APPLICATION NOTE

# Optimal SMU Response by Large Selectable Control Bandwidths for Capacitive Loads

Key Words: SMU, Source Measure Unit, Load Capacitance, Capacitive Load, Bandwidth, Slew Rate, Control Bandwidth, Under-damped, Overshoot

Product Family: Model 52400 series SMU (Source Measure Unit)

October 2013
Chroma ATE Inc.

## SCOPE

Typically, SMUs are considered the user's DUT as part of the control loop. It is difficult for the designer to guess what exact load a user will need to measure. Some capacitive loads can cause ringing in the transient response of the device and make the system unstable.

The "Optimized Control Bandwidth" offers much better settling times with no overshoot. It therefore provides the SMU output an optimized response.

Chroma SMUs provide 16-step programmable slew rate. Users can select the control loop for optimal SMU responses to electrical loads and obtain an ideal response with minimum rise times and without overshoot or oscillations.

SMUs (Source Measure Units) are remarkable instruments to test and measure the current-voltage (I-V) characteristics for a variety of semiconducting devices. These conductive devices include LEDs, Laser Diodes, Solar Cells, Batteries, FETs, MOSFETs, and more.

Generally, SMUs remain stable when sourcing/ driving a capacitive load. Sometimes though, certain capacitive loads can cause ringing in the transient response of the device and make the system unstable.

When the DUT is loaded onto the output of an SMU, attention must be paid as there is a specific limit on the capacitance. Attaching large capacitive loads to the SMU output can result in oscillation, so users need to make sure that the input capacitance does not exceed the specific limit of SMU load capacitance.

## WHAT IS A CAPACITIVE LOAD?

A capacitive Load refers to capacitance external to the SMU, contained within the feedback loop of the oscillator circuit.

A capacitive Load may cause peaking and oscillation. A capacitive load connected to the output of a SMU that causes undesired results and slows down the system.

## BANDWIDTH & SLEW RATE

Bandwidth determines the instrument's ability to respond to time varying signals over a range of frequencies. The measure of the instrument's response is the ability to respond to a step function; the typical measure of response is the rise time of the instrument.

The slew rate is the maximum rate of change of the output voltage as a function of time. The slew rate is limited to the output current limit divided by the total load capacitance, as expressed in the following equation:

$(\Delta V/\Delta t) = (I/C)$

Where $\Delta V$ is the change in the output voltage
$\Delta t$ is the change in time
I is the current limit
C is the total capacitance across the load

In electronics, slew rate is defined as the maximum rate of change of output voltage per unit of time and is expressed as volts over microseconds.

## RESPONSE TIME

The response time or response speed of the SMU directly affects the performance in measurement accuracy and the measurement throughput.

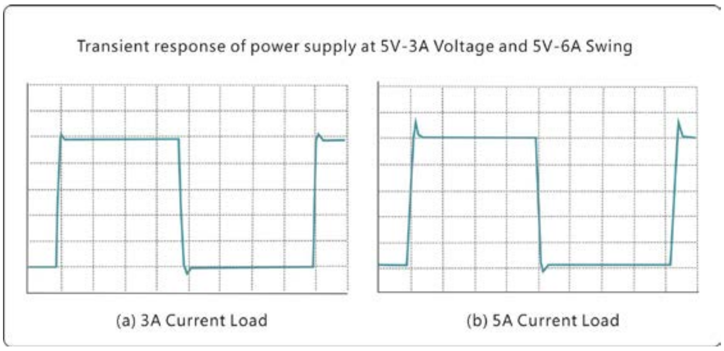


**Figure-1 Transient Response**

Figure-1 shows transient response of the case at 5A current load that shows a slightly large spike compared with the 3A current load that the settle time to the final voltage is quick and stable, without any ringing.

Good transient response is with a small overshoot in the rising and falling edges. The settling to the final voltage is quick and stable without any ringing. A part of the rise time depends on the SMU slew rate and the CR time constant added in series to the analog control input of the SMU.

## SMU STEP RESPONSE

Figure-2 shows the behavior of the control loop with a capacitor as a capacitive load. The response is under-damped, and it overshoots and takes a long time to settle. If the primary concern is to eliminate the overshoot, user can achieve a fast rise time while avoiding overshoots and oscillations by selecting a suitable control bandwidth.

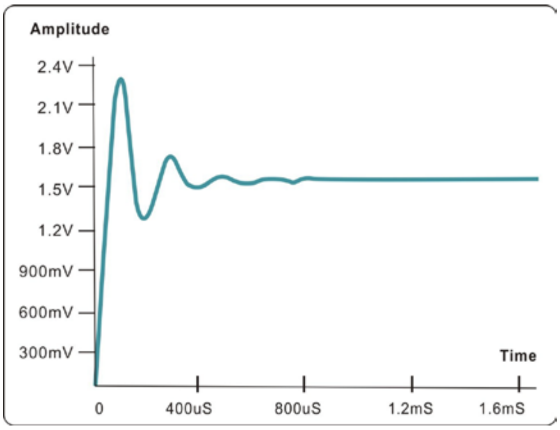


**Figure-2 1.5V Step Response with 0.1 uF Capacitor as capacitive Load**

## CONTROLLABLE BANDWIDTH

To increase test speeds, shorter settling time and faster rise/fall time (or slew rate) are required. This can be achieved by increasing the control bandwidth.

However, with different cable impedance or DUT characterization, high control bandwidth will sometimes cause oscillation. Therefore, to optimize test speed and stability, adjustable bandwidths are required. Figure-3 shows the condition of a voltage waveform under different control bandwidths.

## OPTIMIZED CONTROL BANDWIDTH

SMUs have the unique characteristics that the user's DUT is part of the control loop. It is impossible for the designer to guest what exact load the user needs to measure. Even if known, there is no practical way to match the analog-controlled instrument and the load with programming.

Figure-3 shows three possible responses when driving 1.5 Volt into a 0.1 uF capacitor. The purple response (Saturation or Oscillation) is similar to a high-bandwidth SMU designed with high-sourcing speed. Note the overshoot, which is likely to stress or damage the DUT. Even though the objective was a fast response, the response is so under-damped that it takes a long time to settle to the desired value.

SMUs could also be designed with a lower bandwidth to be stable on a wider range of loads, but the response would look like the brown curve (Undershoot) in Figure-3.

The output amplitude "Optimized Control Bandwidth" is achieved dramatically much better settling times with no overshoot. It lets us understand "Optimized Control Bandwidth" lets the SMU output an optimized response.

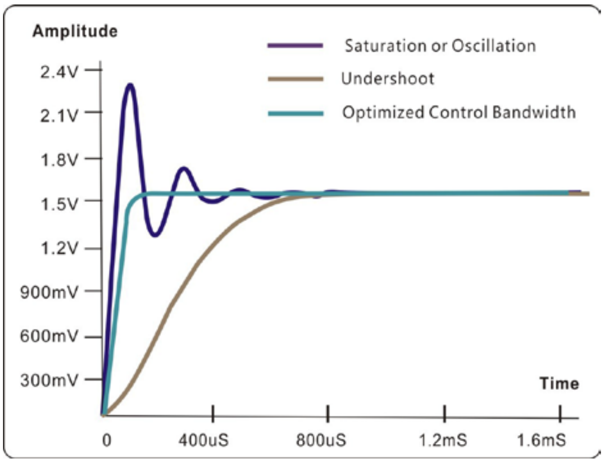


**Figure-3 1.5V Step Response with 0.1 uF Capacitor as capacitive Load**

Figure-4 shows 5 different Bandwidth settings of the 16 available Bandwidth Control of Chroma's SMU. Adjusting the bandwidth of the analog force loop, allows the customer to finely adjust the loop Bandwidth to optimize speed with different capacitance loads. The additional Bandwidth setting becomes important and mandatory for customers who want to go fast.

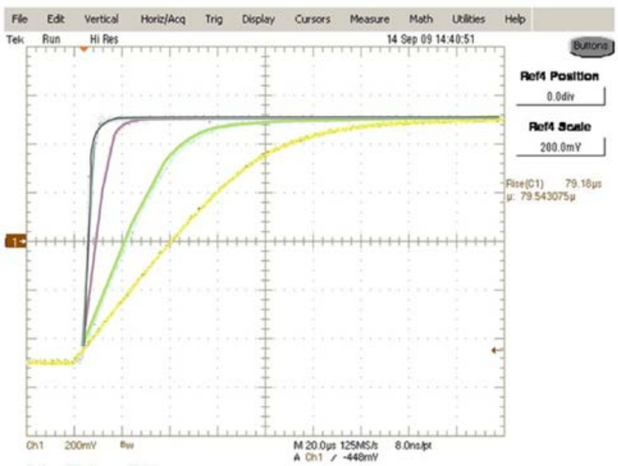


**Figure-4 SMU Output Waveform under Different Control conditions**

### Chroma 52400 Series SMUs

With 16 Control Bandwidths to select from, users can control the SMU's responses to electrical loads, achieving an ideal response with minimum rise times and without overshoot or oscillations.

Control Bandwidths help custom tune Chroma's SMU response to a given load. This provides an optimal SMU response with minimal times (faster measurement speed), it eliminates overshoots to protect the DUT, and oscillation to ensure system stability.

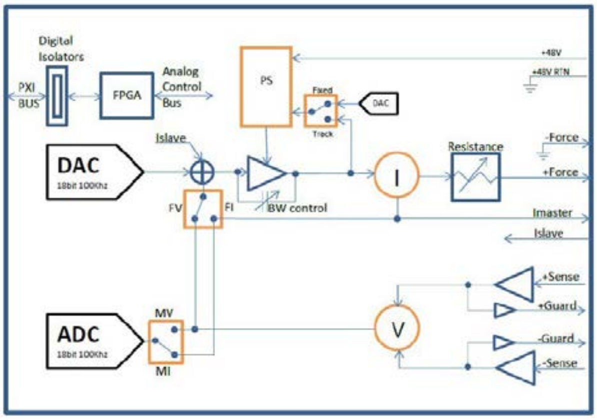


**Figure-5 Chroma's 52405 SMU PXI Card Hardware Structures**

Chroma's SMU provides 16-step programmable slew rate of up to 9V/usec. With this fast slew rate, the test throughput is much higher than conventional SMUs. Figure-5 shows the diagram of Chroma 52405 SMU PXI Card Hardware Structure.

Chroma 52400 series SMU features high precision, settling time in microseconds with accuracy of nano-Volts and nano-Amps, 16 Control Bandwidth Selection to avoid oscillation and for shorter settling time, hardware sequencer for precise output profile control, fast respond clamp circuit to protect DUT, and unique programmable resistance to simulate battery. These features make Chroma 52400 SMUs ideal measurement tools for semiconductor testing.

In addition, the 52400 series SMU complements excellent accuracy and repeatability with fast measurement speed. It can operate as a four quadrant voltage/current source, an electrical load, a voltage/current meter, a pulse generator and an arbitrary waveform generator.

Model 52400 series SMU

For more detailed information about Chroma 52400 series SMU & other Chroma solutions, please visit Chroma's website at: www.chromaus.com

PXI Systems Alliance

www.pxisa.org