Edward Brorein

Applications Specialist

Automated Stimulus and Battery Drain Measurements for Validating and Optimizing Mobile Device Run Time

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Variety of Battery Drain Measurement Needs for Handsets

- In R&D, optimize operating time by visualizing and analyzing current drain results for:
  - Quantifying contribution of sub circuits and components
  - Identifying high peak drain anomalies and root causes
  - Evaluating impact of design changes
- In DV, validate design against a suite of benchmark tests:
  - Current drain for all combinations of channels & power levels
  - Current drain for all main operating modes
- In Software Development, validate impact of new code:
  - Run code regression test suite, correlate against current drain data log
- In Product Launch, validate battery drain for published specs, industry standards, and service provider standard benchmarks

Battery Drain Measurement and Analysis for Validating and Optimizing Mobile Device Run Time

- <u>**Today's Objectives**</u>
- **Review traditional methods for battery drain measurements**
- **Highlight challenges faced with using traditional methods**
- **Highlight aspects of battery drain measurements that drive the need for specialized capabilities for sourcing and measurement**
- **Show how battery drain analysis is effective for characterization and optimization of battery operating time**
- **Illustrate some advantages of automating stimulus and measurement at the system platform level**

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Typical System Requirements for Battery Drain Measurement and Analysis

- When configuring an instrumentation system to measure and analyze battery drain, the system must:
  - Properly source power to the DUT
  - Provide DUT control (RF, digital, or other)
  - Log battery drain results from minutes to days in duration
  - Accurately measure/log current from sub-milliamps to amperes
  - Log battery run-down voltage
  - Store all data for post test access
  - Provide a post test summary of basic results
  - Provide analysis of data for design optimization

Basic Results

- Run time
- Average current
- Average voltage
- Amp-Hrs consumed
- Watt-Hrs consumed

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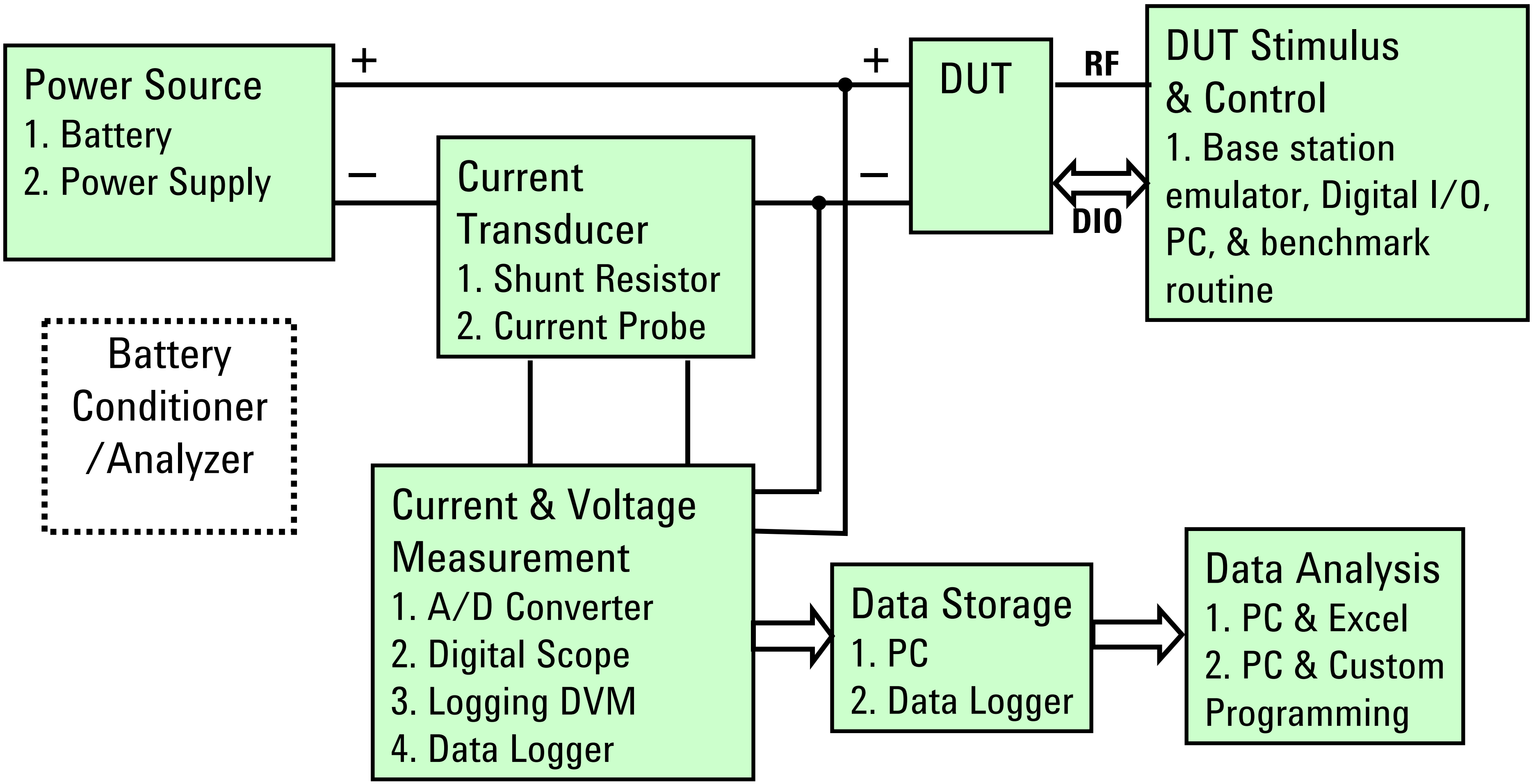
A Generic System for Battery Drain Measurement and Analysis



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Sourcing: Power Sources

Requirements

- Provides controlled power to the DUT

Traditional Solutions

- Battery
- General Purpose Power Supply

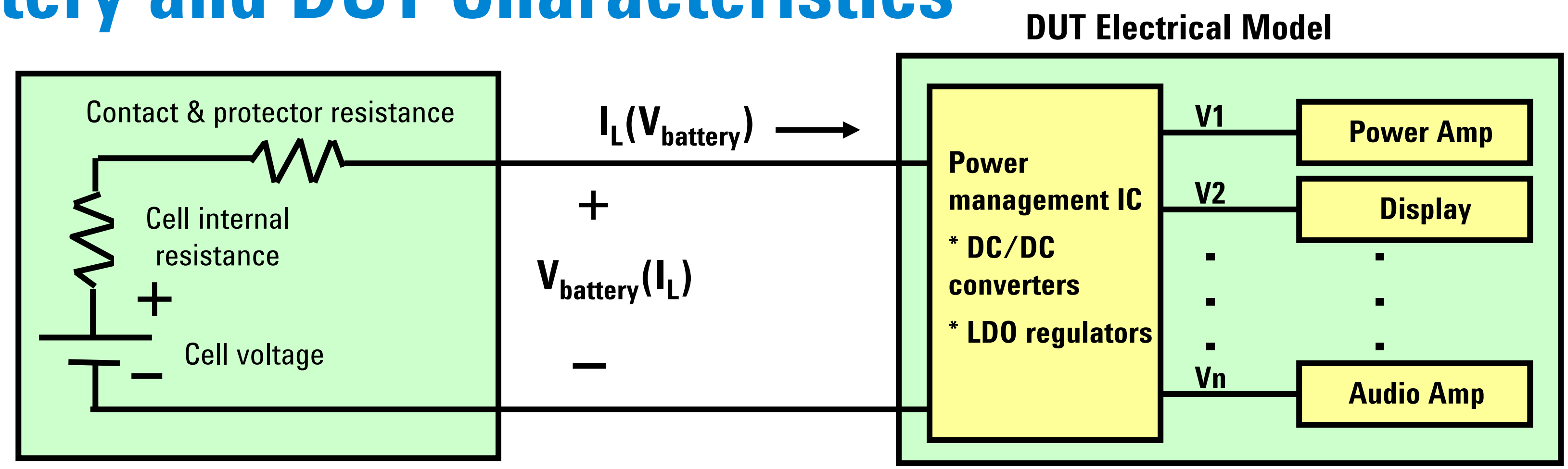
Challenges

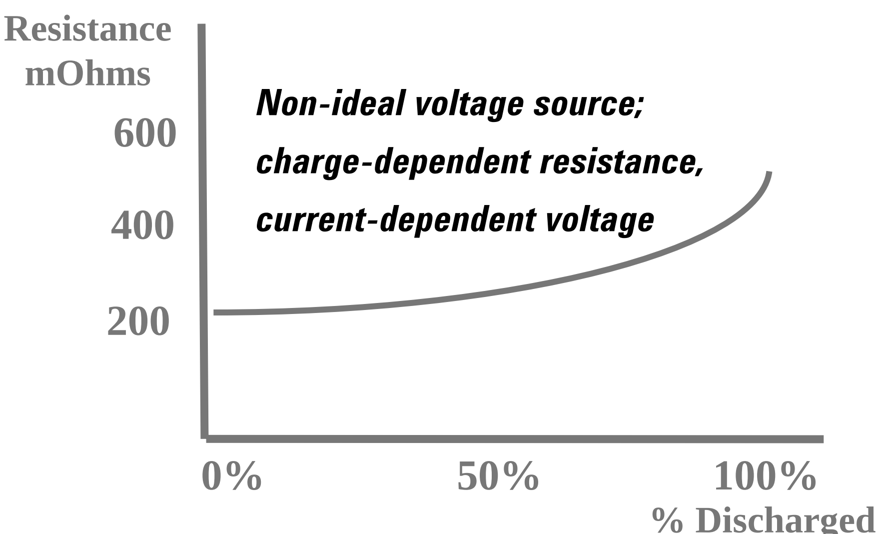
- No control of voltage or resistance
- Best suited for validating rundown time
- Output characteristics are different from that of a battery
  - Impacts resultant current drain

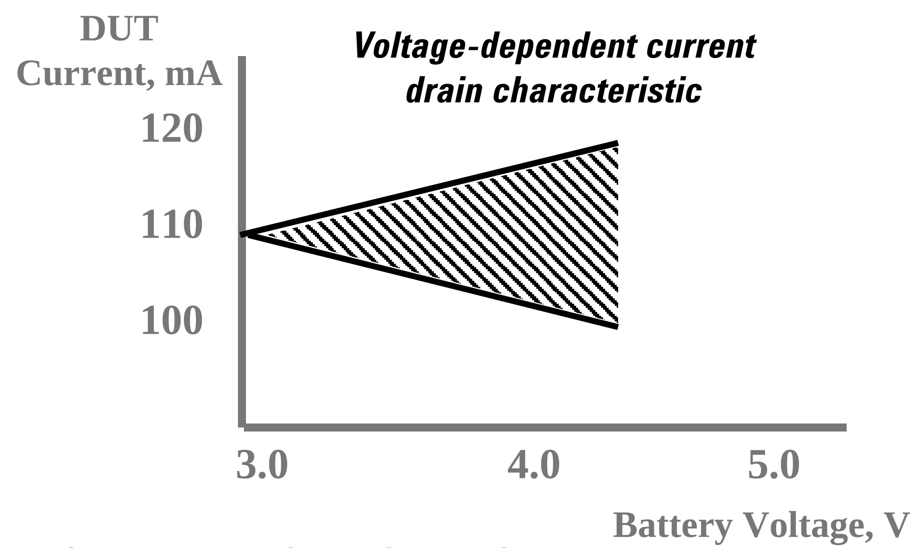
Specialized Solution

- Power supply with fast transient response and battery emulation

Battery and DUT Characteristics







- ✓ *DUT current, battery voltage, and battery resistance are interdependent*
- ✓ *DUT pulsed and average currents are often higher with battery resistance*

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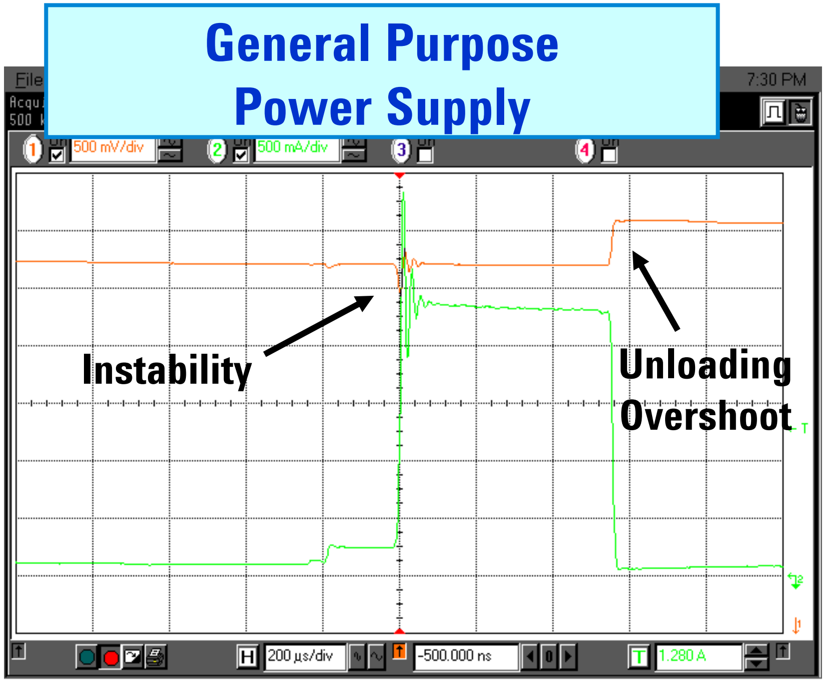
Typical General Purpose Power Supply Powering a GSM Handset



RESULTANT CURRENT DRAIN DOES NOT MATCH THAT OF A BATTERY:

- 10% higher peak and average currents were experienced
- Ringing and instability observed
- Large unloading overshoot

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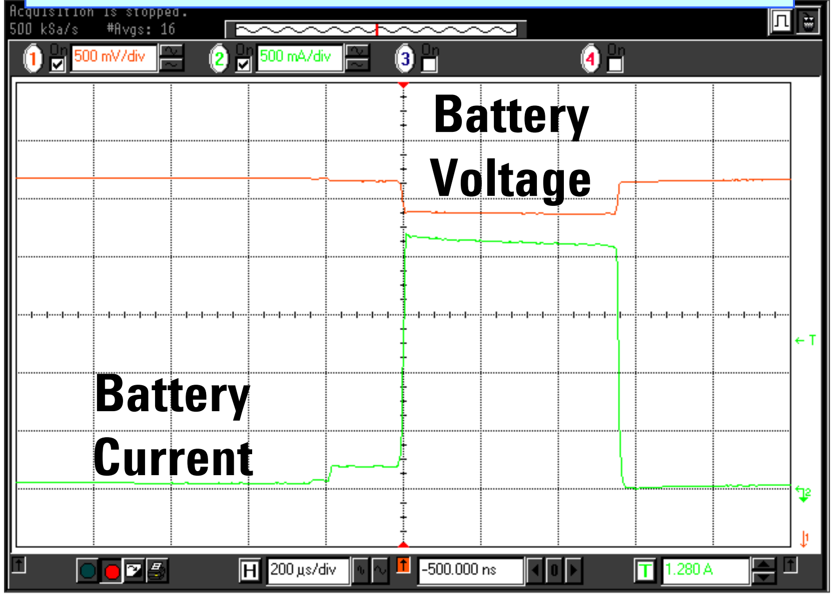
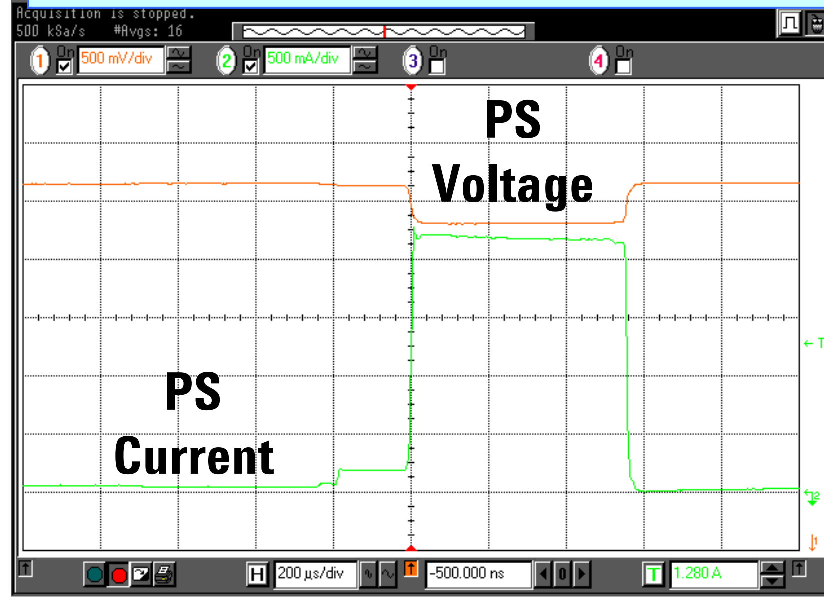
Comparing a Battery to a Specialized Power Supply Powering a GSM Handset

Actual battery response to a current pulse



Battery resistance is 150 milliohms

Agilent 66319 dc Source response to a current pulse



Power supply resistance programmed to 150 milliohms

Current Drain performance is comparable to when using a battery

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Measurement: System Current Transducer

Requirements

- Measurement range: 0.5 A for standby mode; 5 A for active mode
- Measurement accuracy: 0.2 % reading + 0.2% range(0.1 mA, 1 mA)

Traditional Solutions	Challenges
• Current shunt	• Ideally use 0.10 ohms & 0.010 ohms. Yields 50 mV drop • 4-terminal (Kelvin contacts) needed for accuracy • Thermal EMF can easily create >0.2% (>100uV) offset errors • (i.e. 100uA for 0.5A range, 1mA for 5A range) • Need to address grounding and common mode errors
• Current probe	• Requires frequent re-calibration for offset and drift. • Not accurate enough.

Specialized Solution

- Power supply that incorporates accurate current measurements

Measurement: System Digitizer

Requirements

- Sample current at 50 kHz or faster to accurately capture sub-millisecond pulses and anomalies

Traditional Solutions

- High-speed Multiplexing A-to-D Converter with deep memory
- Multiplexer and fast DVM with deep memory
- Digital oscilloscope with deep memory
- High-speed data logging and storage system

Challenges

- High-end data logging & storage solutions can be expensive
- Lower-end solutions require a lot of custom configuring
- High-speed data transfer over long periods is challenging
- Scopes typically low resolution

Specialized Solution

- Power supply with integrated high-speed digitizing measurement system

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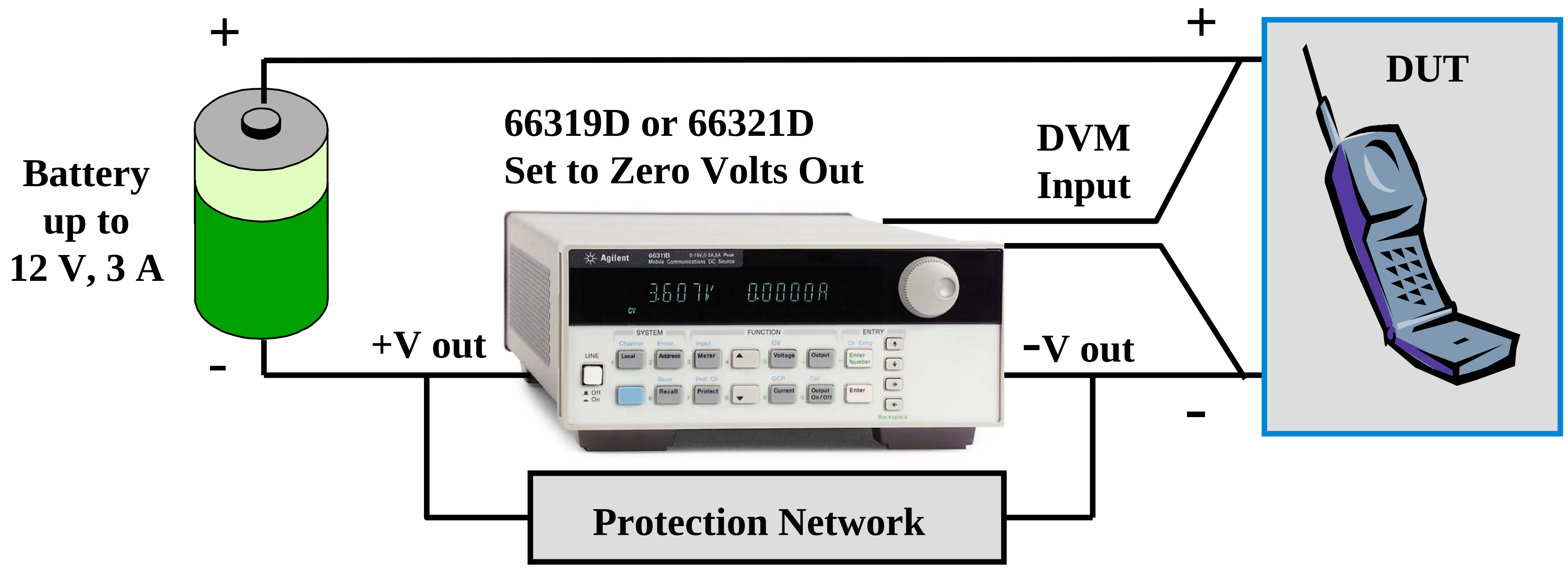
Specialized Solution for Measurement: Agilent Mobile Communications DC Sources

- Simplifies battery drain measurement by eliminating separate instruments
- Accurate Integrated Current Measurement
  - Multiple current ranges (5 A, 1 A, and 0.02 A)
  - Can source full current while in low measurement ranges
- High-Speed Digitizing System
  - High-speed DSP, 16-Bit, 64 kHz ADC and 4,096 byte buffer for waveform digitization with flexible triggering and data processing
  - Works with the 14565B software to continuously process and stream current drain measurement data for long term data logging

Alternately Using the Agilent DC Source as a Logging Ammeter and Voltmeter



- When programmed to zero volts the power supply becomes a zero-ohm shunt/ammeter
- Optional DVM input (on D suffix models) can be used to log battery voltage
- An external network protects against battery over-currents from misapplication
- See application note AN 1427 (5988-8157EN) for details

Analysis: System Data Storage and Post Analysis

Requirements

- Store from minutes to days of high speed digitized data
- Provide a run time summary and post test analysis of captured data
- Identify and analyze anomalies (unusual pulses, random overloads, etc.)

Traditional Solutions

- PC and disk drive
- Data logger with storage
- Spread sheet software
- Search routines for anomalies

Challenges

- High end data logger can be expensive
- Too much data → Cannot open the file!
- Developing analysis routines can be time consuming

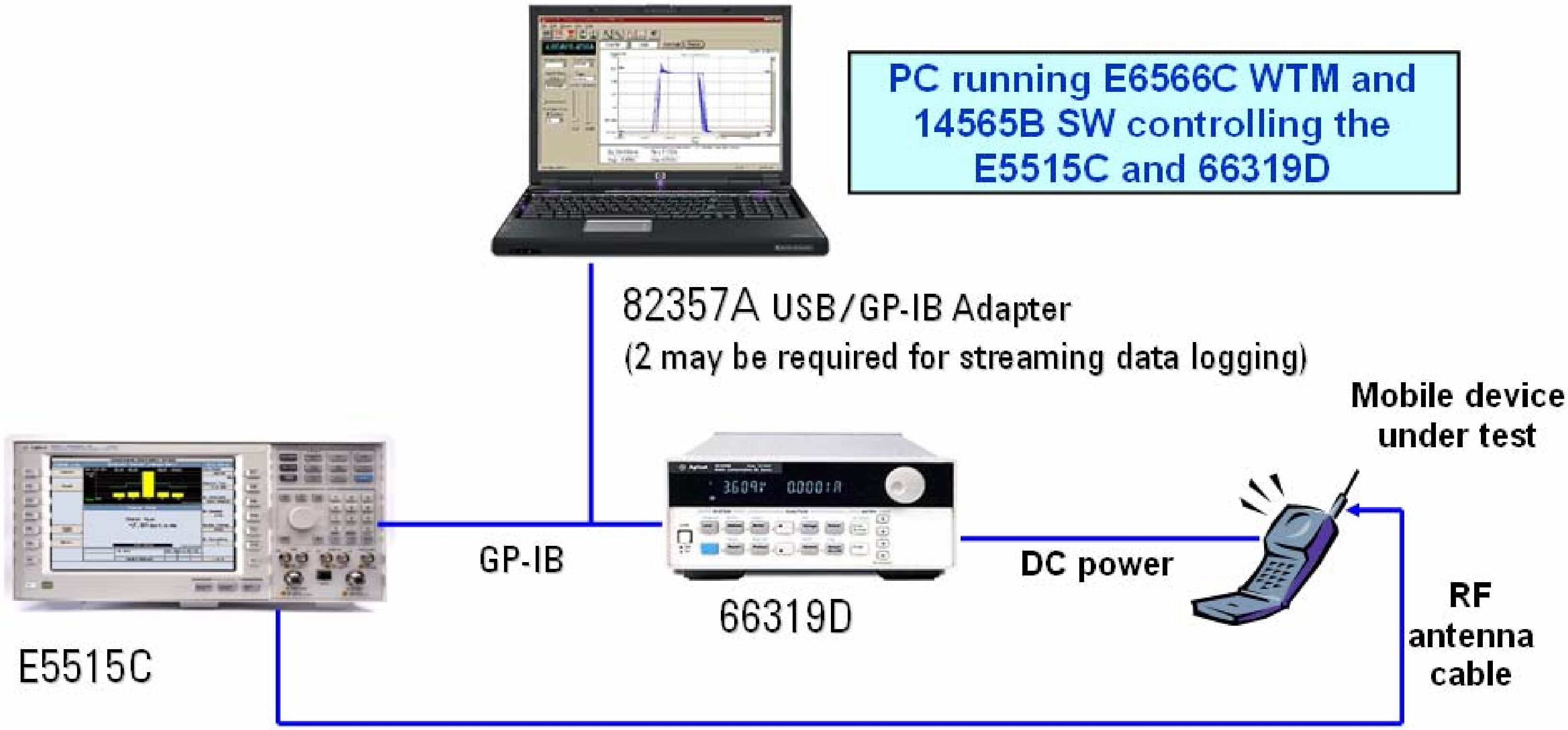
Specialized Solution

- Commercial software providing data reduction, storage, and visualization tools, tailored to battery drain

Specialized Solution for Analysis: Agilent 14565B Device Characterization Software

- Easy-to-use graphical interface works with the Agilent 663xxB/D Mobile Communications dc Sources
- Source, measure, data log, visualize, and analyze current drain
- Three modes of operation
  1. Waveform Capture and Analysis (short-term capture)
  2. Data Logging and Analysis (long-term capture)
  3. CCDF Statistical Distribution Capture and Analysis (long-term capture)
- New! <u>Automation:</u> Control the 14565B from other programs to automate and synchronize DUT activity with its current drain measurements

Example System Setup

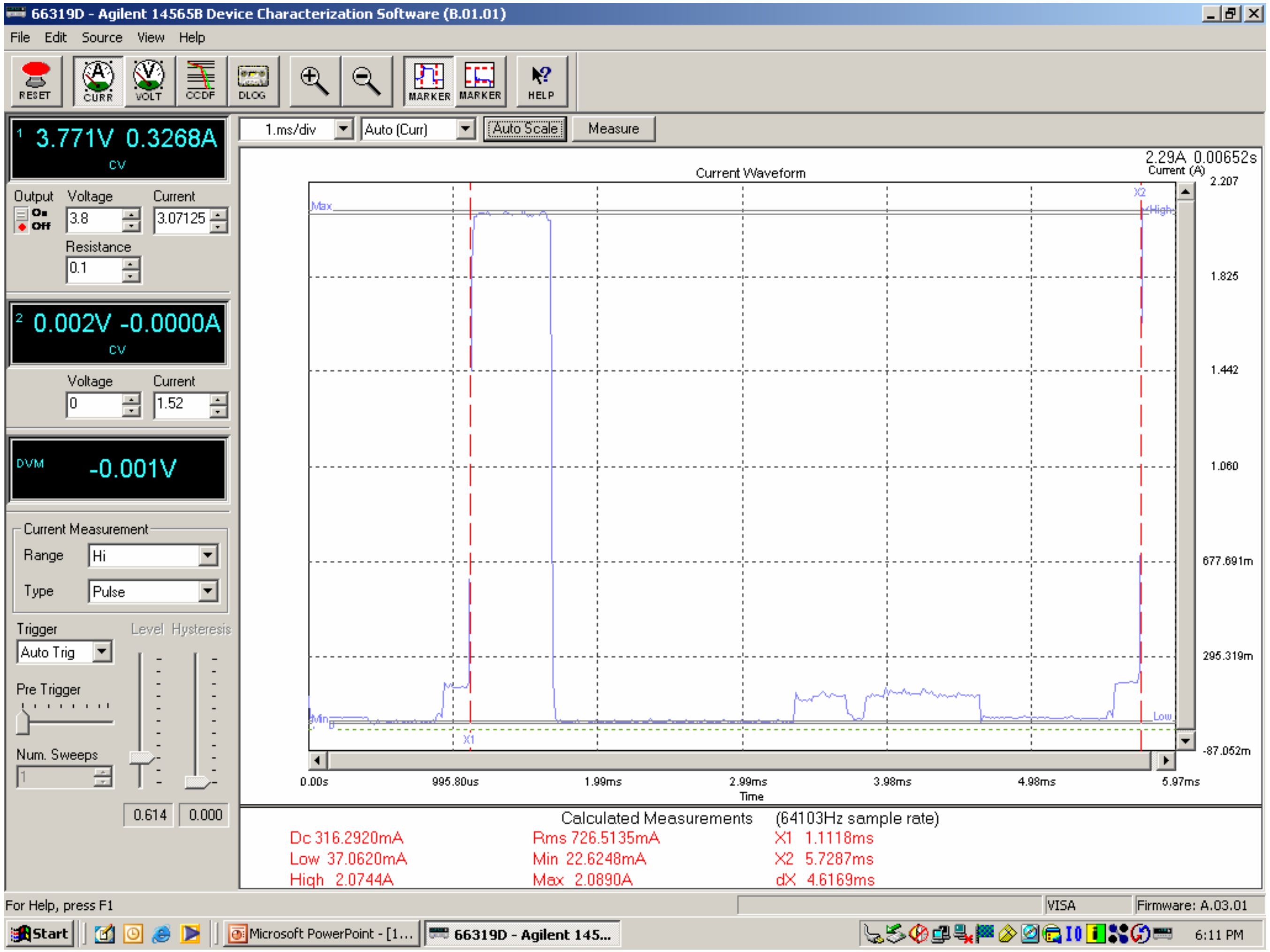


RF Tester used to emulate base station and setup mobile device test conditions

66319D dc source with high speed digitizer measures the battery current drain

Agilent 14565B Waveform Capture and Analysis

- **Oscilloscope-like view of battery current drain**
- **Measurements permit estimating operating time and current drain**
- **Measurements include average, pulse high and peak levels, and timing values**
- **Zoom and markers for analysis**



14565B Device Characterization Software displaying a GSM TX current waveform

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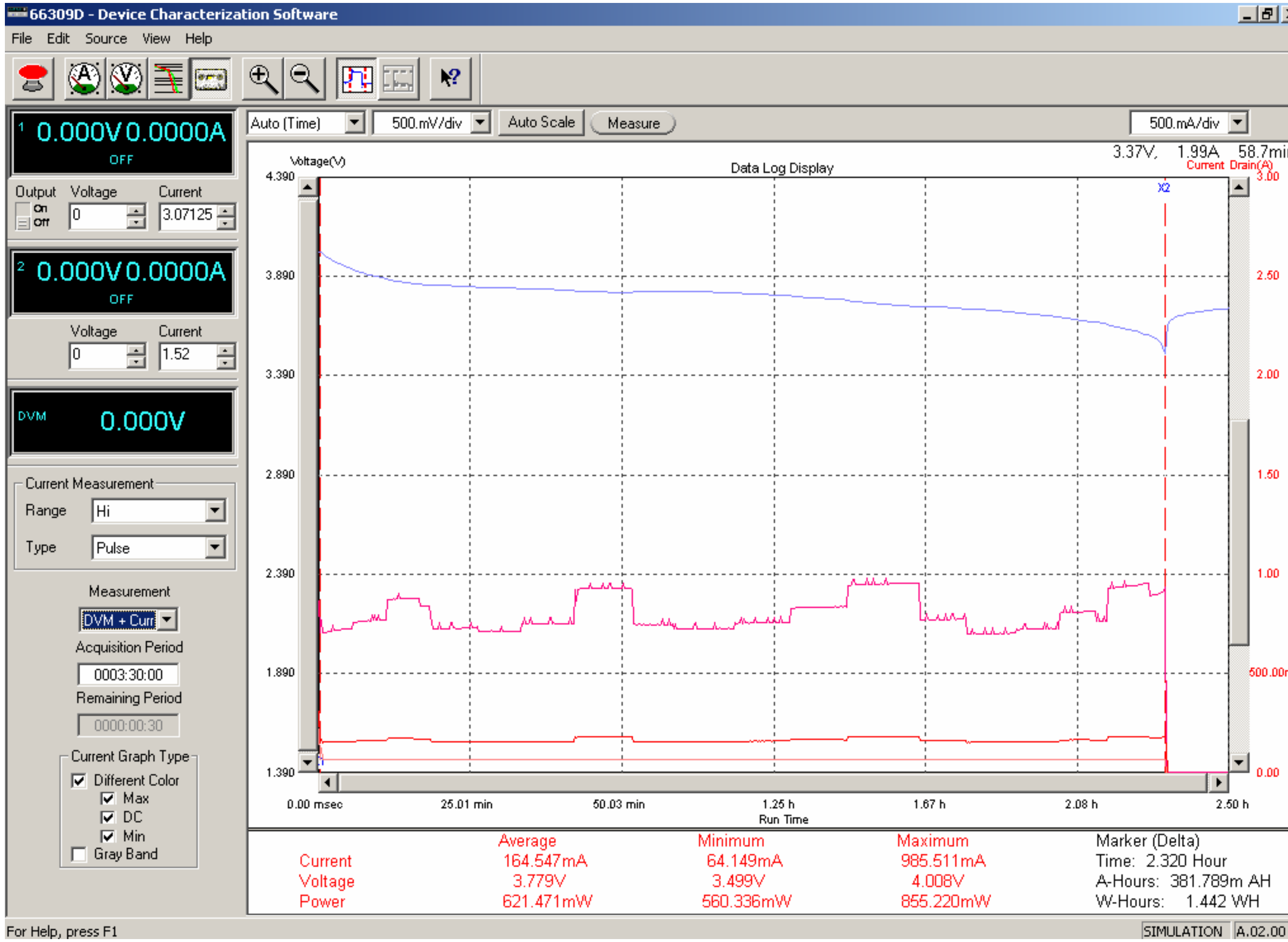
Agilent 14565B Data Logging and Analysis

- Logs from 10 seconds to 1000 hours
- Captures details with current sampled at 64 kHz
- Voltage can be sampled at low rate
- Displays
  - Min, Max, and Avg current, voltage, and power
  - Run time, AH, WH
- Zoom and markers
- Integration reduces data in real time



14565B displaying a long-term data log of a GMS handset battery run-down test

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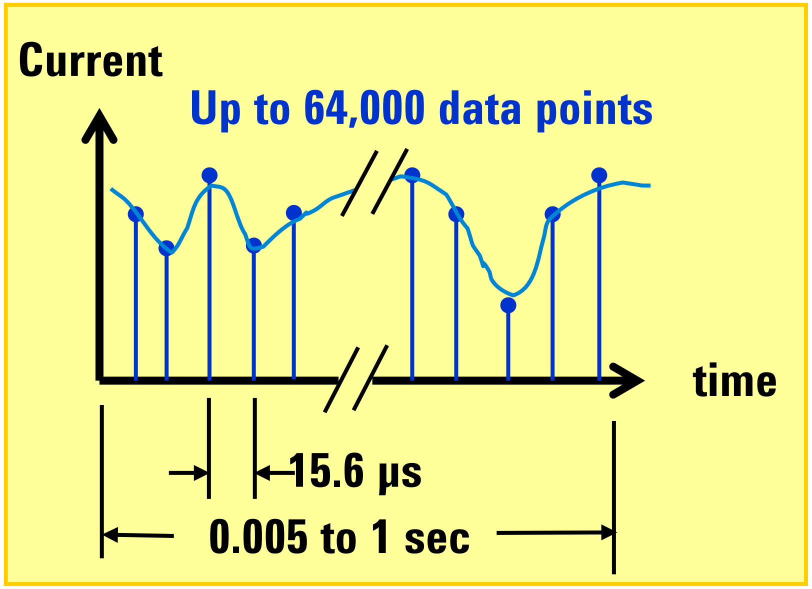
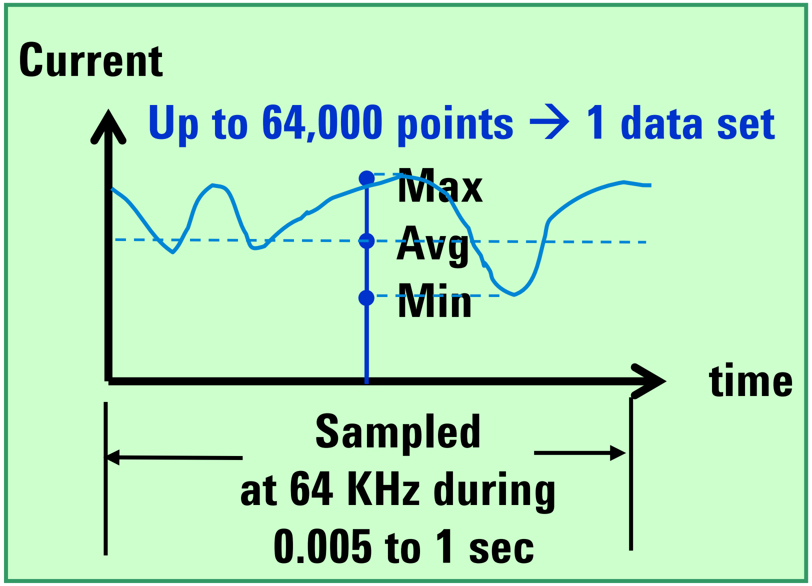
Integrating Feature Reduces Data in Real Time

Normal Digitizing



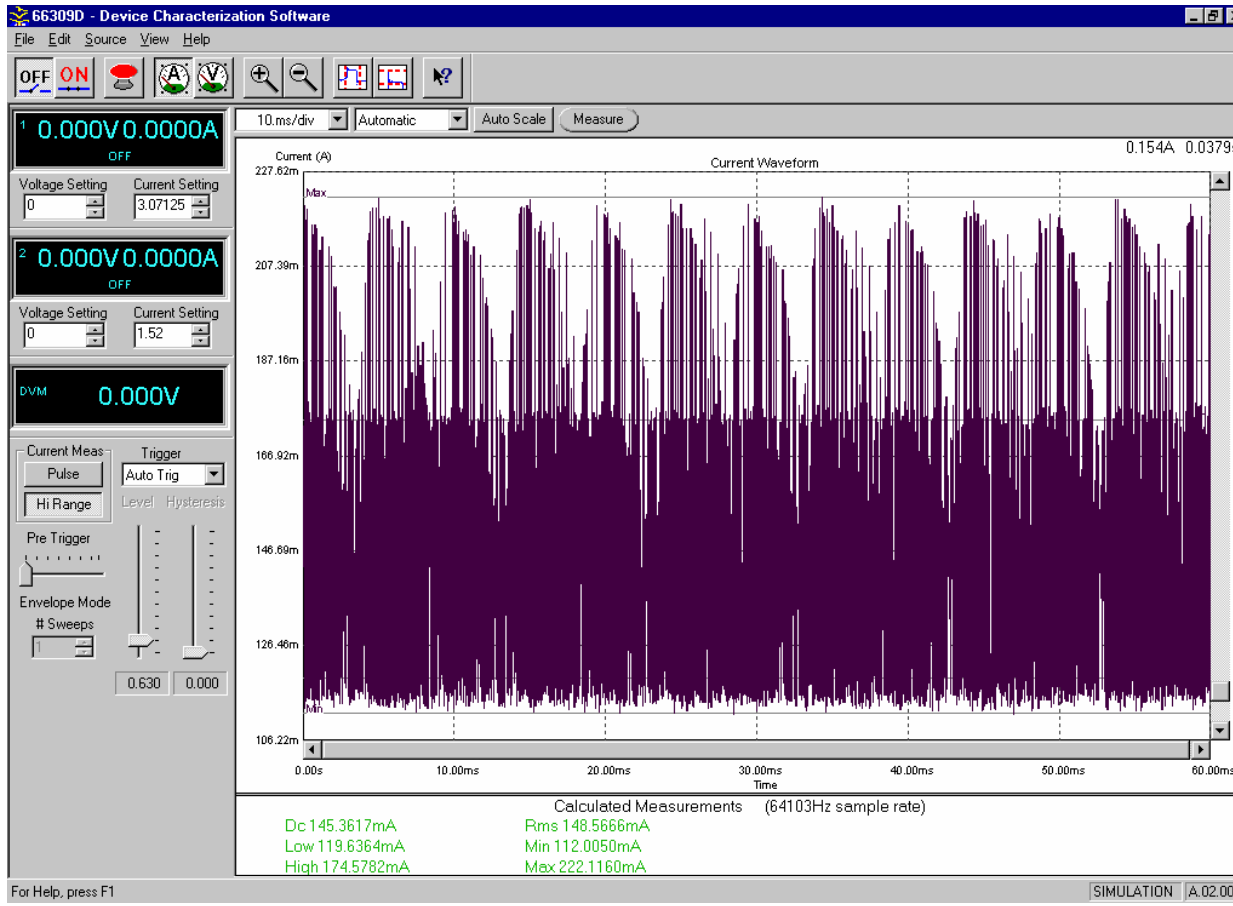
Agilent Data Integration/reduction



- <u>0.005 to 1 second programmable</u> integration period provides a minimum, maximum, and average value for each period of 64 kHz sampled data.
- Manageable data files for post analysis and export (5 MB per 100 hours)
- Logs data to the disk to reduce loss of test data if test is interrupted

Concisely Characterizing Complex Current Drain over Long Time Periods

- Digital communications systems signals are complex & random in the time domain
  - Example: CDMA2000
- Difficult to obtain meaningful average current values for estimating battery life
- Difficult to identify effect of design changes on current drain over long periods of time
- A better way to analyze is using a statistical distribution such as a Complementary Cumulative Distribution Function (CCDF) graph



14565B displaying a CDMA2000 PA Current Waveform

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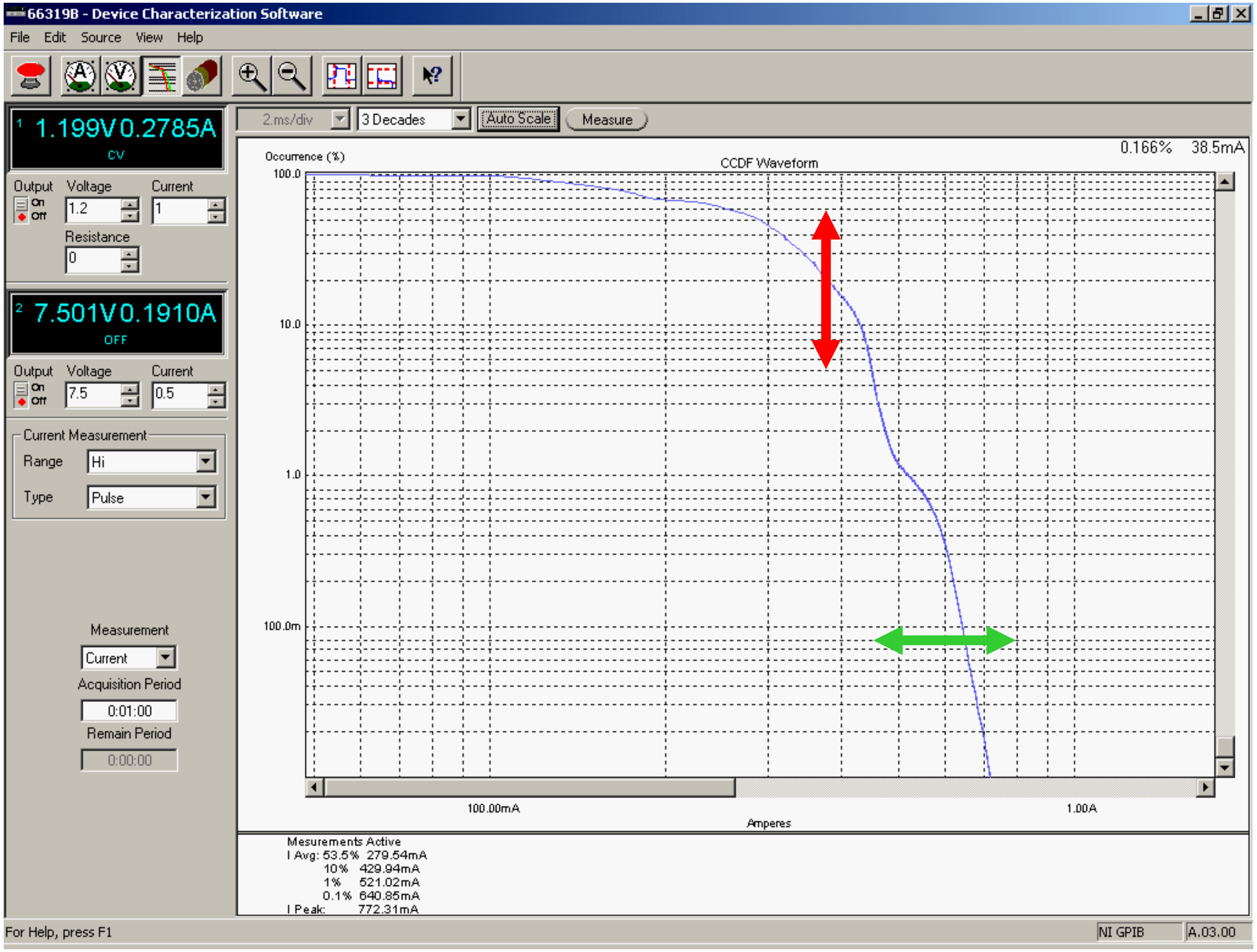
Agilent 14565B Complementary Cumulative Distribution Function CCDF Capture and Analysis

- **CCDF is an alternate form of a histogram useful for visualization and analysis of complex signals**
- **Displays current or voltage on x-axis versus % occurrence on y-axis**
- **Horizontal shifts indicate amplitude related changes**
- **Vertical shifts indicate time related changes**
- **Zoom, markers, save, recall and compare for analysis**
- **Accumulates from 10 seconds to 1000 hours**
- **Captures details with sampling at 64 kHz**



CCDF graph of a *Bluetooth*™ headset talk mode current drain

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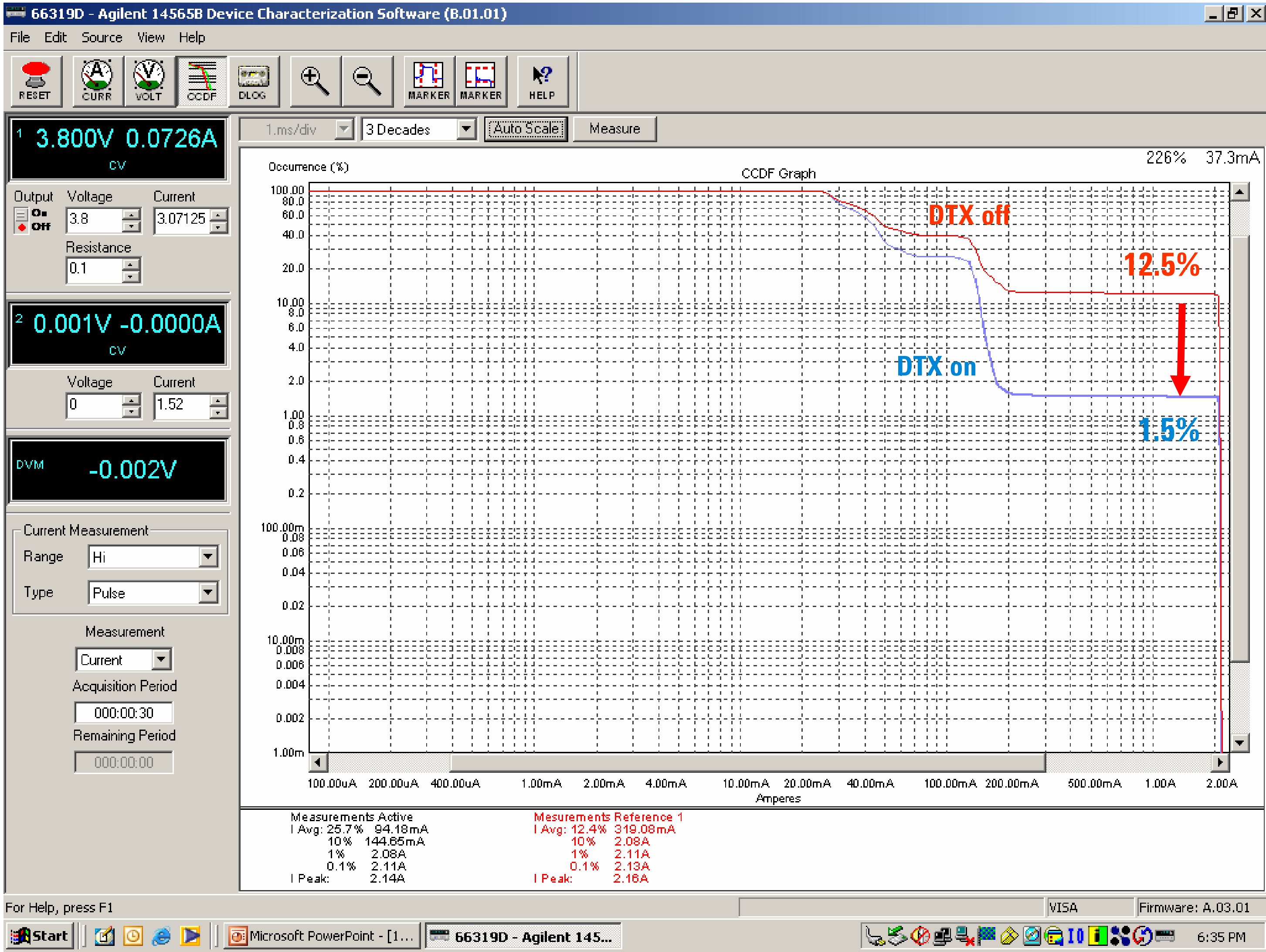
A CCDF Graph Analysis Example: GSM DTX Operation

- **Comparing DTX-off (red trace) to DTX-on (blue trace)**
- **The time-related difference is quickly observed and quantified**
- **Transmit burst occurrence drops from 12.5% to 1.5%**
- **Overall average current drain drops from 319mA to 94mA (71% drop!)**



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Why Automate Current Drain Measurements?

- Save engineering time and resources by automating manual testing:
  - Validate current for suite of TX power levels & channels
- In Software Development, validate impact of new and updated code:
  - Run suite of regression tests, correlate against current drain
  - Place markers in data log to synchronize and validate current drain behavior against changes in DUT activity
- In Product Launch, save time, resources, and improve repeatability by automating numerous, commonly repeated benchmark tests, such as:
  - Product's published specifications
  - Industry standardized benchmarks
  - Service provider sourcing requirements specifications

Agilent 14565B Automation Interface Highlights

- Full set of commands implemented using Component Object Model (COM) automates the 14565B functionality from a client environment
- Client languages include:
  - Visual C++ using MFC
  - Visual Basic for Apps.
  - Visual Basic 6.0
  - Visual C# (.NET)
  - Visual Basic (.NET)

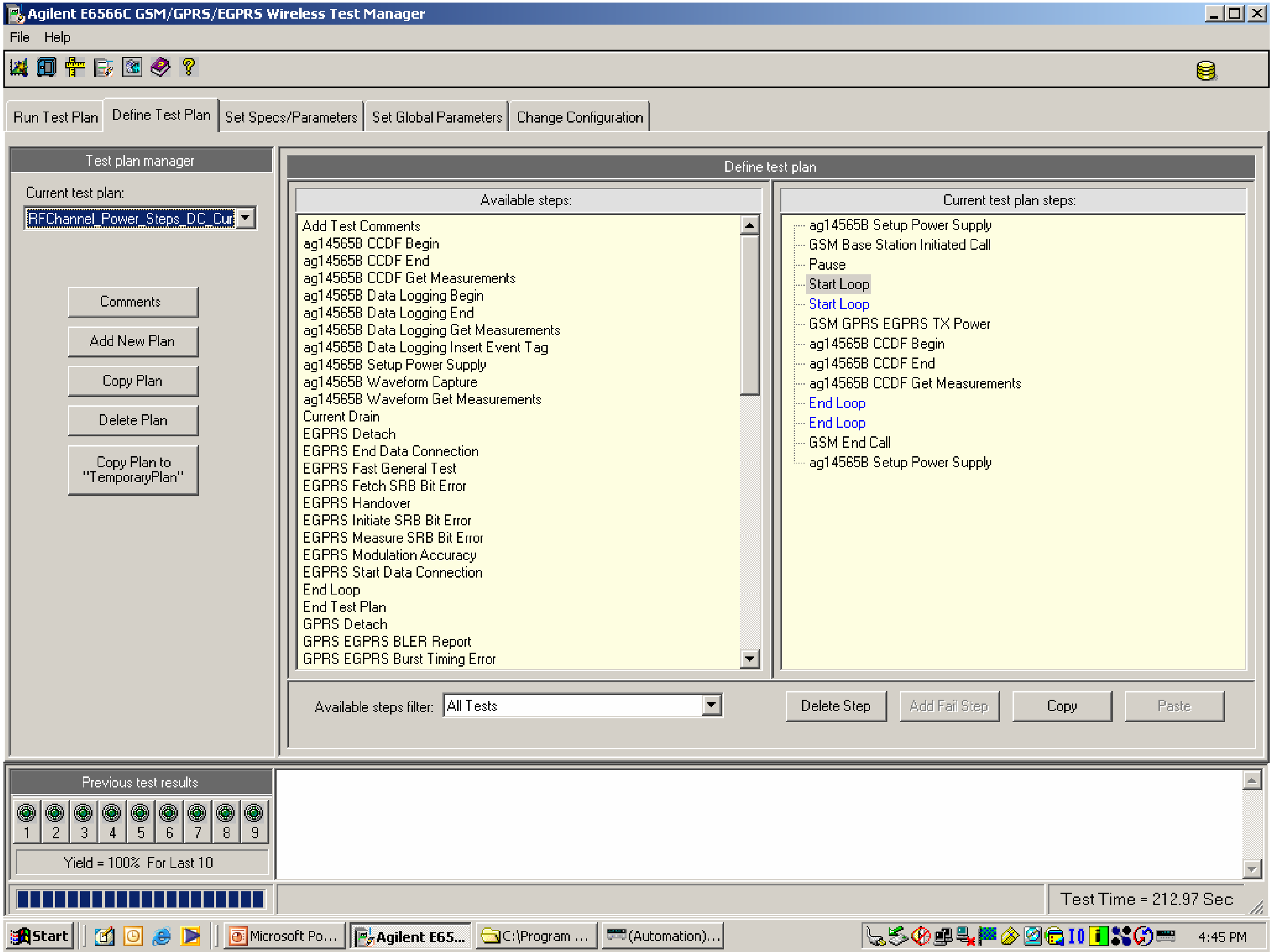
  Client programs include:

  Agilent VEE

  National Instruments Lab View

  Agilent Wireless Test Manager (WTM)
- WTM Driver and integration guide
- Complete programmer's development folder includes;
  - Programming guides, starter programs, automation examples, automation help file, C++ wrapper, WTM driver and test steps, and more

Agilent E6566C WTM Example: Current Drain vs. Channel & Power Level



- **Define the test plan**

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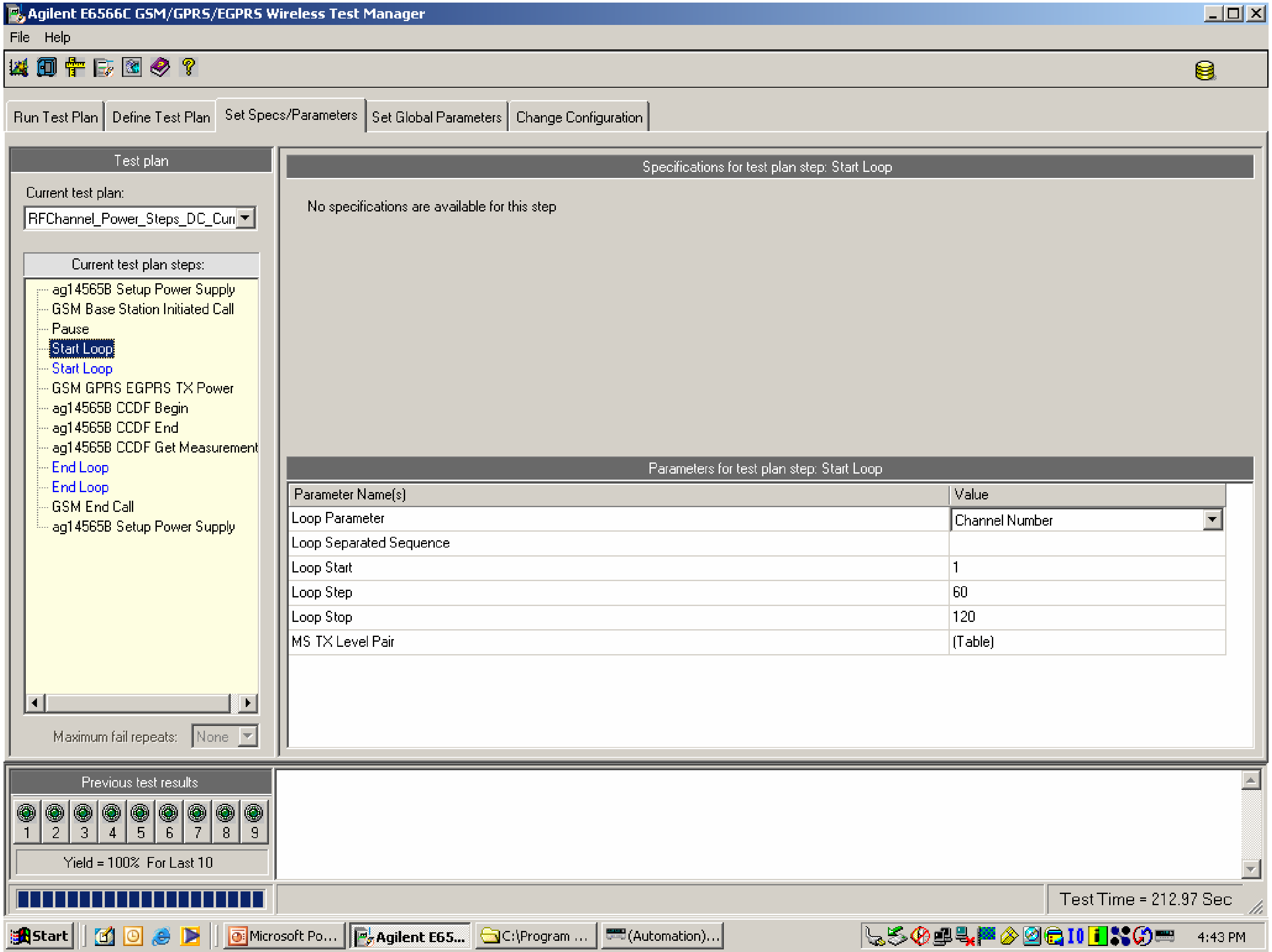
Agilent E6566C WTM Example: Current Drain vs. Channel & Power Level



- **Set specifications and parameters**

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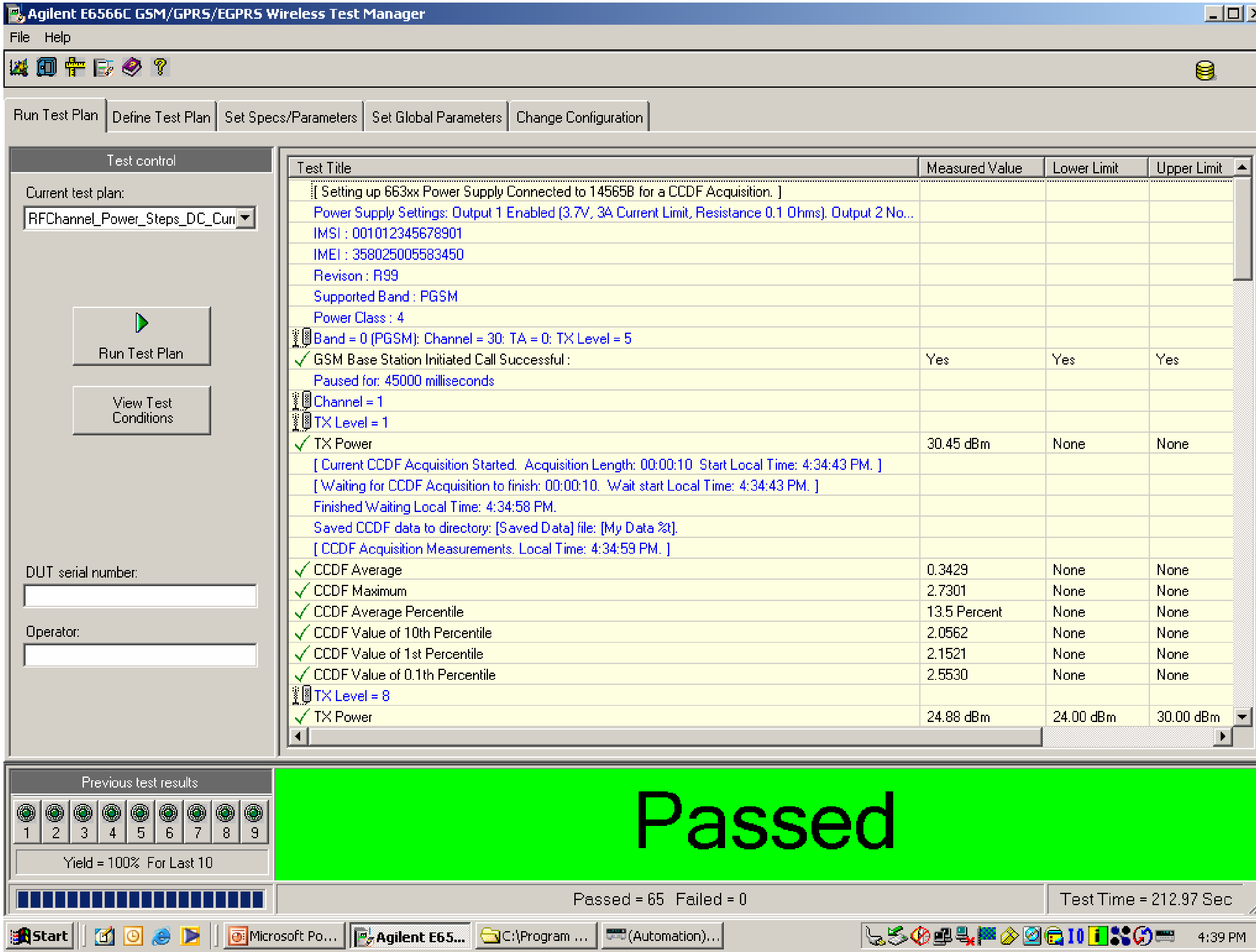
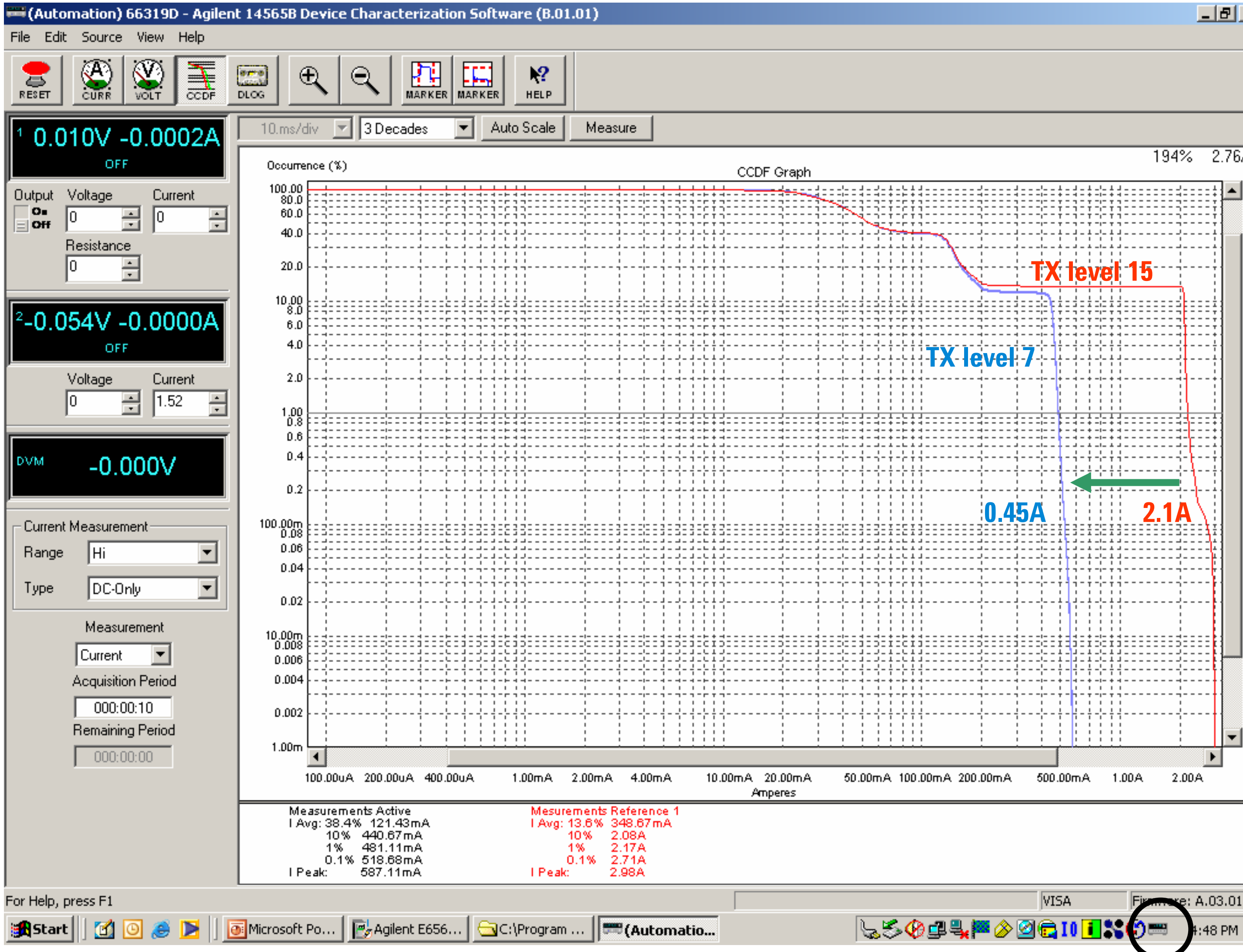
Agilent E6566C WTM Example: Current Drain vs. Channel & Power Level



- **Run the test plan!**

Agilent E6566C WTM Example: Current Drain vs. Channel & Power Level; Corresponding CCDF Current Drain Display

- **14565B runs in back-ground, click on PS icon to bring up**
- **Active (blue) trace is current/last measurement, current drain for TX level 15**
- **Recalled (red) trace for TX level 7, was automatically saved**
- **Primarily horizontal (amplitude related) shift in TX burst current from 2.1A down to 0.45A (79% drop)**
- **Corresponding average current dropped from 349 mA down to 121 mA (65% drop!)**



14545B Icon

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Summary: Battery Drain Measurement Needs for Handsets

- **In R&D, optimize operating time by visualizing and analyzing current drain results for:**
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- **In Application Software Development, validate impact of new code on current drain:**
  - Run code regression test suite, correlated against current drain data log
- **In Product Launch, validate battery drain for published specs, industry standards, and service provider standard benchmarks**

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Summary: Agilent's Solution for Battery Drain Measurement and Analysis

- ***Agilent 66319/21B/D specialized DC sources for mobile wireless devices:***
  - **Power source that simulates a battery**
  - **Integrated, high-accuracy digitizing measurement**
- ***Agilent 14565B device characterization software for battery current drain measurement and analysis:***
  - **Continuous long-term measurement with intelligent data processing and reduction**
  - **Visualization and analysis tools to help you identify anomalies and characterize & quantify battery drain to optimize your design**
  - New! **Automation: Control the 14565B from other programs to automate and synchronize DUT activity with its current drain measurements**

For further information: http://www.agilent.com/find/14565