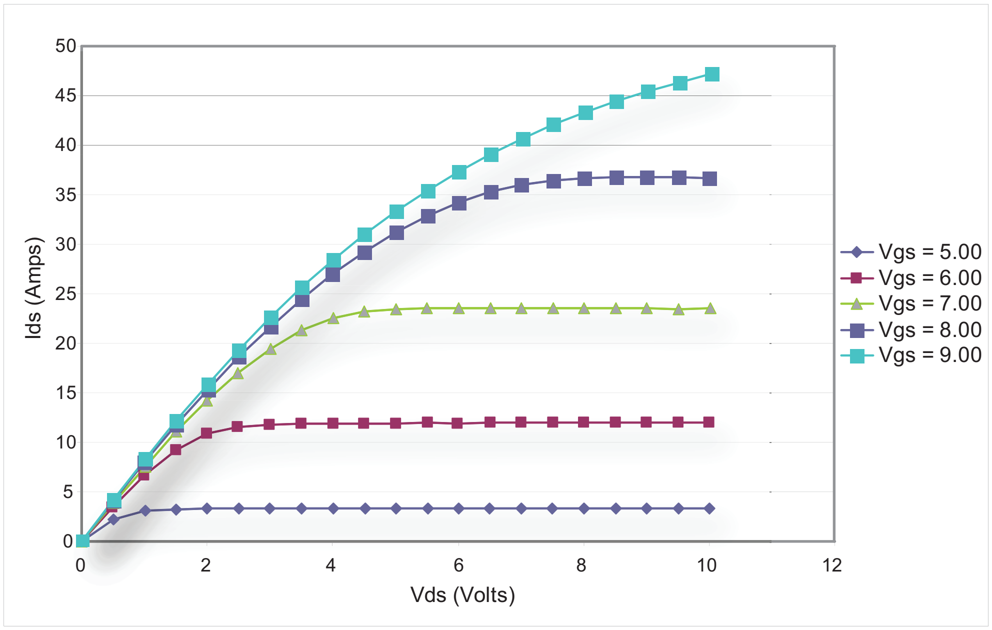
Introduction to power discrete IV curve testing

A common test performed on power MOSFETs and IGBTs characterizes the IV performance of the DUT at various gate voltages. In this test, the gate of the device is held at a constant voltage while the voltage on the drain (or collector) of the device is swept and current is measured. This process is repeated for several different gate voltages and the resulting data is plotted to show a series of IV curves for the device. The following figure illustrates an example of this plot for a power MOSFET device.

Figure 1: Example set of IV curves for a power MOSFET device



In order to avoid device self-heating, this test is usually performed using pulsed measurements. This method pulses voltage across the device for a short duration. During this pulse, after the pulse has settled, the current is measured. The duration of the pulse, as well as the duty cycle in which the pulses are applied to the device, are controlled minimizing self-heating. A single Model 2651A is capable of pulse-measurement testing with precision timing at currents up to 50 A and pulse widths as low as 100 µs.

This example demonstrates how to perform pulsed measurements, and collect IV curves, using the Model 2651A on a MOSFET. The same procedure could be used to test IGBTs.

Equipment needed for this example

To run this test you will need the following equipment:

- Model 2651A .
- Series 26xxA System SourceMeter® Instrument (see Note).
- TSP-Link® Cable (Keithley Instruments part number CA-180-3A).
- GPIB cable or Ethernet cable to connect the Model 2651A to a computer.
- Additional cable and connector assemblies as required to make connections to the DUT (for example, Model 2651A-KIT and Model 2600-KIT). See Device connections (on page 4) for a schematic of required connections.

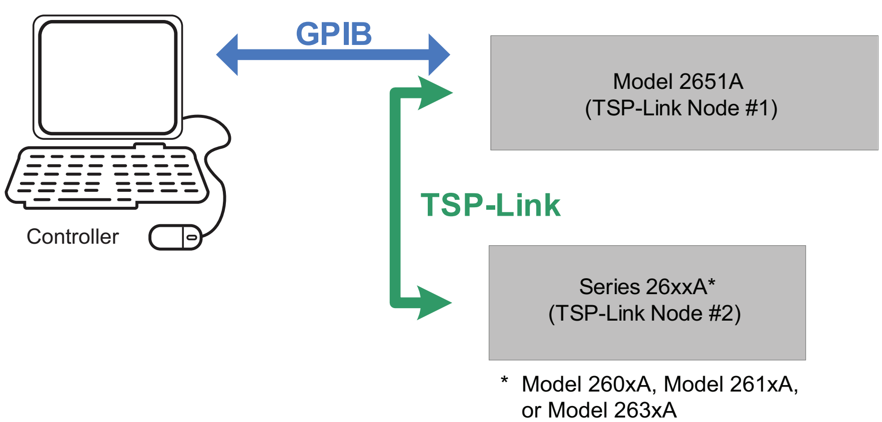
NOTE

For this application, Series 26xxA System SourceMeter® Instrument refers to any of the following instrument models: Model 260xA, Model 261xA, or Model 263xA.

Set up communication

The communication setup is illustrated in the following diagram. GPIB is used as an example, but this application can be run using any of the supported communication interfaces for the instruments. A TSP-Link connection enables communication between the two instruments. Commands for the Series 26xxA (on TSP-Link node 2) are sent over the TSP-Link interface.

Figure 2: GPIB communication overview



When using the TSP-Link communication interface, each instrument must have a unique TSP-Link node number. Configure the node number for the Model 2651A to 1 and the Series 26xxA to 2.

To set the TSP-Link node number using the front panel interface:

Press the **MENU** key.

Select **TSPLink**.

Select **NODE**.

Use the navigation wheel ◷ to adjust the node number.

Press the **ENTER** key to save the TSP-Link node number.

On the Model 2651A SMU #1 (TSP-Link node #1), perform a TSP-Link reset to update it with the linked instruments:

Press the **MENU** key.

Select **TSPLink**.

Select **RESET**.

NOTE

If error 1205 is generated during the TSP-link reset, ensure that the Series 26xxA has a unique TSP-Link node number.

Quick Tip

You can also perform a TSP-Link reset from the remote command interface by sending `tsplink.reset()` to the Model 2651A. This command is also included in the example program code below for completion.

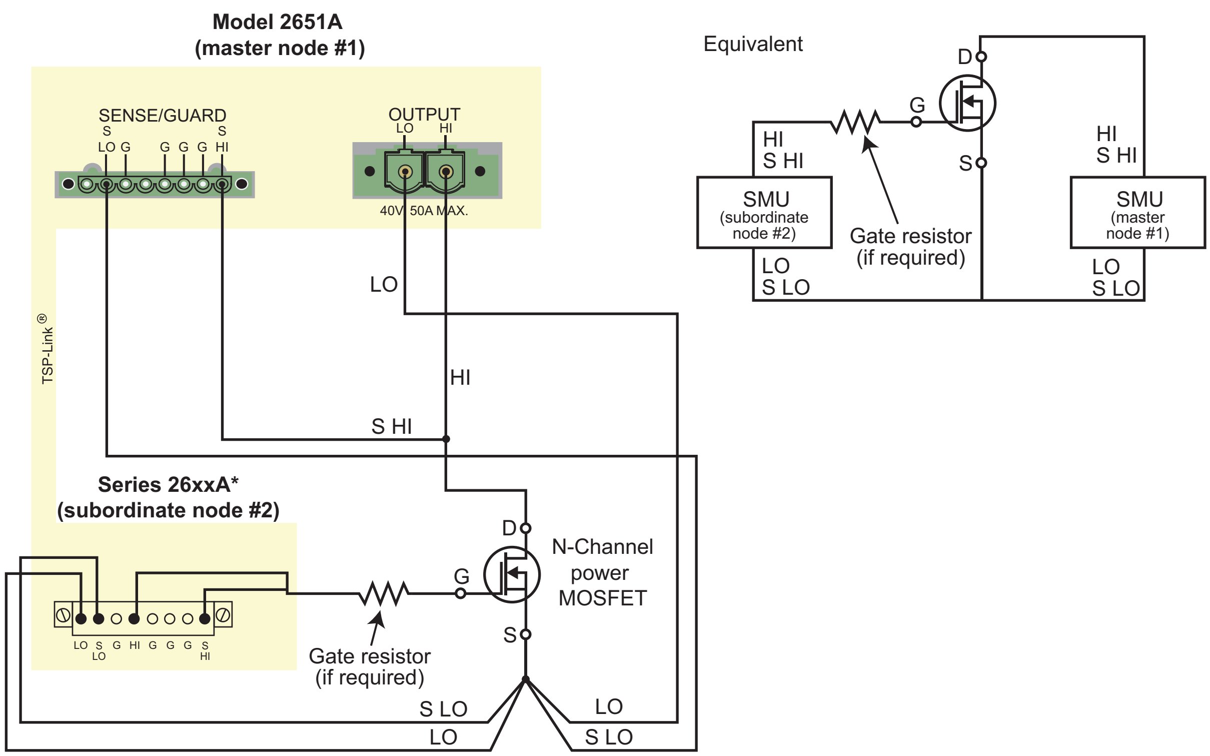
Device connections

To run the test, make the connections as illustrated in the following figure. To ensure good contact, use care when making connections.

NOTE

For best results, all connections should be left floating (no connections should be tied to ground).

Figure 3: Connections for IV curve characterization



* Model 260xA, Model 261xA, or Model 263xA

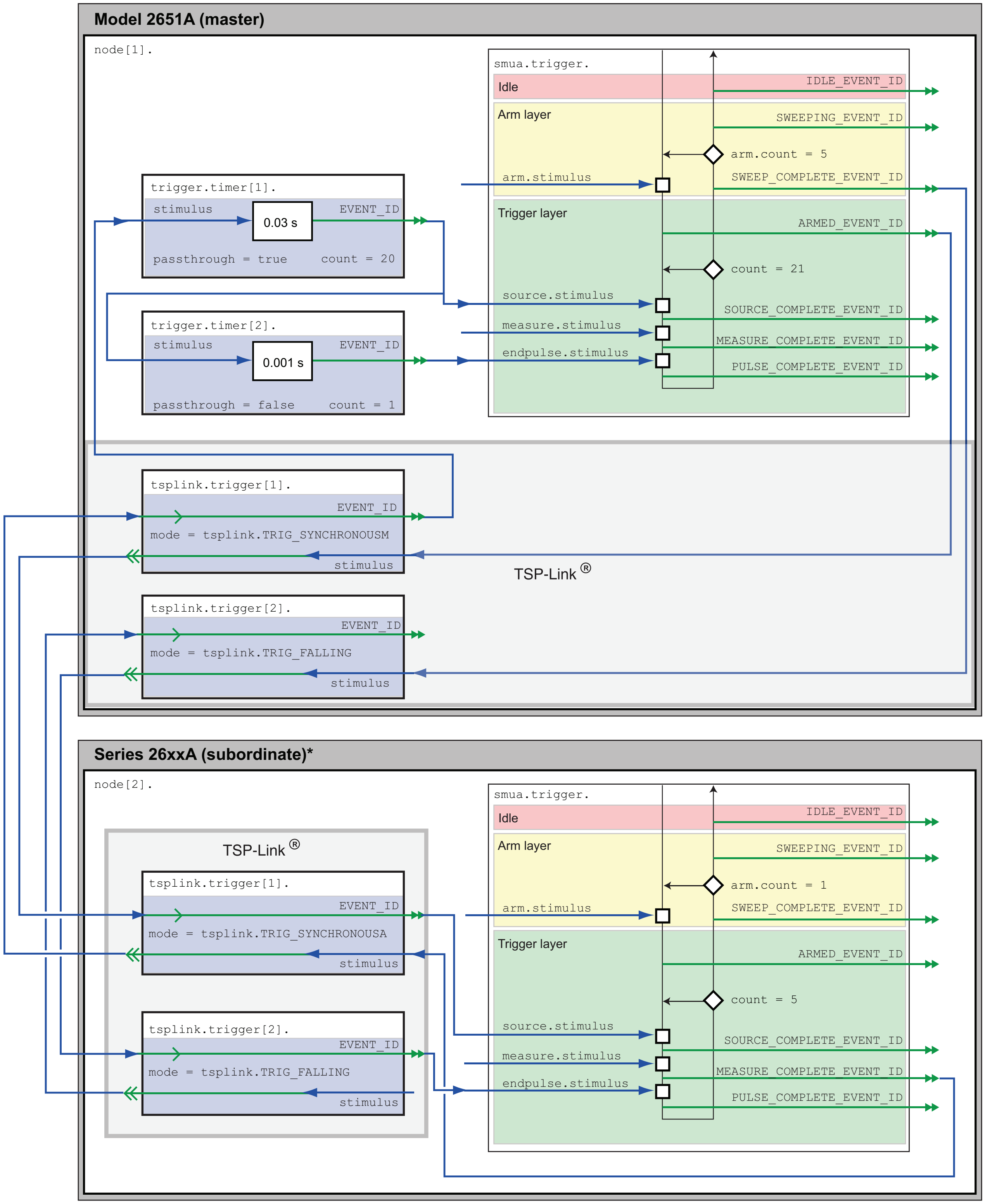
NOTE

During high-current pulsing through the channel of the device, the gate may begin to oscillate. This oscillation creates an unstable voltage on the gate, which may cause unstable measurements through the device channel. You can install a resistor to dampen this oscillation and stabilize the gate. Install the resistor between the gate of the device and the force and sense HI of the Model 2651A. If the gate still remains unstable, enable High-C mode on the Model 2651A source-measure unit (SMU).

Configuring the trigger model

Correctly configuring the trigger model allows us to achieve pulsed measurements with precise timing and current levels up to 50 A on the Model 2651A. The following figure illustrates this test's overall trigger model configuration including the interactions between the Model 2651A and the Series 26xxA instrument. Refer to the Example Program Code for an implementation of this trigger model.

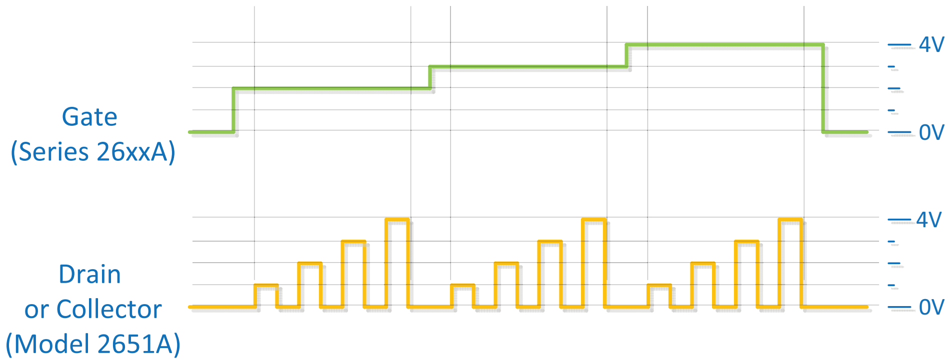
Figure 4: Trigger model configuration for IV curve characterization



* Model 260xA, Model 261xA, or Model 263xA

In this example, each instrument's trigger model is configured to perform a linear sweep. The Series 26xxA is configured to sweep the voltage applied to the gate of the device while the Model 2651A is configured to sweep the voltage across the drain (or collector) of the device. Additionally, the Model 2651A is configured to repeat its sweep and will do so as many times as there are steps in the Series 26xxA instrument's sweep. For example, if the Model 2651A instrument's sweep contains 4 points and the Series 26xxA instrument's sweep contains 3 points, then the Model 2651A instrument's sweep will run 3 times for a total of 12 points. To synchronize the sweeps between instruments, the trigger lines of the TSP-Link are used. The following figure illustrates the 12 point sweep example.

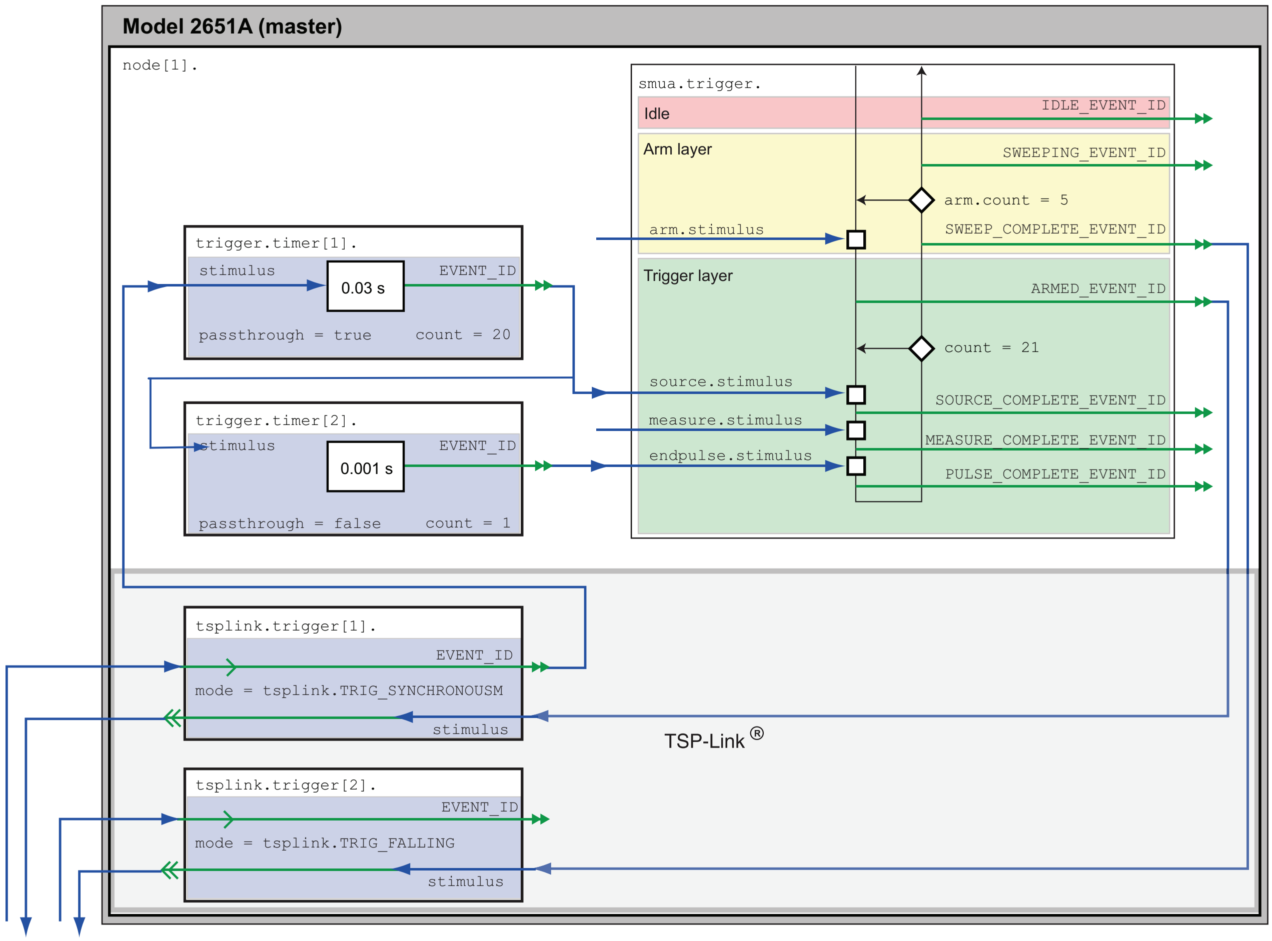
Figure 5: SMU output from configured trigger model



Model 2651A trigger model operation

The following figure illustrates this test's Model 2651A trigger model configuration.

Figure 6: Model 2651A trigger model for IV curve characterization



When the configured trigger model of the Model 2651A is initiated, the following occurs:

The SMU trigger model passes through the Arm Layer, enters the Trigger Layer then outputs the ARMED event trigger.

The ARMED event trigger triggers TSP-Link Trigger 1 which outputs a trigger on TSP-Link line 1. This trigger is meant to tell the Series 26xxA that it should step the gate SMU.

The SMU's trigger model continues until it reaches the Source Event and then pauses and waits for an event trigger

A trigger comes back on TSP-Link Trigger 1 indicating that the gate step is complete and an event trigger is output from TSP-Link Trigger 1 and input to Timer 1

Timer 1 receives the event trigger and begins its countdown while simultaneously passing the event trigger.

The SMU's source event receives the event trigger from Timer 1, sets the SMU output to the pulse level and then waits for a programmed source delay (if any), and then outputs the SOURCE_COMPLETE event to Timer 2.

Timer 2 receives the SOURCE_COMPLETE event trigger and begins its countdown

The SMU's trigger model then moves to the Measure Event where it waits a programmed measure delay (if any) then takes a measurement.

The SMU's trigger model then moves to the End Pulse Event where it stops and waits for an event trigger from Timer 2.

Timer 2's countdown expires and outputs an event trigger to the SMU's End Pulse Event.

The End Pulse Event receives the event trigger from Timer 2, sets the SMU output to the bias level, and then continues.

The trigger model then checks the current Trigger Layer iteration number against the trigger count.

- If the iteration number is less than the trigger count then the trigger model stays in the trigger layer and wraps around to the Source Event where it waits again for an event trigger from Timer 1 (as it did in step 3). This time however, Timer 2 will not receive an event trigger from TSP-Link Trigger 1. Despite this, the trigger model will continue running because Timer 1's count was set to one less than the trigger count, therefore Timer 1 will continue outputting event triggers for as long as the trigger model is in the Trigger Layer, outputting one every trigger event every time the countdown expires. The trigger model continues as described in step 6.
- If the iteration number is greater than the trigger count then the SMU trigger model exits the Trigger Layer and goes into the Arm Layer.

Upon entering the Arm Layer, the SMU trigger model outputs the SWEEP_COMPLETE event trigger.

TSP-Link Trigger 2 receives the SWEEP_COMPLETE event trigger and outputs a trigger on TSP-Link line 2. This trigger is meant to signal the Series 26xxA that it is OK to continue and no longer needs to hold the current gate level.

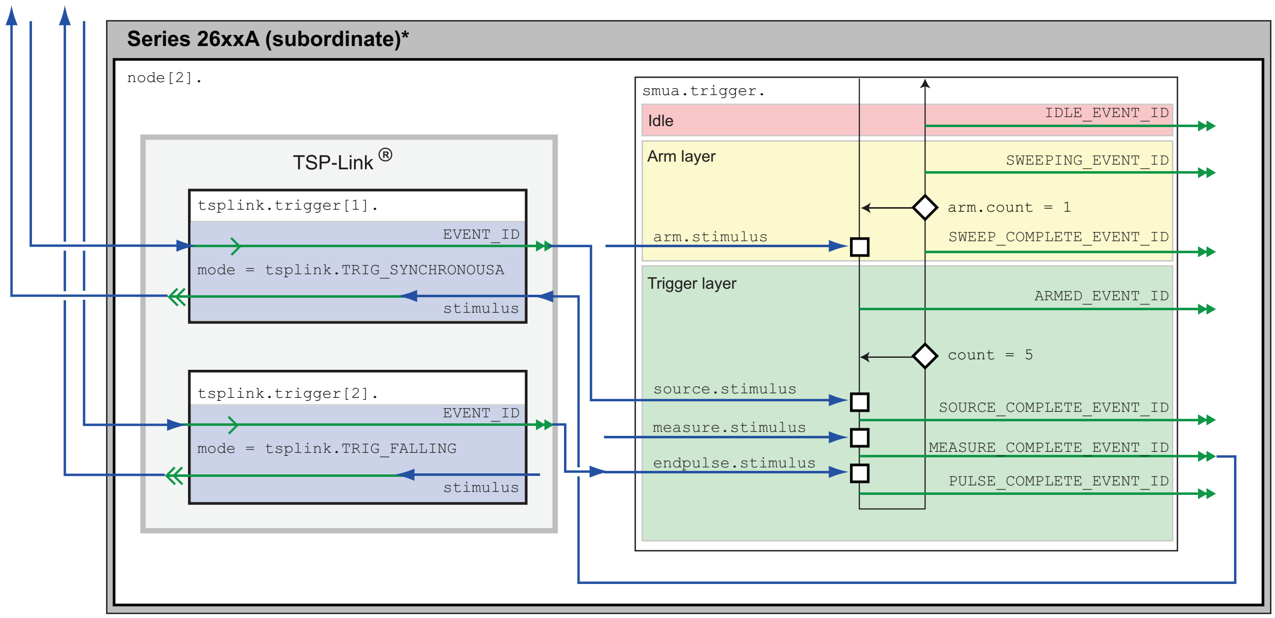
The trigger model then checks the current Arm Layer iteration number against the arm count.

- If the iteration number is less than the arm count, then the trigger model stays in the Arm Layer begins the entire process again from step 1.
- If the iteration number is greater than the arm count, then the trigger model continues, exits the Arm Layer, and returns to Idle.

Series 26xxA instrument's trigger model operation

The following figure illustrates this test's Series 26xxA trigger model configuration.

Figure 7: Series 26xxA instrument's trigger model for IV curve characterization



* Model 260xA, Model 261xA, or Model 263xA

When the configured trigger model of the Series 26xxA instrument is initiated, the following occurs:

The SMU's trigger model passes through the Arm Layer, enters the Trigger Layer, reaches the Source Event the pauses and then waits for an event trigger from TSP-Link Trigger 1.

A TSP-Link trigger is received by TSP-Link Trigger 1. Because TSP-Link Trigger 1 is configured as a synchronous acceptor, it latches the line low and then outputs an event trigger to the SMU's Source Event.

The SMU's Source Event receives the event trigger from TSP-Link Trigger 1 and sets the SMU output to the step level and then waits a programmed source delay (if any) and continues.

The SMU's trigger model then moves to the Measure Event where it waits a programmed measure delay (if any), and takes a measurement, and then outputs the MEASURE_COMPLETE event trigger.

TSP-Link Trigger 1 receives the MEASURE_COMPLETE event trigger and releases the TSP-link trigger line, telling the Model 2651A that it has completed its step and that the Model 2651A may begin its sweep.

The SMU's trigger model then moves to the End Pulse Event where it stops and waits for an event trigger from TSP-Link Trigger 2.

A TSP-Link trigger is received by TSP-Link Trigger 2, indicating that the Model 2651A instrument's sweep has completed and it is safe to go to the next step. TSP-Link Trigger 2 outputs an event trigger to the SMU's End Pulse Event.

The SMU's End Pulse Event receives an event trigger from TSP-Link Trigger 2, completes the End Pulse Action, and then continues.

The trigger model then checks the current Trigger Layer iteration number against the trigger count.

- If the iteration number is less than the trigger count then the trigger model stays in the trigger layer and wraps around to the Source Event where it waits again for an event trigger from TSP-Link Trigger 1. The trigger model repeats from step 2.
- If the iteration number is greater than the trigger count, then the SMU trigger model exits the Trigger Layer and then goes into the Arm Layer.

Because the arm count is set to 1, the trigger model exits the Arm Layer and returns to Idle.

Example program usage

This script's functions allow the sweep parameters of the test to be adjusted without having to rewrite and re-run the script. A test can be executed by calling the function `IV_Curves()` with the appropriate values passed to it in its parameters.

IV_Curves() parameters

Parameter	Units	Description
gstart	Volts	The level of the first step in the gate sweep
gstop	Volts	The level of the last step in the gate sweep
gsteps	Volts	The number of steps in the gate sweep
dstart	Volts	The level of the first step in the drain/collector sweep
dstop	Volts	The level of the last step in the drain/collector sweep
dsteps	Not applicable	The number of steps in the drain/collector sweep
pulseWidth	Seconds	The width of the pulse in the drain/collector sweep
pulsePeriod	Seconds	The time between the start of consecutive pulses in the drain/collector sweep
pulseLimit	Amps	The current limit of the pulses in the drain/collector sweep.

An example call to this function is as follows:

```
IV_Curves(5, 9, 5, 0, 10, 21, 300e-6, 30e-3, 50)
```

This call will sweep the drain of the device from 0 V to 10 V in 21 points. The points of this sweep will be gathered using pulsed measurements with a pulse width of 300 µs and a pulse period of 30 ms for a 1% duty cycle. These pulses will be limited to a maximum of 50 A. This sweep will for be performed at five different gate voltages starting with 5 V and ending at 9 V. The resulting data from this test will be returned in an Excel compatible format (you can cut and paste the output from the console) that can be used for graphing and analysis.