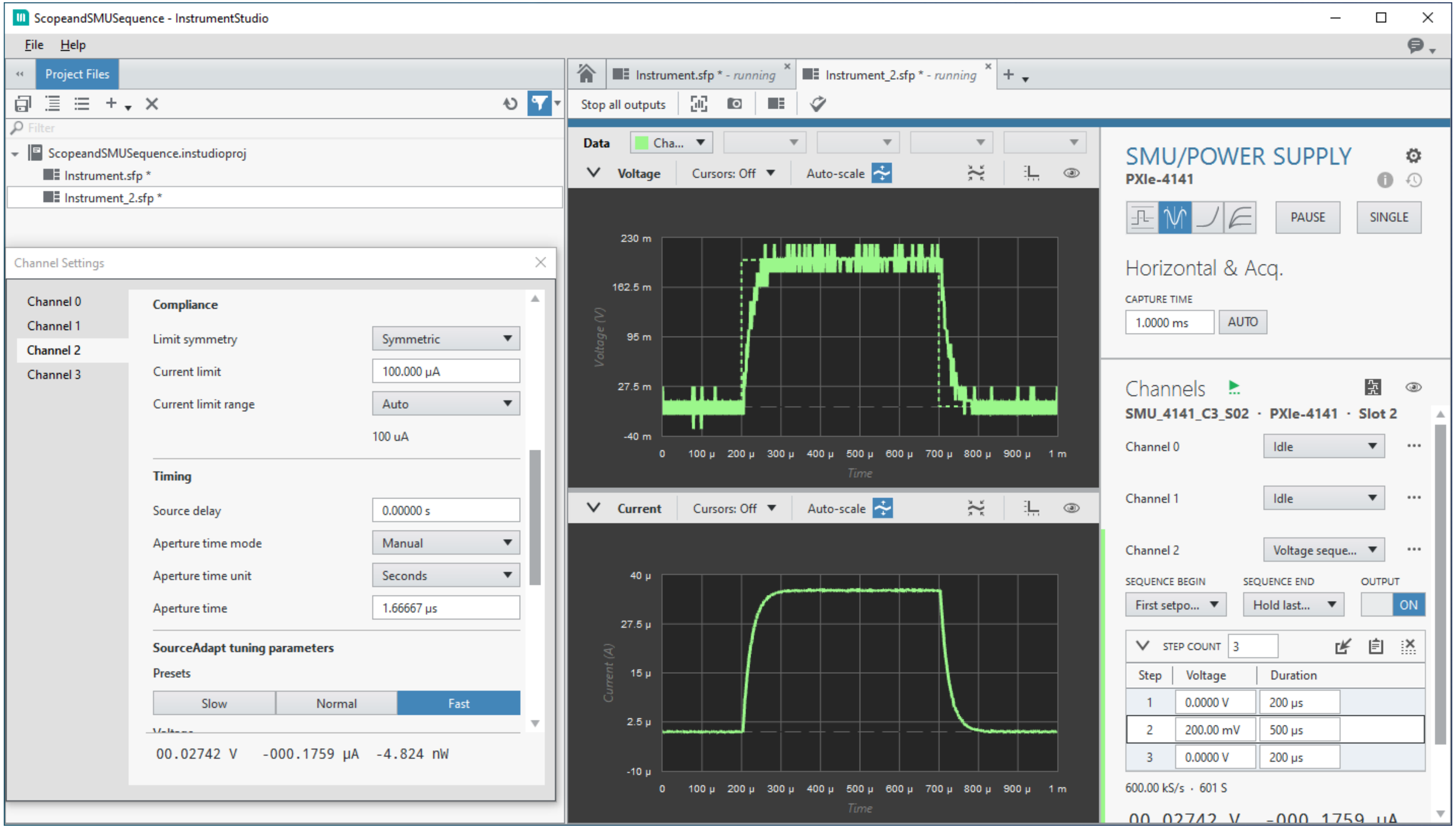
Noise Versus Aperture Time



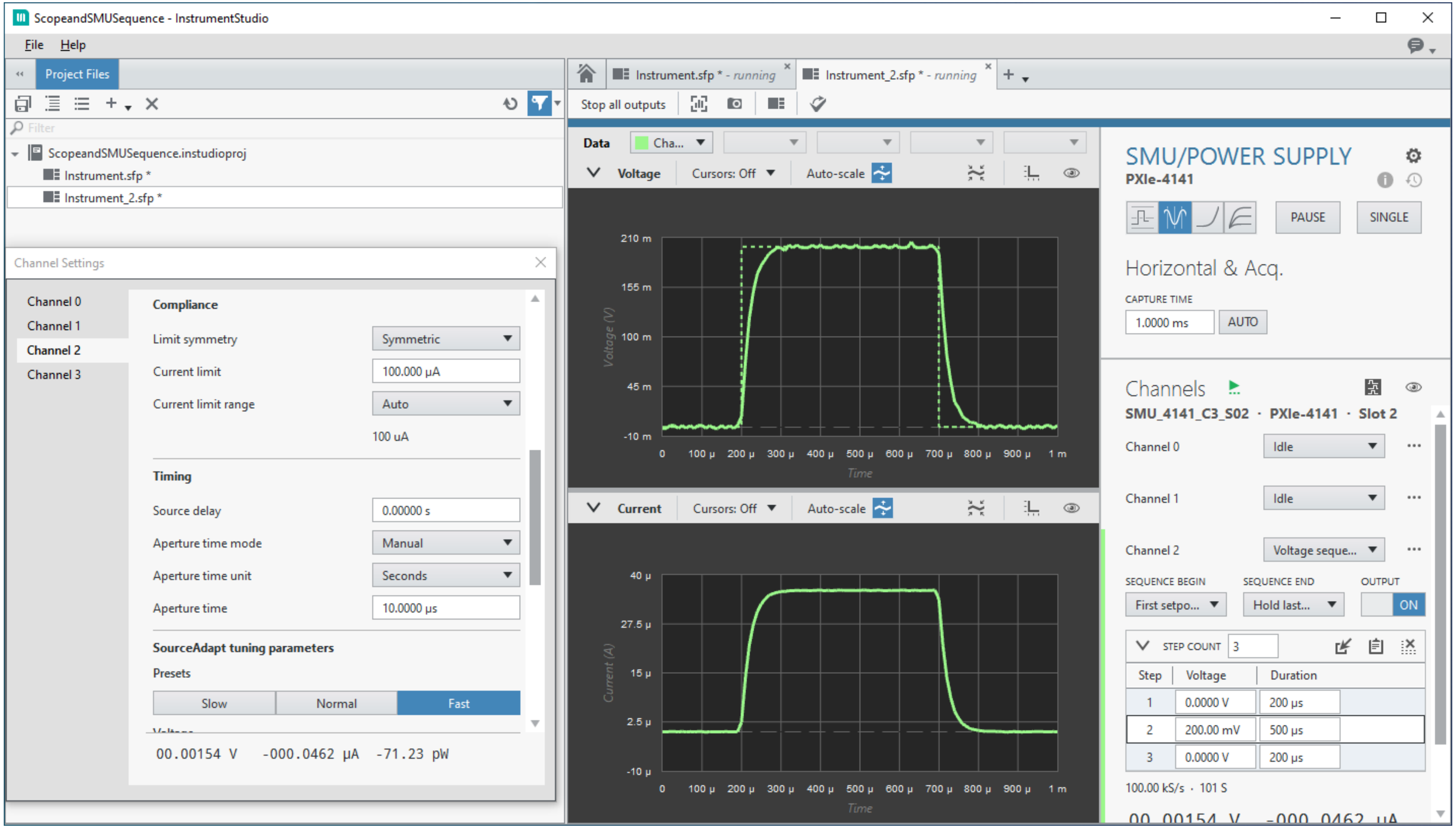
Noise

0	1 µA
1	100 µA
2	100 nA
3	1 nA
4	10 pA

Noise Versus Aperture Time



Noise Versus Aperture Time



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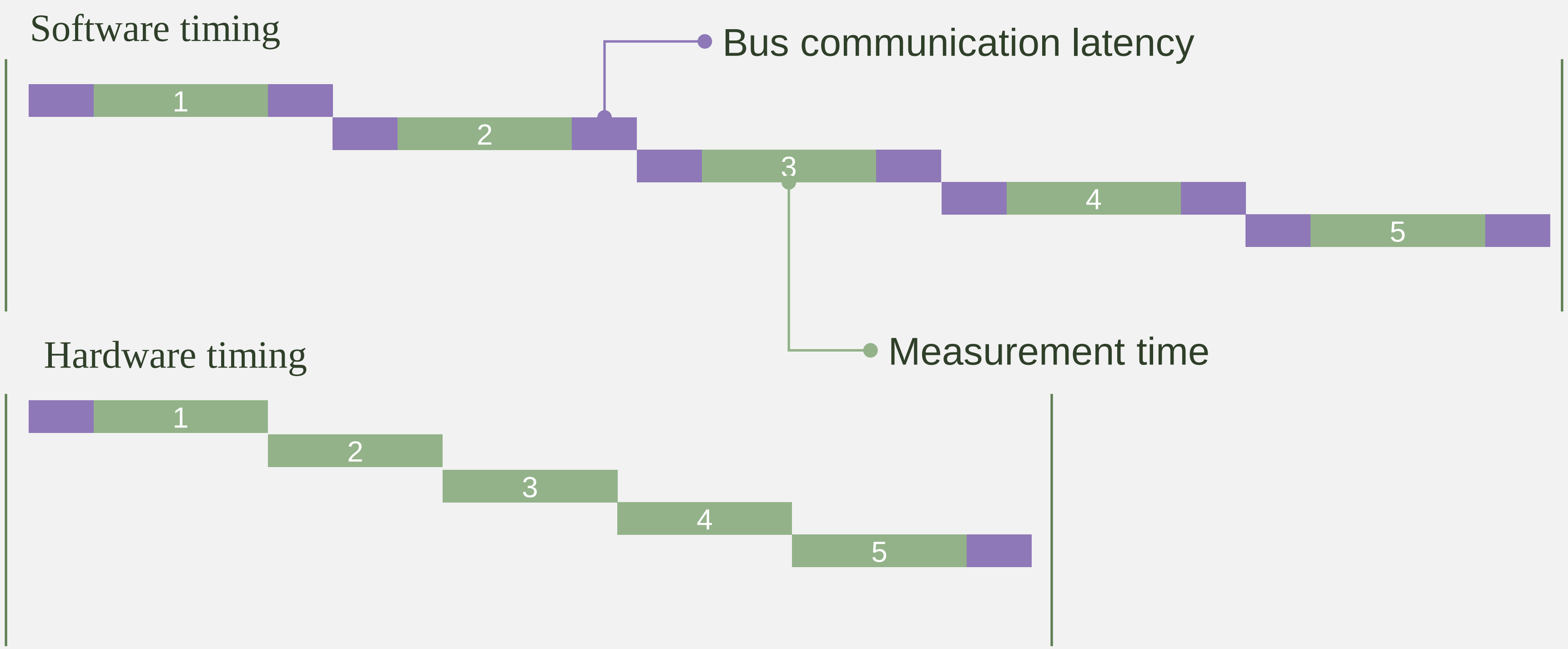
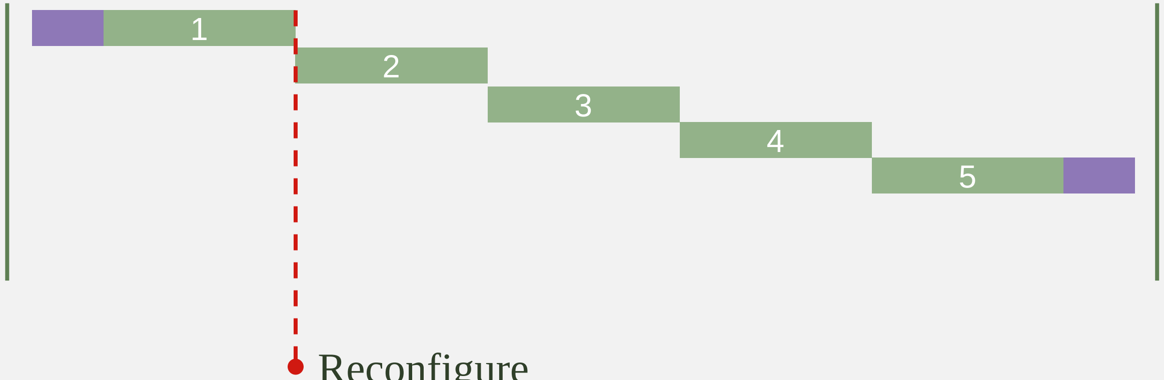
Sequencing: Software Versus Hardware Timing



Hardware-Timed Sequencing



Reconfigure

- Output level
- Source delay

] "basic" sequence

- Aperture time
- Measurement range
- Compliance limit
- Output mode (I or V)
- …

] "advanced" sequence (>30 properties)

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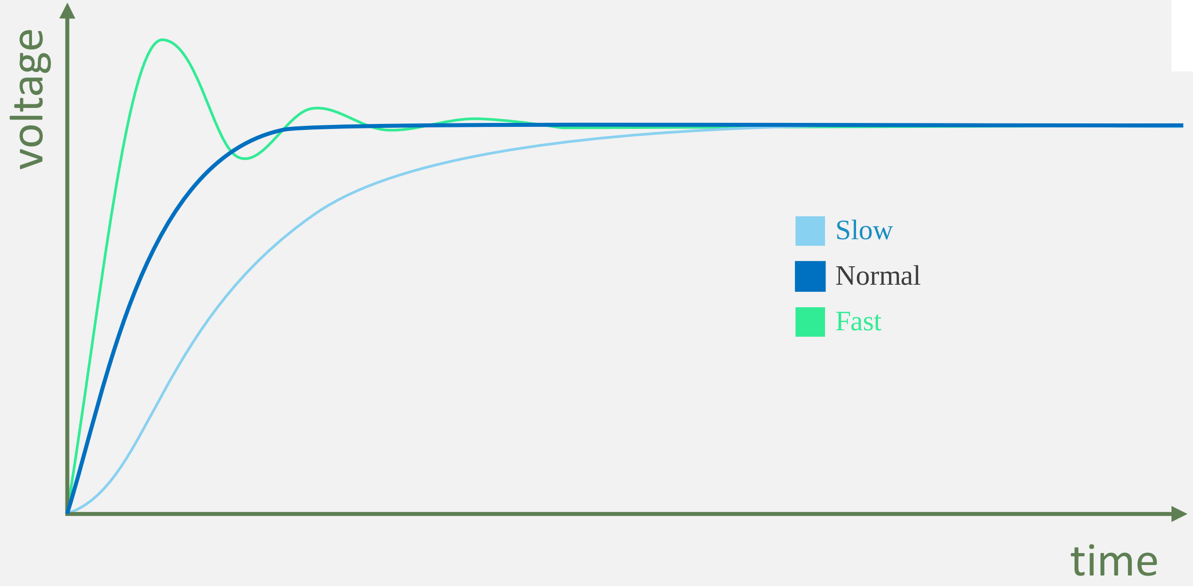
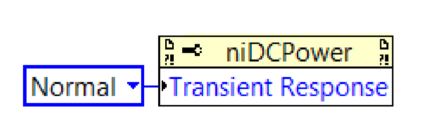
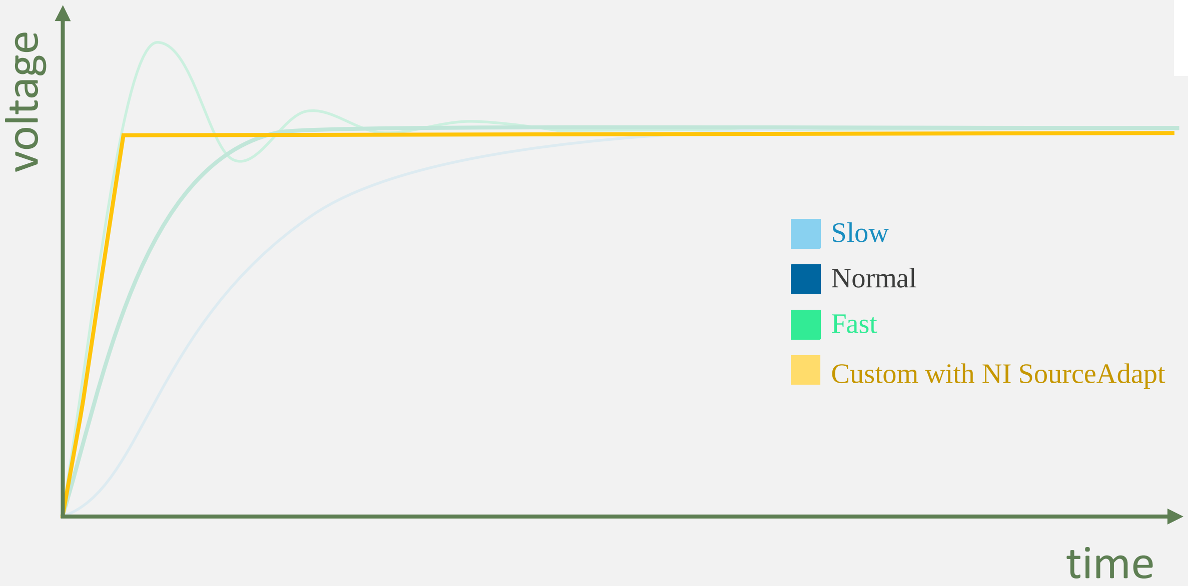
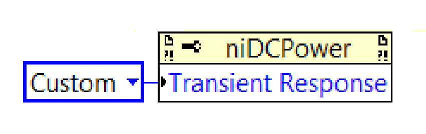
Transient Response and Rise Time



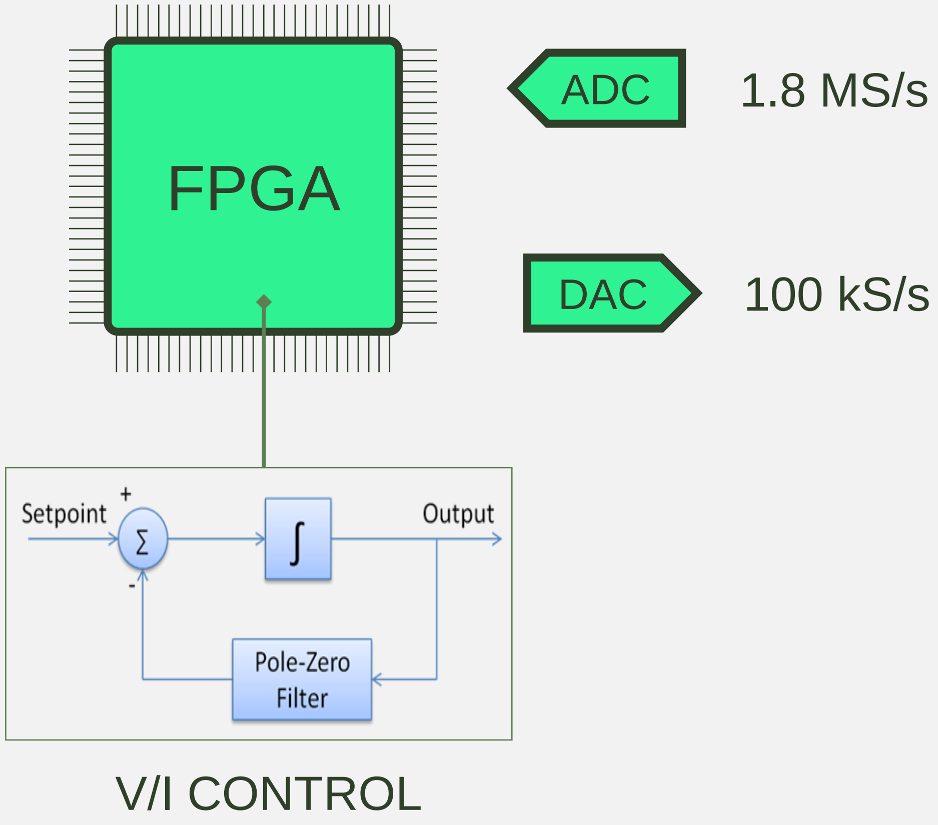


Transient Response and Rise Time

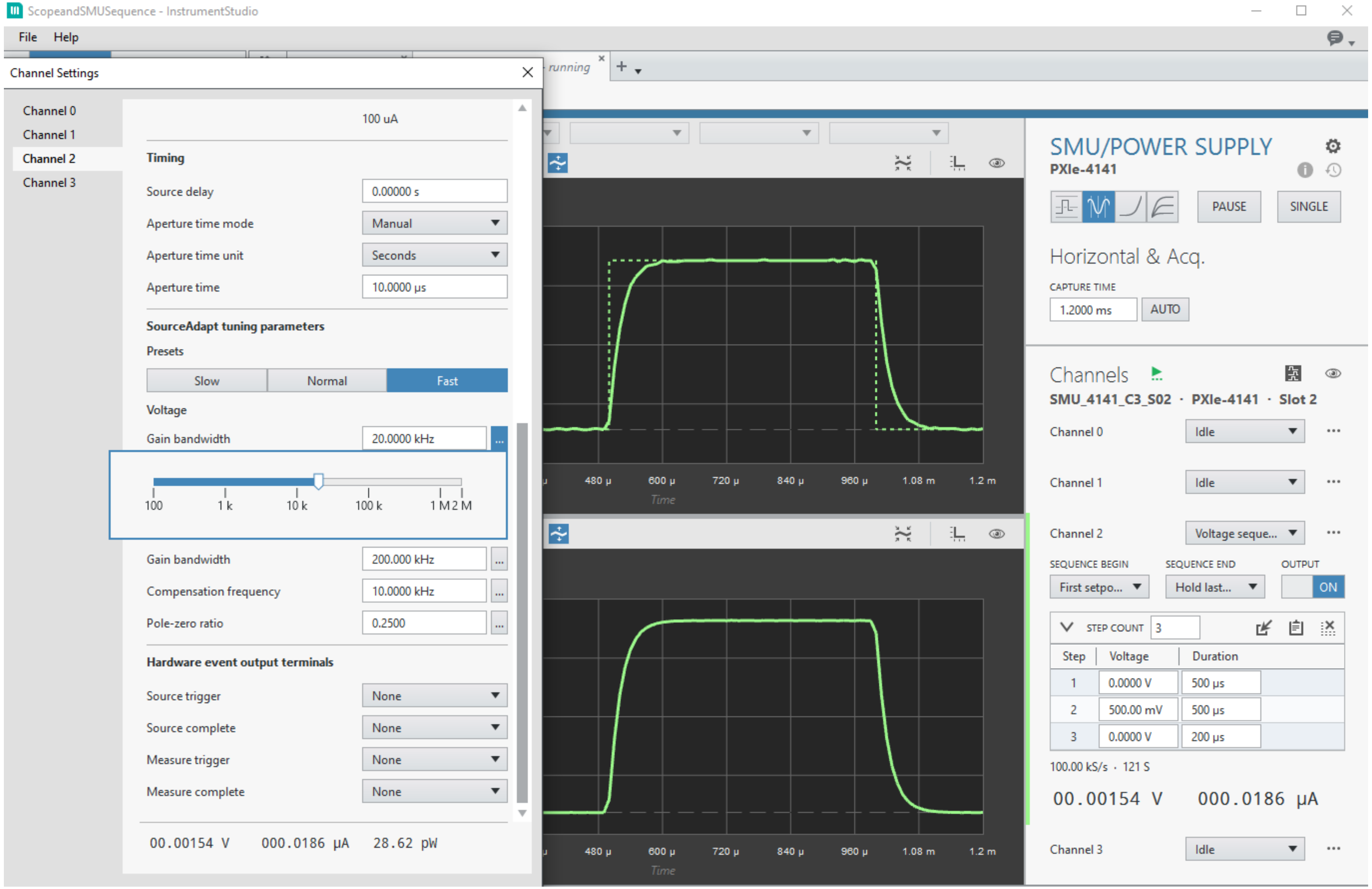




SourceAdapt: Digital Control Loop



SourceAdapt: Tuning in InstrumentStudio



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