IoT Power Consumption Measurement Challenges

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CN Rood

ELECTRONICS & APPLICATIONS '23

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JAARBEURS UTRECHT

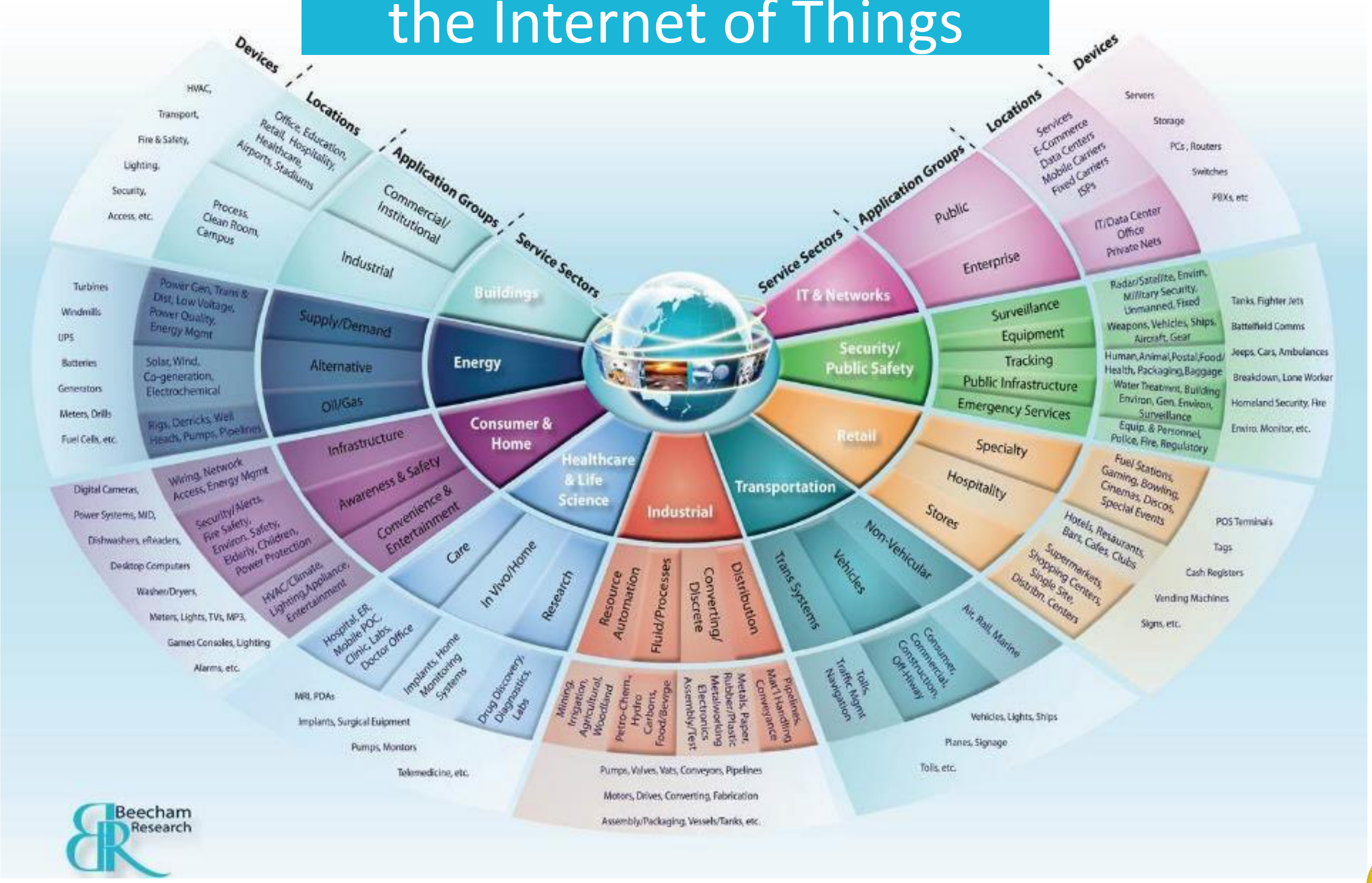
CN Rood

- Largest independent distributor for test- and measurement equipment
- BeNeLux, Nordics and Baltics
- Broad range in t&m for electronics, video, telecom/IP networking, PNT, power grid, RF spectrum, fiber network, ... Even high speed video cameras
- My background
  - Engineer measurement & control; started at Honeywell
  - ‘sabbatical’ at advertising company – marketing knowledge
  - 1996 Tektronix ; 2003 CN Rood (with Tektronix’s move to distributor model)

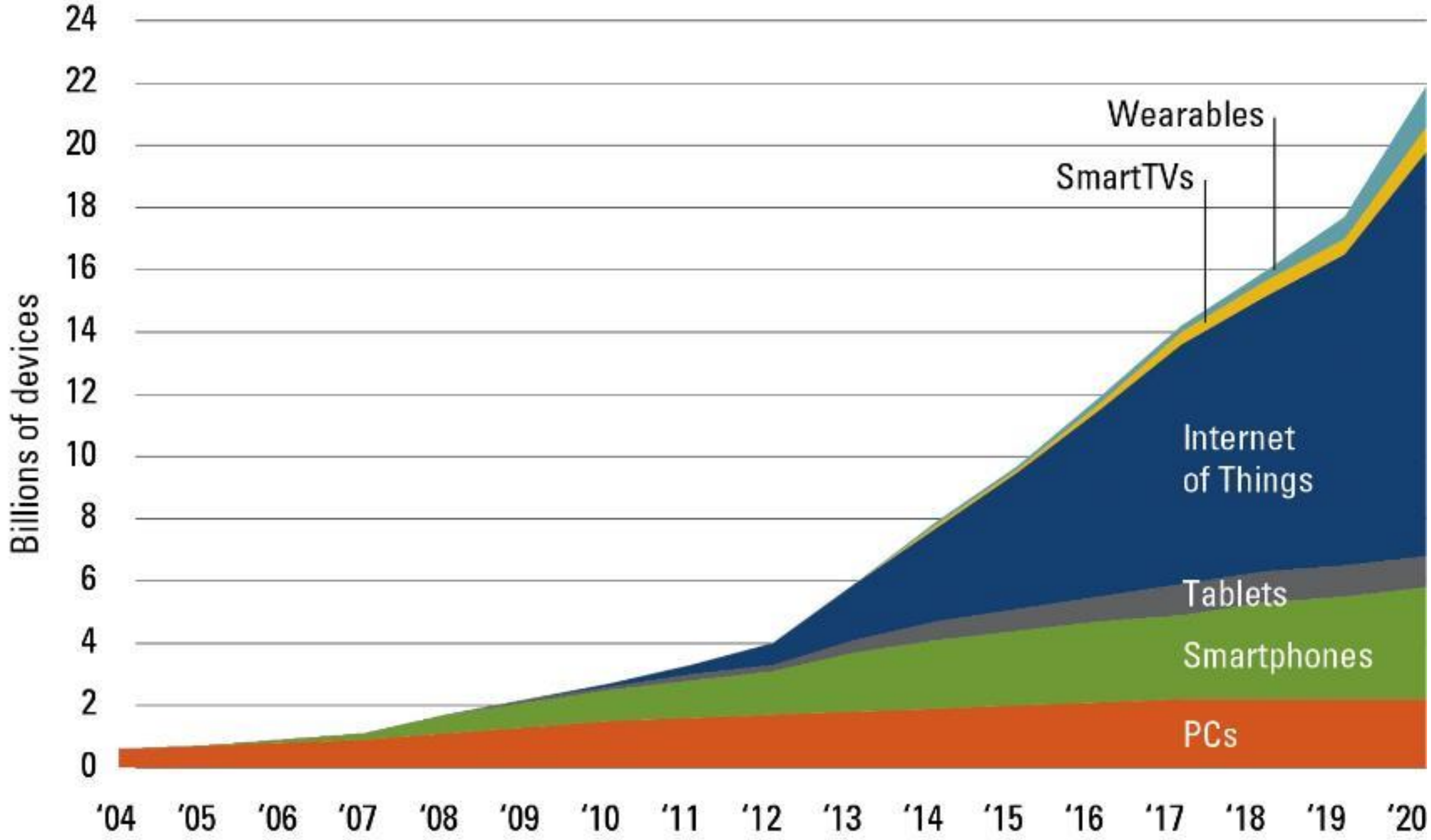
Agenda

- Intro world of connected devices and how to maximize battery life
- Selecting optimum components with I-V characteristics
- The challenge of measuring Power Consumption in all operating states
- Summary

The Expanding World of the Internet of Things



The Number of Connected Devices is Growing Exponentially



Gartner, IDC, Strategy Analytics, Machina research, company filings, BII estimates

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Your Objective: Maximizing Battery Life

your need: instrumentation to:

- Select and qualify low power components
- Measure power consumption
  - Determine power consumed in all operating states
    - Measure sleep mode currents
    - Capture current bursts when your product is active or transmitting
    - Determine the product's average current draw
- Assess how the battery's discharge cycle affects product performance
  - Determine your product's low battery shut-off voltage
- Quantify battery life

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Challenge: Meeting Aggressive Goals

- example low power product requirements

Target

- **Power Budget: *80µW*** (80µW/4V battery = 20µA)
- Battery Life of 6 months

Target budget breakdown

Main Design Blocks	Budget Allocation	
Accelerometer	14uW	17.5%
Bluetooth Low Energy Tx/Rx	12uW	15%
Power Management Unit	20uW	25%
Processing (MCU 100uA/MHz + memory + peripheral + oscillator)	34uW	42.5%

Selecting the Optimum Components

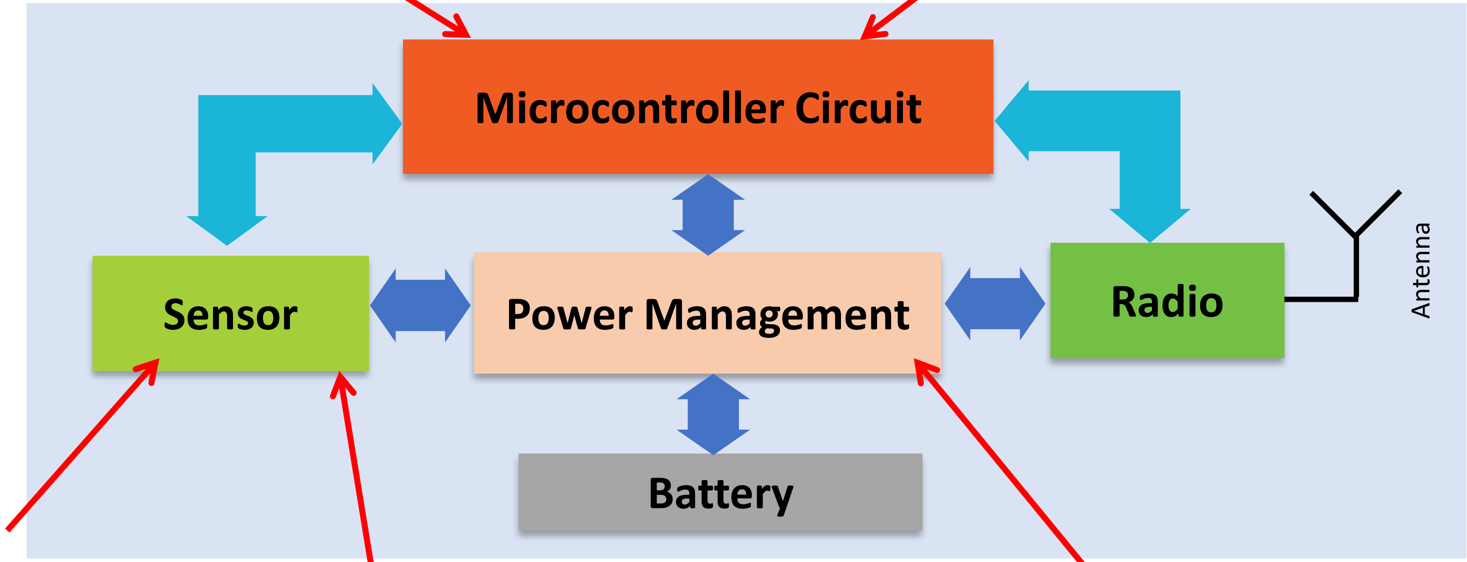
Verifying that critical components meet your requirements

Need to Select Low Power Components

- challenge: qualifying component performance

Low Power Microcontrollers
- Sleep mode: **100nA**
- Standby mode: **1µA**
- Active mode: **35 µA/MHz**

Real Time Clocks
Active Mode: **240nA**



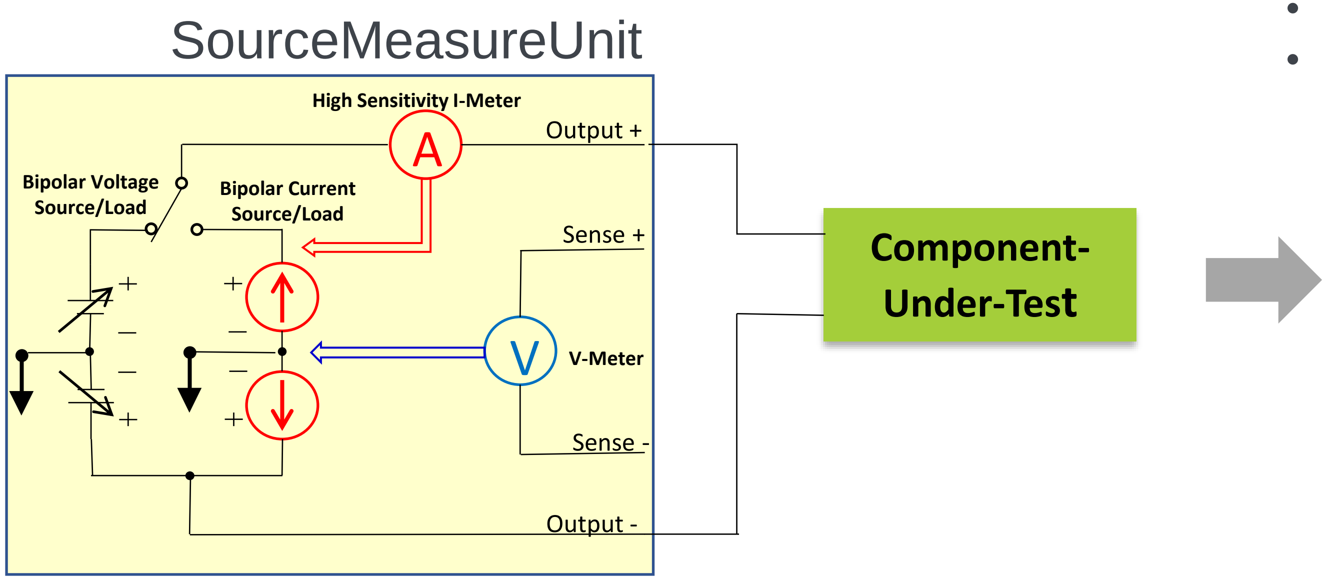
Sensors
Active Mode: **360nA**

Amplifiers:
Supply Current: **<1µA**

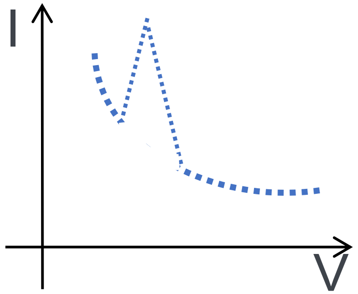
DC-DC Converter:
Quiescent Current: **680nA**

Need to Measure Quiescent nA Currents

- solution: SourceMeasureUnit



- Meet load current specs?
- Efficiency vs Voltage?



- V-Source, I-Source, V-Meter, I-Meter, and Electronic Load
- Very low current measurement with <pA sensitivity
- Accurate low voltage sourcing
- Voltage sweeps
- Tight integration of sourcing and measurement

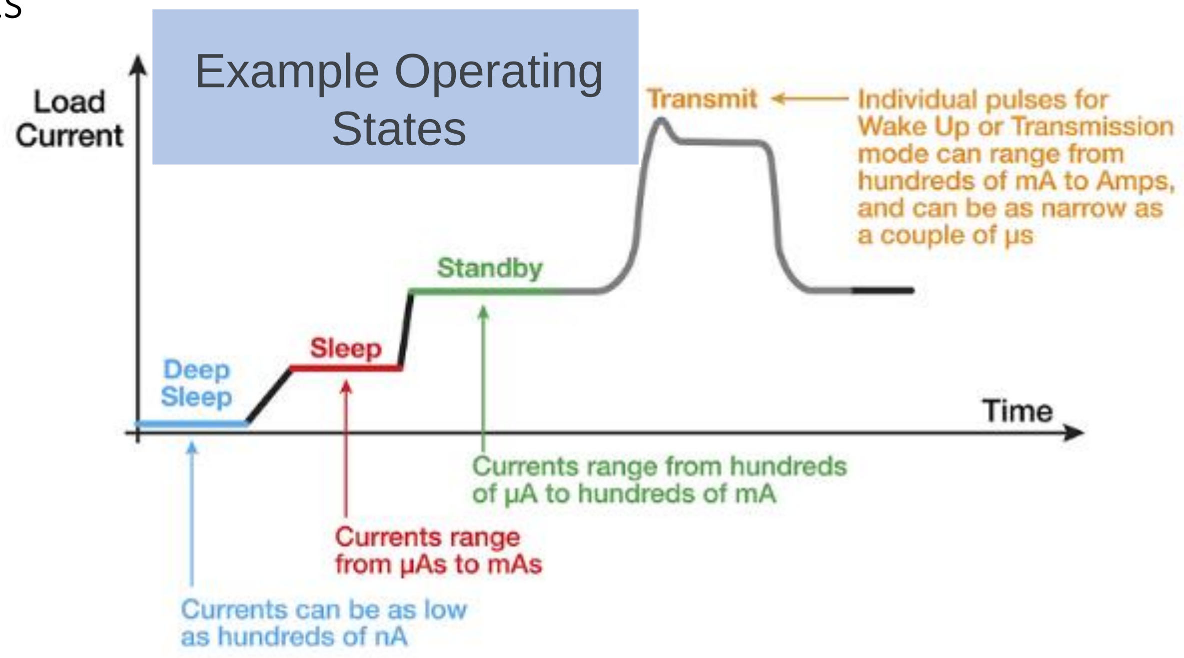
Assessing Your Product's Power Consumption

Measuring load current in all operating states

Need: Determine Product Power Consumption

- challenge: measuring load currents in all operating states

- Measuring low sleep mode currents: 10’s of nA to 10’s of µA
- Measuring transmit load currents
  - Tens of mA to Amps
  - Short duration current bursts: µs’ to 10’s of ms
- Capturing the complete load current profile
- Detecting unwanted transients

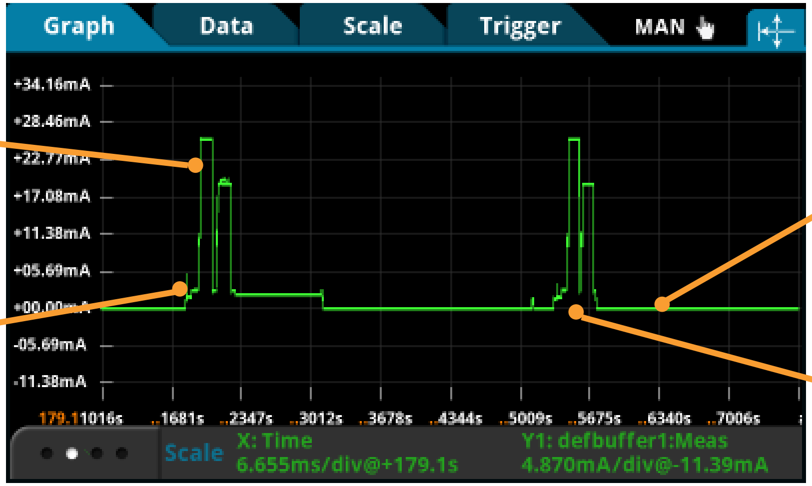


The Importance of Accurately Capturing the Total Current Consumption Profile

- Debug product firmware and software to optimize low power operation
- Capture and debug undesirable hardware anomalies

<u>Peak power consumption</u>
Data Transmission
~29mA

<u>Standby mode consumption</u>
Data acquisition
~2mA

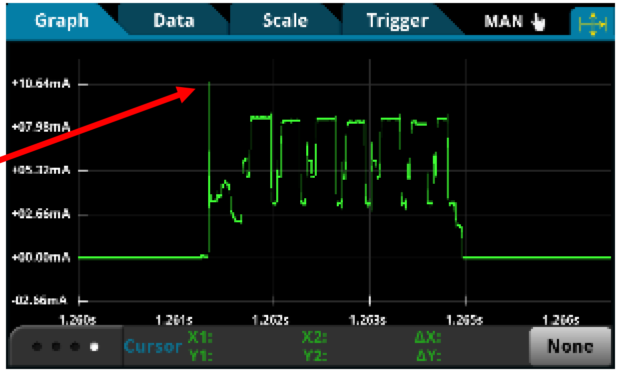


<u>Ultra Low Power Consumption</u>
Sleep Mode
~70nA

<u>Fast Transient Event Capture</u>
Pulse Width
~4ms

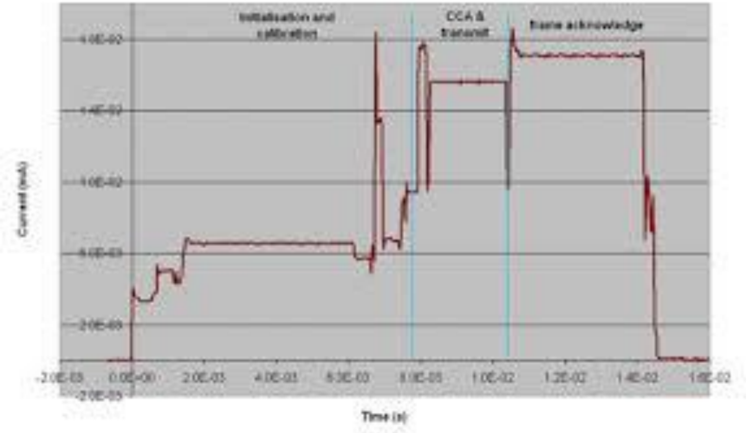
<u>Long datalogging</u>
Device operation > 10s, >10 million data points need to be saved

Transient?

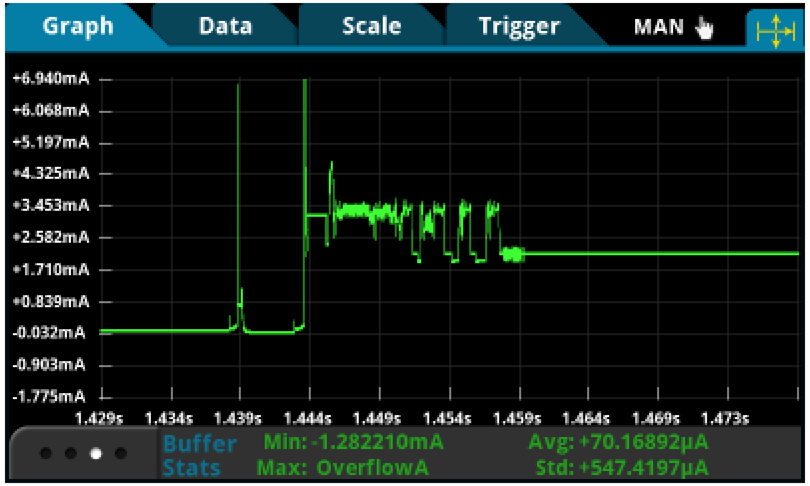


Low Power Bluetooth Module Transmit Current

Measuring Instrument Requirements



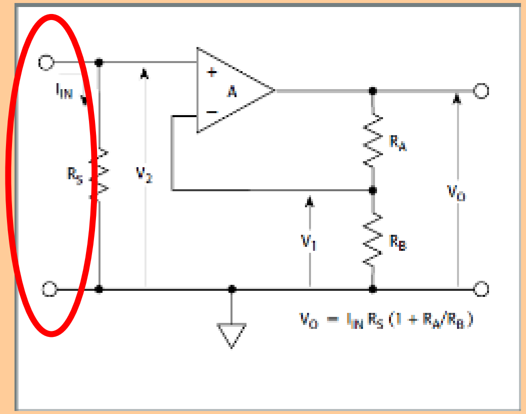
- Measuring sleep mode currents
    - 0.1nA or lower current sensitivity
    - High measurement accuracy
- Capturing current bursts due to the RF transmissions
    - Sufficient sampling speed
    - Sufficient bandwidth
    - Triggering modes
    - Waveform display and signal analysis
- Capturing the load current profile
    - Deep memory to store minutes of data



Minimize Impact of the Measuring Circuit

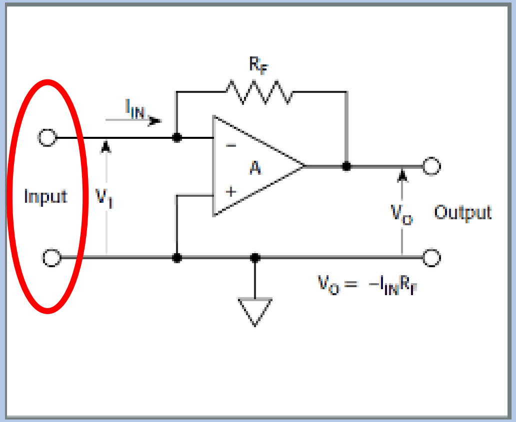
- voltage burden reduces the voltage supplied to the product and the measured current is lower

Shunt Ammeter



- 150mV to 1V voltage burden in typical DMMs
  - Reduces voltage to product-under-test
  - (0.7% to 7% of a 4.2V battery's voltage)
- Lower sensitivity, 0.1µA
- Lower signal-noise ratio

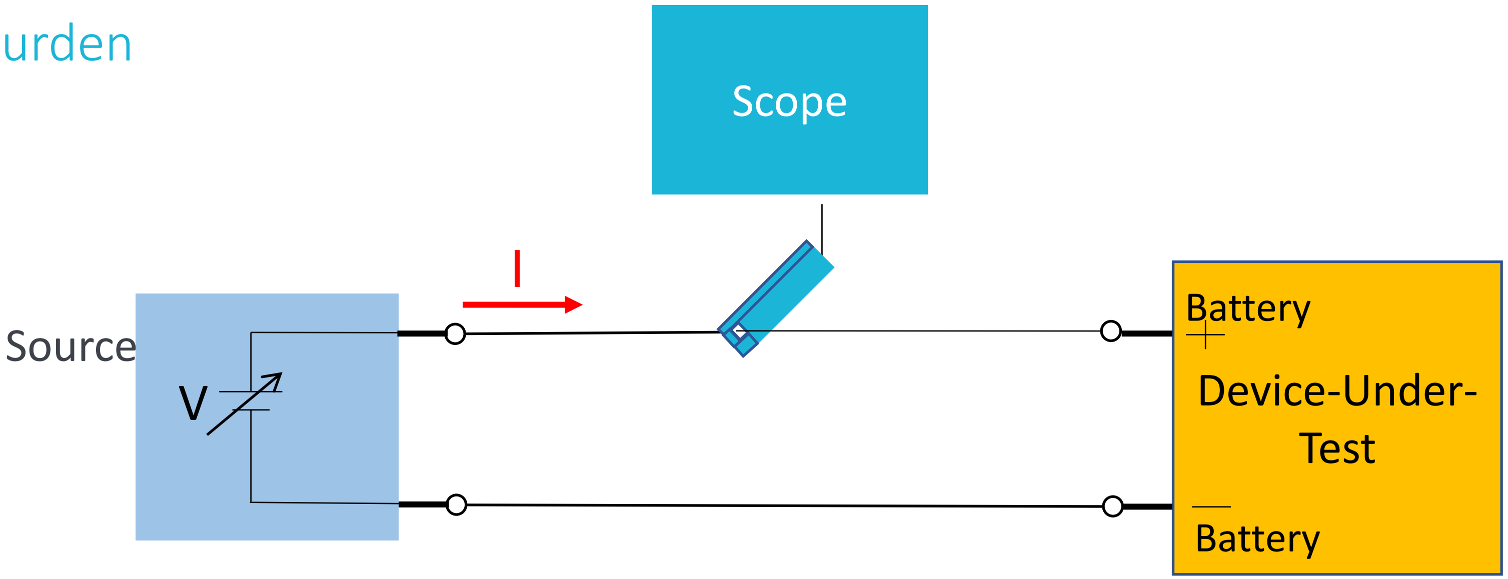
Feedback Ammeter



- <1mV voltage burden
- High current sensitivity
  - Sensitivity down to 10^{-15}A
- Large signal-to-noise ratio
- Bandwidth limited

Scope with Current Probe

- no voltage burden



Requirements	Ability to meet the Requirements
Sleep mode Measurements	Inadequate sensitivity. Current probes can detect down to mA levels
Capturing short current bursts	• **More than sufficient bandwidth** • **More than sufficient sampling rate** • **Numerous triggering options**
Capturing a load current profile	• **Sufficient record length**
Visualizing the data	**Large waveform display**

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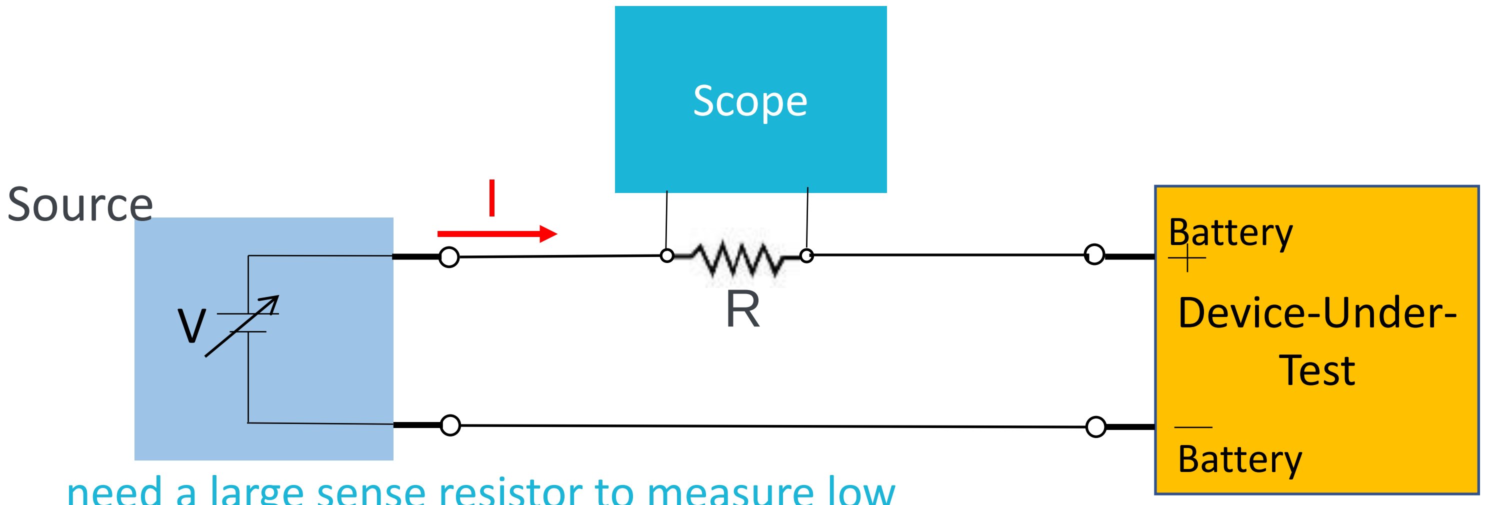
Scope and Sense Resistor

- need a large sense resistor to measure low currents



need a large sense resistor to measure low

Requirements	Ability to meet the Requirements
Sleep mode Measurements	Inadequate sensitivity
Capturing short current bursts	• More than sufficient bandwidth • More than sufficient sampling rate • Numerous triggering options
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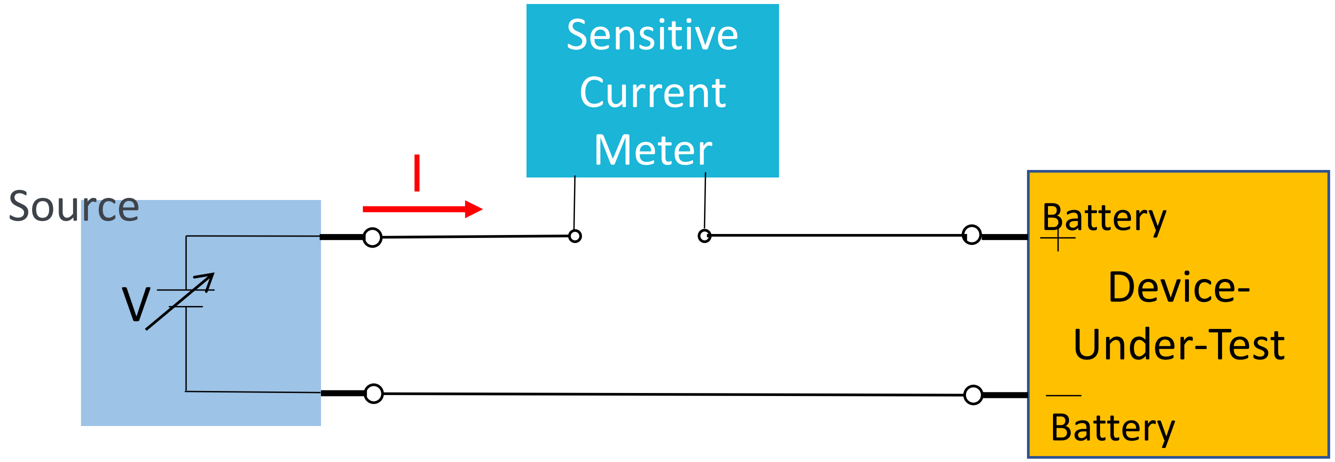
Visualizing the data	Large waveform display

Picoammeter or SourceMeasureUnit

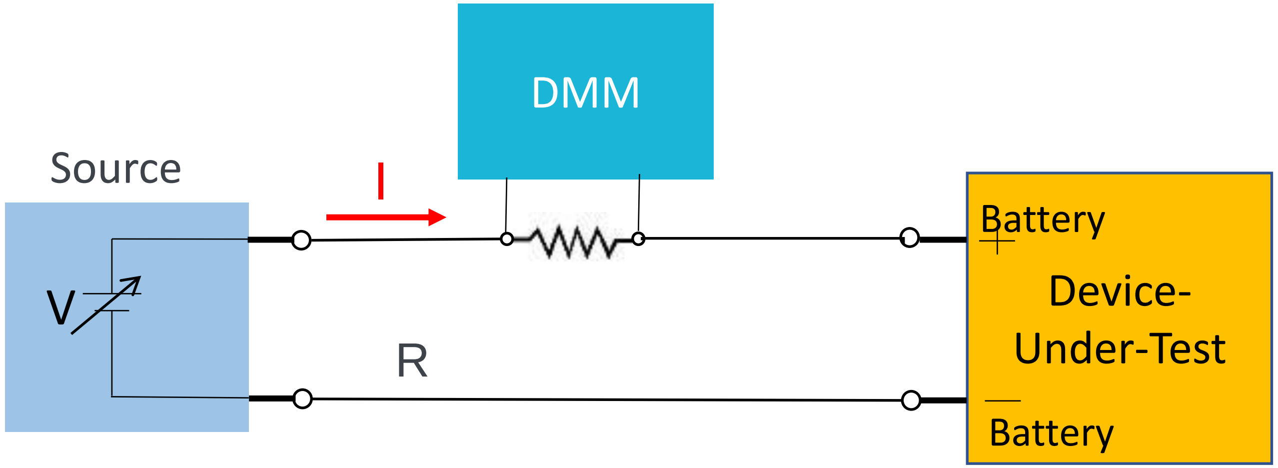
- minimize voltage burden with feedback ammeter



Requirements	Ability to meet the Requirements
Sleep mode Measurements	• pA sensitivity • Extremely low voltage burden, 200µV
Capturing short current bursts	• Very low bandwidth • Very slow measurement rate • limited triggering options
Capturing a load current profile	• Limited data storage
Visualizing the data	Numerical or small graphical display

6 ½ - Digit DMM Measuring Voltage

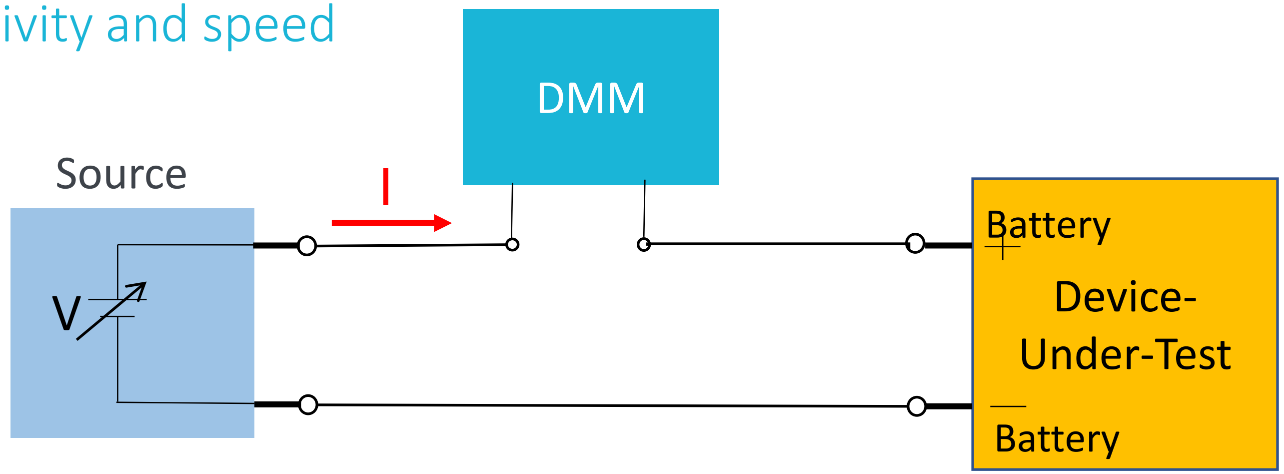
- lacks both sensitivity and speed



Requirements	Ability to meet the Requirements
Sleep mode Measurements	Inadequate sensitivity
Capturing short current bursts	• Bandwidth <300kHz • Sampling rate < 50 ksample/s • No level trigger
Capturing a load current profile	• Record length < 2M samples
Visualizing the data	No waveform display

6 ½ - Digit DMM Measuring Current

- lacks both sensitivity and speed



Requirements	Ability to meet the Requirements
Sleep mode Measurements	• Inadequate sensitivity • ≥ 150mV voltage burden
Capturing short current bursts	• Bandwidth <300kHz • Sampling rate < 50 ksample/s • No level trigger
Capturing a load current profile	• Record length < 2M samples
Visualizing the data	No waveform display

Bringing together Scope and DMM functions

Scope

- 8-bits …12 bits digitizer
- Sample speed typ. > GS/s
- Large Graphical display
- Horizontal / vertical cursors
- Analog triggering

DMM

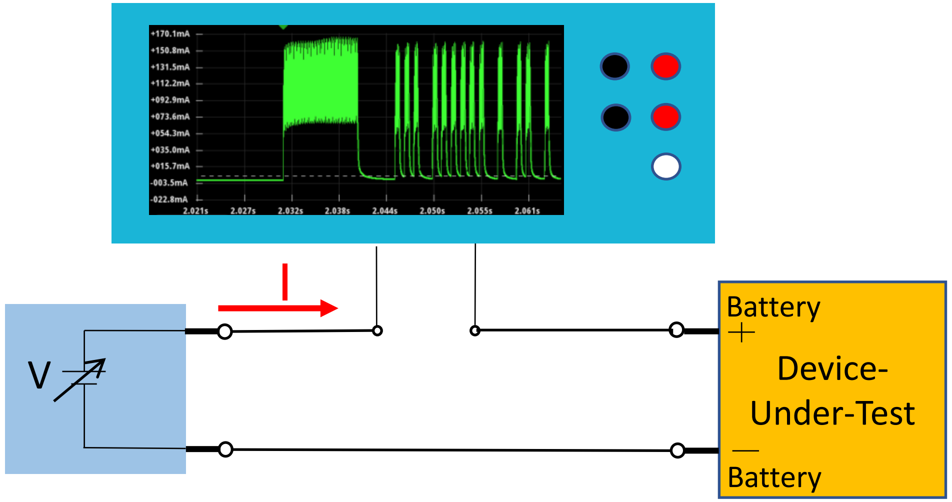
- No digitizer; integrating A/D
- 1 pA DC current measurement sensitivity
- High accuracy

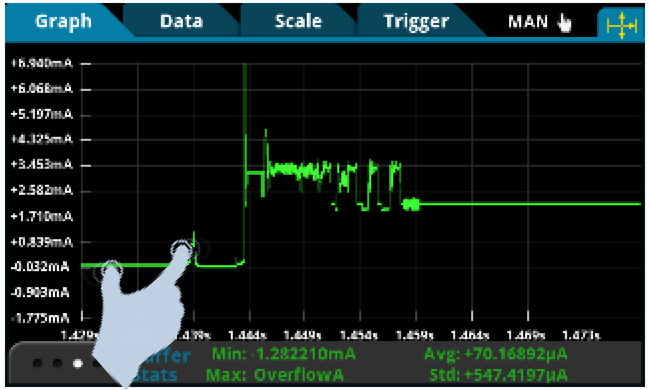
Sensitive high speed sampling DMM with display

- 18-bits digitizer + high res integrating A/D
- Sample speed 1 MS/s
- 100 pA current measurement sensitivity with digitizer
- 1 pA DC current measurement sensitivity
- 5” Graphical TouchScreen Display with cursors
- Analog triggering

Sensitive high Speed Sampling DMM with display

- one-instrument solution with high sensitivity and high speed





Source

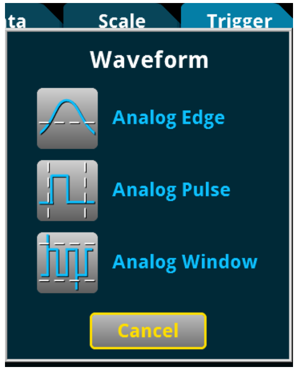
Requirements	Ability to meet the Requirements
Sleep mode Measurements	• 1 pA sensitivity • Low voltage burden, 15mV on lowest ranges
Capturing short current bursts	• 1Msample/s sampling rate • Level, slope, and other triggering modes
Capturing a load current profile	• Millions of readings
Visualizing the data	graphical touchscreen display with statistics

Sensitive high Speed Sampling DMM with display

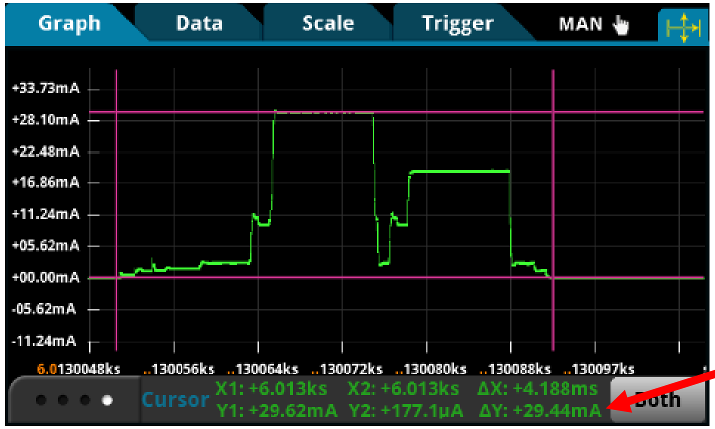
- sensitive measurement with scope-like performance

- high measurement accuracy and resolution
  - 1pA resolution
  - Example: 1µA measurement shows 1.000000µA with ± 0.375nA accuracy
- Scope waveform capture

Analog triggers



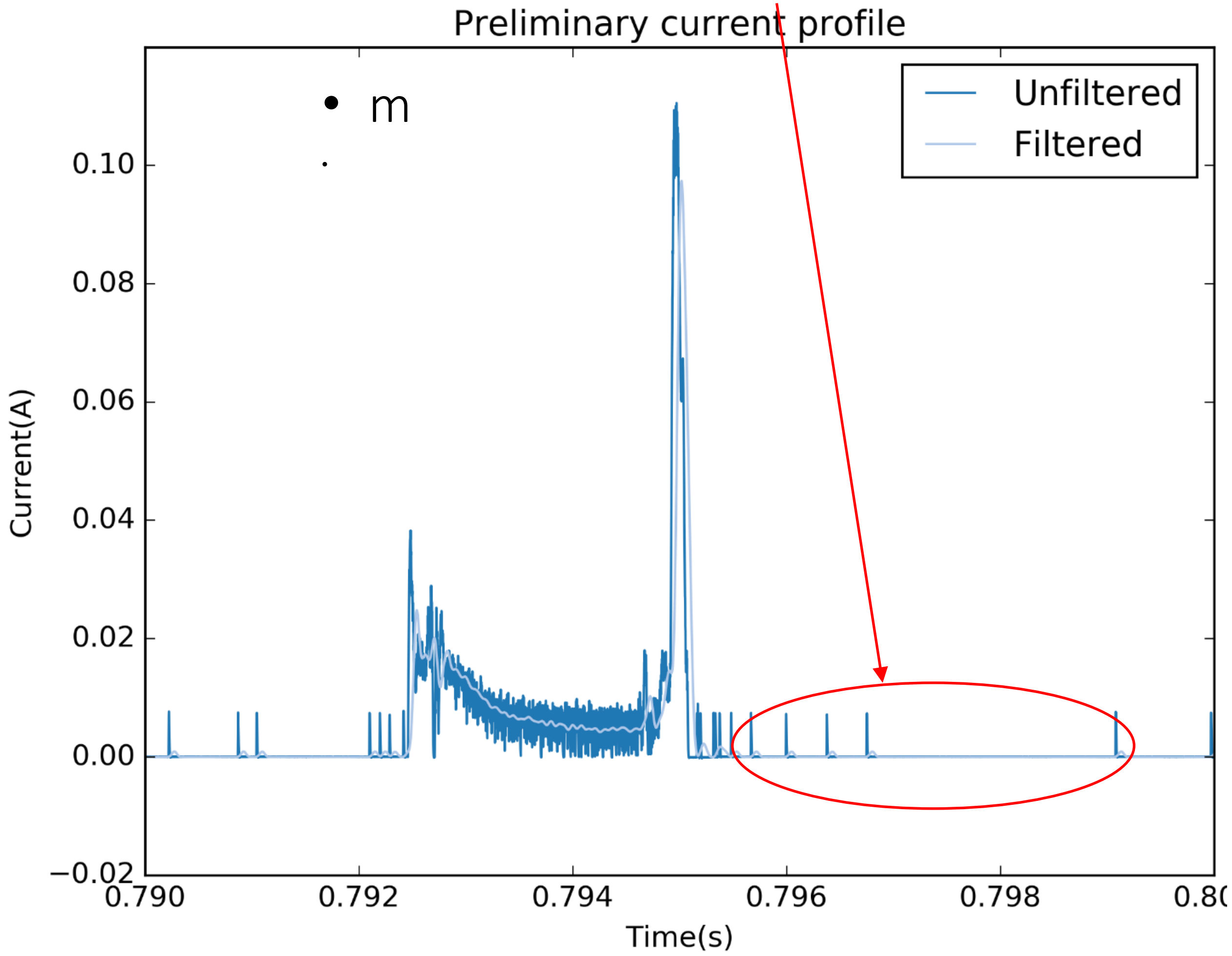
Horizontal and Vertical Cursors

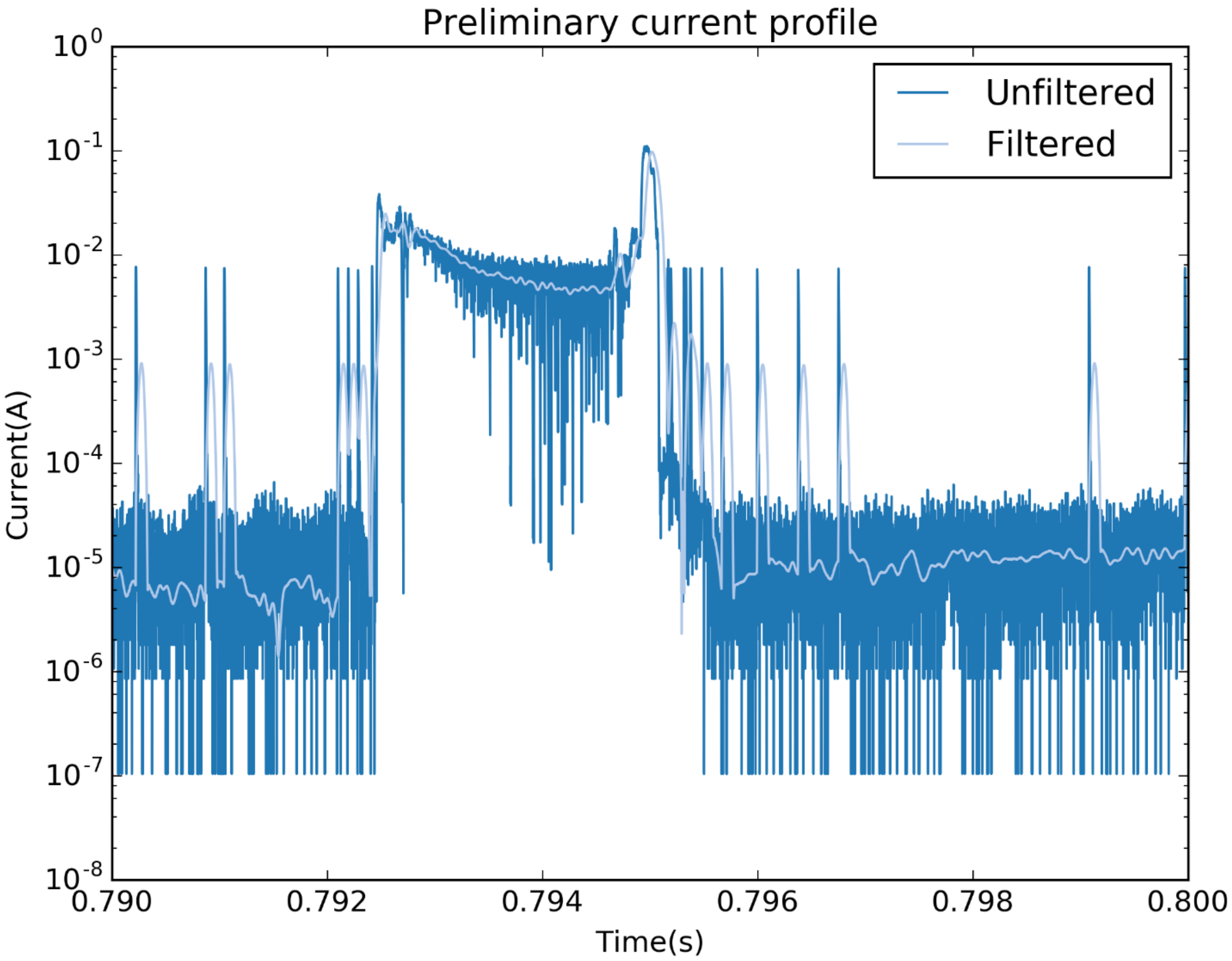


Statistics

Sensitive high Speed Sampling DMM with display

- Practical case: wireless sensor with battery life of 5 years
- “new” measured peaks required re-design





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Power Consumption Measurements Solutions for Your IoT Device Test Needs

Summary

IoT Power Consumption Test Needs

optimum solution

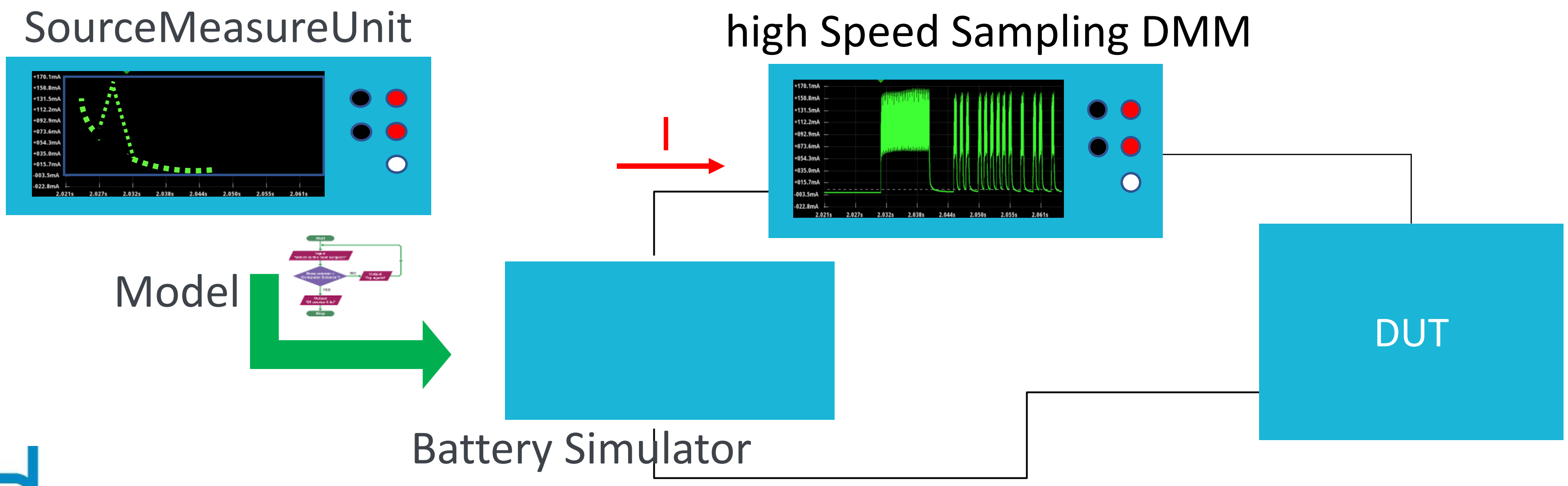
- Qualify low power components with a SourceMeasureUnit

  Can also act as a battery model generator

- Capture all the power with the Sensitive high Speed Sampling DMM with display

  pA sensitivity, 1 MS/s digitizer, and deep memory

- Most realistic simulation of the battery with the Battery Simulator



Thank you for Attending

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