직류전원 공급기를 통한 전원 인가 및 소모 시험의 난점 및 해결책

최 대류 부장

기술지원 부문/ 파워 스페셜리스트

한국 애질런트 테크놀로지스

Agenda

- The need for source-sink solutions for testing bidirectional and regenerative power devices

- Solutions to address this need
  - Non-overlapping source-sink solution with Deadband
  - Overlapping source-sink solution
  - Integrated source-sink solution
- New technologies for enabling integrated source-sink solution
- Conclusion

The Need for High Power Sourcing and Sinking

To test high power bidirectional and regenerative energy systems and devices

Host Device:

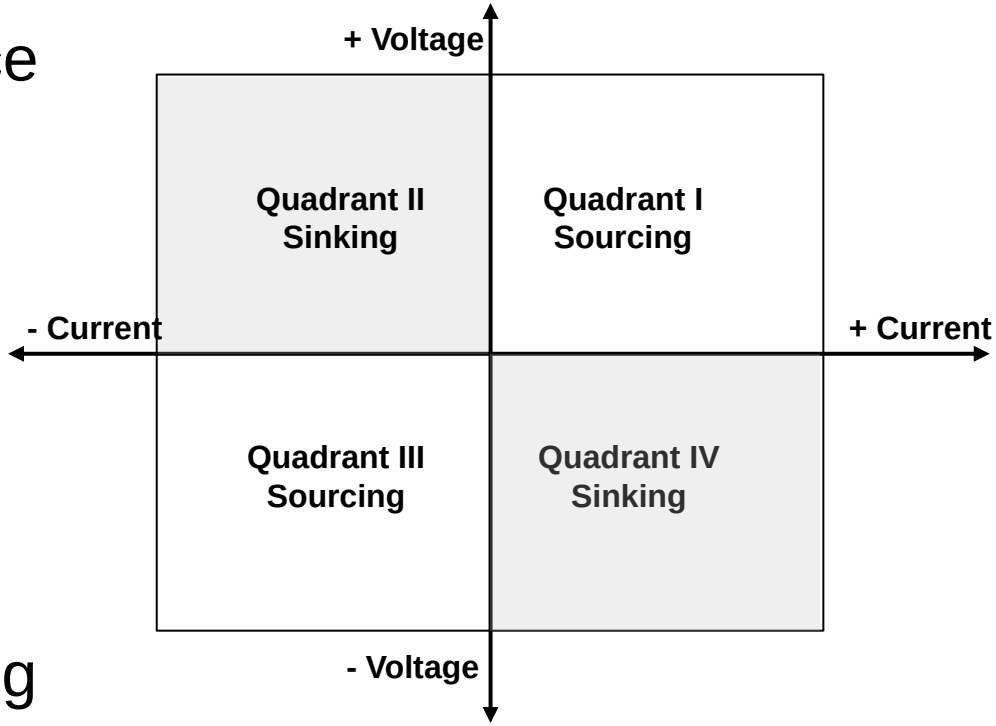
- Satellites
- Electric mobility
- Robotics
- UPSs
- Green energy systems

Bidirectional and regenerative energy systems and devices:

- Rechargeable batteries
- Super capacitors
- Motor-generators
- Bidirectional DC/DC converters
- Battery management systems (BMS)
- Regenerative braking

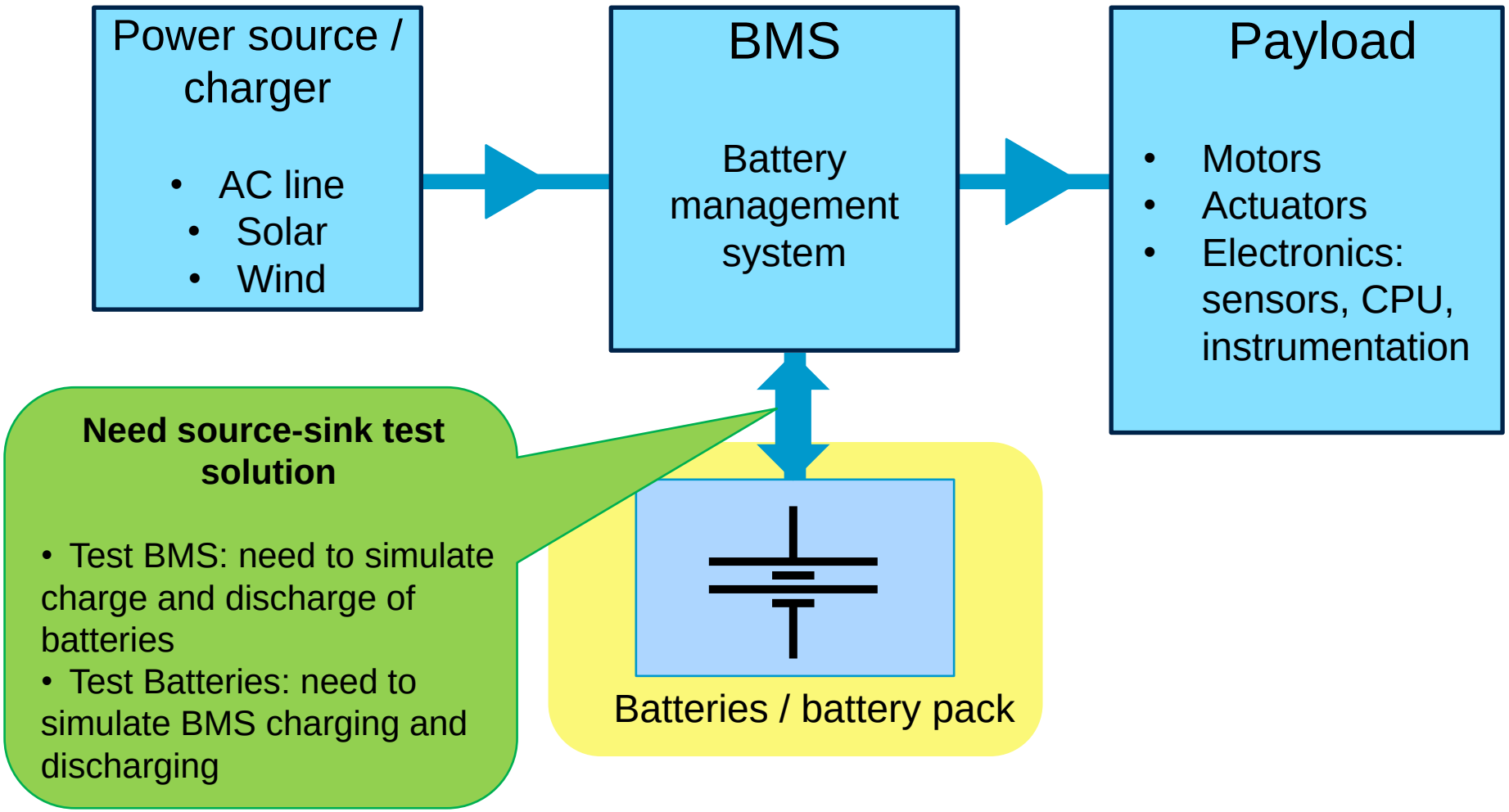
Two-Quadrant vs. Four-Quadrant Source Operation

- Bidirectional vs. bipolar
- Unipolar, bidirectional source (two-quadrant)
- Bipolar source (four-quadrant)
- Typically two-quadrant operation is needed for testing bidirectional and regenerative power devices



The Need for High Power Sourcing and Sinking

Example battery powered device showing power flow



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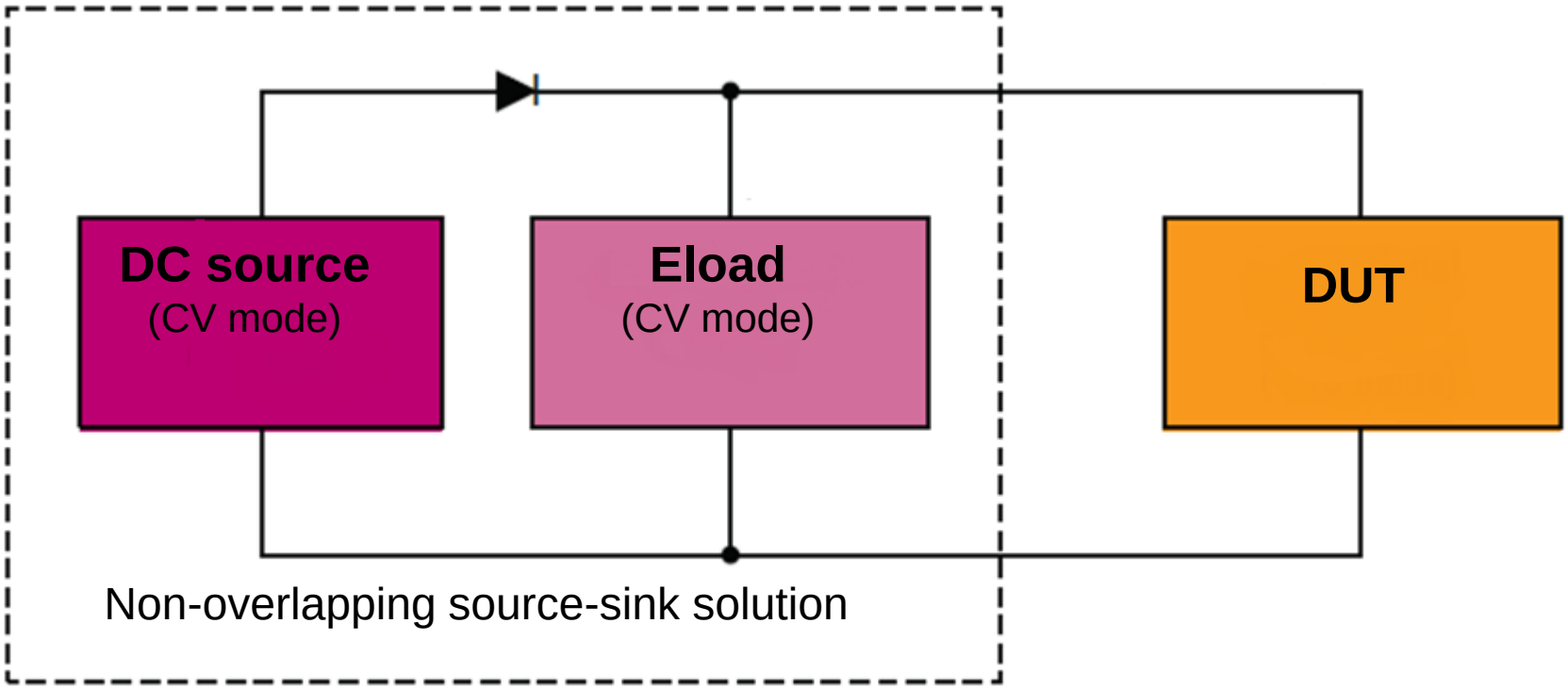
Source-Sink Solution Requirements

- Two-quadrant solution that can seamlessly transition between sourcing and sinking current
- The ability to operate in CV and CC mode (for testing batteries)
- The ability to handle various load / DUT impedance conditions
- Protection features, limit settings, and fast reaction to questionable test conditions
- Reasonable output noise, accuracy levels, size, and weight

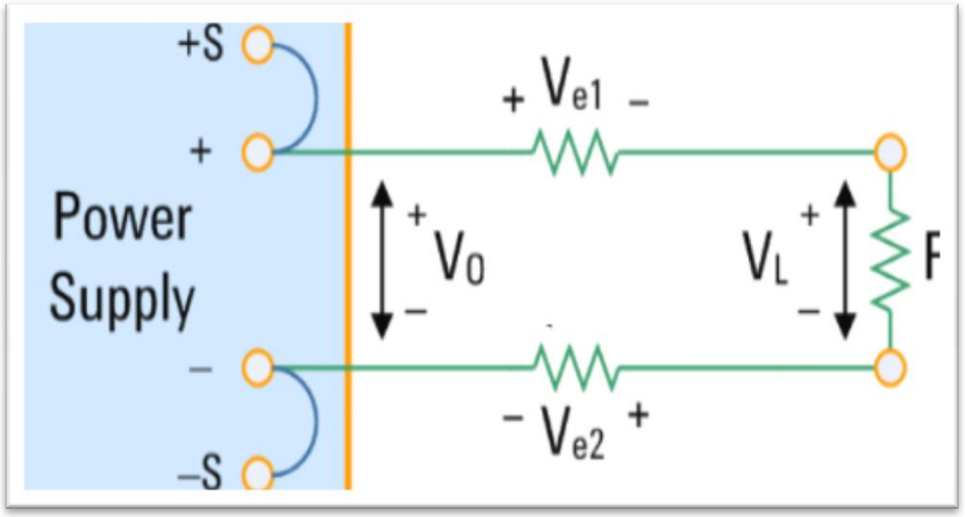
Meeting all these requirements is not easy to find in a single integrated solution

Non-Overlapping Source-Sink Solution with Deadband

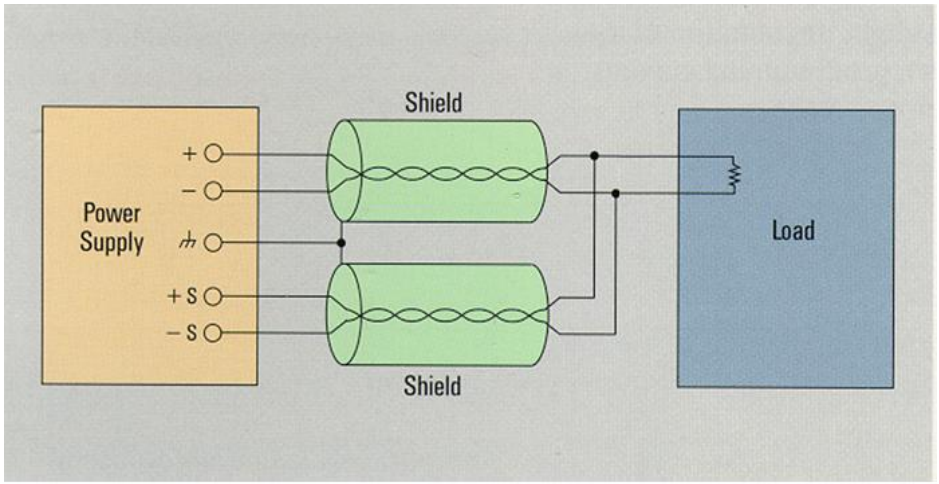


- This solution uses DC source, electronic load, and diode
- This solution is more suitable for BMS testing, battery testing is challenging with this solution

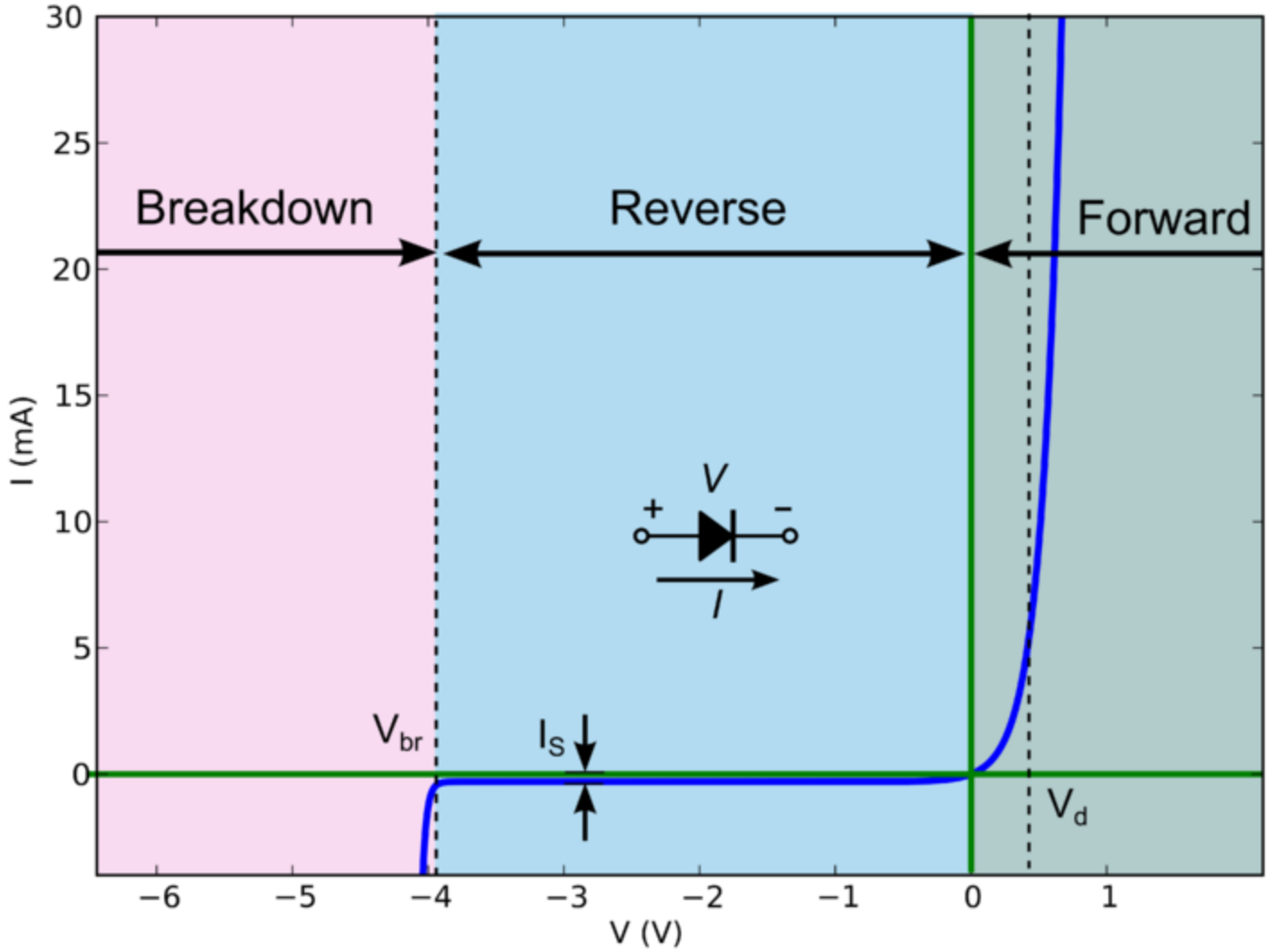
Sensing



Local Sensing

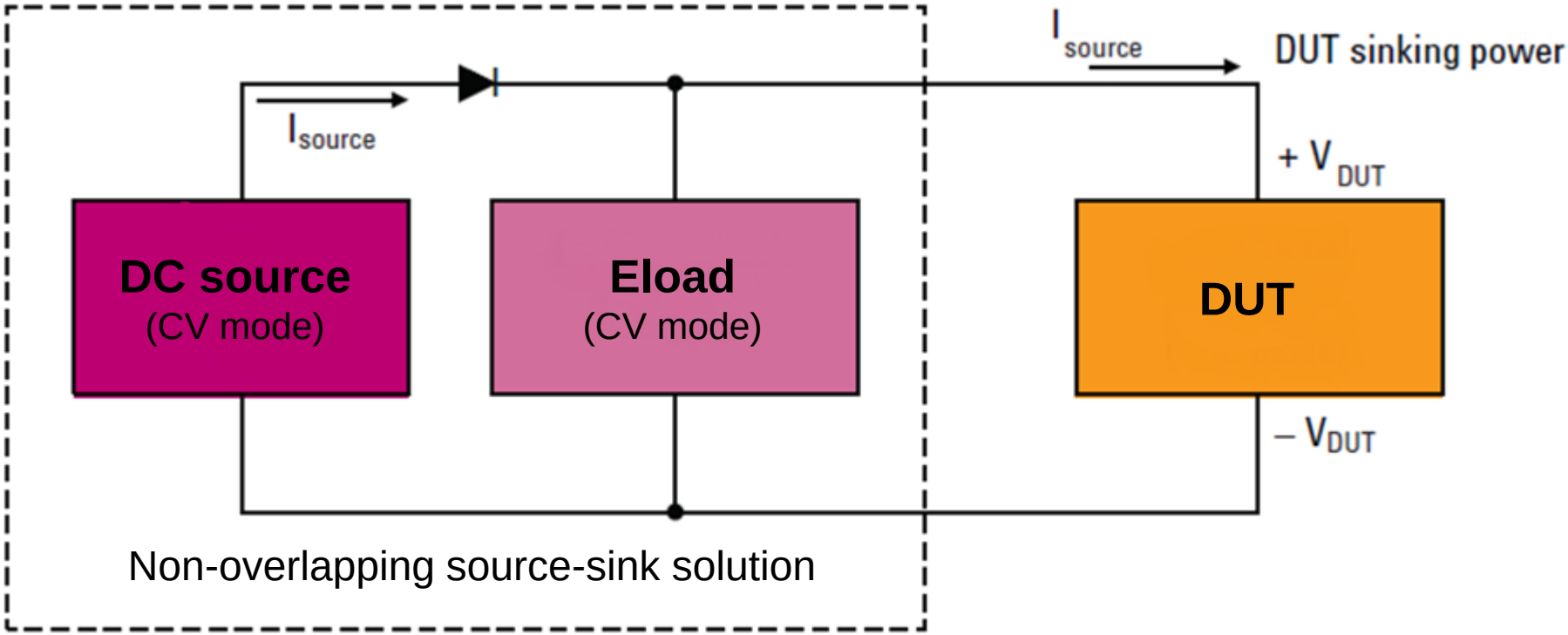


Remote Sensing



Non-Overlapping Source-Sink Solution with Deadband

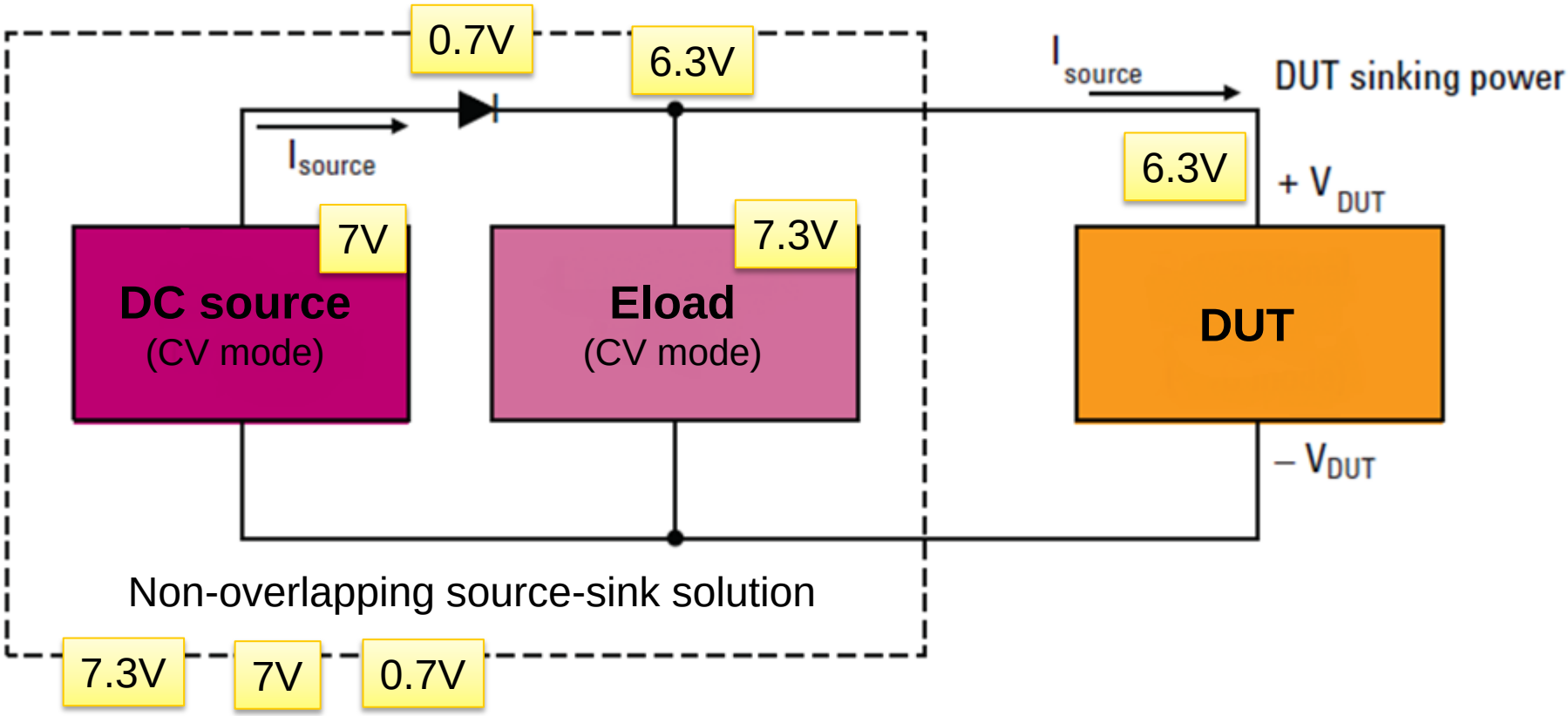
Deadband solution sourcing power, DUT sinking power



- $V_{eload} > (V_{source} - V_{diode})$
- DUT sinking power, DC source active: $V_{DUT} = (V_{source} - V_{diode})$
- Eload is in cutoff so it acts like an open

Non-Overlapping Source-Sink Solution with Deadband

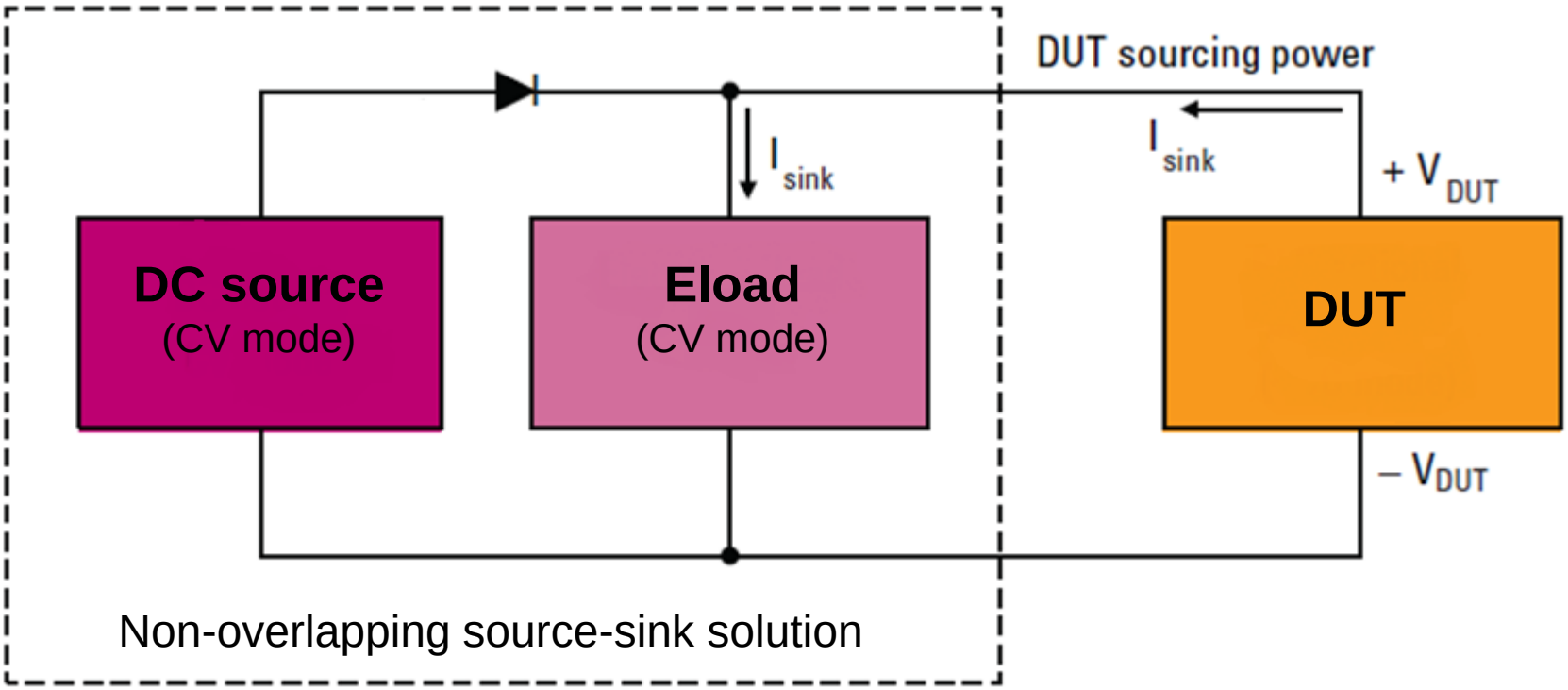
Deadband solution sourcing power, DUT sinking power



- $V_{eload} > (V_{source} - V_{diode})$
- DUT sinking power, DC source active: $V_{DUT} = (V_{source} - V_{diode})$ 6.3V 7V 0.7V
- Eload is in cutoff so it acts like an open

Non-Overlapping Source-Sink Solution with Deadband

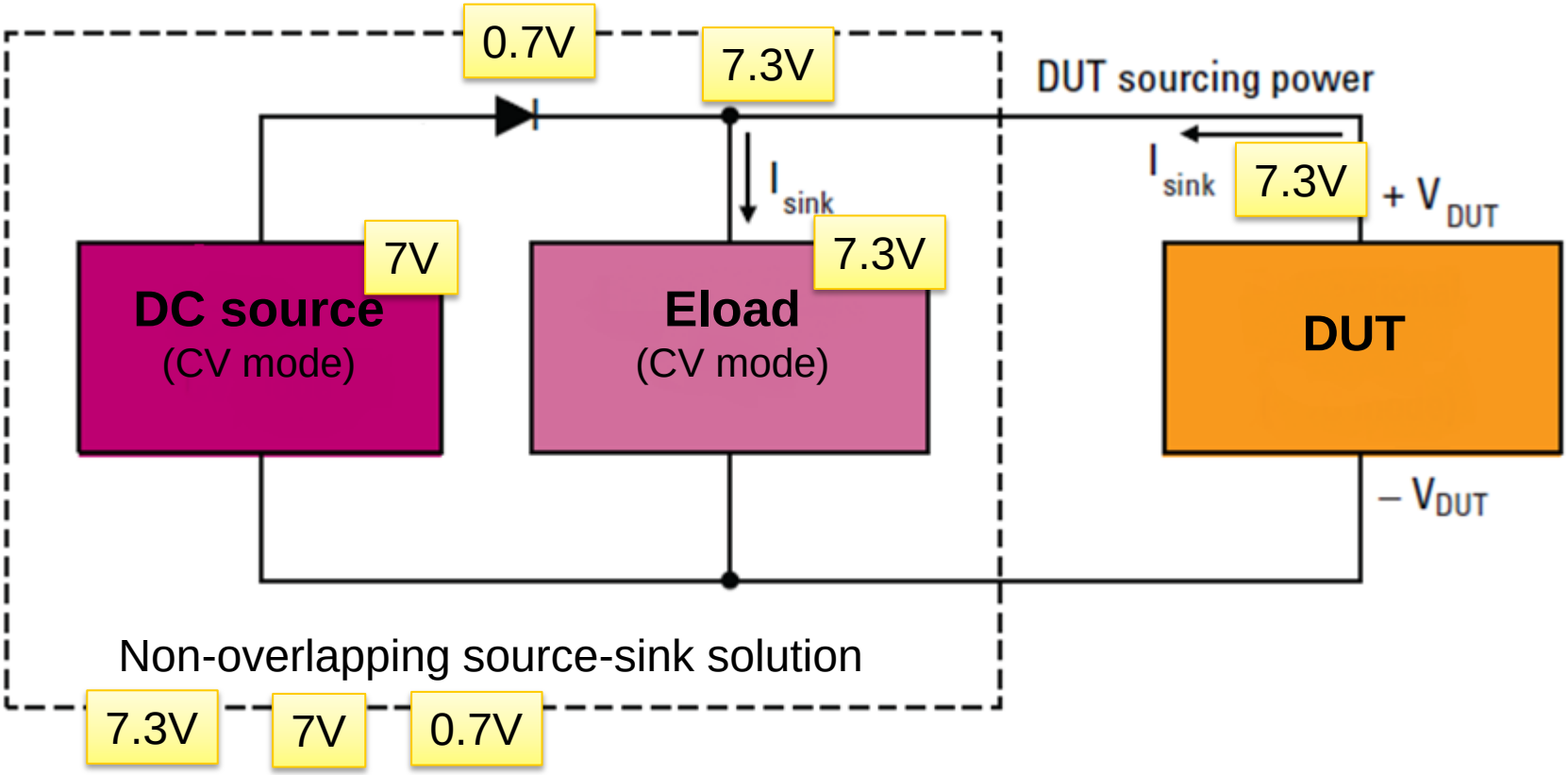
Deadband solution sinking power, DUT sourcing power



- $V_{eload} > (V_{source} - V_{diode})$
- DUT sourcing power, eload active: $V_{DUT} = V_{eload}$
- Diode is reversed biased no current flowing out of DC source

Non-Overlapping Source-Sink Solution with Deadband

Deadband solution sinking power, DUT sourcing power



- $V_{eload} > (V_{source} - V_{diode})$ 7.3V 7.3V
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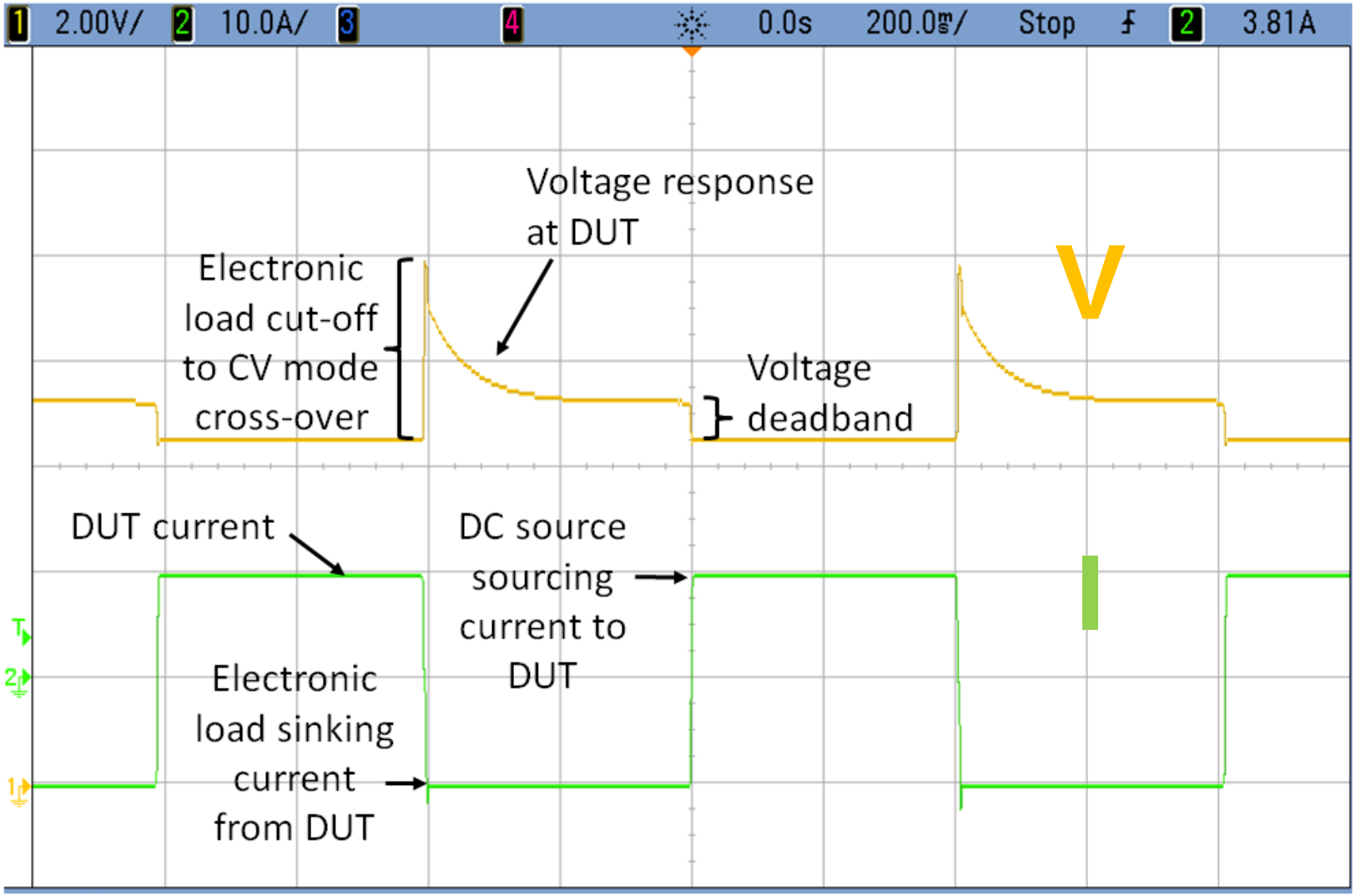
Non-Overlapping Source-Sink Solution with Deadband

Behavior of the solution under dynamic current conditions

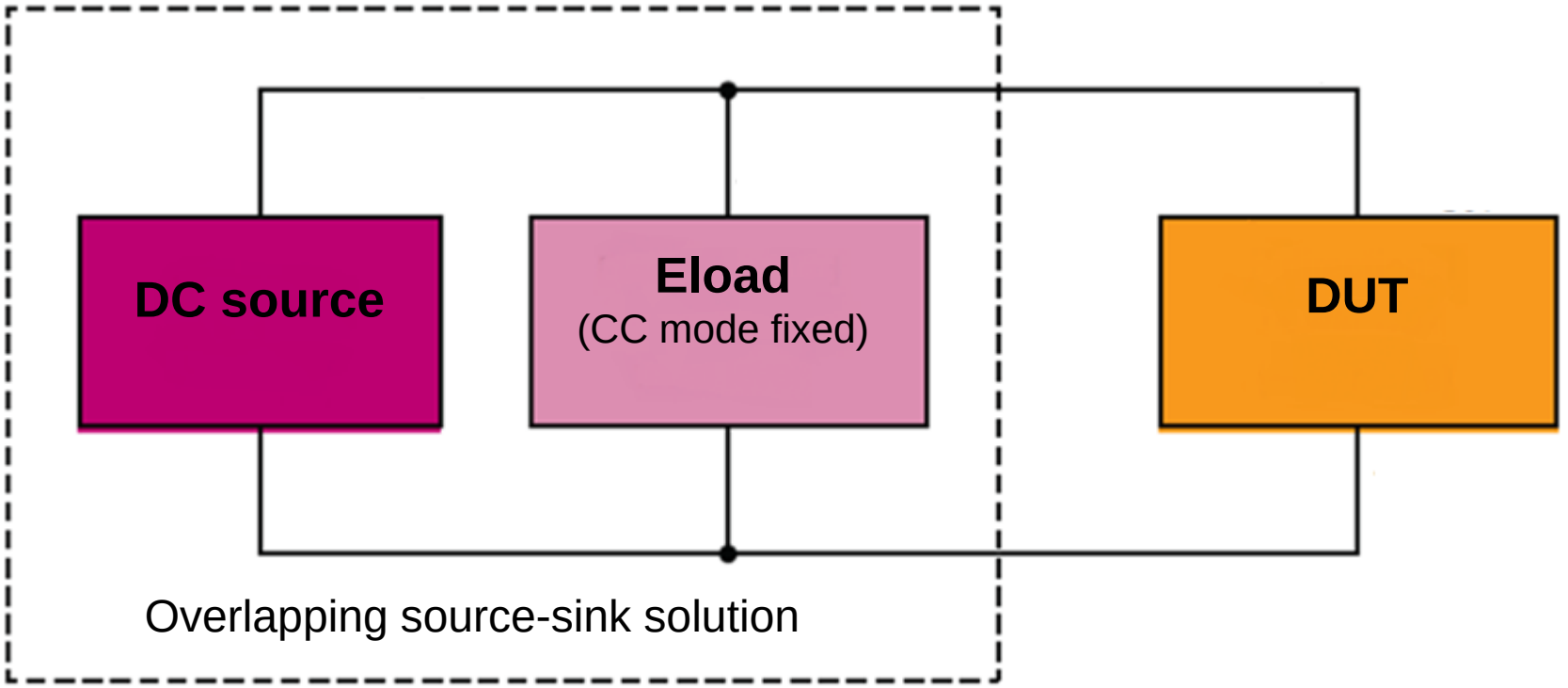


Non-Overlapping Source-Sink Solution with Deadband

Disadvantages:

- Local sensing on DC source before blocking diode needed
- Deadband zone is high impedance
- Deadband voltage needs to be kept large due to diode voltage variance
- Programming is complex
- Electronic load mode cross-over transient compromises dynamic performance

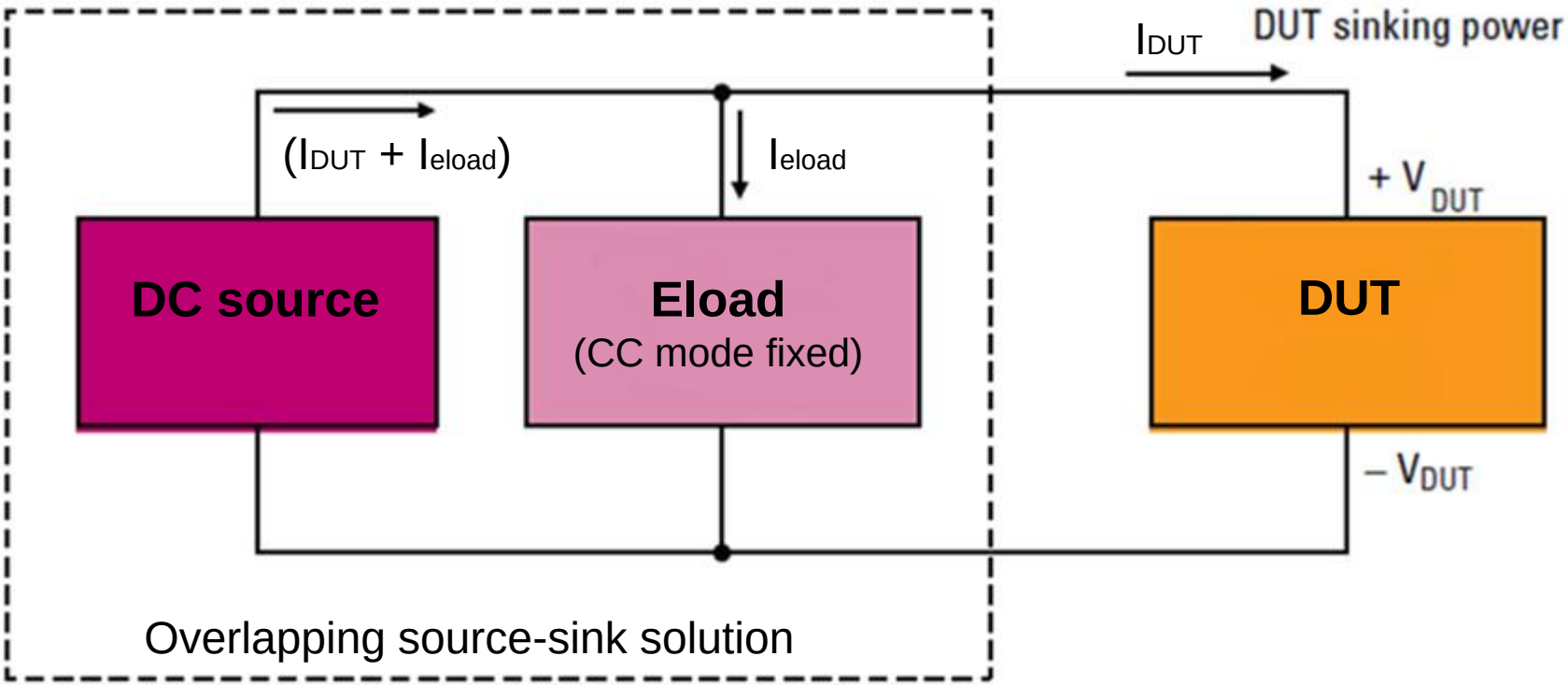
Overlapping Source-Sink Operation



- This solution just uses a DC source and eload
- No deadband, can maintain constant voltage level
- Works better for batteries since CC conditions are easier to implement

Overlapping Source-Sink operation

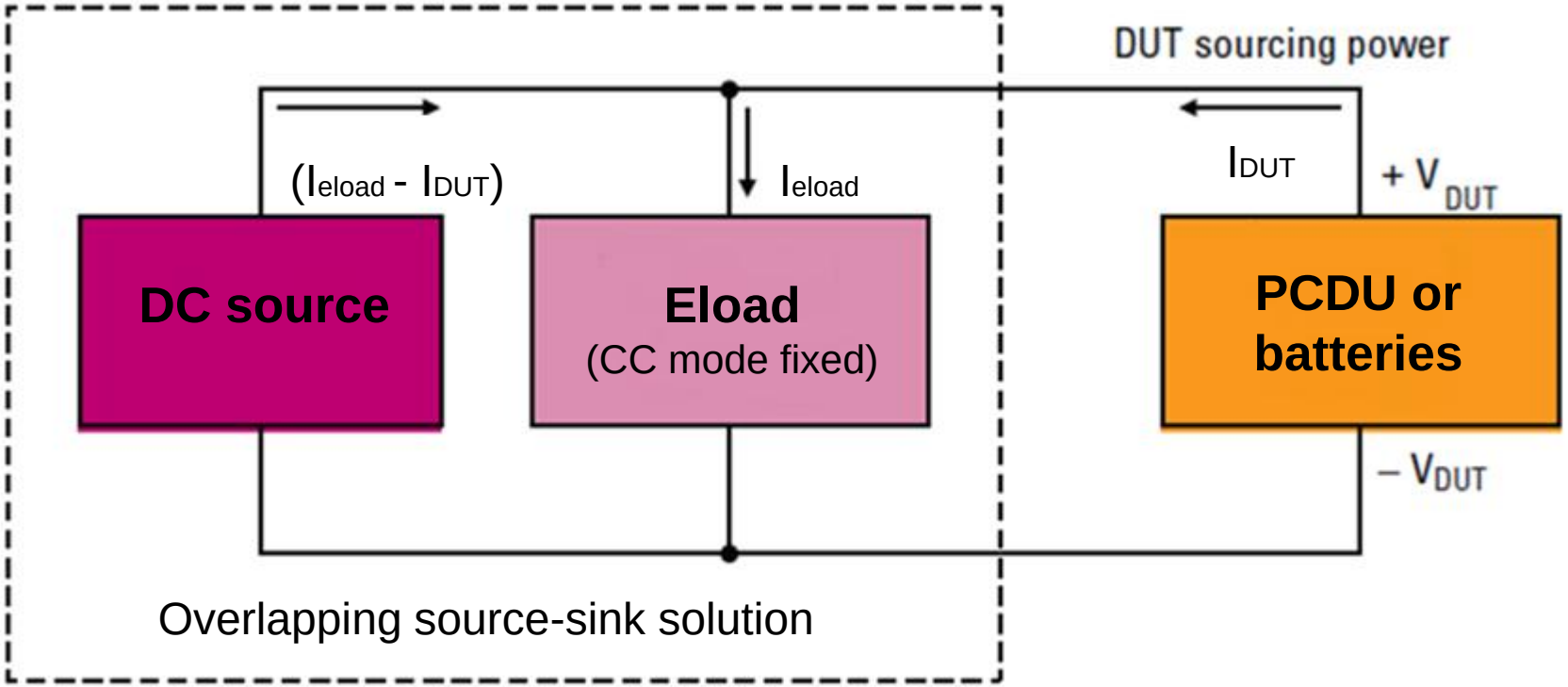
Overlapping solution sourcing power, DUT sinking power



- $V_{DUT} = V_{source}$
- DUT sinking power: $I_{source} = (I_{DUT} + I_{eload})$
- DC source max current must be 2x DUT max sinking current

Overlapping Source-Sink operation

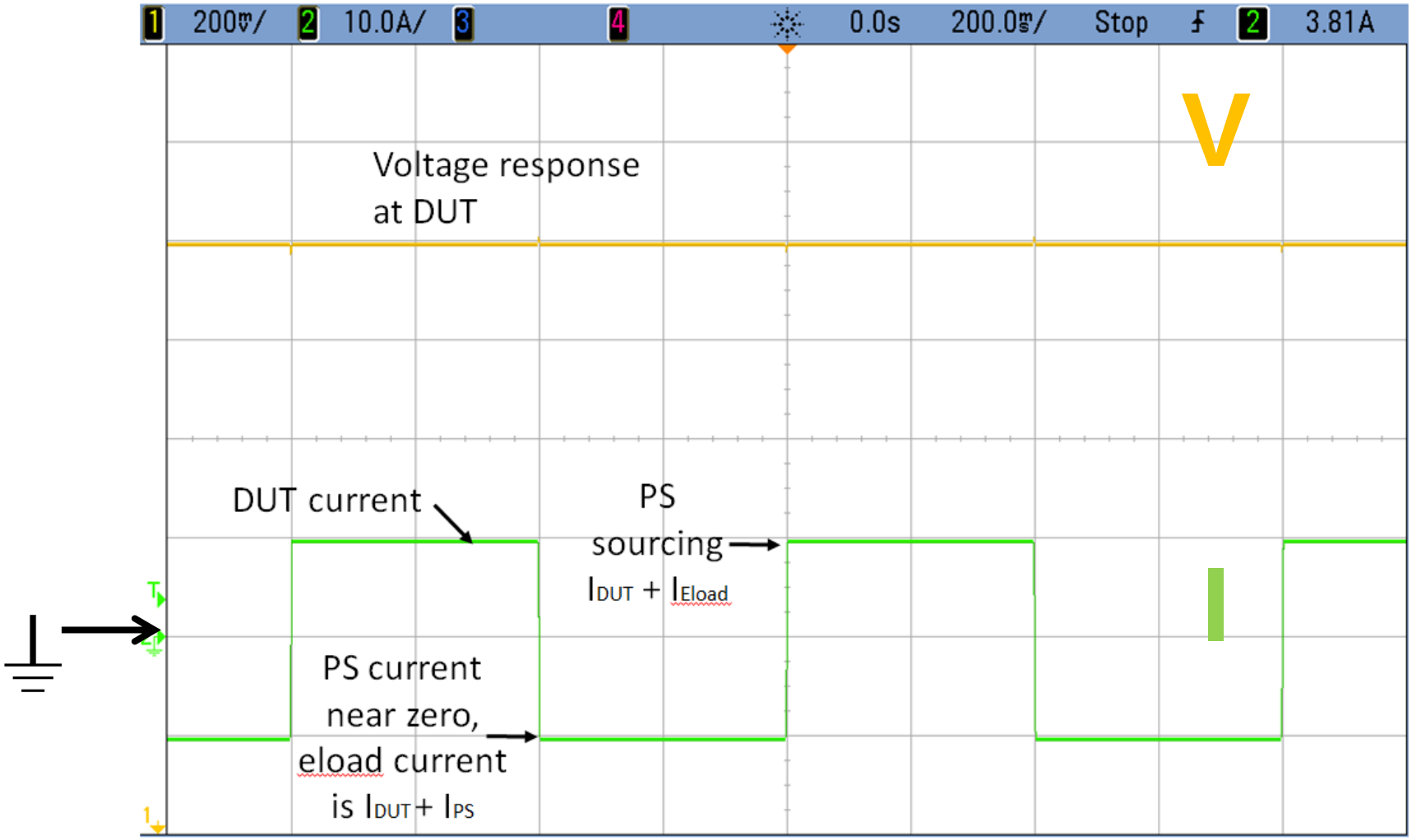
Overlapping solution sinking power, DUT sourcing power



- $V_{DUT} = V_{source}$
- DUT sourcing power: $I_{source} = (I_{eload} - I_{DUT})$
- If the DC Source has downprogramming capabilities it could cause problems
- When testing devices such as BMS, may need to simulate battery Z for proper operation

Overlapping Source-Sink operation

Behavior of the solution under dynamic current conditions



Overlapping Source-Sink Operation

Advantages:

- Voltage response reasonably transient free by eliminating electronic load mode cross-over

•Since power supply is always sourcing power no more deadband

Disadvantages:

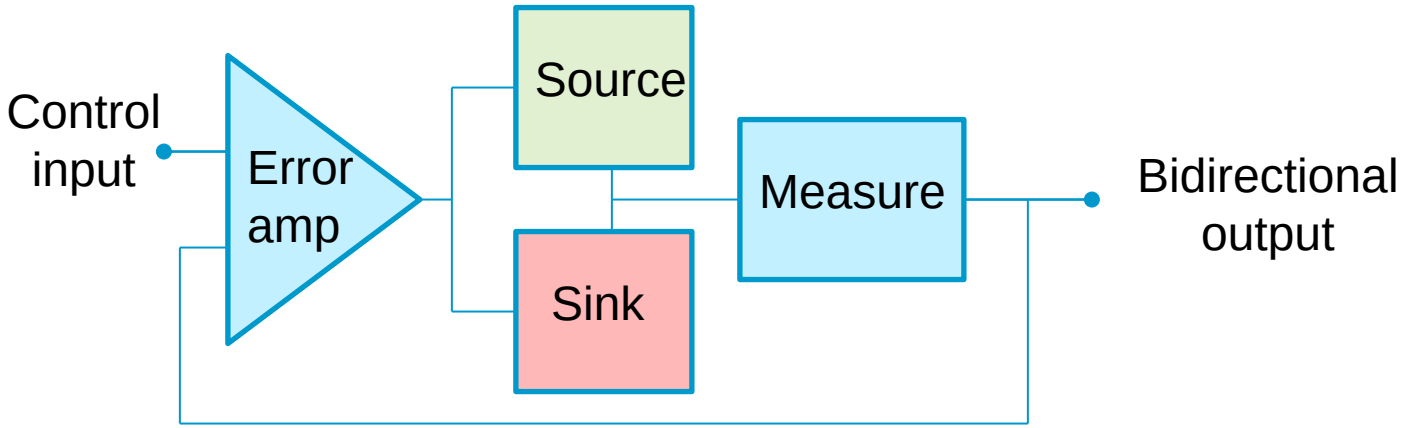
- Requires much larger DC source (2X for 100% sinking)

- Continuously dissipates large amount of power as waste

- Net DUT current is difference of DC source and electronic load readings. Reduces accuracy at low values

•May require additional custom hardware

Integrated Source-Sink Solution



Integrating sourcing and sinking into a single instrument provides several advantages:

- Source and sink operation is controlled by **single regulation loop**
- Seamless transition between sourcing and sinking
- No need to dissipate large amounts of power
- Common measurement system for source and sink measurements

Integrated Source-sink Solution

The challenge is finding an integrated solution in the 1 kW and higher power range:

- Linear DC power supplies offer an architecture that supports two-quadrant operation, but become too large at high power levels
- Switching DC power supplies architecture does not easily support two-quadrant operation

Agilent found a way to address this test challenge based on a switching DC power supply architecture

Agenda

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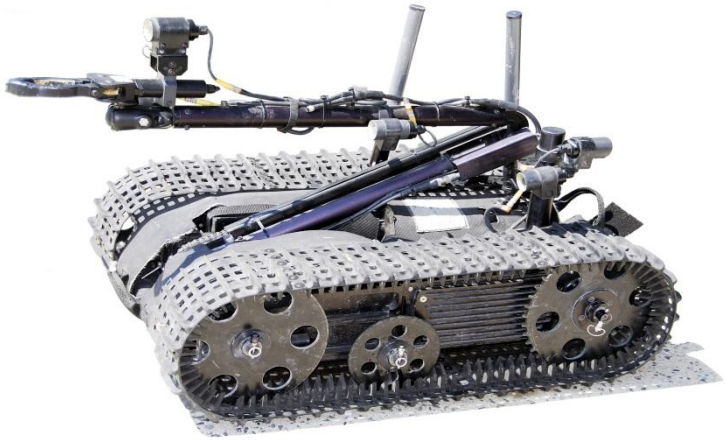
- New technologies for enabling integrated source-sink solution

- Conclusion

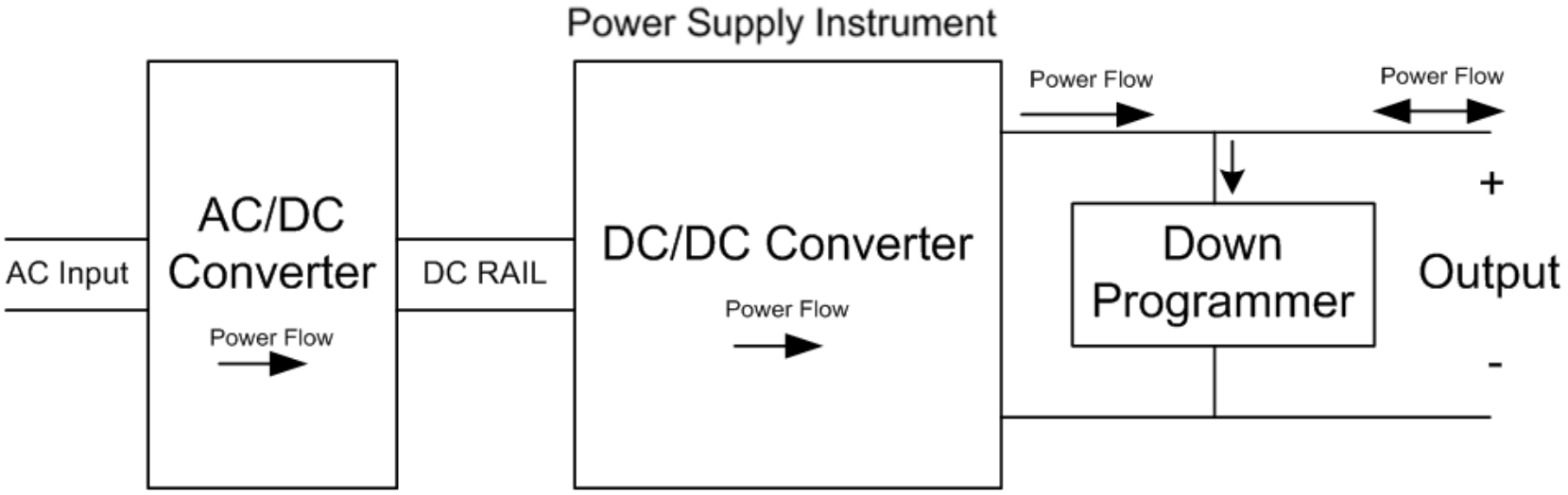
New Technologies for Enabling Integrated Solution

- Agilent has developed two patented technologies that enabled an integrated source-sink solution
  - Regulated by a single control loop
- This solution is built into a switching power supply architecture
- The technologies and story that led to this development:
  - Load-side down-programmer
  - Source-side down-programmer
  - Automatic down-programmer and external dissipater
- In the following slides we will take a look at these technologies and their progression



The Load-Side Down-Programmer

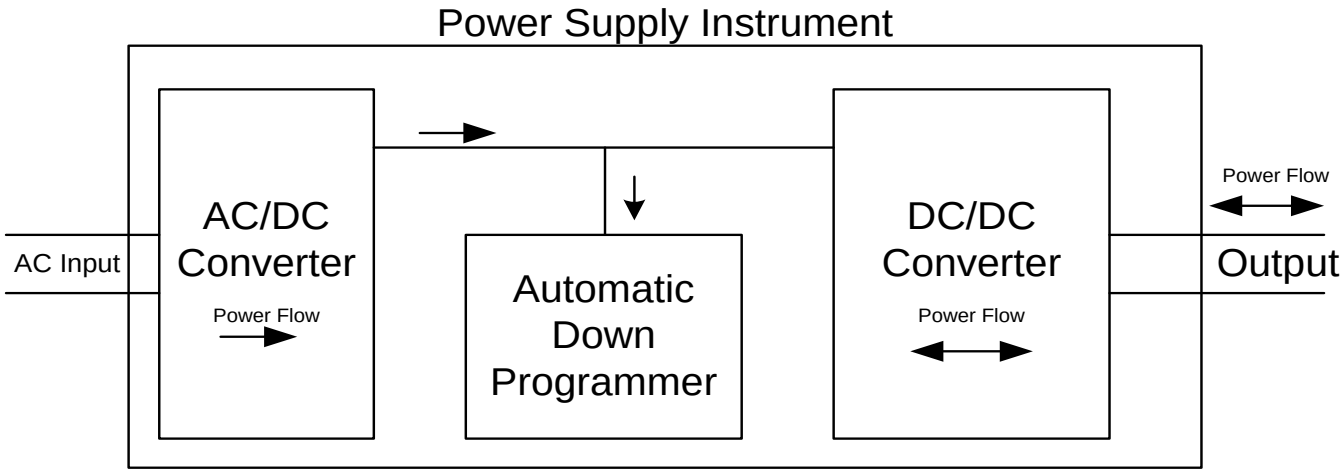
- Customer problem: needed method to discharge stored energy from the output filtering of the power supply as well as from the DUT input so output voltage could be quickly lowered.
- To solve this Agilent added active dissipative elements across the power supply's output, this subsystem became known as a down-programmer



Disadvantage: different down-programmer had to be designed for each unique voltage and power range.

Input-Side Down-Programmer

- To avoid the disadvantage of load-side down-programmers, we made our DC to DC conversion stage bi-directional
- This allowed us to perform down-programming on the DC bus between the conversion stages where the DC level was common across many of our power supply families

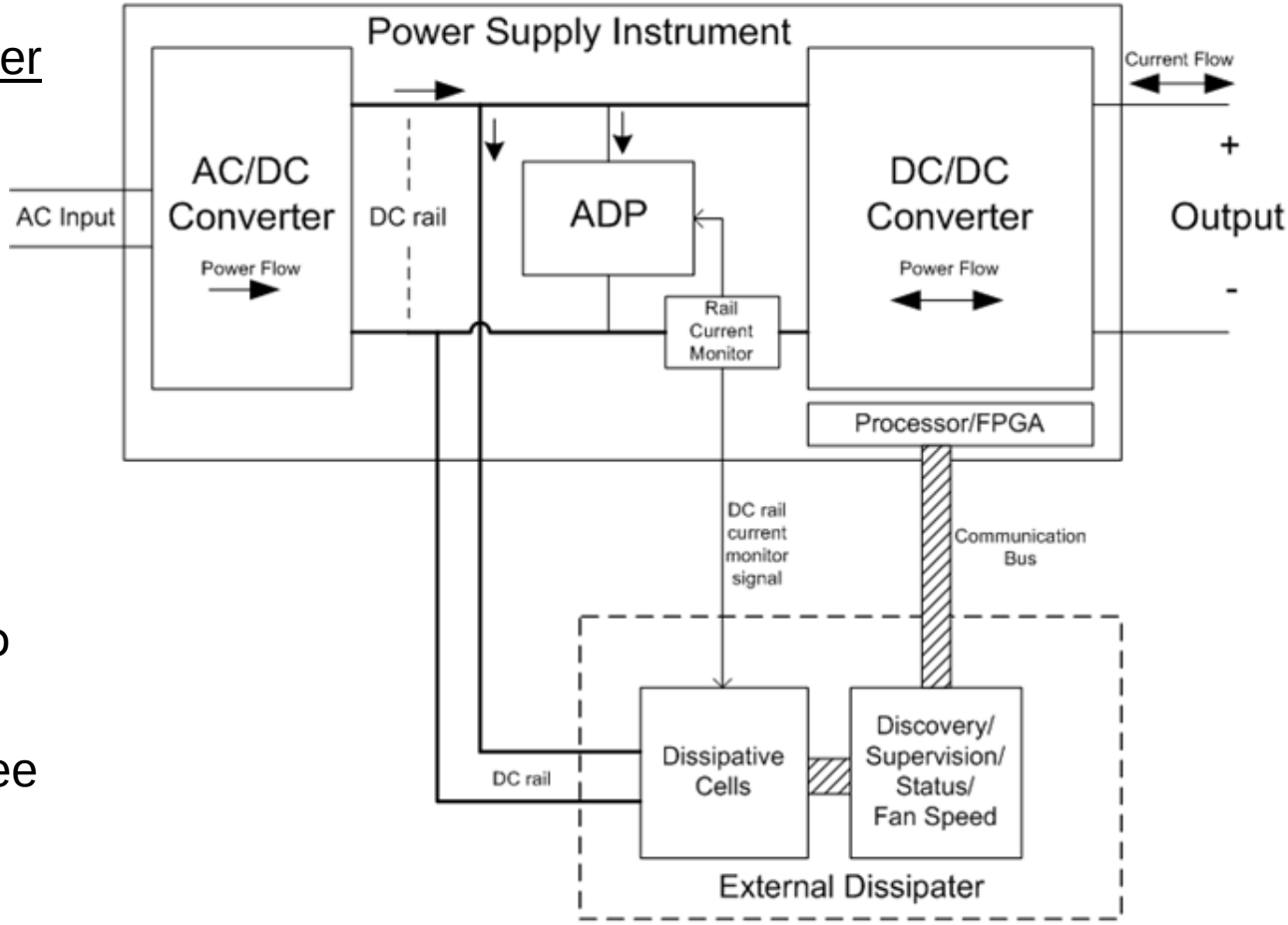


- We developed the Automatic Down Programmer (ADP) to monitor the DC bus and sink current if the voltage went up
- The ADP is an Agilent only patented technology

Automatic Down-Programmer and External Dissipater

For our newest system power supply family:

- We made the ADP programmable
- ADP can sink 10% rated current of supply
- We added the patented External Dissipater (ED)
- The ED can extend the supply's sink capability to 100% full rated current
- The ED provides glitchfree two-quadrant operation



The patented ADP and ED technologies allow us to deliver a integrated source-sink solution for testing bi-directional and regenerative power devices

New Agilent Advanced Power System (APS)

DC power supplies with integrated sourcing and sinking

1000 W in 1U

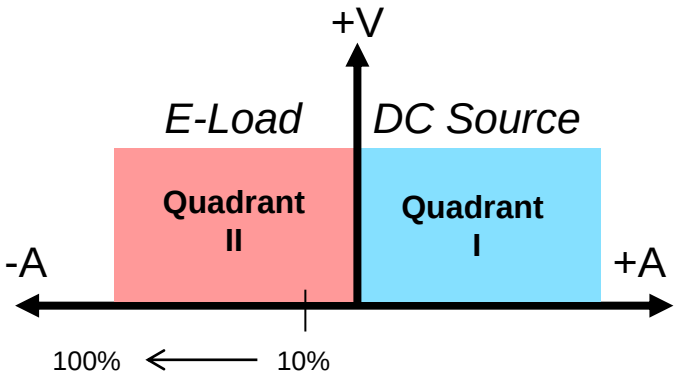
2000 W in 2U

Parallel up to 10 kW

The APS has 2 performance levels	
N6900 Series DC Power Supply	Designed for ATE applications where high performance is critical
N7900 Series Dynamic DC Power Supply	Designed for ATE applications where high-speed dynamic sourcing and measurement is needed

APS N7909A Power Dissipater Unit

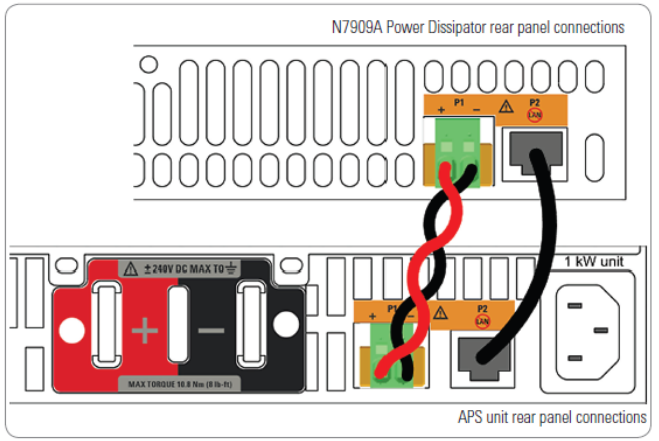
1000 W in 1U Full Rack



Add a Power Dissipater Unit to any APS power supply
to provide continuous sink current at up to 100% with no limits on duty cycle

Provides seamless transition between source and sink.
All control comes from the DC Source.

Add one dissipater for each 1 kW unit; add two dissipaters for each 2 kW unit

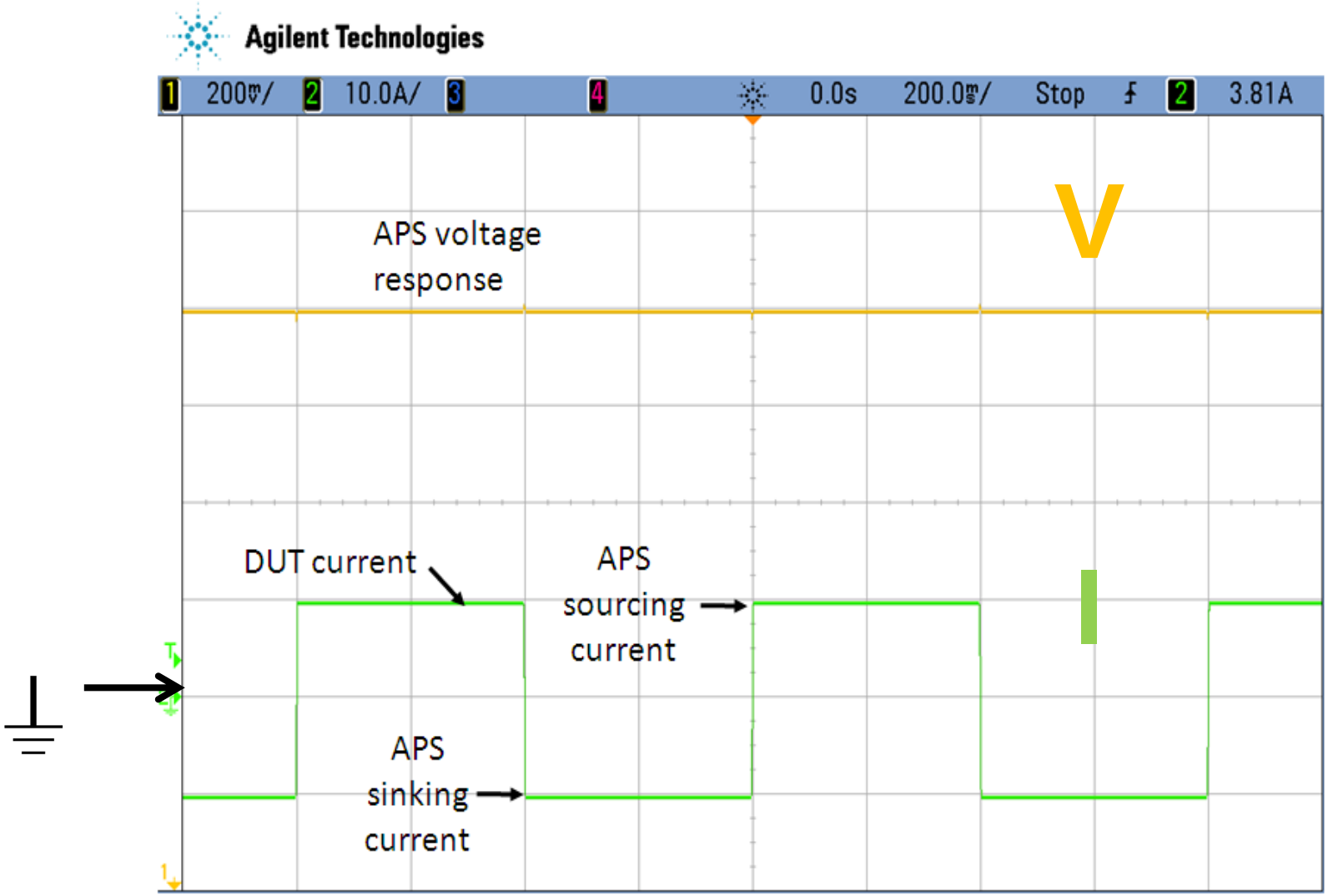


Gives you a DC Source and E-load in one setup with measurement and control of current flow in either direction (source or sink)

Ideal for testing bi-directional and regenerative power devices

The APS as an Integrated Source-Sink Solution

Behavior of the solution under dynamic current conditions



The APS as an Integrated Source-Sink Solution

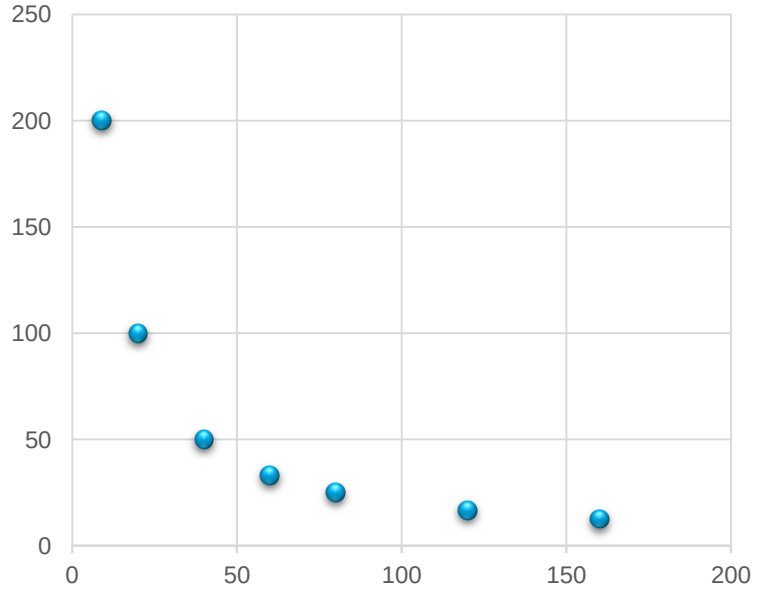
Benefits over other solutions:

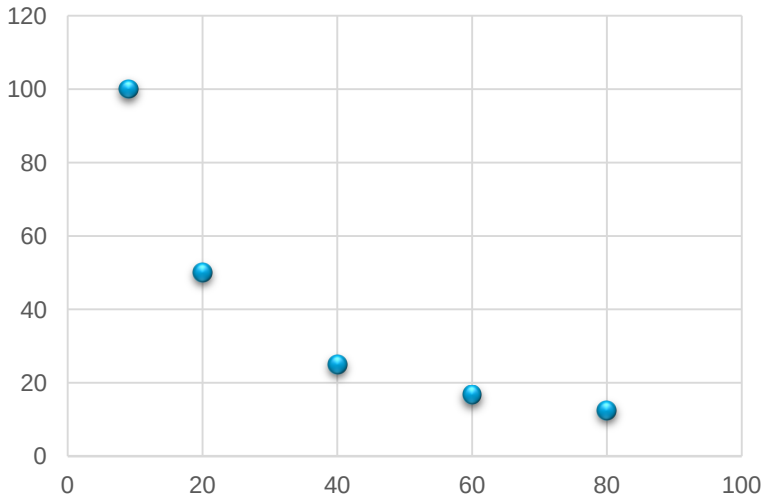
- Source and sink operation is controlled by single regulation loop
- Seamless glitchfree transitions between source and sink operation
- No large amounts of power wasted
- Reduced hardware and software complexity
- Reduced hardware size and weight

Additional APS Capabilities that make it an Integrated Solution

- Meeting power storage measurements needs
  - 18 bit measurement capability captures: voltage, current, power, amp hour, and watt hour measurements
- Flexibility to adjust to your DUT's power needs
  - Built-in paralleling capability that ensures proper current sharing across units for maximum performance
  - Paralleling capability works whether current is being sourced or sinked
- Ensure your DUT is properly protected
  - Smart triggering system allows you to trigger off any measured level and create logical trigger expressions
  - Fast output speed to quickly react to OV and OC conditions
  - Built-in protection features such as watchdog timer, output relays, broken sense line detection, and more

Agilent N6900 Series DC power supplies	
1 kW models	**2 kW models**
N6950A 9V, 100A	N6970A 9V, 200A
N6951A 20V, 50A	N6971A 20V, 100A
N6952A 40V, 25A	N6972A 40V, 50A
N6953A 60V, 16.7A	N6973A 60V, 33A
N6954A 80V, 12.5A	N6974A 80V, 25A
	N6976A 120V, 16.7A
	N6977A 160V, 12.5A





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N7953A 60V, 16.7A	N7973A 60V, 33A
N7954A 80V, 12.5A	N7974A 80V, 25A
	N7976A 120V, 16.7A
	N7977A 160V, 12.5A

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Conclusion

Methods for creating a source-sink solution for testing bi-directional and regenerative power devices:

- Non-Overlapping Source-Sink Solution with Deadband
  - Disadvantage: complexity and does not provide constant voltage
- Overlapping source-sink solution
  - Disadvantage: complexity and uses a lot of power
- Integrated source-sink solution
  - Disadvantage: not many viable solutions available

New technologies for enabling integrated source-sink solution

- Automatic down-programmer: provides partial sinking capability
- External dissipater: provides optional full two quadrant operation
- Both these technologies can be found in the Advanced Power System N6900 and N7900 family

Questions?

Learn more about the test challenges the APS can help you overcome:
www.agilent.com/find/TestChallenges

Increasing test system throughput

Challenge: Reducing test time to increase test throughput is a continuous goal in high volume manufacturing

How the APS overcomes this:
- Fast output speed
- Output List mode
- Smart triggering
- Fast command processing

www.agilent.com/find/throughput

Building a continuous source and load

Challenge: Building a continuous source and load solution >500W for testing power storage related DUTs.

How the APS overcomes this:
- 2-quadrant operation
- V and I level triggering
- Fast output speed and response

www.agilent.com/find/SourceLoad

Protecting against power related damage

Challenge: Protecting costly DUTs from power related damage during test.

How the APS overcomes this:
- Smart triggering
- Fast output response
- Output disconnect relays
- Watchdog timer

www.agilent.com/find/ProtectDUT

Characterizing dynamic current profiles

Challenge: Capturing the current profile of a DUT that has a large dynamic current range.

How the APS overcomes this:
- Current digitizer
- Seamless ranging
- Adjustable sample rate
- External logging

www.agilent.com/find/DynamicCurrent

Generating power transients

Challenge: Simulating power transients during test to ensure the DUT can standup to real world power conditions

How the APS overcomes this:
- AWG capability
- Step function capability
- High bandwidth mode

www.agilent.com/find/PowerTransients

Characterizing inrush current

Challenge: Capturing the large current surge that occurs powering on DUTs with reactive elements at the input.

How the APS overcomes this:
- V and I digitizers
- Pre- and post-triggering
- Large measurement range

www.agilent.com/find/InrushCurrent

Maintaining output integrity under dynamic load conditions

Challenge: Maintaining a stable output voltage free of oscillations and voltage droop while under a very dynamic load

How the APS overcomes this:
- Fast transient response
- High and low output bandwidth modes
- Long test lead tolerance

www.agilent.com/find/PowerIntegrity

Tracking power events for root-cause analysis

Challenge: Tracking power events during test for root cause analysis if your expensive DUT is damaged during test.

How the APS overcomes this:
- Built-in Black Box Recorder
- Records voltage, current, power, trigger events and more

www.agilent.com/find/PowerTracking

Properly powering on/off a DUT

Challenge: Properly sequencing on multiple supplies and tuning slew rates to prevent damage.

How the APS overcomes this:
- Sequencing across mainframes
- Sequencing with N6700 mainframes
- Adjustable slew rate control

www.agilent.com/find/PoweringDUT