克服物聯網功耗與生產挑戰

KEYSIGHT TECHNOLOGIES

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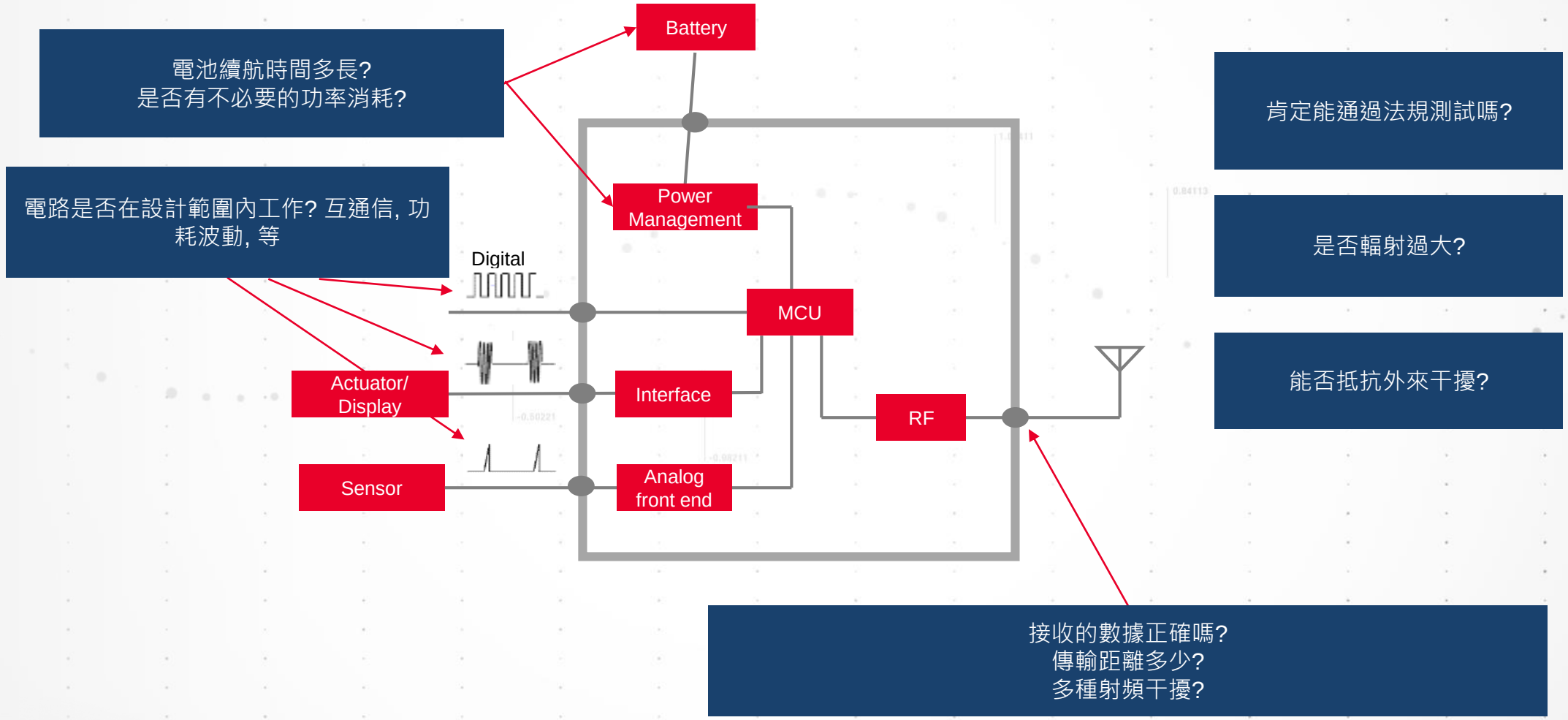
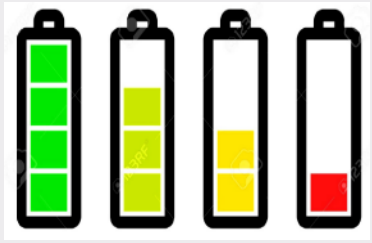
IoT終端測試的挑戰


電池續航時間多長?
是否有不必要的功率消耗?
電路是否在設計範圍內工作? 互通信, 功耗波動, 等
Battery
Power Management
Digital
MCU
Actuator/ Display
Interface
RF
Sensor
Analog front end
肯定能通過法規測試嗎?
是否輻射過大?
能否抵抗外來干擾?
接收的數據正確嗎?
傳輸距離多少?
多種射頻干擾?

Top challenges for IoT devices

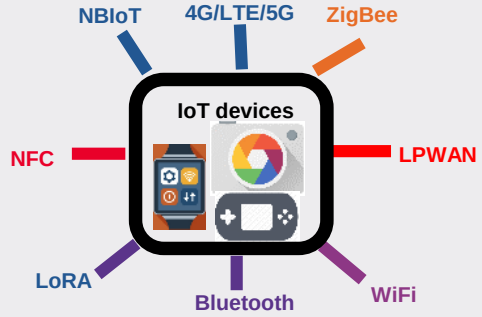
THE CHALLENGES FROM R&D, MANUFACTURING TO DEPLOYMENT

Energy Efficiency



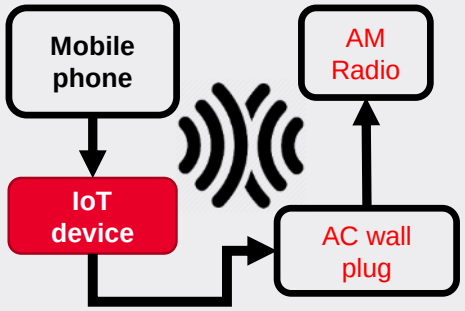
- Maximize battery run time
- Design trade off:
  - Battery type & capacity
  - Processing power
  - Component size & quality
  - Cost
  - Firmware behaviour

Multi-Technologies & Standards



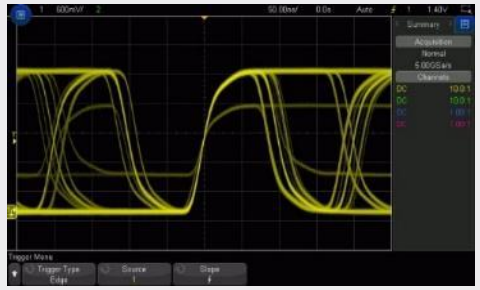
- Complex testing
- Fast evolving standards
- Device interoperability
- Inter and intra-device interference
- Wireless coexistence

Interference, Compliance, Regulatory test



- Radiated emission
- Radiated immunity
- Conducted emission
- Conducted immunity
- Spectrum regulatory

Signal and Power Integrity

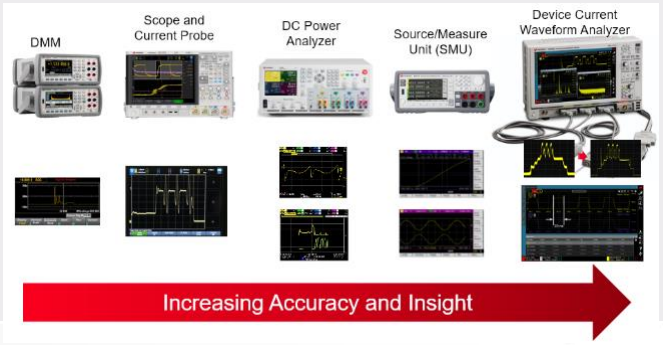


- Reflections / crosstalk
- Impedance mismatch
- Excessive losses and noise
- Unwanted transients
- Voltage drops
- Overheating
- Jitter, clock and data error

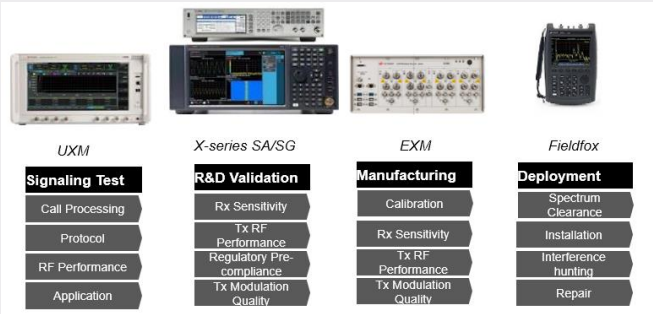
Top challenges for IoT devices – the solutions

THE CHALLENGES FROM R&D, MANUFACTURING TO DEPLOYMENT

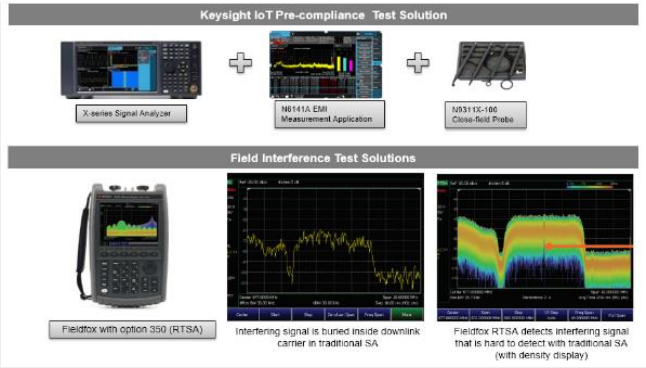
Energy Efficiency



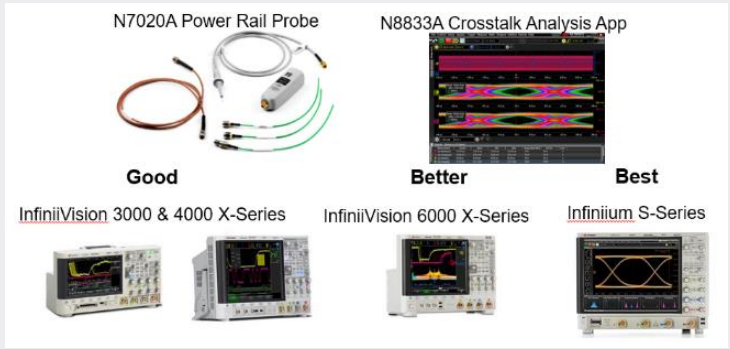
Multi-Technologies & Standards



Interference, Compliance, Regulatory test



Signal and Power Integrity



新發報: IoT 終端設計和測試方案

KESYSIGHT全方位測試方案,克服各種挑戰

功耗測試

X8712A IoT Device Battery Life Optimization Solution

Detect design weaknesses early with event based power consumption analysis. Accurately predict the battery life of IoT devices.

CX3300 enhancements & new sensors

信號完整性測試

Best visibility of your signal and data integrity issues

法規和一致性測試

One box for EMI and spectrum regulatory pre-compliance tests

Conformance test systems for operator acceptance test

用於生產的OTA 功能測試

X8711A IoT Device Functional Test Solution

Failproof your IoT device against the rigors of real world

無線共存測試

Ixia VeriWave

LoRa物理層測試

模擬和設計軟件

Complete tools for ecosystems from component, IC, Board to System level.

X8712A
IoT 設備電池續航時間優化方案

關鍵的電池續航時間



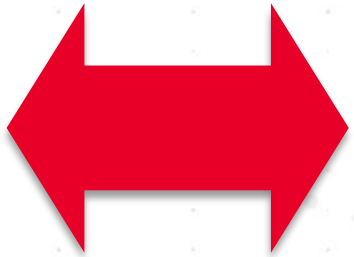
工業傳感器/網絡



消費電子設備



醫療電子設備



	SIGFOX	LoRaWAN	NB-IoT	Cat M	EC-GPRS
Release	Now	Now	H2 2016	H2 2016	H2 2016
Link budget	~162dB	~157dB	~164dB	~156dB	~164dB
Battery life	>10 years	>10 years	>10 years	>10 years	>10 years
Spectrum	un & lightly-license bands e.g. 868, 915 MHz	un & lightly-license bands e.g. 169, 433, 470, 868, 915 MHz	GSM & LTE Licensed bands	LTE Licensed bands	GSM Licensed bands
Rates and modulation	Uplink: 100bps BPSK 100Hz BW Downlink: 500bps GFSK 600Hz BW	GFSK, CSS (Chirp Spread Spectrum) ~0.3 to 50kbps 125kHz BW	Up to ~250kbps Uplink π/4-QPSK, rotated π/2 BPSK, 8PSK, opt 16QAM Downlink BSK-16QAM 180kHz BW	1Mbps QPSK, 16 or 64QAM 1.4MHz BW	~10 to ~240kbps GMSK, opt 8PSK, 200kHz BW
Silicon	Multi-vendor	Semtech (2nd vendor announced)	Multi-vendor	Multi-vendor	TBC
Protocol	SIGFOX	Semtech (2nd vendor announced)	3GPP Multi-vendor	3GPP Multi-vendor	3GPP Multi-vendor
Certification	SIGFOX	LoRa Alliance	GCF/PTCRB TBC	GCF/PTCRB TBC	GCF/PTCRB TBC

挑戰:

1. 如何定義電池的續航時間?

2. 什麼東西/情況最耗電? 這種情況的頻次很大嗎?

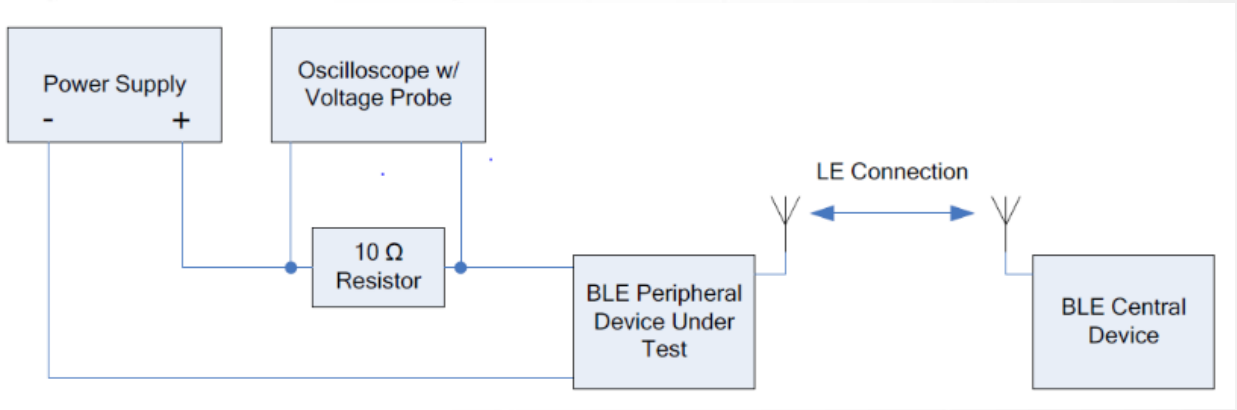
3. 什麼設計改變或可以優化電池的續航時間?

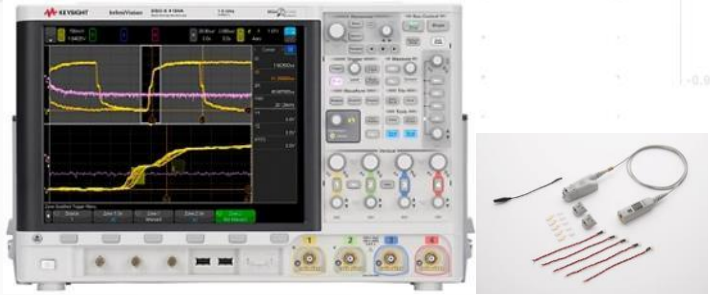
當前電流測試的常用方法

電源，DMM和示波器

DMM

電源



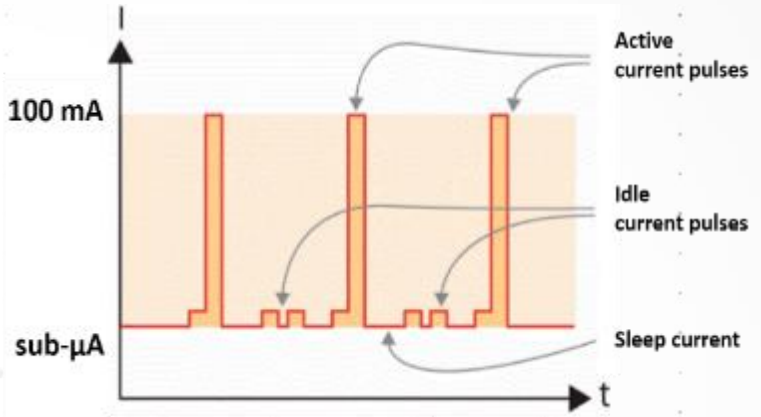


示波器+電流探頭

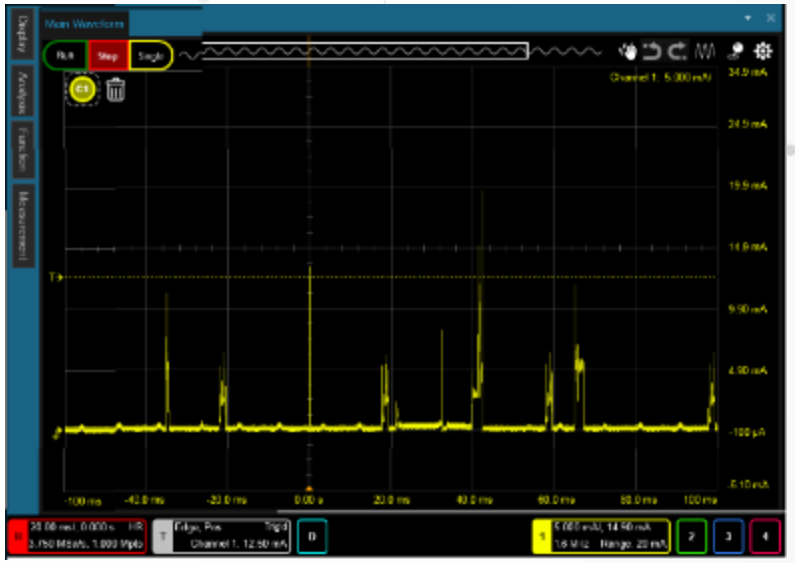
容易用，靈活，成本低

IoT 電流測試為何難?

- 睡眠/待機模式電流非常低
- 高動態電流切換需要高帶寬
- 功耗分析複雜(事件->功耗)



無線血壓計的電流



可穿戴設備的電流

優化 IoT 終端電池續航時間的新方案

KEYSIGHT X8712A

同步RF事件和功耗水平

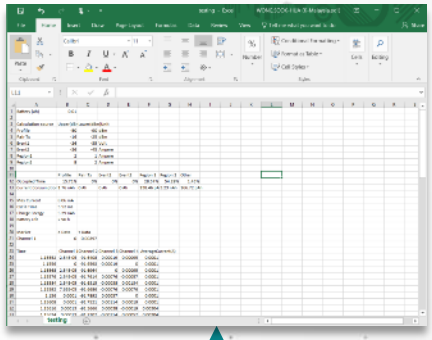
- Easily correlate current consumption to critical RF events
- Pinpoint critical events consuming the most current

可深入分析功耗情況

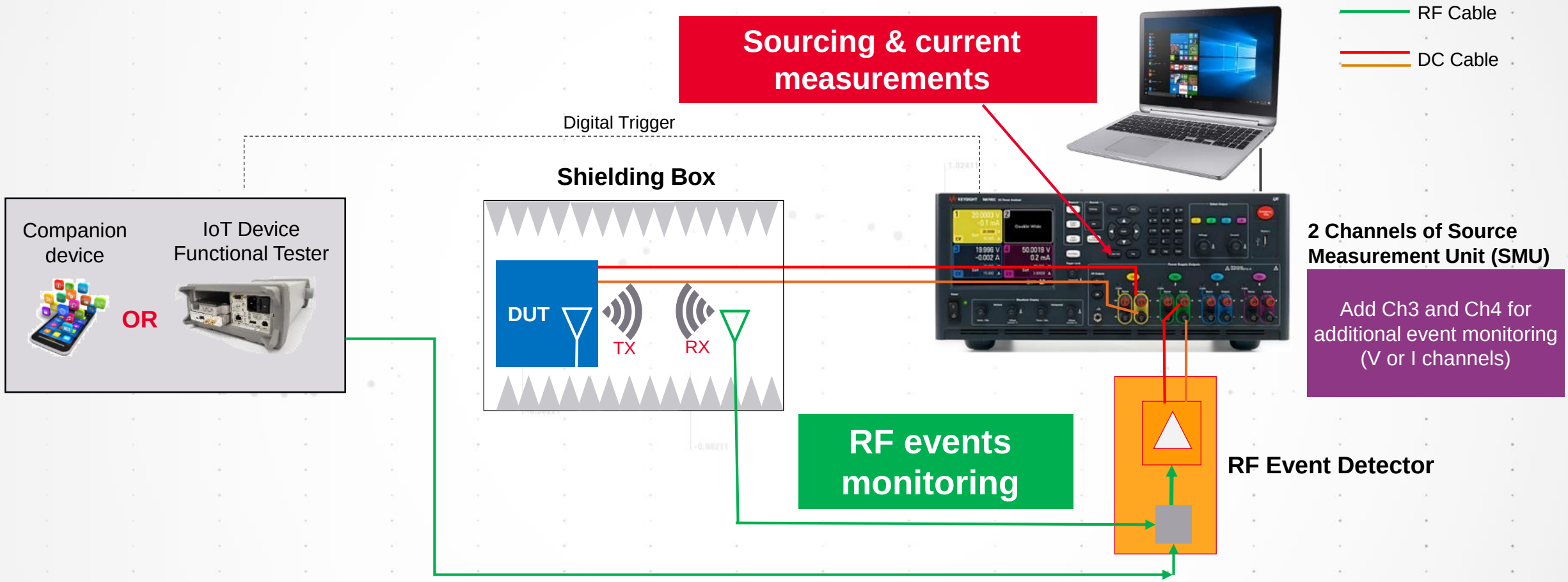
- Calculate RF or DC event's occupancy time and current consumption contribution in percentage to get the estimated battery life in hours according to the measured event
- Statistical current consumption CCDF analysis by user defined time span

數據記錄容易

- Simplify report creation
- Log event occupied time, current consumed and estimated battery life
- Online instrument control or off-line data record for real time comparison and future post analysis



X8712A Battery Life Optimization Solution in Action



Synchronize and correlate current consumption with RF events.
Identify critical events that contribute to the most power consumption.

X8712A 基於事件的功耗分析系統簡介

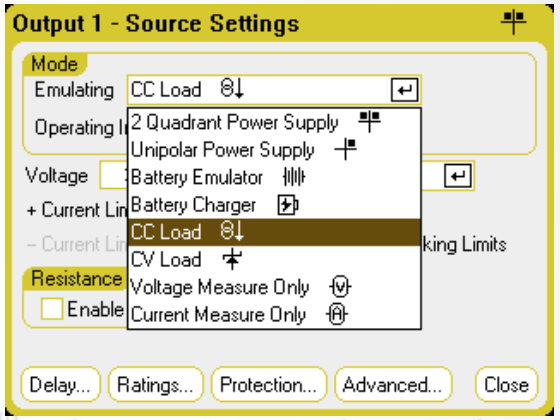
DC 功率分析儀

Integrates multiple instrument functions into a single system:

- 1 to 4 advanced power supplies
- Digital voltmeter and ammeter
- Arbitrary waveform generator
- Oscilloscope-like display
- Data Logger

✓ All functions and measurements are available from the front panel

✓ Boosts the productivity of the R&D Engineer



電源模塊 2-象限 SMU

Voltage Source
Current Source
Electronic Load

3 合 1

- “Glitch free” sourcing and measurement
- Multiple measurement ranges or seamless auto
- Excellent transient response to pulse sourcing
- Stable with capacitive loads up to 150 µF
- Programmable output resistance simulates battery internal resistance
- Zero burden ammeter
- Auxiliary voltage measurement input for battery rundown test

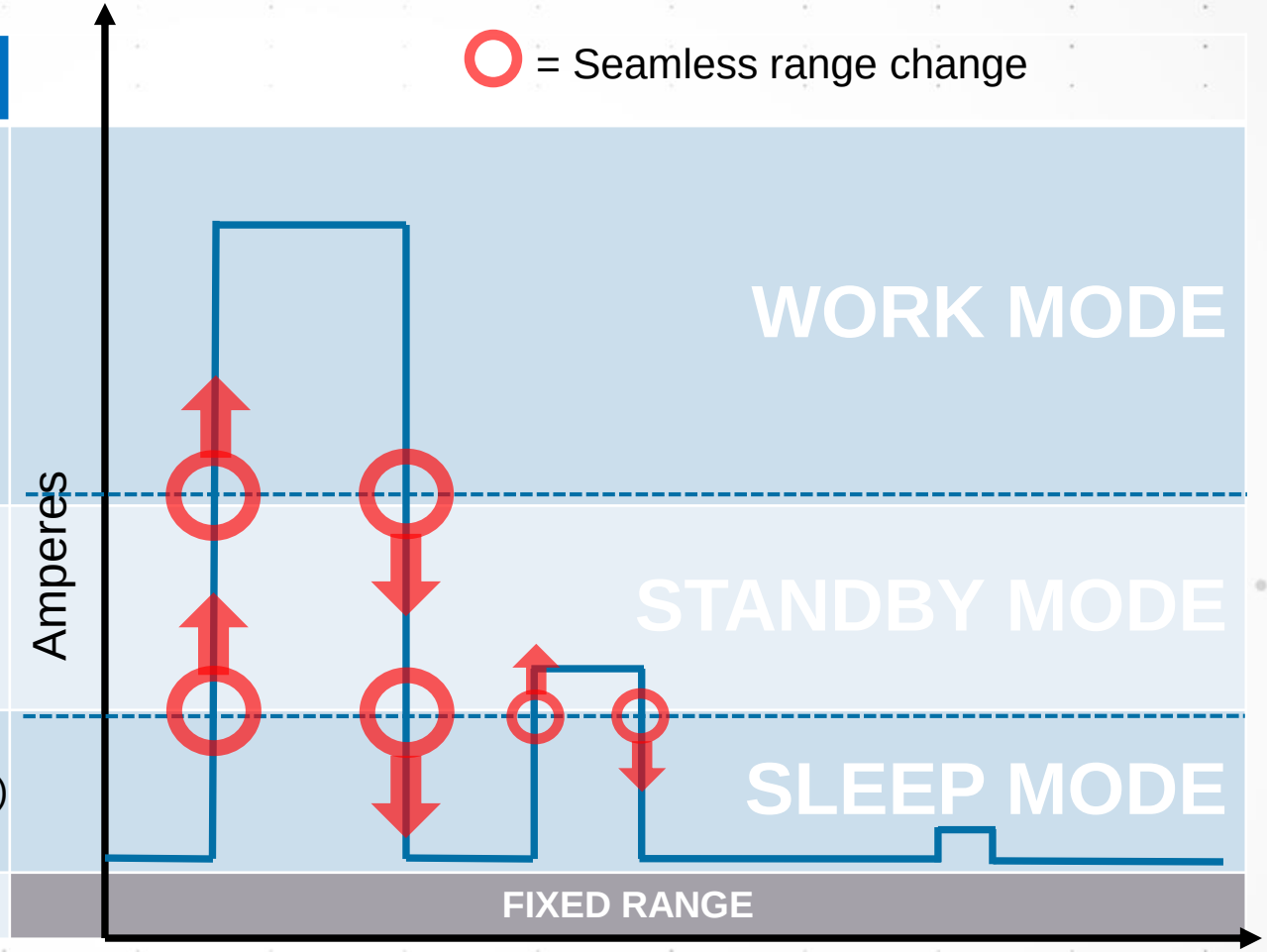
Measurement

- Built-in digitizer of 200,000 samples/second

X8712A Key System Specification – Seamless Measurement

Range	Measurement Accuracy
3 A	±(0.03% + 250 µA)
100 mA	±(0.025% + 10 µA)
1 mA	±(0.025% + 100 nA)
10 µA	±(0.025% + 8 nA)

Seamless Range Changes

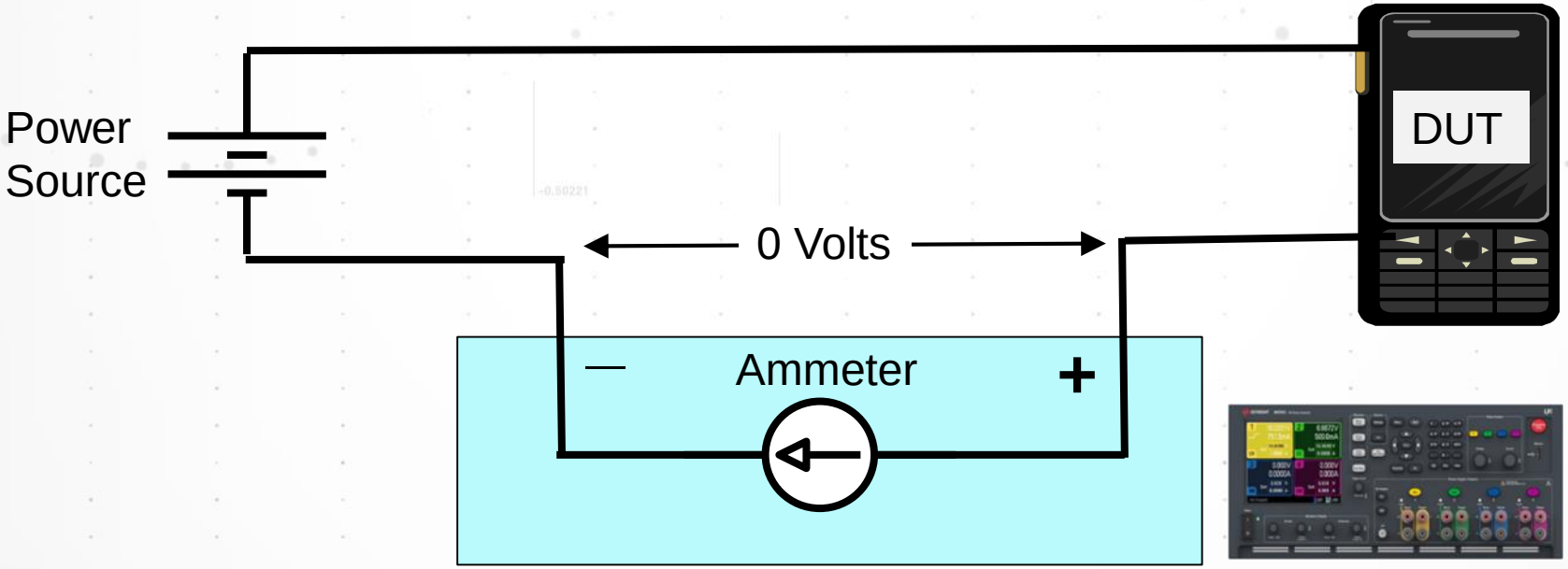


See the complete current waveform you've never seen before
– from nA to A –
in one pass and one picture, with effective 28-bit resolution

Key System Specification - Zero Burden Ammeter

Zero-Burden Ammeter (Single reading, Scope or Data log)

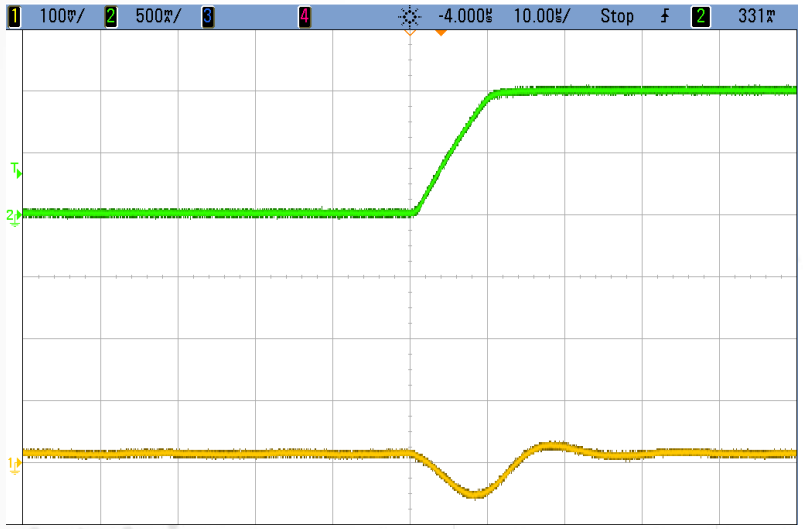
- Put SMU module in series with your power source and your DUT
- You source the current while the SMU module measures current flow
- SMU module uses its power output to regulate zero volts across itself while measuring current (in either direction of flow)
- No simulation: Most realistic way to determine how DUT will work on battery



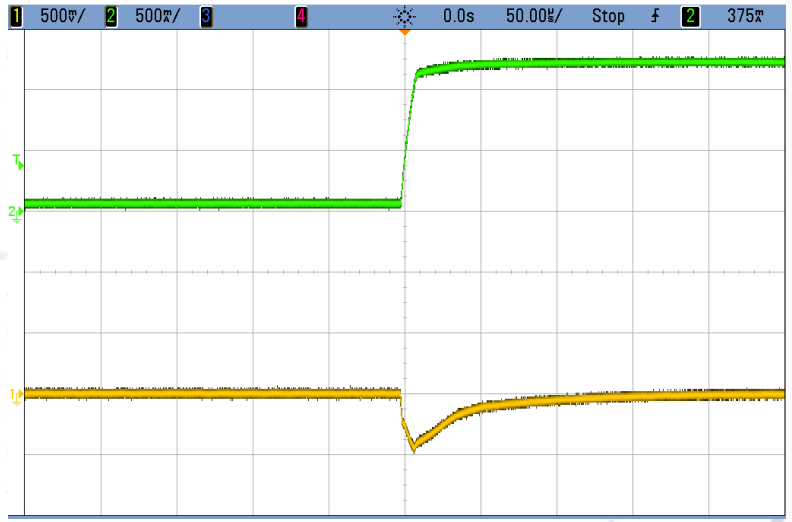
"Current Measure Only" mode

Up to 4 per mainframe

Key System Specification - Fast Voltage Transient Response Performance



N6781A (high performance Source Measure Unit SMU) providing ~60 mV transient drop



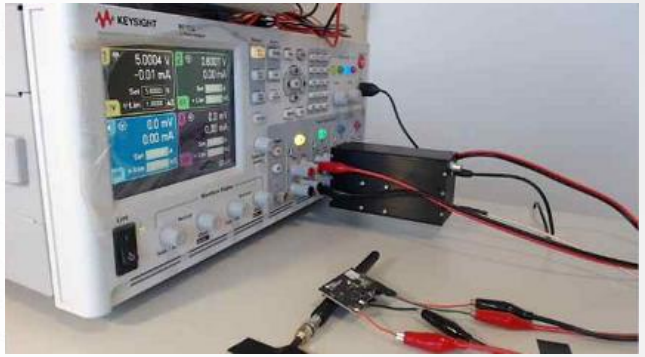
N6762A (a general purpose power supply module) providing ~500 mV transient drop

- Mobile digital wireless devices draw current in fast pulses
- Requires a stable voltage with minimum transient voltage drop
- The N678xA SMUs provide about 8X or better performance over GP DC sources
- The same transient response is achieve regardless of seamless ranging operation!

BLE傳感器測試演示

BLE/WLAN SENSOR TAG EVENT MONITORING

Yellow：DUT Current consumption
Green：RF Transmissions between DUT companion device
BLUE: LED supply voltage



Waveform Zoom & Analysis

Events Tags

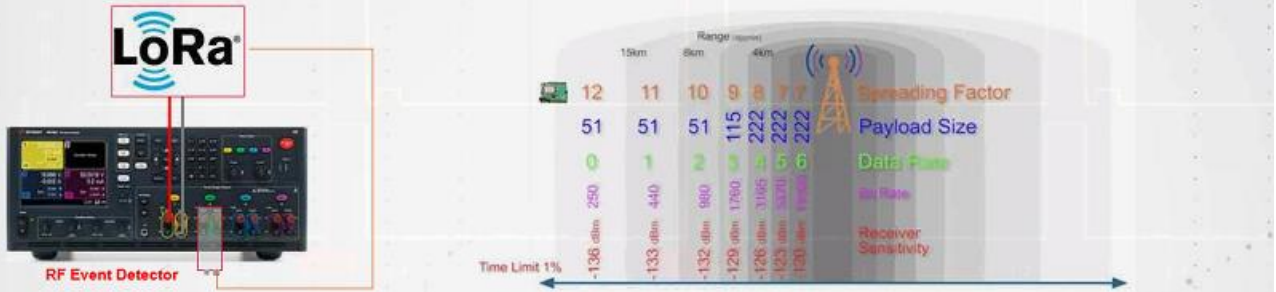
Occupied Time by event

Event based analysis
(Max current, cycle time, charge energy, battery life, occupied time, current consumption, and more)

Current CCDF

測試案例 #1: LoRa 模塊測試

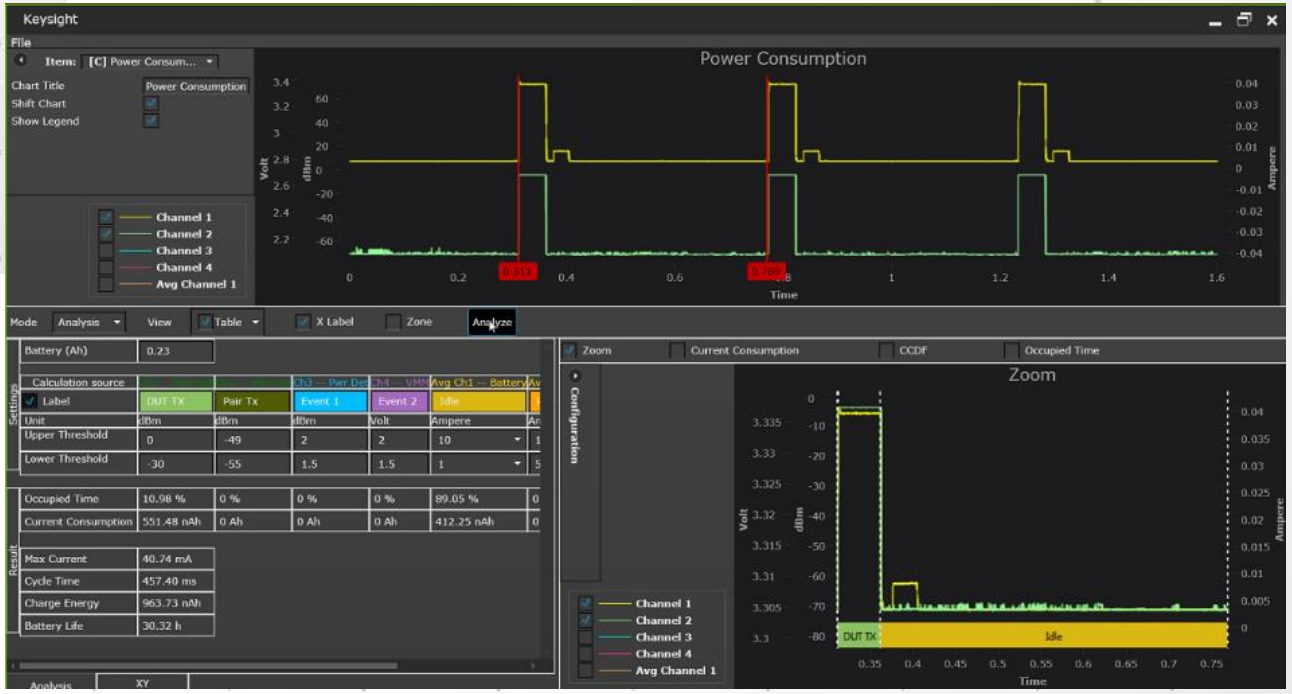
CUSTOMER APPLICATION EXAMPLE



Packet transmission efficiency

Spread Factor	Max Current (mA)	Battery Life (Hr)	COT (%)
7	40.74	30.32	10.97
8	40.74	22.92	17.8
9	39.9	17.25	26.92

The battery life of LoRa module varies depending on the signaling condition it is operating in. We can vary the spreading factor and measure the changes in maximum current and battery life. We can also use this info to help us choose the appropriate battery capacity to meet the battery life specification.



Customer’s LoRa Module Current Waveform

NORMAL MODE OPERATION

RF signal in dBm

Current consumption waveform

Statistical data tools

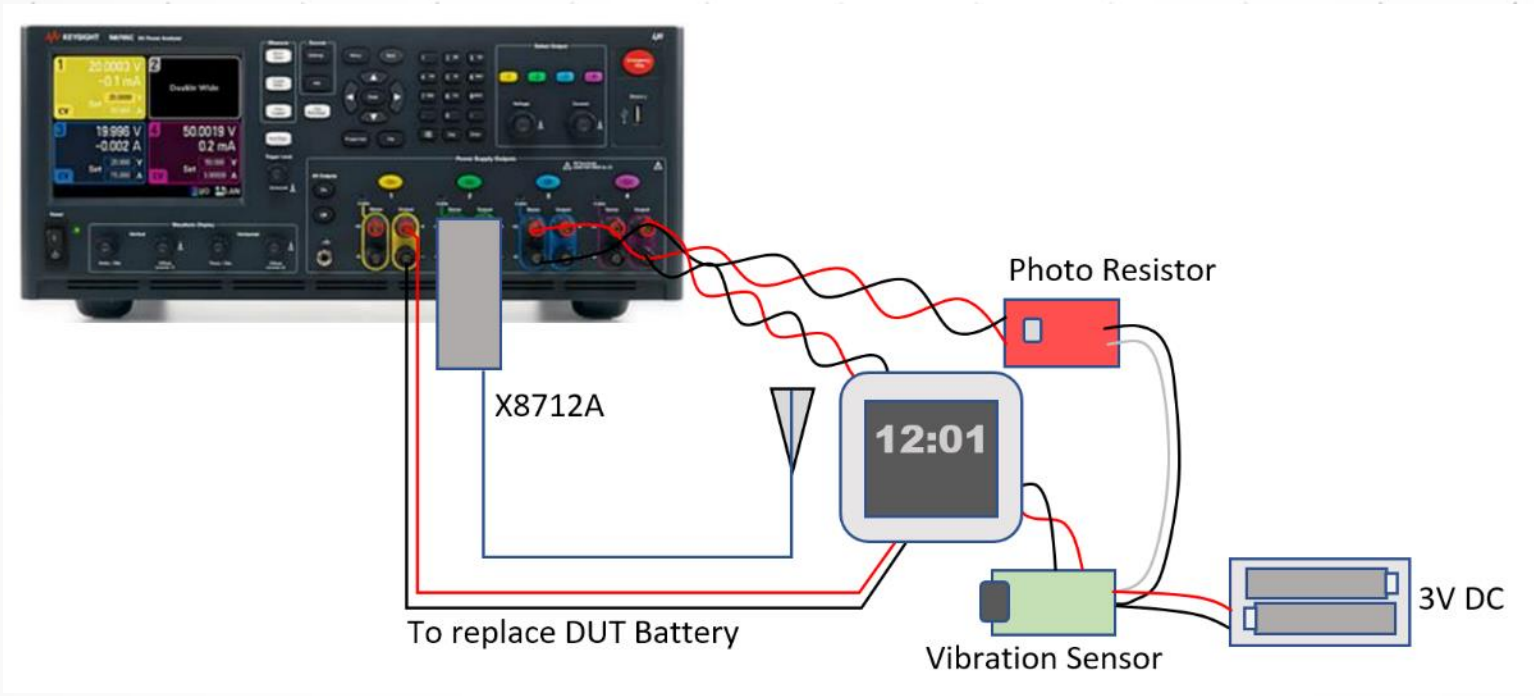
Key readings

LoRa Module Current Spike

IRREGULAR CURRENT SPIKE IN SLEEP MODE

測試案例 #2: 智能可穿戴設備

CUSTOMER APPLICATION EXAMPLE



Test Setting:
Ch-1: Battery Simulator, 4V/1A, connects smart watch as the battery.
Ch-2: Voltmeter, CC-Mode/0A, connects to a 2.4GHz antenna placing near the DUT via the X8712A RF Event Detector
Ch-3: Voltmeter, connects to the photoresistor.
Ch-4: Voltmeter, connects to the vibration sensor.

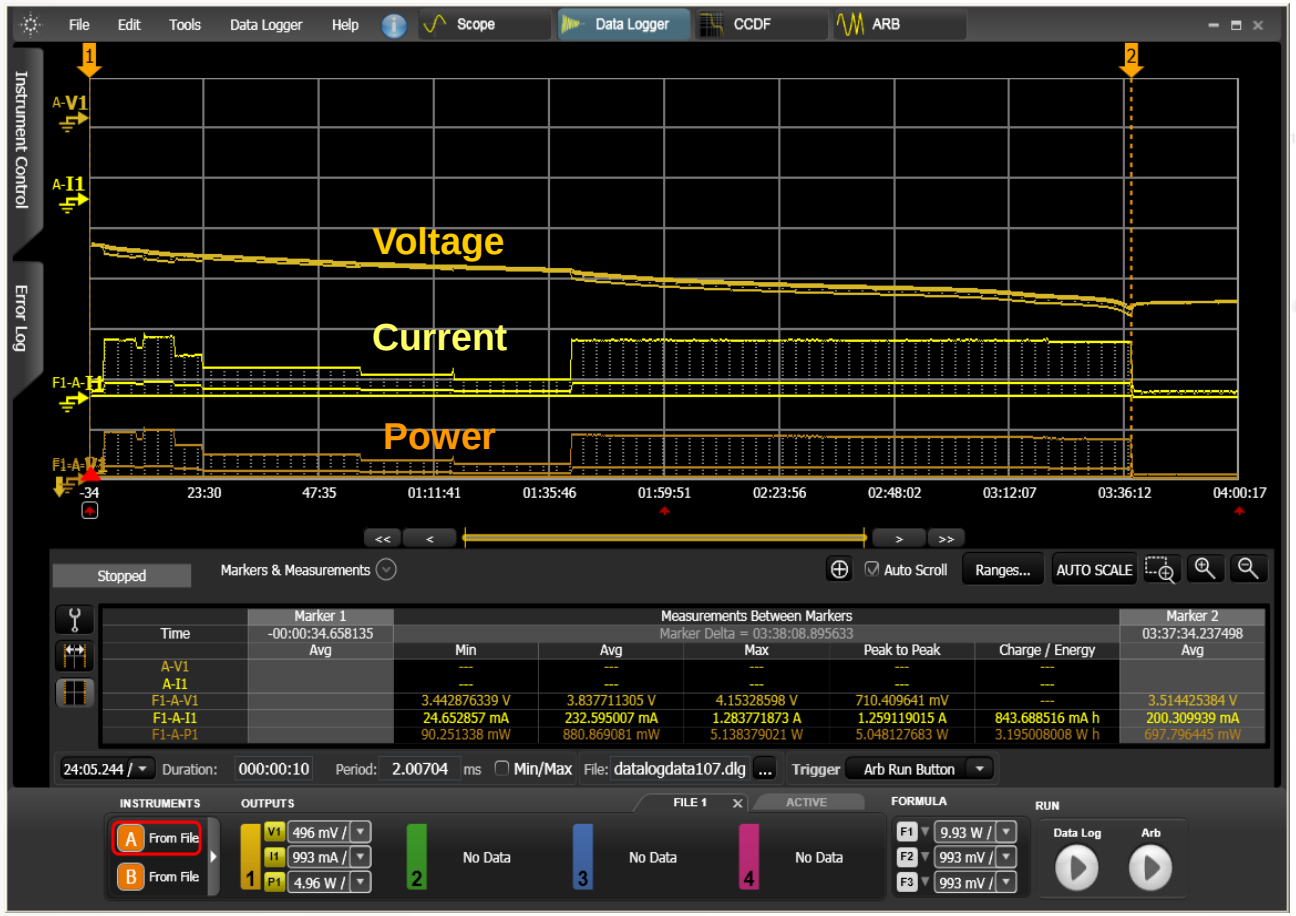
The photoresistor is about 1V in the dark and 1.5 to 2.5V in the light (depending on the brightness level). Note that the vibration sensor requires an additional 3V DC supply. The actual operating of all sensors in the watch is powered by the build-in battery cell.

Other Application #1: Battery Run Down using Zero-Burden Ammeter

- Module uses its power output to regulate zero volts across itself while measuring current (in either direction of flow)
- Single reading, scope, or data log
- N6781A Aux DVM input measures battery voltage
- Gives most realistic assessment of DUT operation with actual battery

Up to 4 per mainframe

Other Application #1: Battery Run-down Test Example



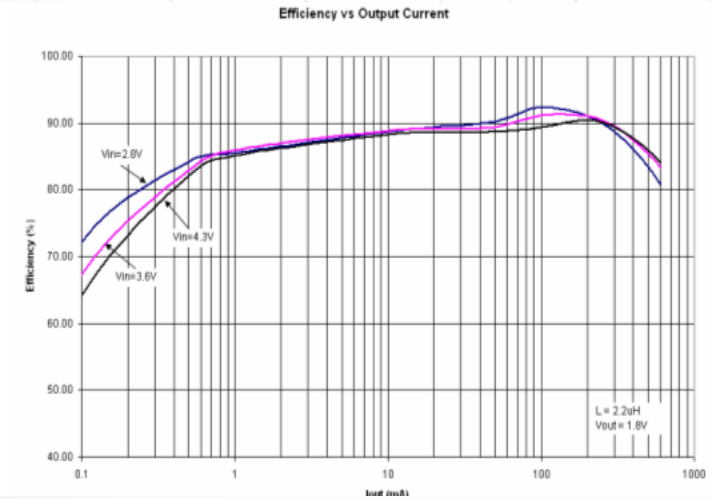
- Battery run-down for a GSM/GPRS handset logged with an N6781A SMU
- Logged min, avg & max volts, amps, & watts
- By placing markers at start & shutdown points:
  - Avg current = 233 mA
  - Avg voltage = 3.82 V
  - Charge = 843 mA h
  - Energy = 3.19 W h
  - Run time = 3 hr 38 min

Other Application #2: DC-DC Converters Measurements

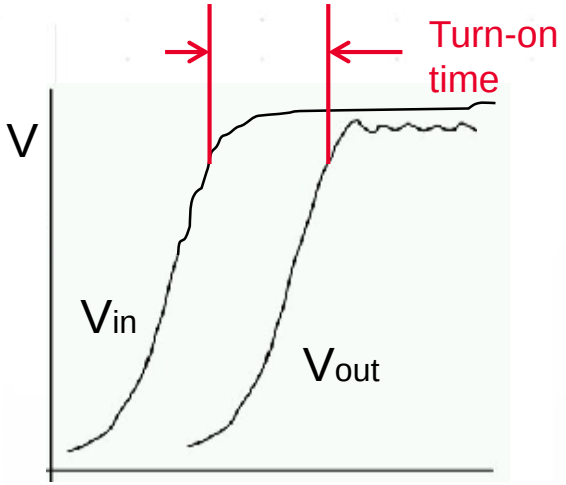
Typical Design Validation Measurements

- Power efficiency vs. load current vs. input voltage
- Transient response
  - Output V & I vs. Input V (line regulation)
  - Output V vs. Output I (load regulation)
  - Start-up and shut-down times (impacts how quickly a circuit can be turned on/off which affects battery life)
  - Output V rise times

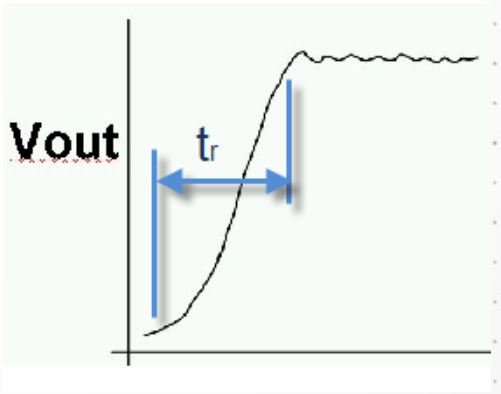
Customer Goal: Longer Operational (Battery) Life



Efficiency vs. I_{out} vs. V_{in}



Turn-on time



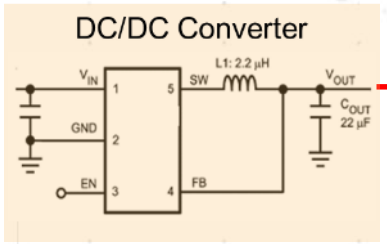
V_{out} rise time

Other Application #2: DC-DC Converters Measurements

USB or LAN

Add Ch3 and Ch4 for additional event monitoring (V, I or RF power channels)

V & I sourcing and V, I, & P measurements

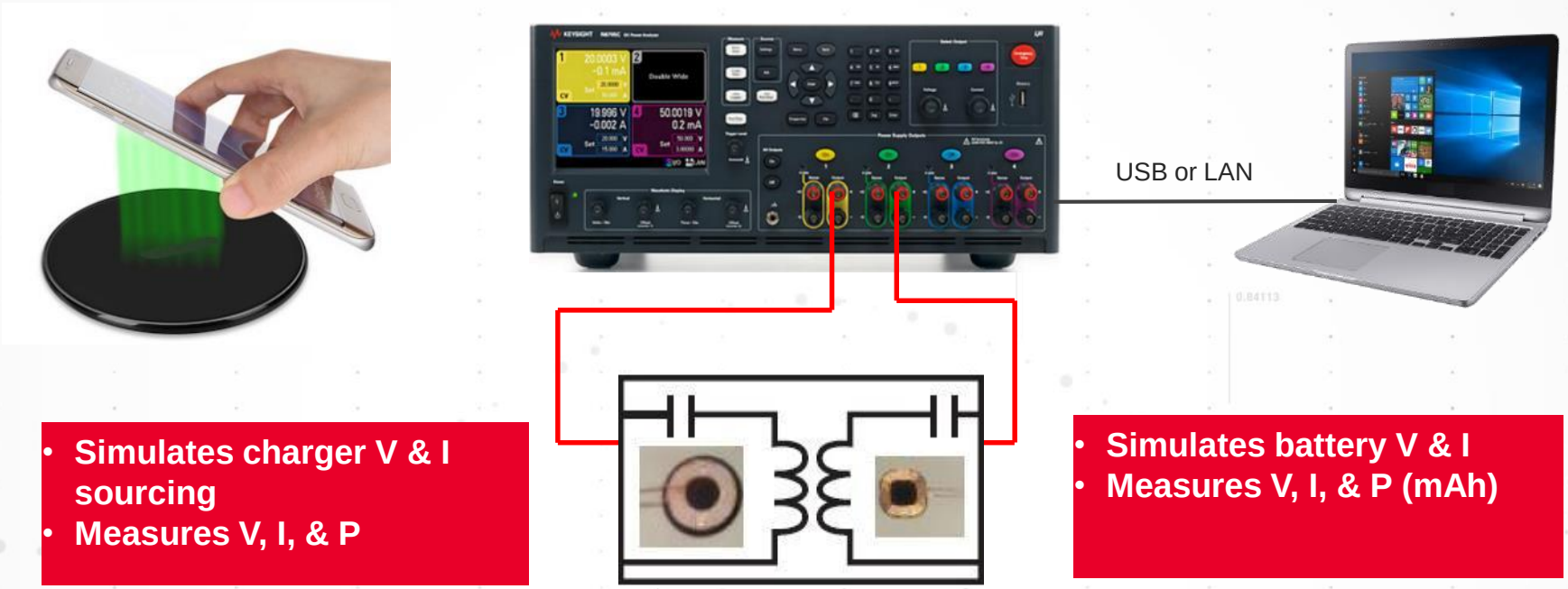


Current (I) sinking and V, I, & P measurements

Synchronize and correlate current drawn with multiple power events to the key event that caused the highest power consumption

- **X8712A's (N6705C + 2x N6781A) compact size allows placement close to thermal chamber**
- **Customer making radio communication products can now perform new tests like:**
  - **V ramp testing**
  - **I load ramp testing**

Other Application #3: Wireless Charging and Efficiency



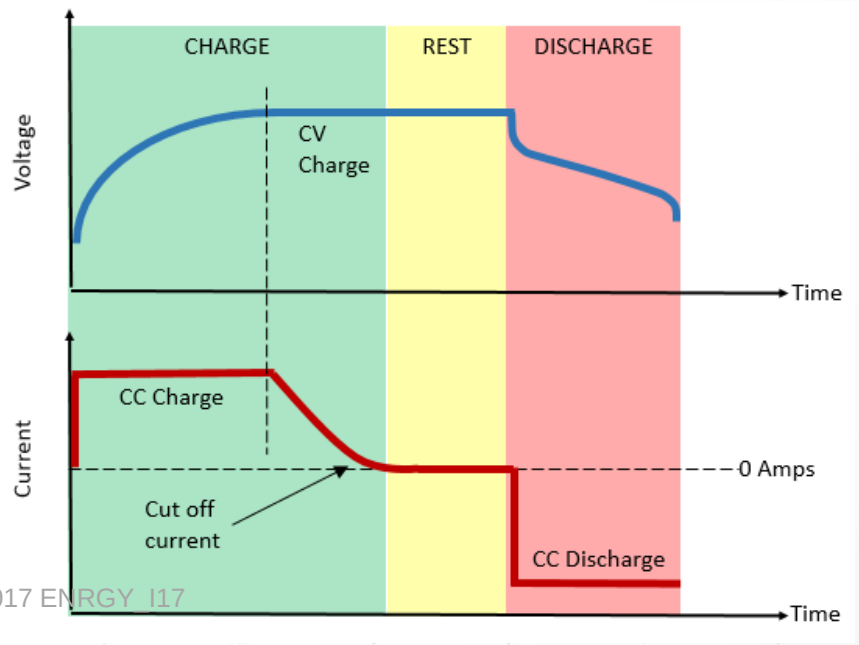
Dual-channel power system for wireless charging efficiency test:

- Channel-1 simulate 5V charger
- Channel-2 simulates the battery and calculates charge efficiency in real time

Other Application #4: What is cell characterization?

- Testing to determine:
  - Cell capacity (Ah), internal resistance
  - How capacity varies with age, discharge rate, cell temp
  - Cell voltage vs. SoC (family of curves for different discharge rates, temps)
- Done by one or more charge and discharge cycles.
- Fundamental measurements are current, time, voltage, temperature.
- Classic test done for many years. Many vendors at various performance levels.

- Also known as cell or battery “cycling” or “cyclers”
  - Classic method is CC-CV Charge – Rest – CC Discharge.
  - *What if this pattern doesn’t match the actual application?*



Other Application #4: Cell and Battery Characterization Platform

Charge-Discharge-Measurement

- High-accuracy measurement of
  - Cell capacity (Ah) and energy (Wh)
  - Internal resistance
  - Current, voltage, temperature, power
- User-controlled dynamic charge-discharge algorithms
- Individual channelized charge/discharge instrumentation allows for different tests to run on each channel, and easy scaling of number of channels.

MPS

- *For low power cells & batteries*
- *Up to 20V, up to +/ 8A*

APS

- *For high power cells and batteries*
- *Up to 160V, up to +/-200A*
- *Can parallel for higher power*

34972A

- *Cell temperature*

Other Power Consumption Test Solutions

34465/70A
Truevolt DMM

Scope and
N2820A probe

B2900
SMU

DC power
analyzer and
SMU module

CX3300 device current
waveform analyzer

Increased performance and insights

X8711A
一種全新的 IoT 終端功能測試方案

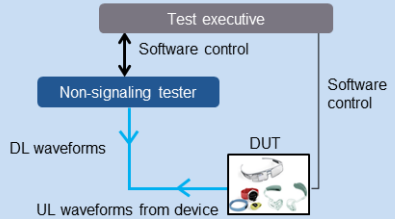
為什麼是OTA Signaling信令測試?

SIGNALING VS NON-SIGNALING TEST

- 特別小的產品, 沒有測試接口
- 不需要特定的晶片控製或驅動
- 適用於最終的產品應用軟件測試

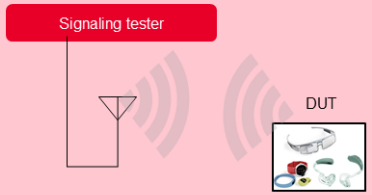
非信令测试

Non-signaling test, or test mode, is carried out by putting the device-under-test (DUT) into a known state, allowing test equipment to measure predefined transmission patterns.



信令测试

Signaling test is conducted with test equipment emulating a base station that sends a signal, and the device-under-test (DUT) that will respond to the signal.



Characteristics

Requires wired connection	Conducts testing over-the-air (OTA)
Uses test firmware to test in predefined test mode	Uses commercial firmware to test in the DUT's operating mode
Requires chipset control	Do not require DUT control.
Covers a comprehensive list of test parameters	Performs only basic TX/RX tests during final verification tests
Often used in high volume chipsets or modules manufacturing	Often used as end-of-line (EOL) manufacturing test of end devices or pre-test for complex system

X8711A IoT Device Functional Test Solution

DESIGN VALIDATION AND MANUFACTURING TEST OF IOT DEVICES

Test Challenges

- IoT devices are becoming smaller and integrated, and no longer has I/O footprint for DUT control.
- Conventional non-signaling test via DUT control using physical I/O is time consuming. The set up process is complicated and requires access to chipset for controlling the DUT.

Keysight Solution

- IoT Device Functional Test solution provides Over-the-Air BLE and WiFi tests.
- The solution is complete with shield-box and TAP based software applications.

Customer Benefits

- Test IoT devices in actual operation mode and in its final form
- Assure the devices meet quality levels and that there is less risk of manufacturing defects or field failures
- Maximize throughput on the manufacturing line and accelerate time to market
- Simplify test development with the TAP measurement suites

✓ **Up to 4X reduction in test time**

✓ **Faster test development – no DUT control required**

✓ **Simple set up**

X8711A IoT Device Functional Test Solution

KEY SPECIFICATIONS

Key Specifications:

Output Power (Rx sensitivity measurements):
BLE Output: -40 to -90 dBm, 0.5dB step; accuracy ±2dB
WiFi Output: -33 to -73 dBm, 0.5dB step; accuracy ±2dB

RF Power measurement (Tx power measurements) :
Range: 0 to -30 dBm at RFIO port
Accuracy: ±2dB

Test Parameters	RF Module (BLE/WLAN)	Power Supply (optional)
DC Test		
• Power On/Off		✓
• DC Power measurement		✓
RF/Radio Test		
• Radio Format	BLE 4.2, WLAN 802.11b/g/n (BT5.0 & Zigbee upgrade option)	
• Tx RF Power	✓	
• Rx PER Test	✓	
• Rx Sensitivity Test	✓	

BLE 4.2 System Software

SAMPLE SCREENSHOT

Initial configurations

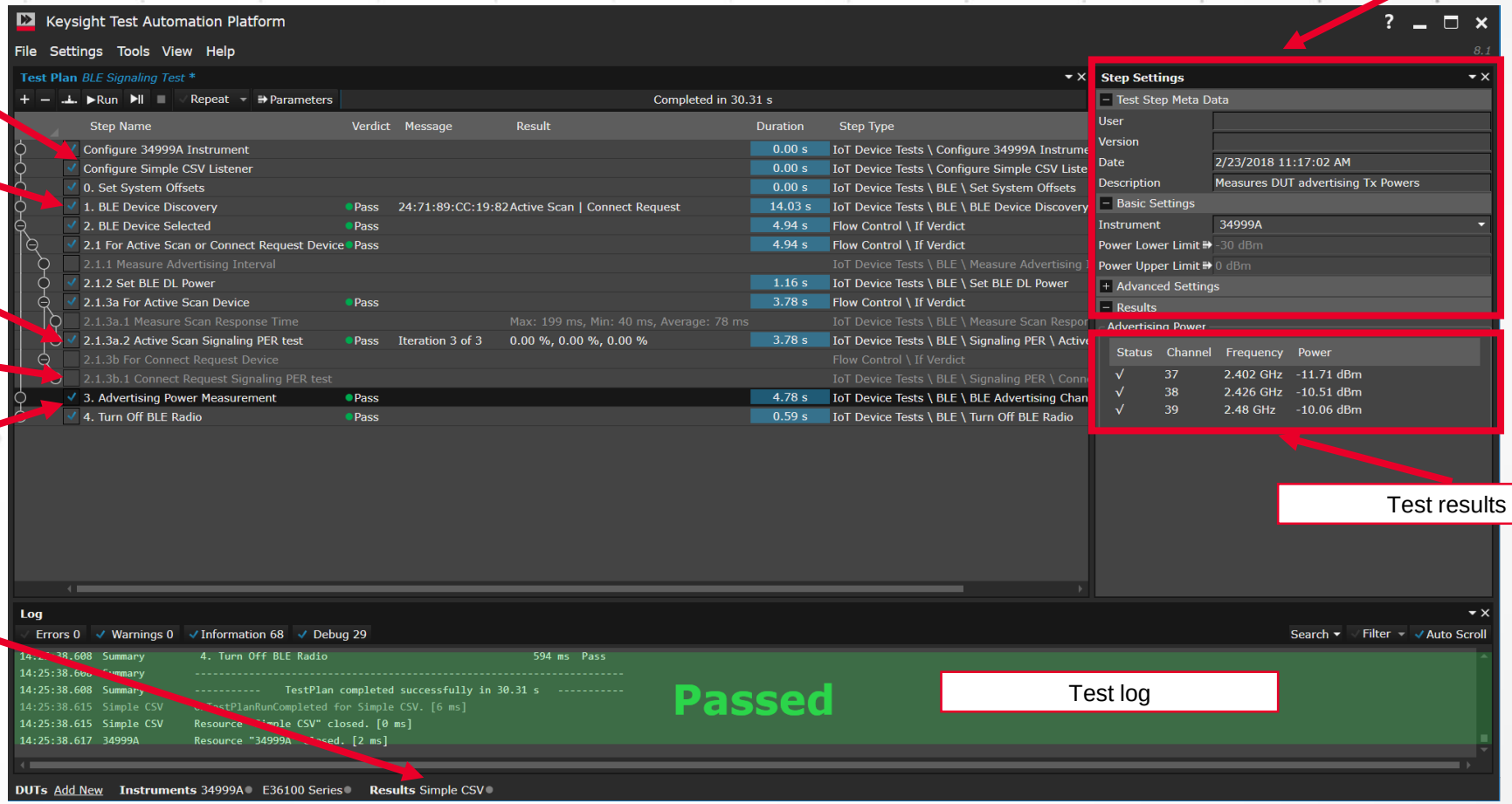
Device discovery & connection

Active Scan PER test

Connect Request PER test

TX power measurement

Data logging



Setting configurations

Test results

Test log

X8711A Case Study

HEARING AID BLE SIGNALING TEST

Medical device company

A leading hearing aid product company who is currently making MFI hearing aids in Singapore with BLE integrated.

Current way / issues

- Existing BLE solution is too expensive for manufacturing
- Need cost-down options as production volume increases

New Way (X8711A beta)

- Cost-effective and cover all essential tests to verify product quality
- Reduces test time (a few minutes to < 35s)

Results

- Reduce test time by >50%
- Reduce manufacturing test cost by >20%
- Enable manufacturing test software standardization with Keysight TAP platform

"Amazing! This solution is going to streamline my manufacturing process significantly" VOC

Download case study flyer in Chinese

X8711A Case Study

AC CONTROLLER BLE SIGNALING TEST

Air conditioning system provider

This company is a leading air conditioning (AC) system provider. Their current products have already supported NFC. They are developing next generation AC controller with BLE to improve usability and maintenance operations.

Current way / issues
- Requires hardwire connection
- Complex and expensive

New Way (X8711A)
- No physical connection, enable OTA testing
- Cost-effective and cover all essential tests they need

Results
- Significant time saving in product design and verification tests
- Another group is evaluating the WLAN version of this solution
- Their subsidiaries in US and China are evaluating this solution

"I like the contactless test setup and the small form factor of the modular solution" - VOC

Download case study flyer in Chinese

X8711A Multi-Up Configuration [Custom solution]

FOR HIGH VOLUME MANUFACTURING

Sample configuration for 1x2.

TAP plugin to control X8711A and Switch

USB

RF cable

U1810B USB Coaxial Switch, DC to 18 GHz, SPDT

RF cable

DUT 1

DUT 2

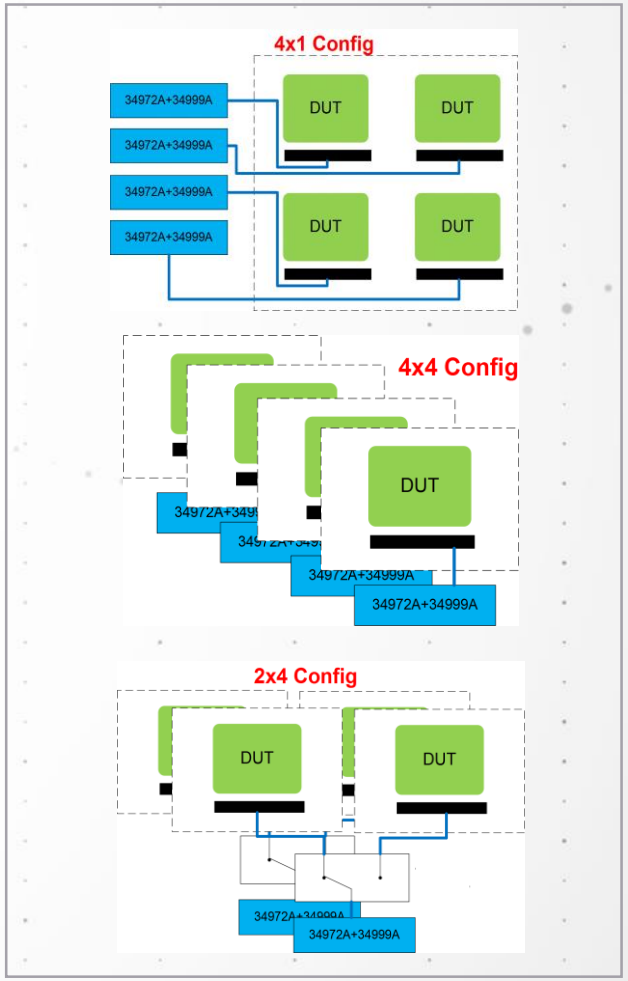
Shield box 1

Shield box 2

USB

$25K for 1x2 system (exclude shield box)

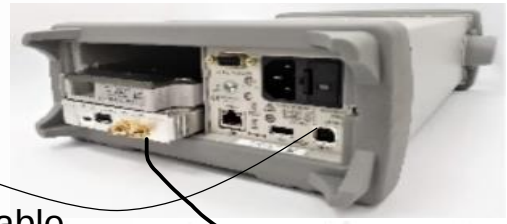
It could be any NxN configuration depending on customer's needs



X8711A new accessory – X8752A near field coupler

OTA MEASUREMENT FOR BIG APPLIANCES

Laptop / PC (Controller)



USB cable

Innovative **coupling antenna design** with **great signal directivity in the front** and sufficient **shielding from the back and side** to isolate interference signals from the surrounding environment

RF cable to connect antenna coupler to the RFIO port of the X8711A

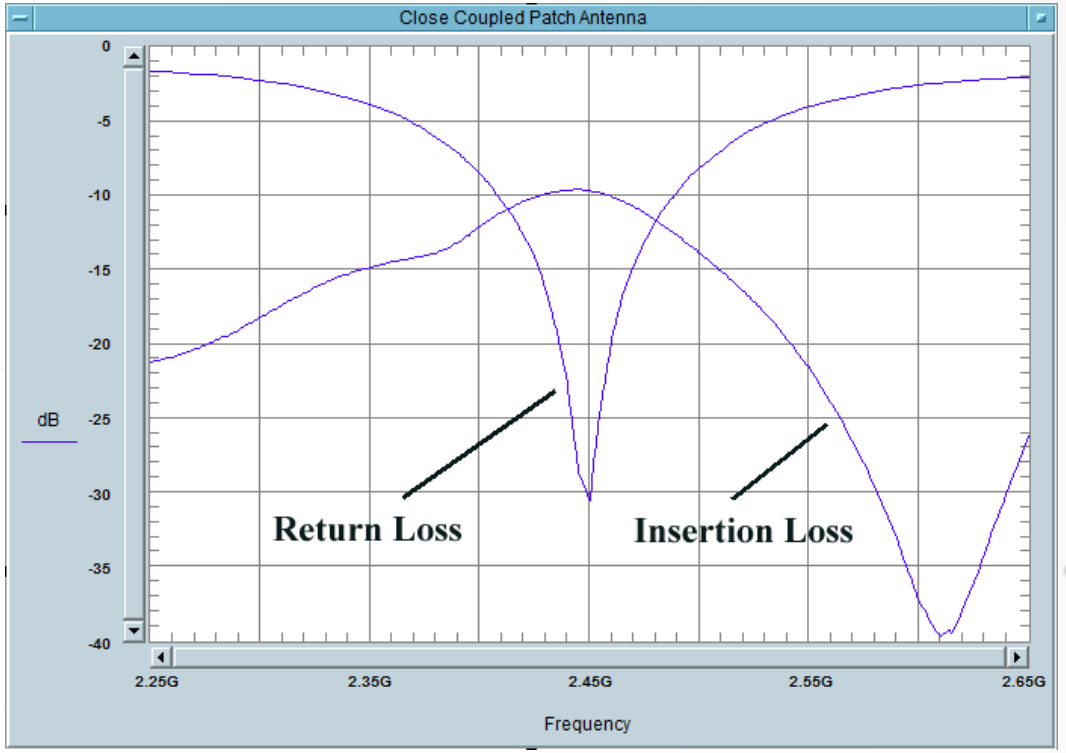
Place near-field coupler as close as possible (< 5cm) to the wireless module of the DUT

Wireless module inside the AC (DUT)

This Solution enables OTA TX/RX measurements on finished products (big appliances) in noisy environment without the need of large anechoic chamber

X8752A - Return Loss and Coupling (Insertion) Loss

- External dimensions 50mm*50mm*26mm
- Including flange 80mm*50mm*26mm



- Coupling (Insertion) loss is measured with 2 complete antennas face to face
- Equates to 2.5cm between patches

On Axis Gap	0cm	5cm	10cm	20cm	30cm
2.45GHz Loss	9dB	17dB	22dB	29dB	31dB

X8751A Shield box

As part of the X8751A RF Shield Enclosure Kit, Keysight will provide:

- One (1) Tescom TC-5910D Shield box comprised of One (1) M591012B I/O module, One (1) TC-93023B Antenna coupler, One (1) F59105A Universal grid fixture.
- One (1) RF cable.
- One (1) SMA jack to N plug adapter.
- One (1) RF terminator N 50 ohm.

Keysight will not conduct any regulatory or safety testing on the X8751A RF Shield Enclosure Kit. If this is required it will be the sole responsibility of CUSTOMERS. Customer is responsible for any additional certification testing and marking such as CE, CSA, NRTL as deemed necessary by Customer. Keysight will not evaluate EMC compliance of the system. The customer is responsible for the EMC compliance upon final system integration & configuration completed at customer assembly site.

Estimated delivery time: 7 weeks

Price: $6,000

Note that this shield box is not available for sale in Europe due to non-RoHS compliant.

http://en.tescom.co.kr/exec/file/download.asp?filepath=/file/board&filename=5910D_Data%20sheet_E_v180820.pdf

Keysight New IoT Test Solutions

X8711A BLE/WLAN Device Functional Test Solution

X8712A Event Based Power Analysis Solution

Back Up

Maximum N6781A Digitizing Rate Performance Summary

	14565 with 66319/21	N6705C with N6781A	14585A with N6705C & N6781A
Scope Capture	• 4 kSamples • 15.6 µs sample interval • Can capture 64 msec @ max rate	• 512 kSamples • (5.12 µs * # of traces) sample interval[1] • Can capture 2.62 sec @ max rate	• 1.024 Msamples • (5.12µs * # of traces) sample interval[1] • Can capture 5.24 sec @ max rate
Data Logging	5 msec integration period (200 points/sec) 15.6 µs sample interval Can capture 5 hours @ max rate	(20.48 µs * # of traces) integration period[2] (50k / # of traces) points/sec 5.12 µs sample interval Can capture ~45 min @ max rate w/ 512 int. RAM Can capture ~6 hours @ max rate w/ 4G USB RAM	(102.4 µs * # of traces) integration period[2] (10k / # of traces) points/sec 5.12 µs sample interval Writes to PC hard drive. Capture time limited only by available space
CCDF/Histo-gram Logging	15.6 µs sample interval Up to 1K hrs @ any rate	Not Available	20.48 µs sample interval Up to 1K hrs @ any rate

Notes:

1. The sample interval time is proportional to number of measurement traces selected. Power traces are calculated so they do not increase sample interval time.
2. The integration period is effectively the sample interval for data logging, with the 5.12µs the underlying rate of sampling that gets averaged into the integration period. Likewise, the integration period is proportional to the number of measurement traces selected excluding power traces which are calculated.

14585A Control and Analysis Software

- Compliments N6705C by enhancing & adding capabilities through a PC graphical user interface:
  - Simultaneously control & display up to 4 N6705Bs / 16 outputs
  - Large PC monitor greatly enhances viewing details
  - Data log direct to PC hard drive, limited only be available space
  - Doubles scope mode memory space (1.024 Meg vs. 512 K)
  - Enables battery drain analysis testing (battery run-down, statistics)
  - Adds statistics capabilities (histogram & CCDF) with direct logging for N6781A BDA SMU module only and data logging conversion for others
  - Adds more ARB waveform generation capabilities; new pre-configured waveforms, formula-based generation, record and playback
  - Formula-based traces available enable re-scaling and unit conversion
  - Works with new and existing 22 modules; useful for a lot more than just Battery Drain Analysis
- Some limiting considerations
  - External app; limits data-logging maximum speed (10 Ksps vs. 50 Ksps for the N6705C mainframe directly)

Scope Mode

Data Log Mode

Statistics Mode

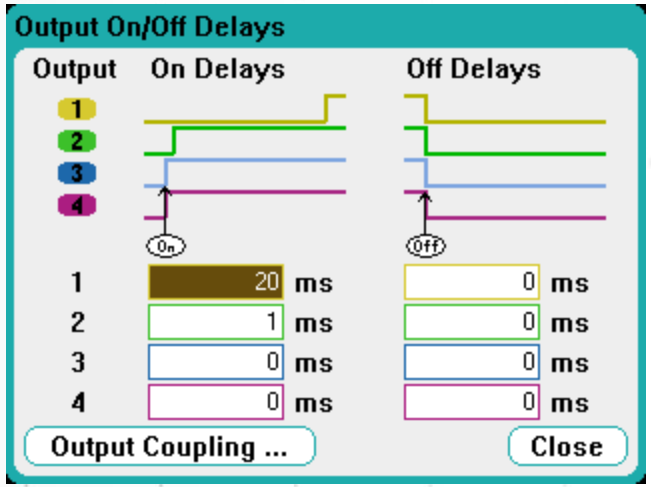
Keysight IoT Battery Drain Test Solutions

For more info, refer to AN: Battery drain analysis for low power IoT devices:
http://literature.cdn.keysight.com/litweb/pdf/5992-1765EN.pdf

	34470 DMM	N2820A scope probe	N6705C + N6781A	B2900 SMU	CX3300 DCWA
Display size	4.3”	Scope dependent	5.9”	4.3”	14.1”
BW, sample rate	17 kHz, 50 kSA/s	500 kHz, 5 Gsa/s	29 kHz, 200 kSa/s	10 kHz, 100 kSa/s	140 MHz, 1 GSa/s
Meas. Res	14 bits	14 bits	18/ 28 bits	20 bits	14 bits
Min measurable static current	10 pA	500 nA	800 nA	1 pA	150 pA
Min measurable dynamic current	10 nA	500 nA	1.4 uA	10 fA	150 pA
Max meas current	10 A	5 A	3 A	3 A	10 A
Min/Max source current	None	None	3 A	3 A	None
Burden voltage	27 mV	1 mV	0 mV	0 mV	4 mV
Price	+	++	++	++	++++
Typical use	R&D / Mfg	R&D	R&D / Mfg	R&D	R&D

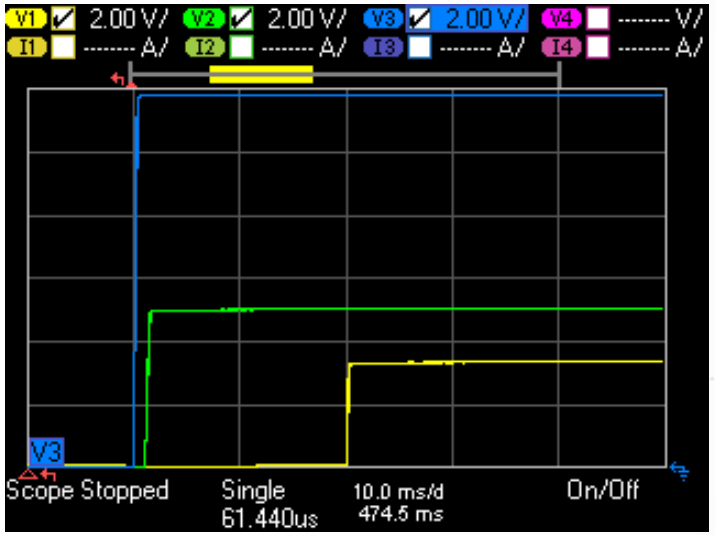
Example Application: Design Validation of PC Motherboard (continued)

- **Solution:** N6705A output sequencing was used to precisely time the individual power inputs to the board isolating the problem and helping to define the PC power supply turn-on sequence requirements



Output sequencing setup

- Output 3: 12V comes on first (0ms delay)
- Output 2: 5V follows 1ms later
- Output 1: 3.3V turns on 19ms later at 20ms
- Experiment with settings to isolate problem



Scope view

- Shows turn-on sequence
- 12V & 5V must always be > 3.3V

Capacity vs. Discharge Rate Characteristics

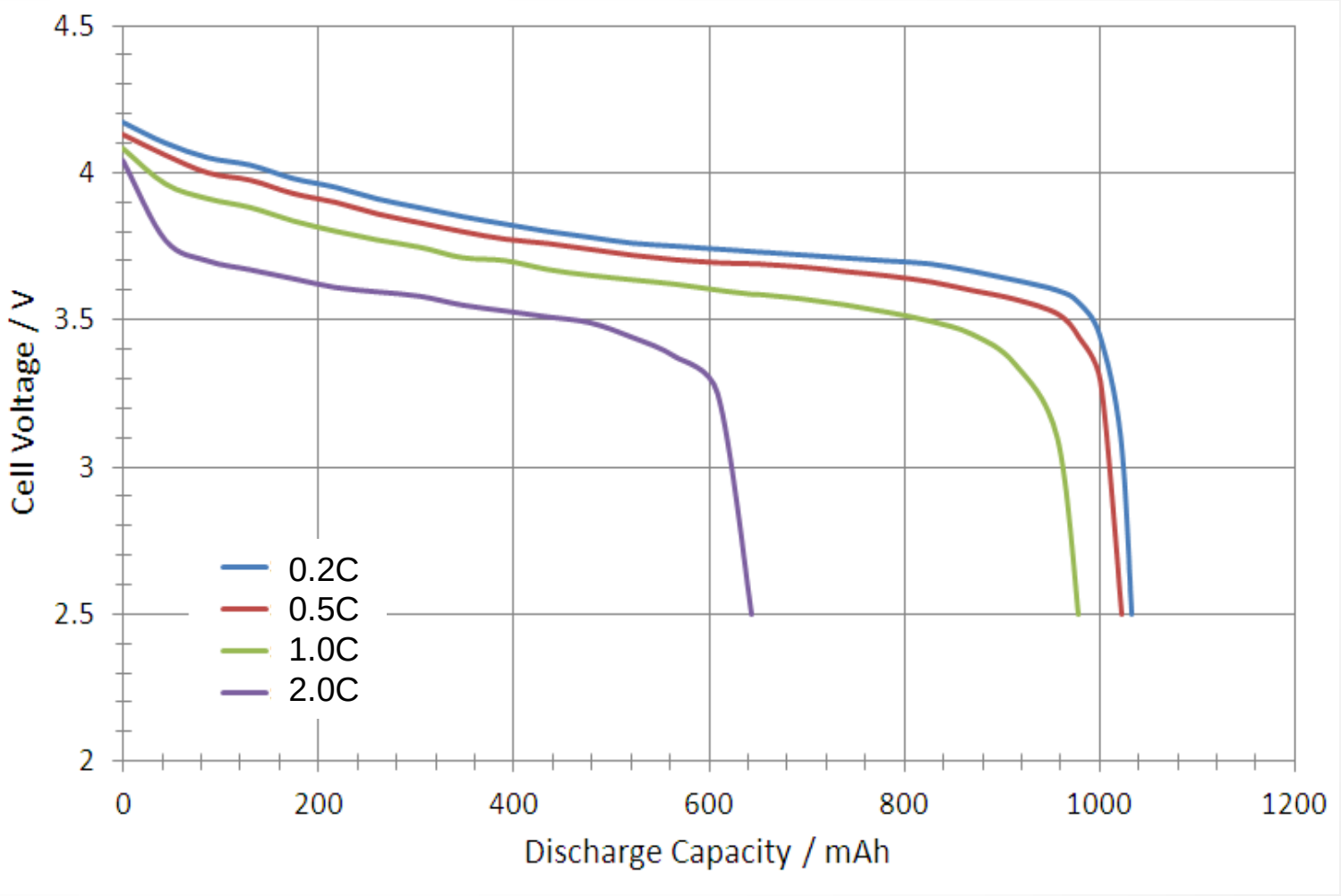
Prismatic Lithium Ion Cell Example

Cell Parameters:

- Capacity rating: 1,000 mAh
  - 0.2C (200mA), 4.2V float to 0.02C (2%) CCCV charge
  - 0.2C (200 mA) discharge
  - 3V cutoff voltage
    (2.75V also often specified)
  - 20 °C ambient

- ~99% of capacity for 0.5C
- ~95% of capacity for 1C
- ~62% of capacity for 2C

- Energy rating: 3.7 Wh:
  - 3.7 V rating for 0.2C discharge



1,000 mAh LiIon cell capacity vs. C rate loading