

Keysight 精密電流測量與 CX3300 器件電流波形分析儀

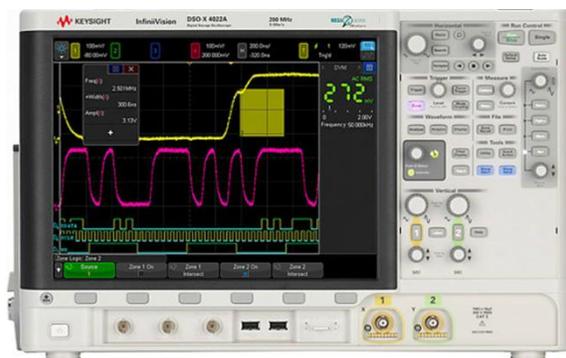
品勛科技股份有限公司
(keysight正式授權經銷商)

www.pinsyun.com.tw

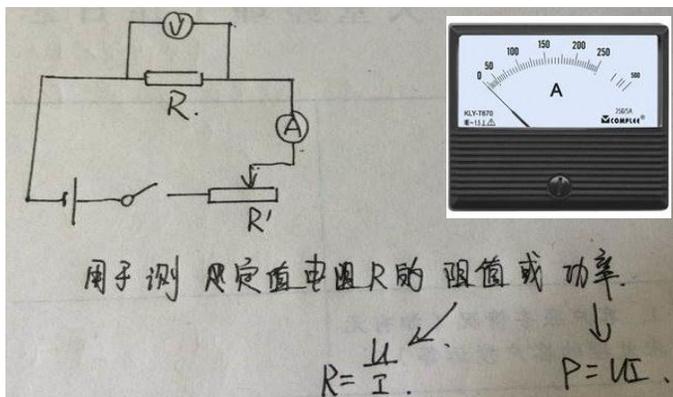
線上詢問



精密电流测量与 CX3300 器件电流波形分析仪



电流的认知



电流的定义

单位时间里通过导体任一横截面的电量叫做电流强度，简称电流。它的单位是安培，简称“安”，符号“A”

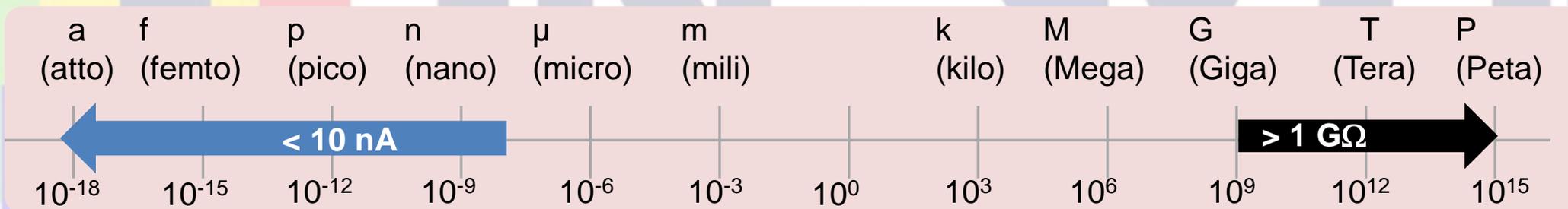
$$I = \frac{dQ}{dt} \quad (1A=1C/s)$$

一个电子的电量, $e=1.6 \times 10^{-19} \text{ C}$?

1A安培，表示1秒钟流过大约 6.25×10^{18} 个电子

电流产生条件

- 1.有电场。（电路当中，电源会产生电场）
- 2.有自由移动的带电粒子。（导体，且闭合电路）

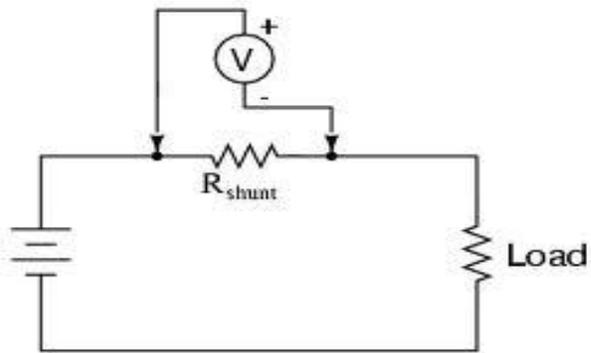


一些常见的电流：

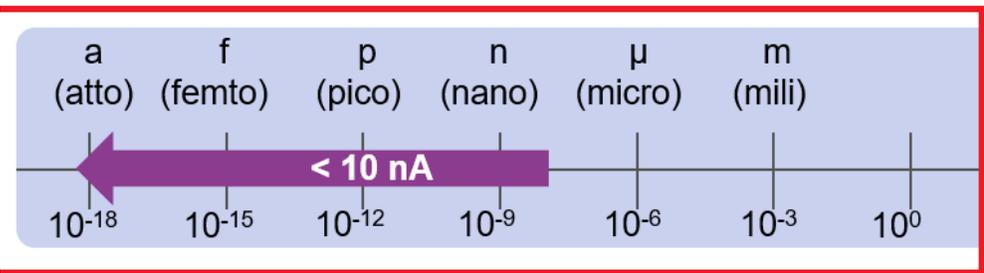
绝缘材料漏电流 8pA，MOS FET开关管漏电流 200nA，电子手表1.5μA至10μA，LED灯 1至10mA，白炽灯泡200mA，手机显示屏500mA，空调家电5A 至 10A，电动汽车 200A - 1000A.

电流测量方法

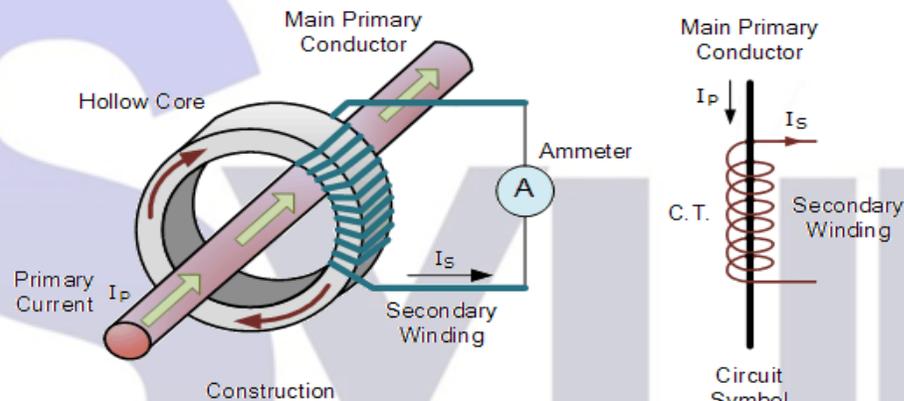
欧姆定律, $I = U/R$



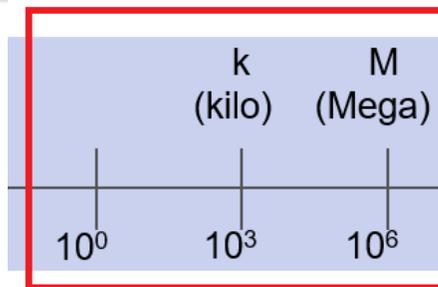
取样电阻“Rshunt”串联到回路，通过测试其端电压U，依据欧姆定律获得电流： $I = U / R$



磁效应



依据电流的磁效应，将待测大电流转换为测试仪表可量测的小电流I_s或电压U_s



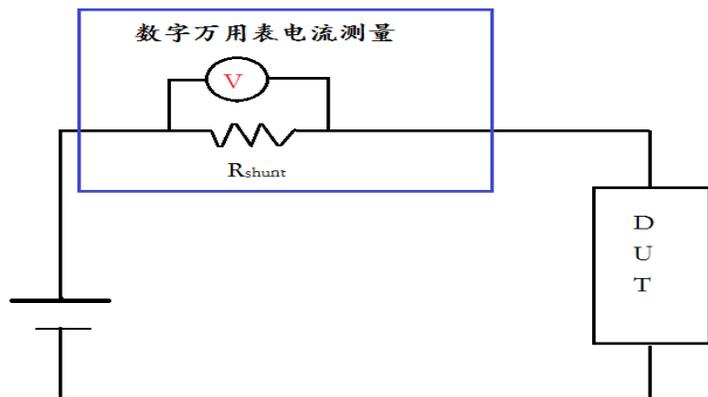
热效应

化学效应

内容安排

- 通用电流测试方案
- N6705C 直流电源分析仪
- CX3300 器件电流波形分析仪

通用电流测试仪表——数字万用表



- 1) 取样电阻与量程关联!
- 2) 分辨率与积分时间PLC关联

如上图所示，万用表的电流测量是通过“取样电阻”Rshunt两端电压，依据欧姆定律： $I = U / R$ 。

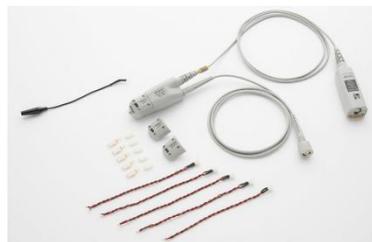
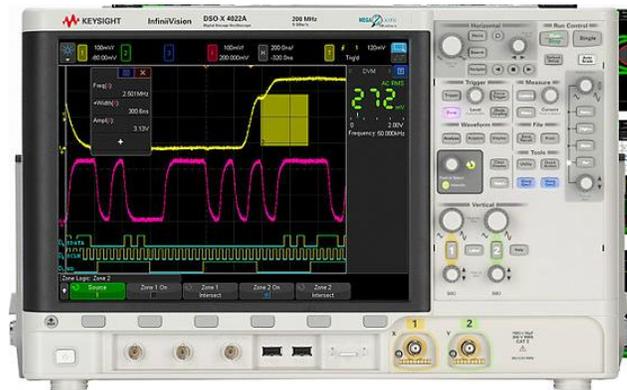


Range	10 μ A	100 μ A	1 mA	10 mA	100 mA	1 A	3 A	10 A
Effective Internal Shunt Value	1 k Ω	100 Ω	10 Ω	1 Ω	0.1 Ω	0.1 Ω	0.1 Ω	0.005 Ω
Autozero Off Error	150 pA	1.5 nA	15 nA	150 nA	15 μ A	150 μ A	150 μ A	3 mA

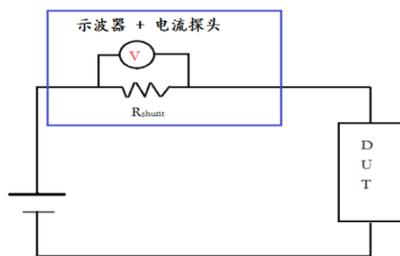
Up to 1Kohm Shunt Resistor under 10uA range

NPLC	Digits	10 μ A	100 μ A	1 mA	10 mA	100 mA	1A	3A	10A ⁴³
5	7½	0.0005 PLC = 0.0005 x 20ms = 10 us	0.0005 PLC = 0.0005 x 20ms = 10 us	0.0005 PLC = 0.0005 x 20ms = 10 us	0.0005 PLC = 0.0005 x 20ms = 10 us	0.0005 PLC = 0.0005 x 20ms = 10 us	0.0005 PLC = 0.0005 x 20ms = 10 us	0.0005 PLC = 0.0005 x 20ms = 10 us	0.0005 PLC = 0.0005 x 20ms = 10 us
1	7½								
0.2	6½								
0.2 ⁴⁴	6½								
0.06	5½								
0.006	4½								
0.0005	3½								

通用电流测试仪表——示波器的电流测量



N2820 接入式电流探头



带宽 (-3 dB)

放大通道: 直流至 3 MHz
缩小通道: 直流至 500 kHz

上升时间

放大通道: < 0.116 μs
缩小通道: < 0.7 μs

最小可测量电流*

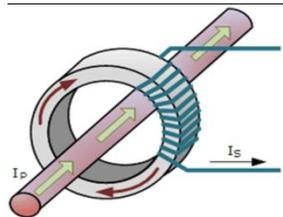
250 μA (使用 N2822A 20 mΩ, 500 mW)
50 μA (使用 N2824A 100 mΩ, 500 mW)
50 μA (使用 N2825A 用户定义 1 kΩ, 500 mW)

最大可测量电流

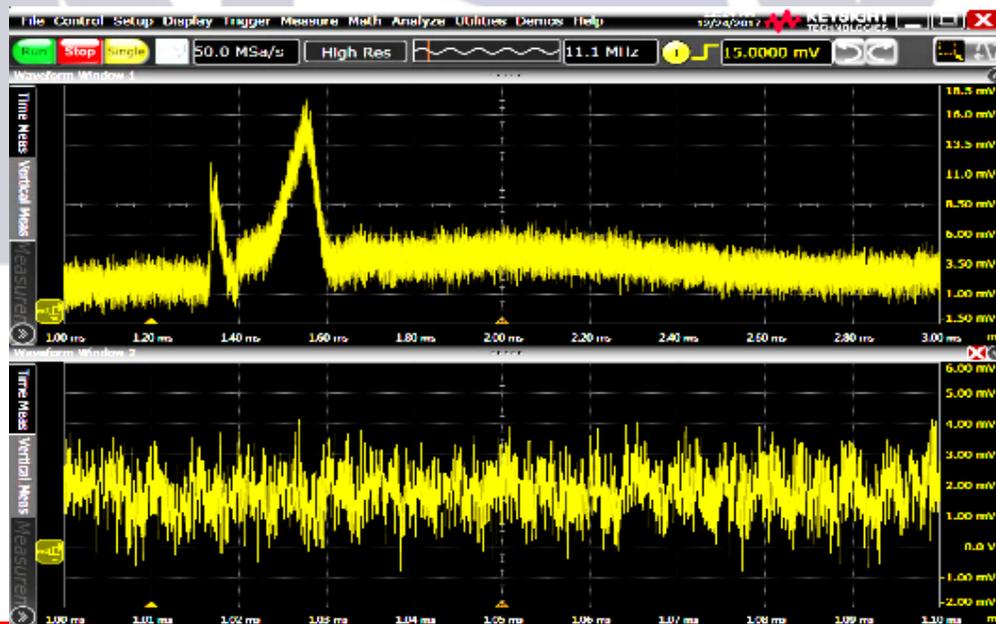
5 A (使用 N2822A 20 mΩ, 500 mW)
2.2 A (使用 N2824A 100 mΩ, 500 mW)
22 mA² (使用 N2825A 用户定义 1 kΩ, 500 mW)



型号	N2780B	N2783B
带宽 (-3 dB)	直流至 2 MHz	直流至 100 MHz
上升时间	175 ns 或更低	3.5 ns 或更低
最大电流 (连续) RMS	500 A	30 A
最大电流峰值 (不连续)	700 A 峰值	50 A 峰值
最低测量电流 (直流 ±3% 的精度, 示波器设置为 1 mV/div 并启动高分辨率模式)	20 mA	5 mA
输出电压比	0.01 V/A (100:1)	0.1 V/A (10:1)



高带宽、大电流
高底噪



小电流测量
同DMM，取样电阻决定测量电流大小，且
带宽 < 500 KHz

通用电流测试仪表——电源的电流测量



设定电压

电压测量值

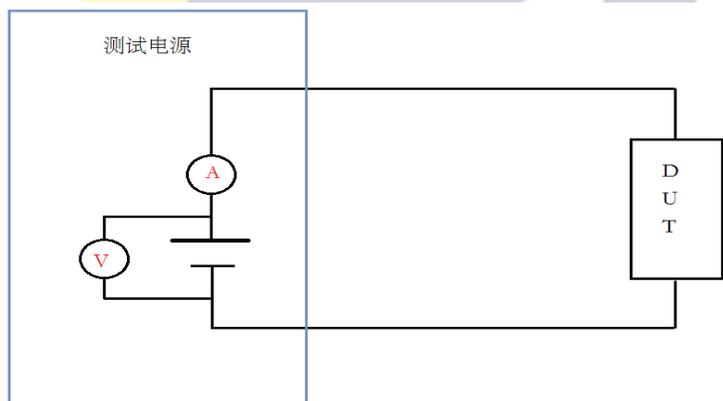
设定电流

电流测量值

适用于给被测件供电的同时进行电流测量场合

- ✓ 测试电源通常都具有电流测量功能
- ✓ 通常精度约0.1%，精密电源甚至0.01%
- ✓ 同DMM，直流或低频电流测量，高性能电源可达200K Sa/s，如N6705, N7900, RP7900等。

电流测量与电流输出范围一致，如下是RP7900大功率电源的电压和电流范围：



型号	电压	电流	功率
RP7961A	500V	± 20A	5kW
RP7962A	500V	± 40A	10kW
RP7963A	950V	± 20A	10kW
RP7941A	20V	± 400A	5kW
RP7942A	80V	± 125A	5kW
RP7943A	20V	± 800A	10kW
RP7945A	80V	± 250A	10kW
RP7946A	160V	± 125A	10kW

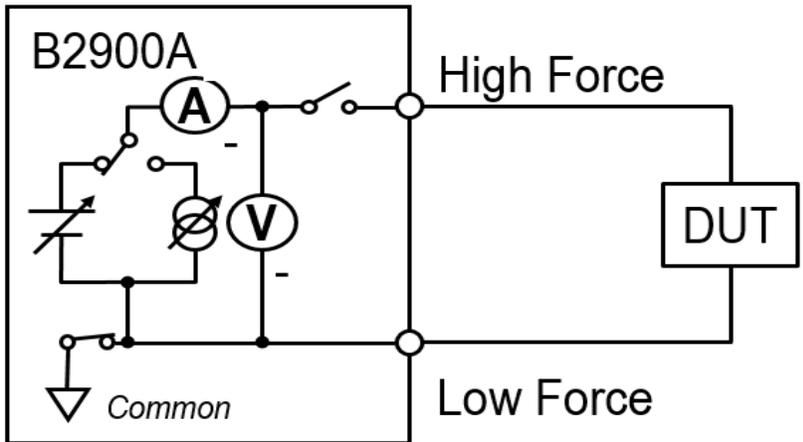
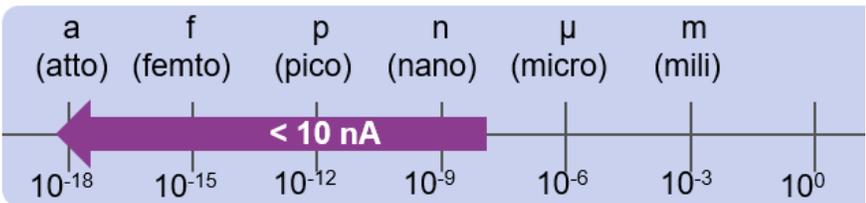
特殊电流测量仪表——SMU源表/皮安表的电流测量



B2980 皮安表/高阻计



B2900 精密源表



4象限 精密电源和测量——电压源或电流源，电压电流同时测量；

电源 测量 主要指标：

- 1) 电压 210V ， 3A直流 / 10.5A脉冲
- 2) 分辨率100nV/10fA， (6¹/₂ 位， 22比特)
- 3) 任意波形和扫描，速率100KHz

Model	皮安表	皮安表/高阻计
	B2981A/B2983A	B2985A/B2987A
分辨率	6 ¹ / ₂	
电流范围	0.01 fA - 20 mA	
最小电流量程	2 pA	
电阻测量		Up to 10 PΩ
电压测量		1 μV - 20 V
输入阻抗		> 200 TΩ
电荷测量		1 fC - 2 μC
温度测量		✓
湿度测量	✓	
电压源	Up to ±1,000 V	
读数	20,000 rdg/s	
电池供电	B2983A	B2987A

内容安排

- 通用电流测试方案
- N6705C 直流电源分析仪
- CX3300 器件电流波形分析仪



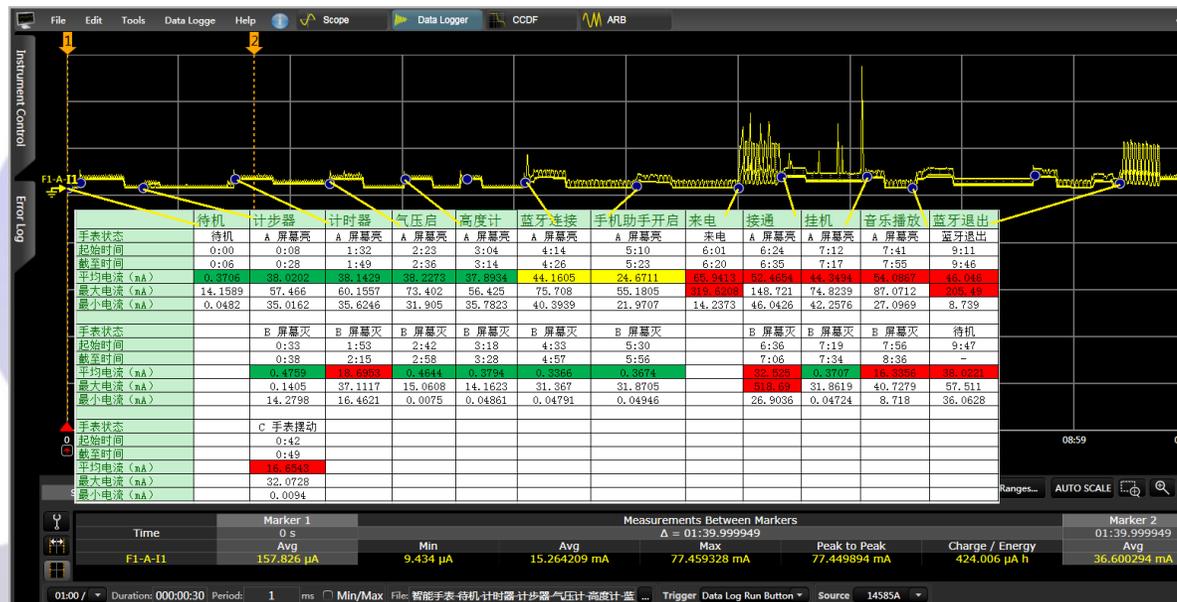
特殊电流测量仪表—— N6705C 直流电源分析仪



14585A 功耗分析软件

N6705功耗测试四个独特优点：

1. 无缝量程切换技术，实现28比特动态，可以轻松测量大范围（8A-80nA）快速变化的耗电电流波形；
2. 高达200 KHz（5us）电流采样率，精确测量脉冲电流；
3. 长达1000小时连续数据记录；
4. 可视化电流测试软件，电流测试与操作同步测量。



耗电测量的挑战

——智能终端、IoT(物联网)、AI(人工智能)、VR(虚拟现实)

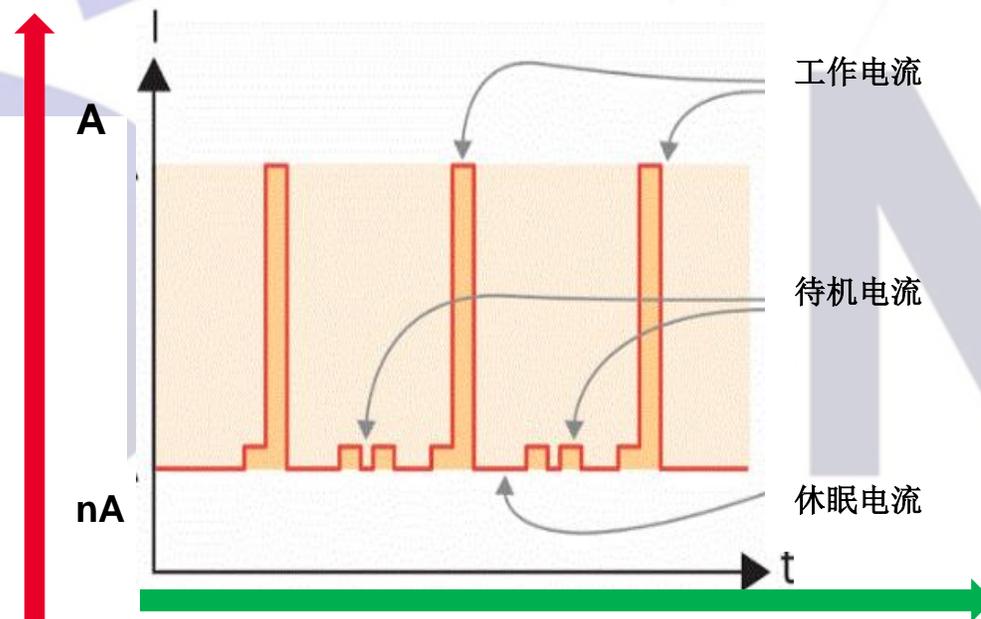
» 设备耗电特性——大范围变化、持续时间极短的动态脉冲电流

水平刻度(时间)来看:

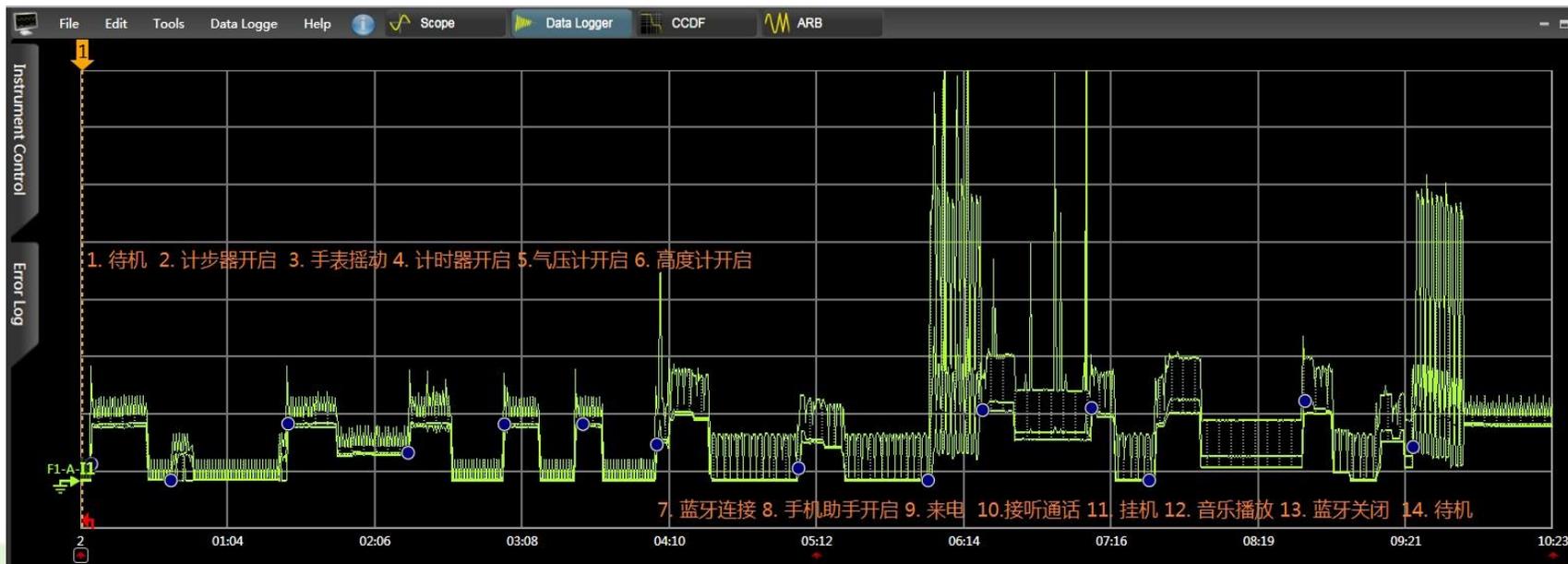
1. 窄电流脉冲测量, 采样速度快(采样率)
2. 应用场景测量持续测量, 采样时间要长(存储深度)

垂直刻度(电流幅值)上:

1. 休眠电流小, μA , 甚至 nA 以下(底噪)
2. 工作电流大, 数十 mA 甚至 A , 需要极高的动态电流测量能力(A/D垂直分辨率)



“智能手表”功耗实测/分析——各种模式及状态（10分钟）



	待机	计步器	计时器	气压启	高度计	蓝牙连接	手机助手开启	来电	接通	挂机	音乐播放	蓝牙退出
手表状态	待机	A 屏幕亮	来电	A 屏幕亮	A 屏幕亮	A 屏幕亮	蓝牙退出					
起始时间	0:00	0:08	1:32	2:23	3:04	4:14	5:10	6:01	6:24	7:12	7:41	9:11
截至时间	0:06	0:28	1:49	2:36	3:14	4:26	5:23	6:20	6:35	7:17	7:55	9:46
平均电流 (mA)	0.3706	38.0202	38.1429	38.2273	37.8934	44.1605	24.6711	65.9413	52.4654	44.3494	54.0867	46.046
最大电流 (mA)	14.1589	57.466	60.1557	73.402	56.425	75.708	55.1805	319.6208	148.721	74.8239	87.0712	205.49
最小电流 (mA)	0.0482	35.0162	35.6246	31.905	35.7823	40.3939	21.9707	14.2373	46.0426	42.2576	27.0969	8.739
手表状态		B 屏幕灭		B 屏幕灭	B 屏幕灭	B 屏幕灭	待机					
起始时间		0:33	1:53	2:42	3:18	4:33	5:30		6:36	7:19	7:56	9:47
截至时间		0:38	2:15	2:58	3:28	4:57	5:56		7:06	7:34	8:36	-
平均电流 (mA)		0.4759	18.6953	0.4644	0.3794	0.3366	0.3674		32.525	0.3707	16.3356	38.0221
最大电流 (mA)		0.1405	37.1117	15.0608	14.1623	31.367	31.8705		518.69	31.8619	40.7279	57.511
最小电流 (mA)		14.2798	16.4621	0.0075	0.04861	0.04791	0.04946		26.9036	0.04724	8.718	36.0628
手表状态		C 手表摆动										
起始时间		0:42										
截至时间		0:49										
平均电流 (mA)		16.6543										
最大电流 (mA)		32.0728										
最小电流 (mA)		0.0094										

这样的N6705是否你正在寻找的功耗分析手段？



1. 高达200 KHz (5us)电流采样率，精确测量脉冲电流；
2. 无缝量程切换技术，28 比特动态，可以轻松测量大范围（8A-80nA）快速变化的耗电电流波形；
3. 长达1000小时连续数据记录；
4. 可视化电流测试软件，电流测试与操作同步测量（电流优化必备）。

功率升级...N6705 → N7900 → RP7900



N6705C, 60V, 50A, 500W

- 电源和负载功能的无缝转换
- 大功率任意波形发生器
- 电压、电流示波器
- 电压、电流数据记录仪
- 内置电池内阻仿真
- 内置电量计



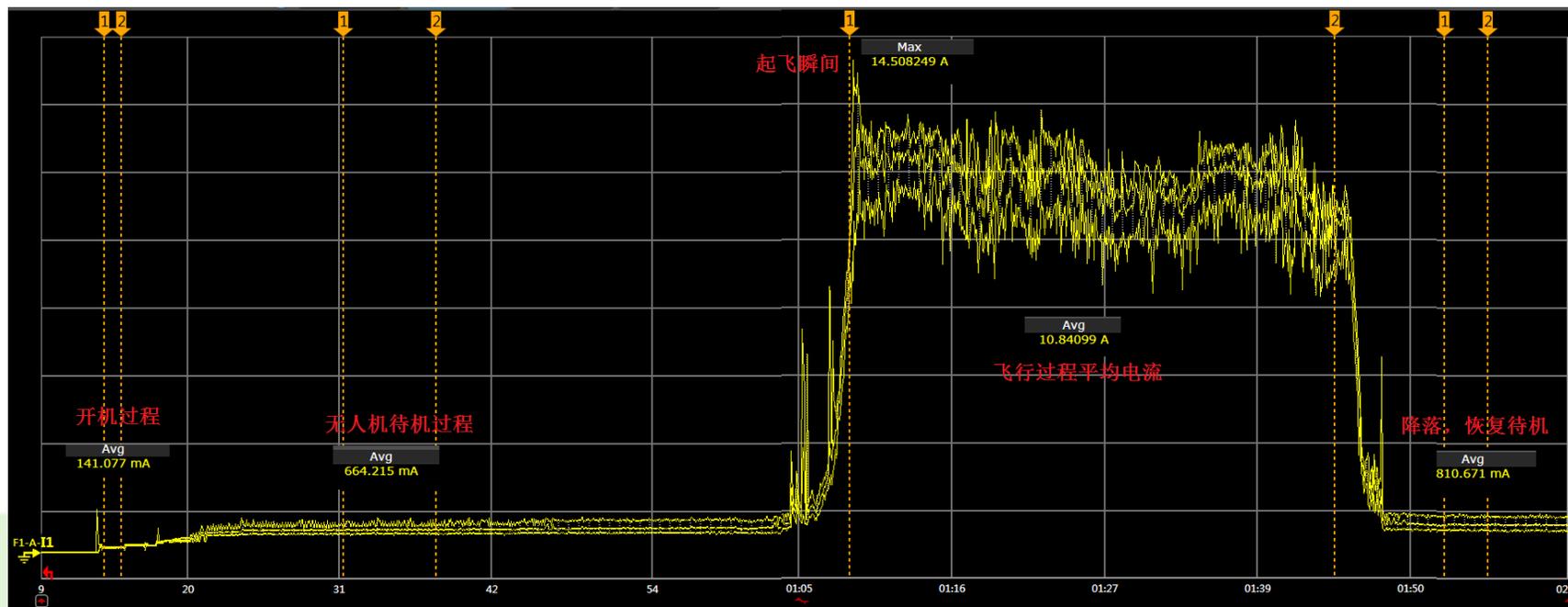
RP7900, 950V, ± 800A, 10KW



N7900, 160V, ± 200A, 2KW



“无人机”功耗实测——起飞 & 降落



飞行性能	最大飞行距离:	100米
	最大飞行高度:	10米
	最大飞行速度:	8m/s
	最长飞行时间:	13分钟
电池	可拆卸电池:	1.1AH/3.8V

- ✓ 14585A启动数据记录仪 Data Logger ;
- ✓ “操作无人机起飞, 降落” 从开机->连接WIFI->起飞->降落过程 ;
- ✓ 软件实时记录所有操作过程电流变化。

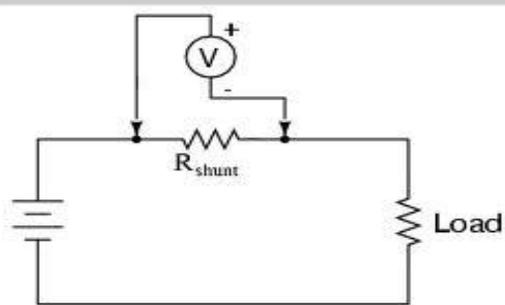
模式/ 状态	开机	待机	起飞和飞行	降落待机
起始时间	0:14	00: 34	1:09	1: 52
截至时间	0:16	00: 44	1:45	1: 56
平均电流 (A)	0.14108	0.66421	10.84	0.81067
最大电流 (A)	0.18558	1.03	14.51	1.128

内容安排

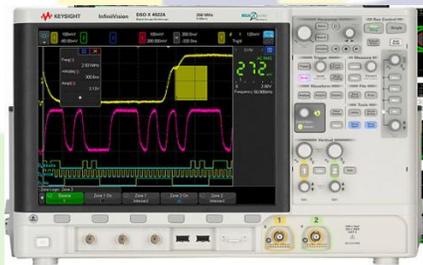
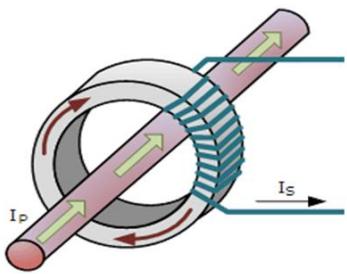
- 通用电流测试方案
- N6705C直流电源分析仪
- CX3300 器件电流波形分析仪



以上电流测试方案回顾



<200KHz Sa/s



示波器/
电流探头



高带宽、大电流
动态小、高底噪



N2820 接入式电流探头



344XX数字万用表
测量范围：10A至 nA, nPLC



B2980皮安表
测量范围：20mA至 0.01fA, nPLC



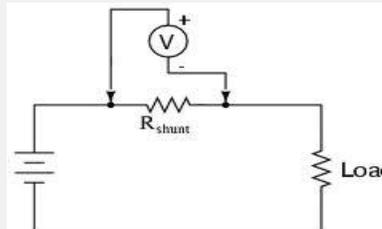
测试电源
测量范围：800A 至 mA, nPLC

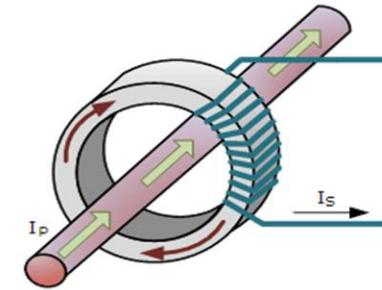


N6705C直流源分析仪
测量范围：8A 至 80nA, 5us

小电流测量 (>50uA)
同DMM, 取样电阻决定测量电流大小, 且
带宽<500KHz

高带宽、小电流测量的挑战分析？

NPLC	Digits	10 μ A	100 μ A	1 mA	10 mA	100 mA	1A	3A	10A ⁴³
5	7½	0.0005 PLC = 0.0005 x 20ms = 10 us 							
1	7½								
0.2	6½								
0.2 ⁴⁴	6½								
0.06	5½								
0.006	4½								
0.0005	3½								



无法分析uA级甚至mA级的电流

Range	10 μ A	100 μ A	1 mA	10 mA	100 mA	1 A	3 A	10 A
Effective Internal Shunt Value	1 k Ω	100 Ω	10 Ω	1 Ω	0.1 Ω	0.1 Ω	0.1 Ω	0.005 Ω
Autozero Off Error	150 pA	1.5 nA	15 nA	150 nA	15 μ A	150 μ A	150 μ A	3 mA

Up to 1Kohm Shunt Resistor under 10uA range

- 1) 取样电阻与量程关联！
- 2) 分辨率与积分时间PLC关联

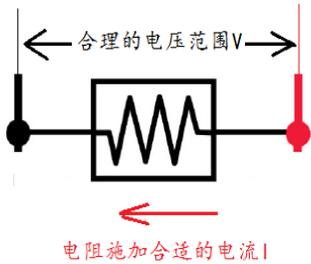
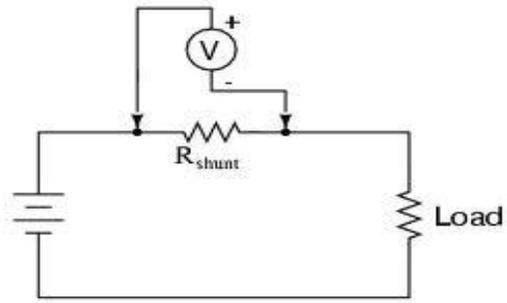
1) 10A时，5m Ω ； 10mA, 1 Ω ； 10uA, 1000 Ω ；

2) 1PLC(50Hz) 分辨率为1.0000000； 0.0005PLC (100KHz) 分辨率为1.000

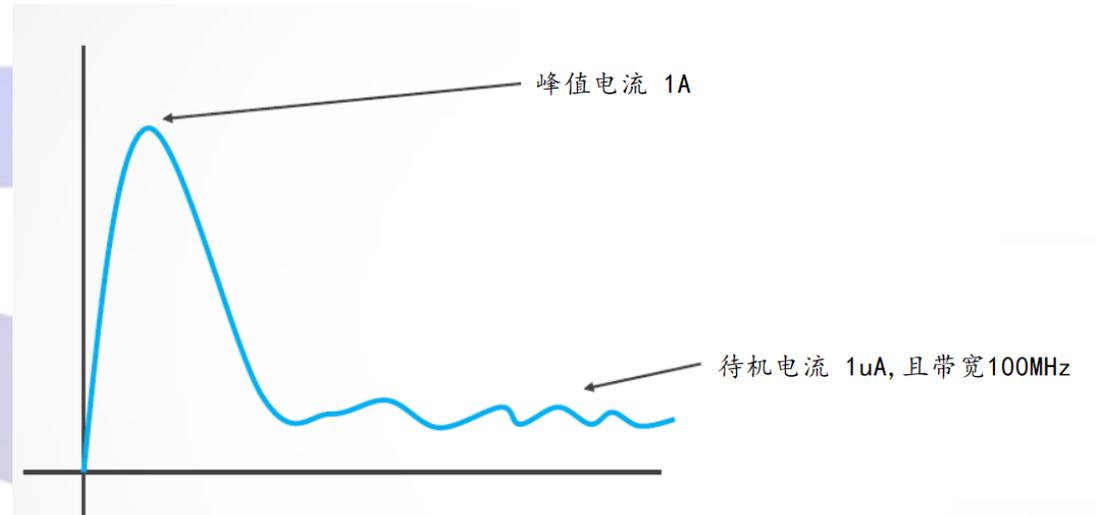
7位数

3位数

取样电阻的影响及如何选取？



$$V = I \times R$$



电压表的测量分辨率

1) 不改变电压表测量能力 (假设分辨率1mV)

- a) 电流小，电阻大， $1\text{mV} = 1\mu\text{A} \times 1\text{K}\Omega$
- b) 反之，电流大，电阻小， $1\text{mV} = 1\text{A} \times 1\text{m}\Omega$

2) 提升电压表测量能力 (假设分辨率从1mV 提高至1uV)

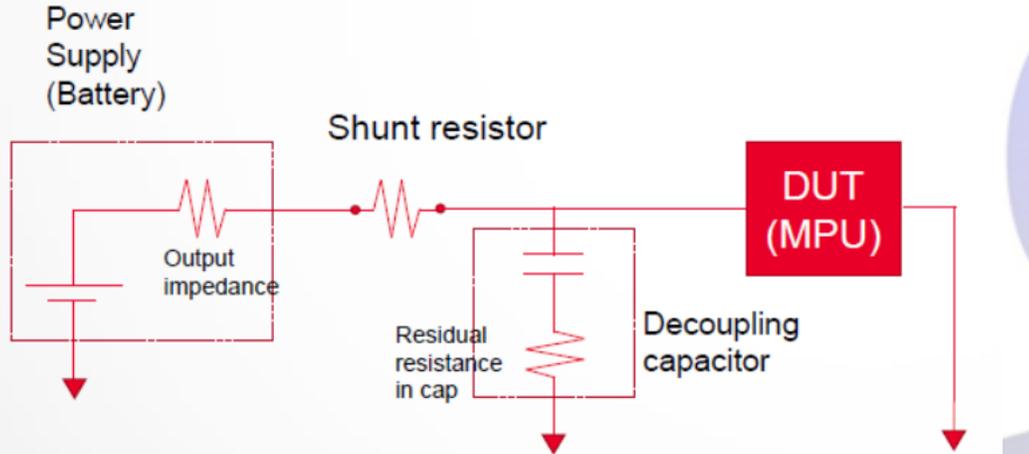
$$1\text{mV} = 1\mu\text{A} \times 1\text{K}\Omega \quad \longrightarrow \quad 1\mu\text{V} = 1\mu\text{A} \times 1\Omega$$
$$1\mu\text{V} = 1\text{A} \times 1\mu\Omega$$

峰值电流1A，待机电流1uA？

$1\mu\text{A} \times 1\Omega = 1\mu\text{V}$
 $1\text{A} \times 1\Omega = 1\text{V}$
1V 量程时，能分辨1uV，
需要6 1/2 (21比特) 分辨率，即1.000000

取样电阻的影响及如何选取？（续1）

Max. current = (3 V) / (Rshunt + Rcap + Routput)



假如选取 1Ω 的取样电阻，请问最大电流是多少？



Rshunt= 50 mohm

V=3V



Rshunt= 10 mohm



Rshunt= 5 mohm

峰值Inrush电流究竟是多少？

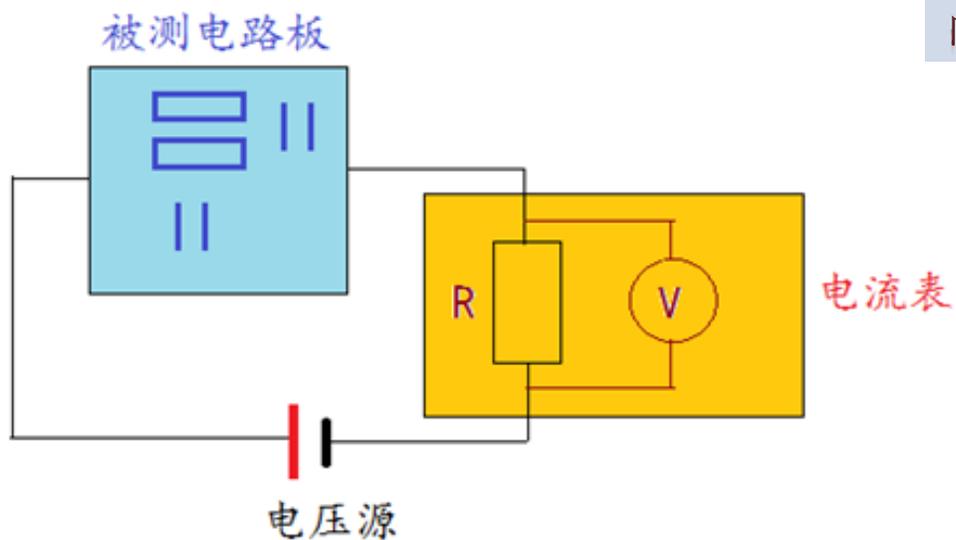
Table 10. CX1105A Differential Sensor, Single Channel

Range	RMS noise		Maximum bandwidth (-3 dB)	Maximum common mode voltage
	20 MHz NBW	2.5 kHz NBW ⁴		
2.5 V	1100 μ V	200 μ V	100 MHz	± 40 V
1 V	1100 μ V	200 μ V		
250 mV	45 μ V	3.0 μ V		
100 mV	24 μ V	1.3 μ V		
25 mV	20 μ V	400 nV		± 6 V

Shunt R	CX1105A			
	Range	Max. Current	Noise (rms) 20 MHz NBW	Noise (rms) 2.5 kHz NBW
2.5 m Ω	2.5 V	1000 A	440 mA	80 mA
	1 V	400 A	440 mA	80 mA
	250 mV	100 A	18 mA	1.2 mA
	100 mV	40 A	9.6 mA	0.52 mA
	25 mV	10 A	8 mA	0.16 mA
5 m Ω	2.5 V	500 A	220 mA	40 mA
	1 V	200 A	220 mA	40 mA
	250 mV	50 A	9 mA	0.6 mA
	100 mV	20 A	4.8 mA	0.26 mA
	25 mV	5 A	4 mA	0.08 mA
20 m Ω	2.5 V	125 A	55 mA	10 mA
	1 V	50 A	55 mA	10 mA
	250 mV	12.5 A	2.25 mA	150 μ A
	100 mV	5 A	1.2 mA	65 μ A
	25 mV	1.25 A	1 mA	20 μ A
50 m Ω	2.5 V	50 A	22 mA	4 mA
	1 V	20 A	22 mA	4 mA
	250 mV	5 A	900 μ A	60 μ A
	100 mV	2 A	480 μ A	26 μ A
	25 mV	500 mA	400 μ A	8 μ A
100 m Ω	2.5 V	25 A	11 mA	2 mA
	1 V	10 A	11 mA	2 mA
	250 mV	2.5 A	450 μ A	30 μ A
	100 mV	1 A	240 μ A	13 μ A
	25 mV	250 mA	200 μ A	4 μ A
1 Ω	2.5 V	2.5 A	1.1 mA	0.2 mA
	1 V	1 A	1.1 mA	0.2 mA
	250 mV	250 mA	45 μ A	3 μ A
	100 mV	100 mA	24 μ A	1.3 μ A
	25 mV	25 mA	20 μ A	0.4 μ A

取样电阻的影响及如何选取？（续2）

高带宽，小电流的精确测量是一个世纪难题！！！！



取样电阻选取原则：

1. 清楚被测电路的电流特征，最大值、最小值、带宽
2. 选择电压噪声尽可能低的仪器
3. 按照仪表的电压噪声，计算最小电流时对应的电阻值
4. 在该电阻时，计算最大电流时的压降

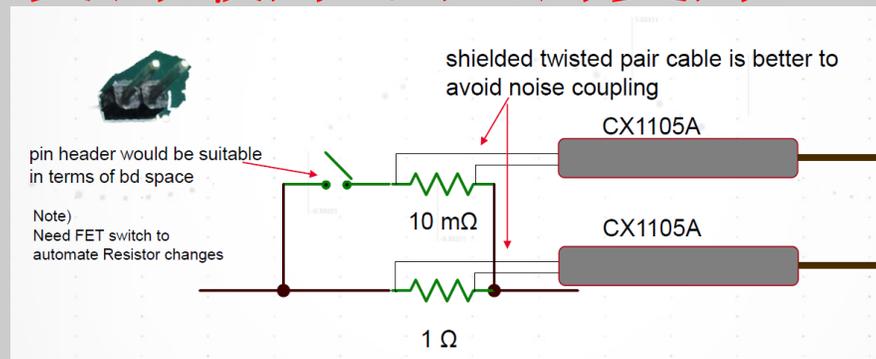
如果电压表测量能力（假设分辨率1mV）

$$1\text{mV} = 1\mu\text{A} \times 1\text{K}\Omega$$

RC电路的时间常数 $t = RC$ ，

截止频率 $f = 1/2 \pi RC$ ，RC越大，截止频率越低。

没有最好，只有更好！



CX3300 器件电流波形分析仪

洞察秋毫，电流测试专家

CX3322A 2 通道
CX3324A 4 通道
CX1101A
CX1102A
CX1103A
CX1104A
CX1105A
CX1151A
CX1152A

新品种



- ✓ 低至400nV电压噪声
- ✓ 低至150pA电流噪声

连接灵活

- ✓ 支持多种电流范围和接入方式的适配器
- ✓ 单端、差分电压探头
- ✓ 数字和逻辑探头



高性能

- ✓ 低至400nV电压噪声
- ✓ 低至150pA电流噪声
- ✓ 1GSa/s采样，200MHz带宽
- ✓ 14/16比特分辨率
- ✓ 电流范围100A至150pA

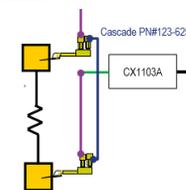
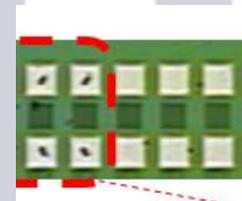
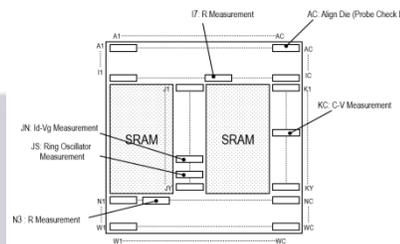
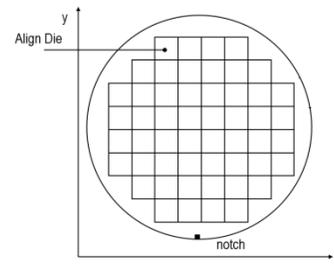
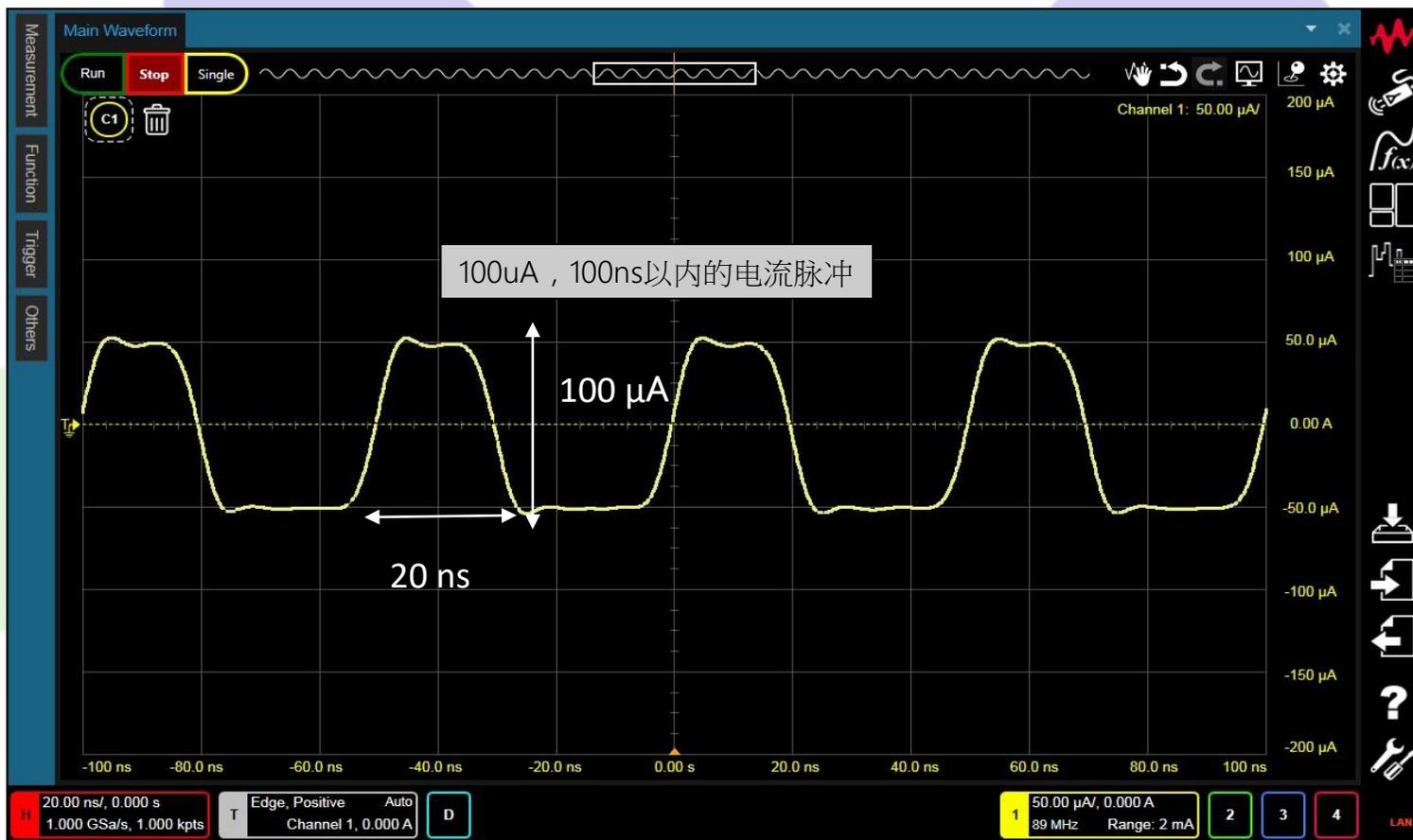


易用、高效

- ✓ Window操作系统
- ✓ 14.1英寸电容多点触屏
- ✓ 一键式“功耗特征提取”
- ✓ 自动波形存储
- ✓ 区域测量
- ✓ 任意区域放大

CX3300 初创应用——测量NVM的电流脉冲

100uA, 100ns脉冲电流实测波形
新型NVM (ReRAM, PRAM等)特性分析, 需要测量下图的电流脉冲。



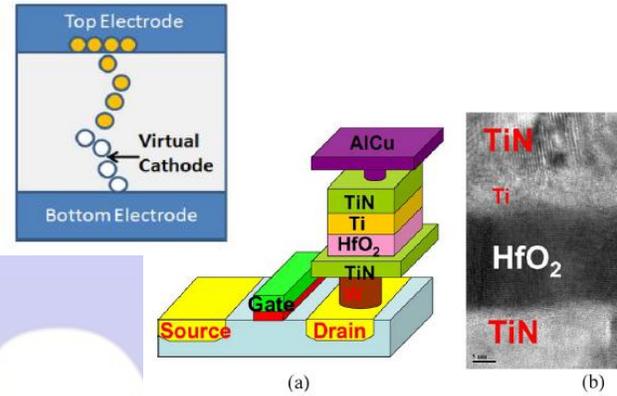
PWRP_248

新存储NVM——新材料

	FRAM	MRAM	PCM	RRAM
	FeRAM EEPROM NVSRAM BBSRAM	EEPROM NVSRAM BBSRAM	PRAM	ReRAM EEPROM NVSRAM BBSRAM
Industrial & Transportation				
Smart Card MCU		EEPROM eFlash NOR	EEPROM eFlash NOR	
Cache Memory for Enterprise Storage		NVSRAM BB SRAM DRAM	NVSRAM BB SRAM DRAM	NVSRAM BB SRAM DRAM
Mobile Phones		SRAM	NOR	
Mass Storage				NAND

Emerging NVM positioning

Non-Volatile Memory
Volatile Memory



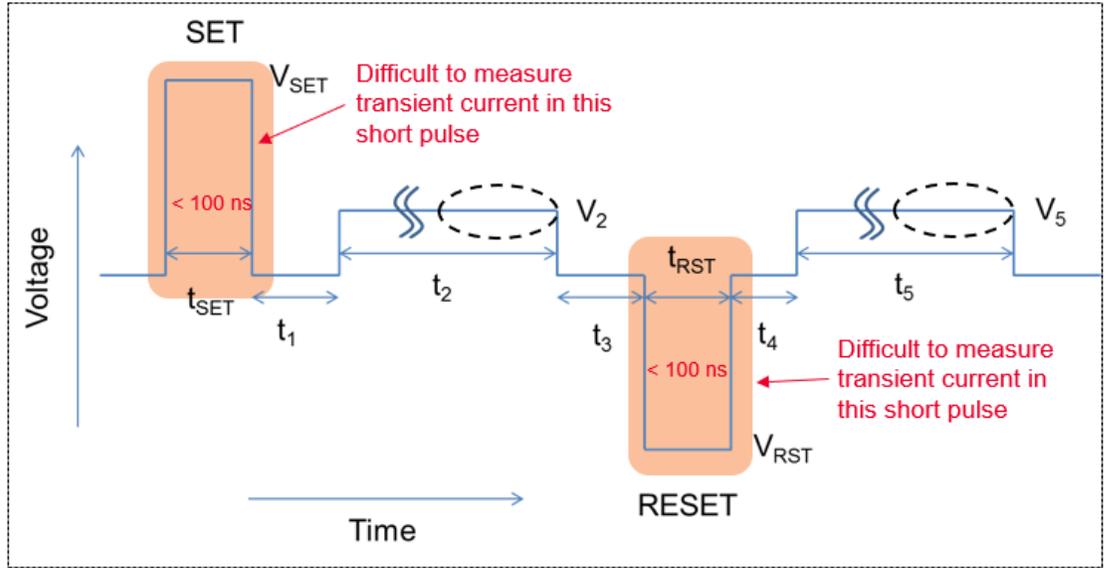
The Periodic Table of the Elements

corresponding binary oxide that exhibits bistable resistance switching

metal that is used for electrode

1	2																	11	12
H	He																	H	He
3	4																	9	10
Li	Be																	F	Ne
11	12																	17	18
Na	Mg																	Cl	Ar
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86		
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
87	88	89	104	105	106	107	108	109	110	111	112	114	116	118					
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt											
119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136		
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu						
90	91	92	93	94	95	96	97	98	99	100	101	102	103						
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr						

Voltage pulse for ReRAM evaluation



- ✓ Pulse width: 10 ns to 100 ns
- ✓ Dynamic current: from 1 μ A level

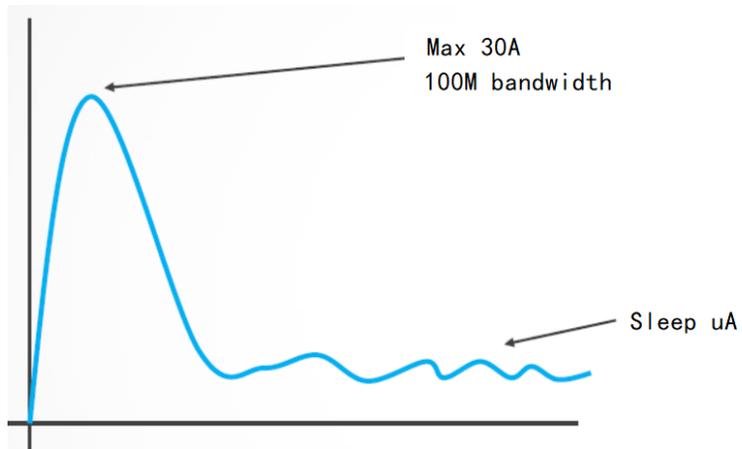
➔ 1 μ A measurement under > 100 MHz BW

RRAM – 阻变存储器

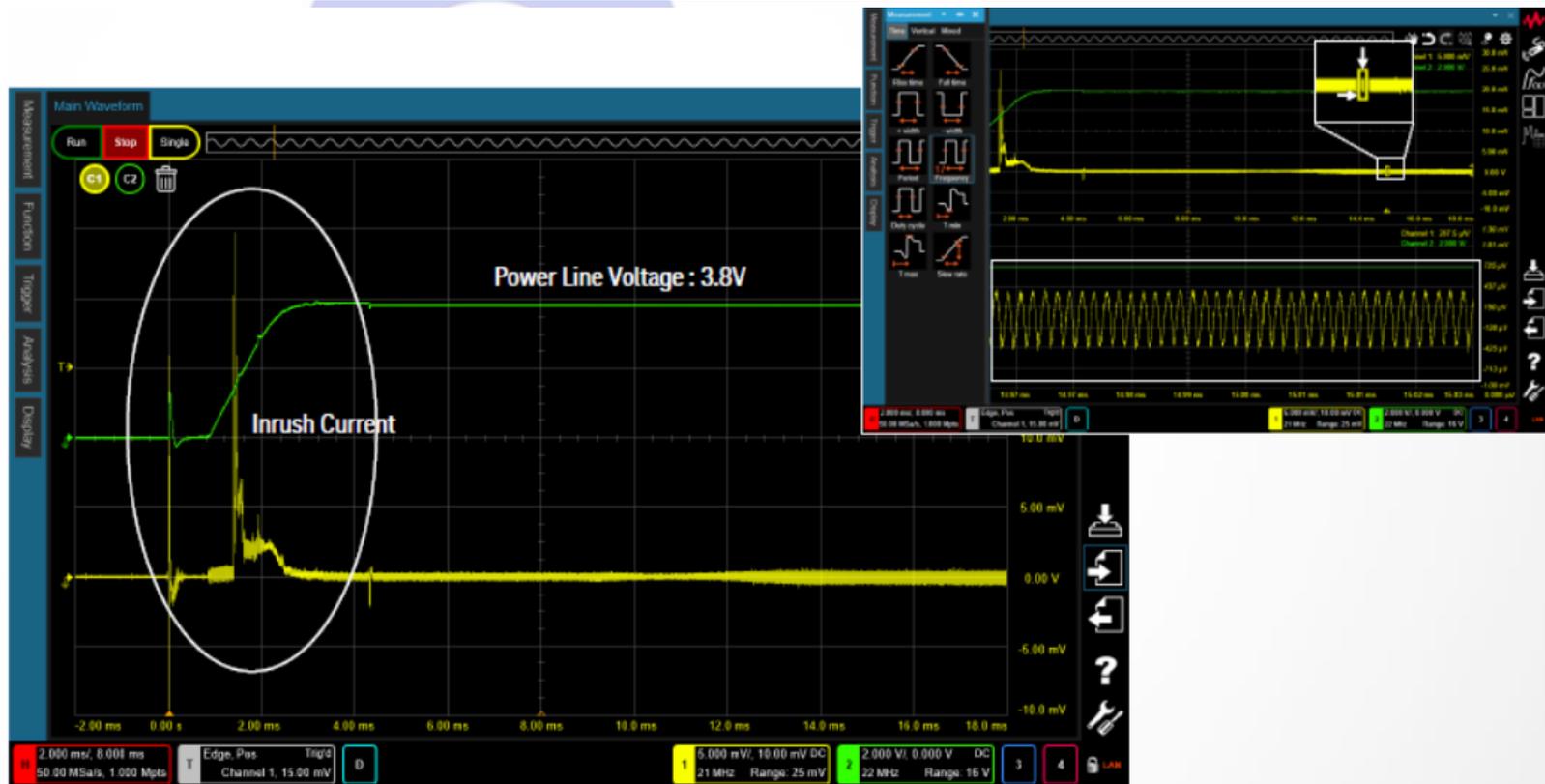
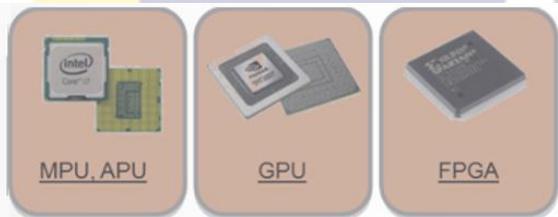
数字“0” – 低阻 (如10K Ω 读写电压 $V = 1.5V$)
 $I = V/R = 1.5V/10K\Omega = 150\mu A$

数字“1” – 高阻 (如100K Ω 读写电压 $V = 1.5V$)
 $I = V/R = 1.5V/100K\Omega = 15\mu A$

CX3300典型应用1——XPU处理器芯片的大动态电流测量

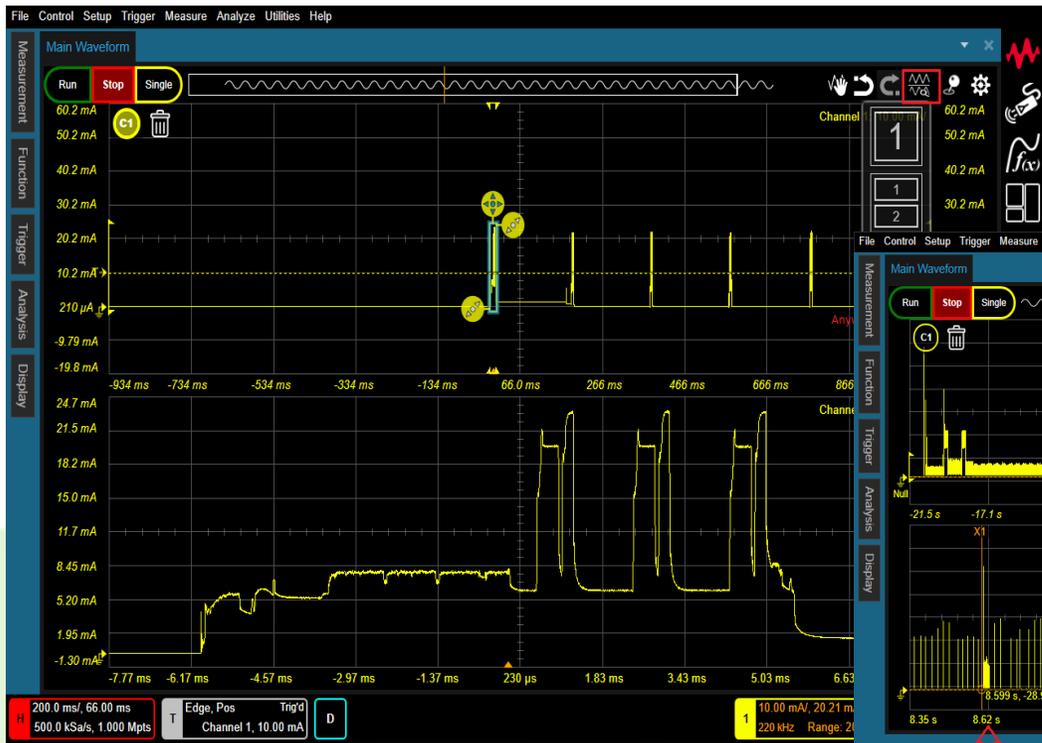
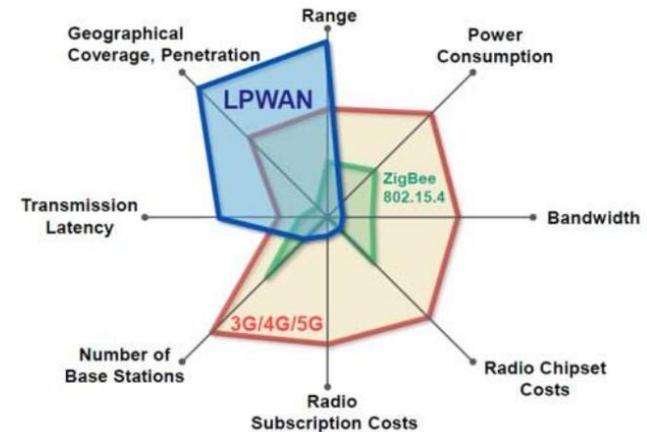


处理器电流特征：
带宽高、动态大、低噪声
测试要求，测量瞬间大电流时，同时测量小信号。

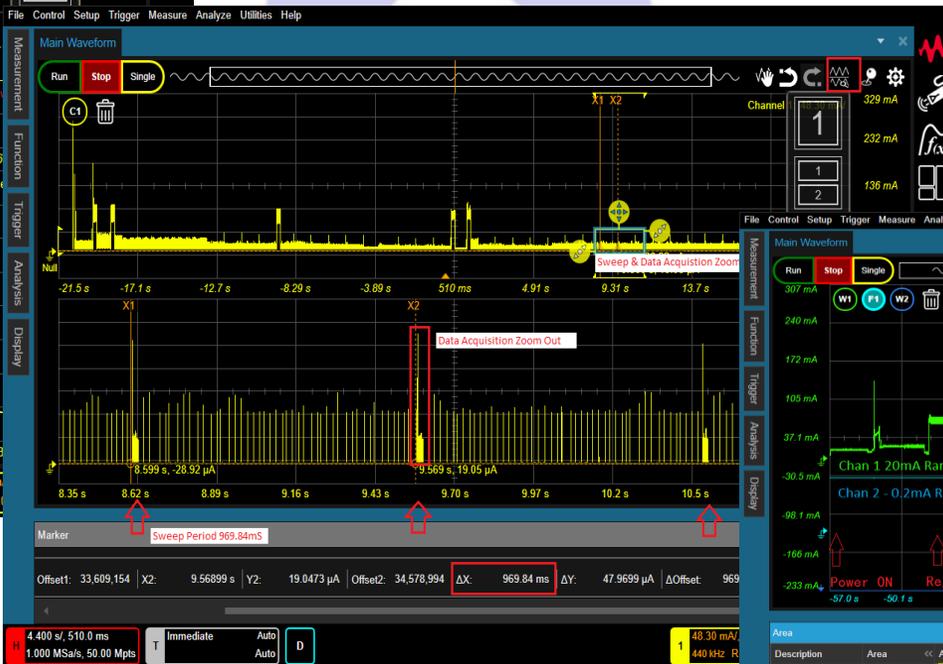


CX3324A 配合CX1105A实测结果

CX3300典型应用2——无线模块功耗分析



BLE蓝牙电流表波形



Lora电流表波形



NB-IoT电流表波形

CX3300 电流波形分析仪综述

CX3322A 2 通道
CX3324A 4 通道
CX1101A
CX1102A
CX1103A
CX1104A
CX1105A
CX1151A
CX1152A

新品种



洞察秋毫，电流测试专家

连接灵活

- ✓ 支持多种电流范围和接入方式的适配器
- ✓ 单端、差分电压探头
- ✓ 数字和逻辑探头



高性能

- ✓ 1GSa/s采样，200MHz带宽
- ✓ 14/16比特分辨率
- ✓ 电流范围100A至150pA
- ✓ 低至150pA电流噪声
- ✓ 低至400nV电压噪声

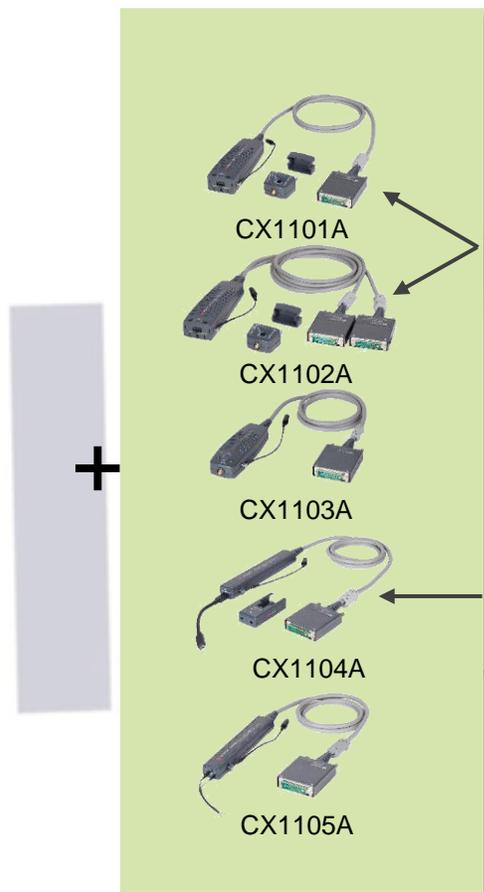
易用、高效

- ✓ Window操作系统
- ✓ 14.1英寸电容多点触屏
- ✓ 一键式“功耗特征提取”
- ✓ 自动波形存储
- ✓ 区域测量
- ✓ 任意区域放大

CX3300 构成及配置



主机



电流及差分电压探头



CX1100 电流探头系列

Sensor	Image in new color	Features	Key applications
CX1101A Single Channel Current Sensor		<ul style="list-style-type: none"> • 40 nA to 1 A (10 A) • 100 MHz • +/-40 V 	<ul style="list-style-type: none"> • General purpose • IoT, Wearable, Medical • Sensor • Semiconductor
CX1102A Dual Channel Current Sensor		<ul style="list-style-type: none"> • 40 nA to 1 A • 100 MHz • +/-12 V 	<ul style="list-style-type: none"> • IoT, Wearable, Medical
CX1103A Low Side 100 pA Current Sensor		<ul style="list-style-type: none"> • 150 pA to 20 mA • 200 MHz • +/-0.5 V 	<ul style="list-style-type: none"> • On wafer semiconductor device • NVM (ReRAM, PRAM, MRAM) • Display devices (OLED)
CX1104A Selectable Shunt Current Sensor		<ul style="list-style-type: none"> • 1 μA to 15 A • 20 MHz • +/-40 V 	<ul style="list-style-type: none"> • General purpose • WiFi • Actuator, Sensor,
CX1105A Ultra-Low Noise Differential Sensor		<ul style="list-style-type: none"> • 1 μA to 100 A • 100 MHz • +/-40 V / 6 V 	<ul style="list-style-type: none"> • Mobile device, SoC, FPGA, APU, MPU, • ECU • Semiconductor

CX1101A-03A小电流探头

表 6. CX1101A 电流传感器, 单通道, ± 40 V, 100 MHz, 40 nA 至 1 A

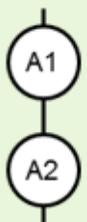
通道	范围	噪声有效值 ¹	最大带宽 (-3 dB)	输入电阻 (典型值)	最大共模电压
	10 A	10 mA	3 MHz ²	15 m Ω	
	1 A	2 mA			
	200 mA	0.2 mA	100 MHz	410 m Ω	
	20 mA	20 μ A			
	2 mA	3 μ A			± 40 V
	200 μ A	500 nA ⁵	500 kHz ⁵		
		400 nA ³	25 kHz ³		
	20 μ A	150 nA ⁵	500 kHz ⁵	50 Ω	
		40 nA ³	25 kHz ³		

CX1101A 通用型探头



- ✓ 占用CX3300一个通道
- ✓ 最大带宽: 100 MHz
- ✓ 测量范围: 40nA to 10A
- ✓ 浮地电压: ± 40 V
- ✓ 配合转接头使用

CX1102A 双量程探头



- ✓ 占用CX3300 两个通道
- ✓ 最大带宽: 100 MHz
- ✓ 量程范围: 40nA to 1A
- ✓ 浮地电压: ± 12 V
- ✓ 支持更大的电流动态
- ✓ 配合转接头使用

更高动态电流测量 (100dB)

CX1103A 小电流探头



- ✓ 占用CX3300一个通道
- ✓ 最大带宽: 200 MHz
- ✓ 测量范围: 150pA至20mA
- ✓ 浮地电压: ± 0.5 V
- ✓ 固定的 SMA端子

低噪声(nA)
&
高带宽 (200MHz)

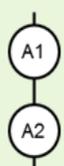
CX1102A 扩展动态电流测量

2 mA 3 μ A

CX1101A



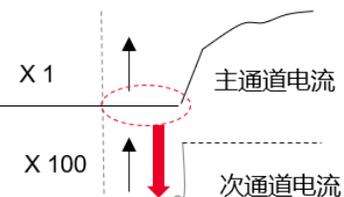
CX1102A 双量程探头



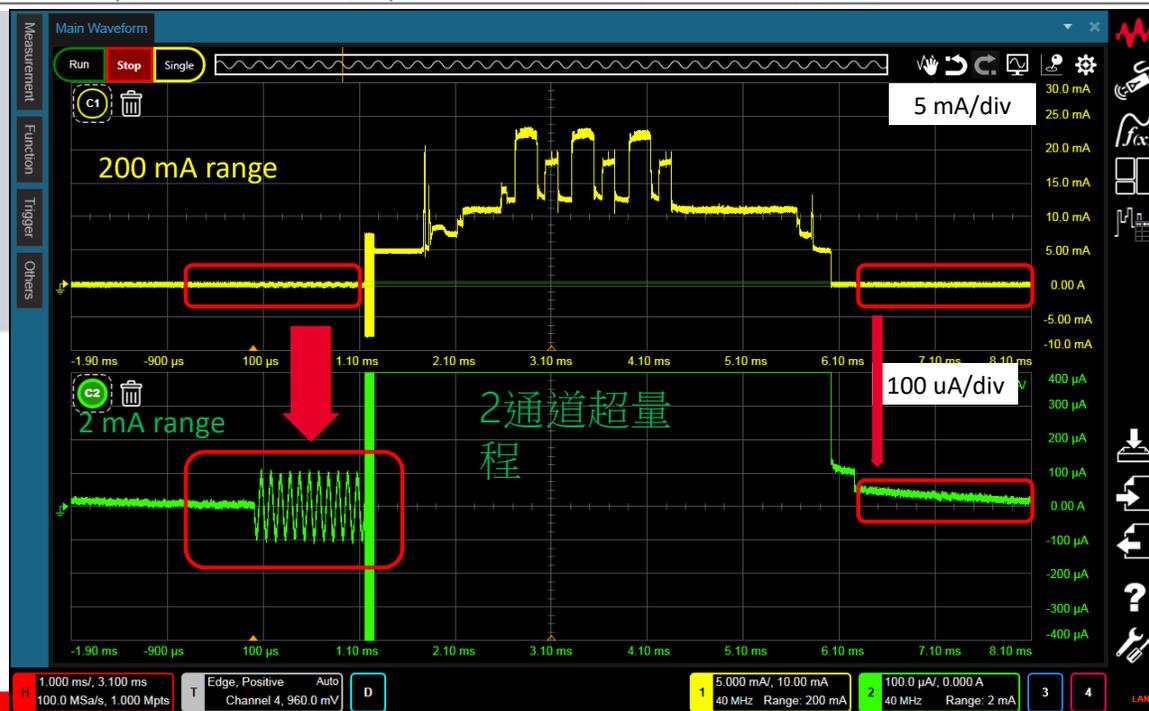
- ✓ 占用CX3300 两个通道
- ✓ 最大带宽: 100 MHz
- ✓ 量程范围: 40nA to 1A
- ✓ 浮地电压: +/-12V
- ✓ 支持更大的电流动态
- ✓ 配合转接头使用

更高动态电流测量 (100dB)

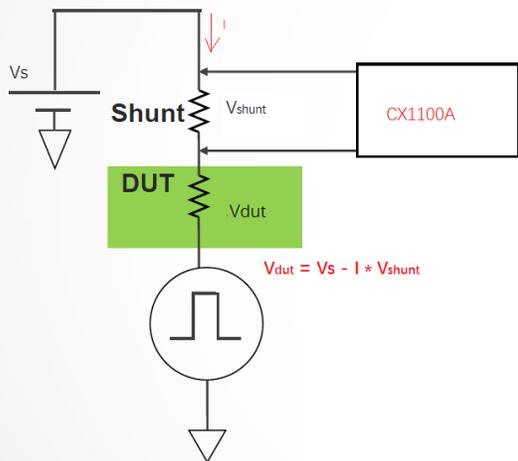
100 dB 测量动态



主通道		辅助通道		最大带宽 (-3 dB)	输入电阻 (典型值)	最大共模电压
范围	噪声有效值 ¹	范围	噪声有效值 ¹			
1 A	2 mA	20 mA	20 μ A	100 MHz	410 m Ω	\pm 12 V
200 mA	0.2 mA	2 mA	3 μ A			
20 mA	20 μ A	200 μ A	500 nA	500 kHz	50 Ω	
2 mA	2 μ A	20 μ A	200 nA			
20 mA ³	8 μ A ³	200 μ A ³	400 nA ³	90 kHz ³		
2 mA ³	1 μ A ³	20 μ A ³	40 nA ³	25 kHz ³		



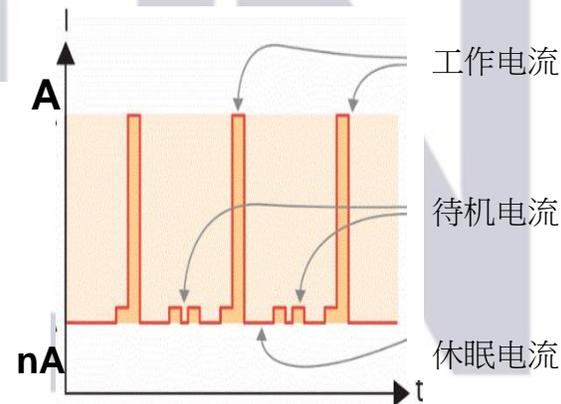
CX1104A大电流可选取样电阻值 (5.5mΩ-1.0Ω)



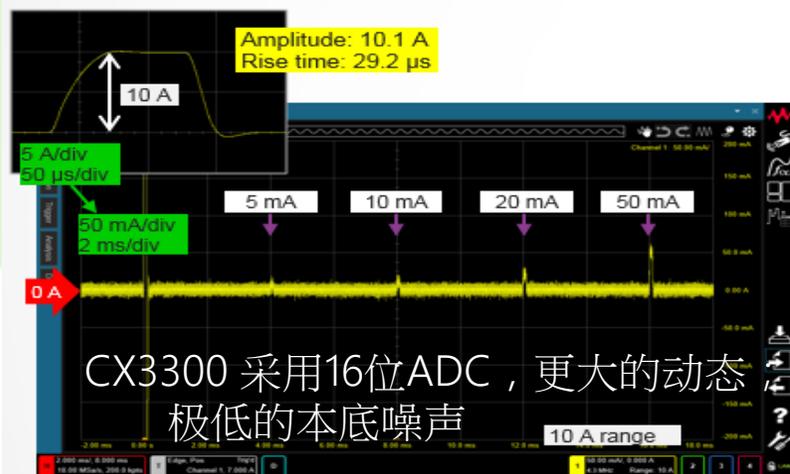
Resistive Sensor Head	Range (Upper /Lower)	Typical R_{IN}^1	Noise (rms) @20 MHz NBW	Noise (rms) @2.5 kHz NBW ²	Maximum Bandwidth (-3 dB) ³
CX1211A	15.0 A 10.0 A	5.5 mΩ	48 mA 8.8 mA	1.6 mA 160 μA	20 MHz
CX1212A	10.0 A 5.0 A	8.0 mΩ	24 mA 4.4 mA	800 μA 80 μA	
CX1213A	5.0 A 1.25 A	23 mΩ	6.0 mA 1.1 mA	200 μA 20 μA	
CX1214A	3.0 A 500 mA	53 mΩ	2.4 mA 440 μA	80 μA 8.0 μA	
CX1215A	2.0 A 250 mA	103 mΩ	1.2 mA 220 μA	40 μA 4.0 μA	
CX1216A	250 mA 25 mA	1.0 Ω	120 μA 22 μA	4.0 μA 400 nA	

- R_{shunt} 大，小电流测量分辨率、精度高；但 V_{dut} 上压降大，影响DUT工作。
- R_{shunt} 小， V_{dut} 上压降小；但小电流测量分辨率，测试精度差。

处理器通常都是如下图的动态电流：



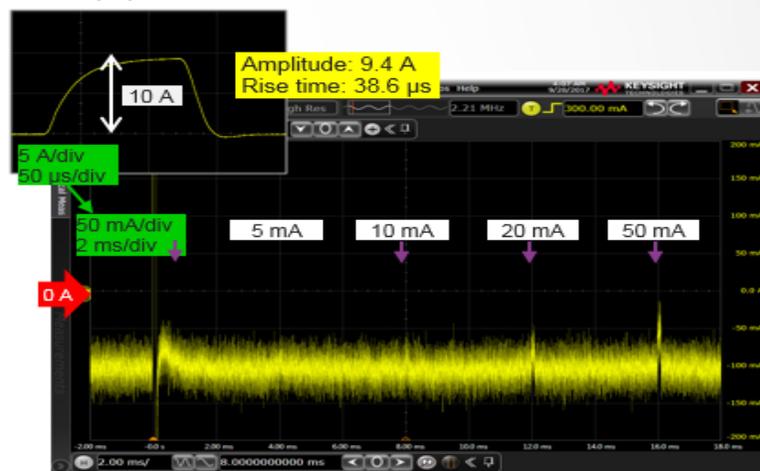
Keysight CX3324A with CX1104A/CX1121A($R_{in}=5.5\text{ m}\Omega$)
(Measure with 10 MSa/s, 5 A/div)



CX3300 采用16位ADC，更大的动态极低的本底噪声

- Clean 10 A pulse waveform
- Lower noise floor
- Smaller offset current

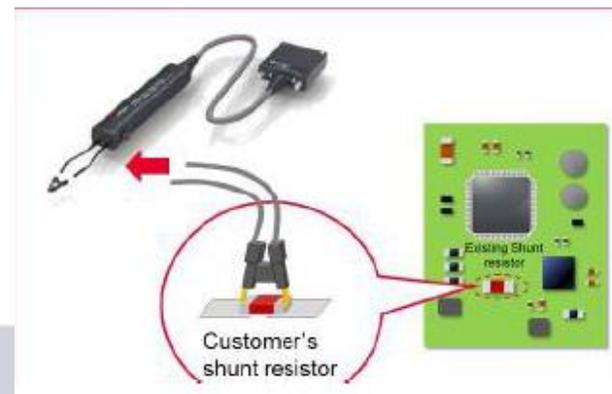
Tektronix TCP312A current probe
High Res, 5 A/div with Keysight a S-Series oscilloscope)



洽詢專線: 02-2278-9886

CX1105A 差分电压（电流）探头——直接使用电路板上的电阻取样

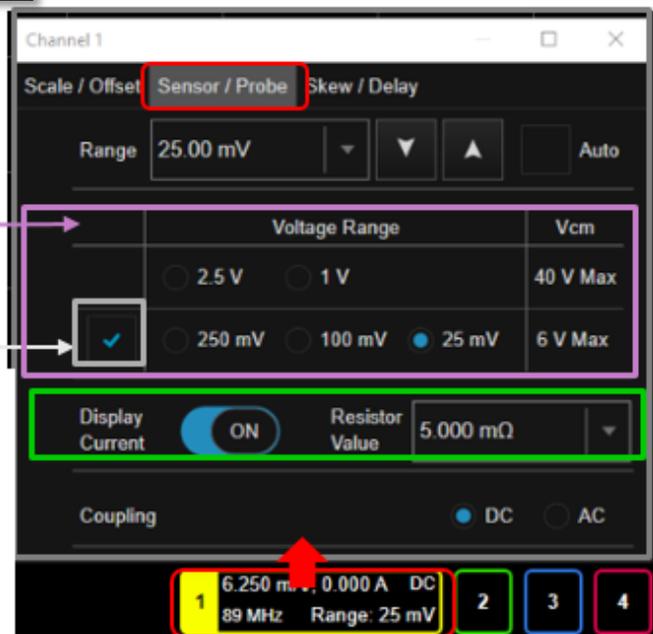
CX1105A			
Range	Noise (typ.; rms) @20 MHz NBW	Noise (typ.; rms) @2.5 kHz NBW	V _{CM}
2.5 V	1100 μV	200 μV	40 V
1 V	1100 μV	200 μV	
250 mV	45 μV	3.0 μV	6 V
100 mV	24 μV	1.3 μV	
25 mV	20 μV	0.4 μV	



$$I = \frac{V_{diff}}{R_{shunt}}$$



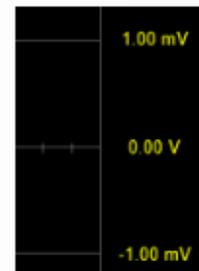
Check to enable the ranges those Max.



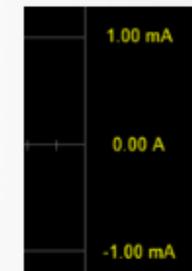
Display Current

- Off: Unit = Voltage
- On: Unit = Current calculated by V_{diff} / Resistor Value

Off

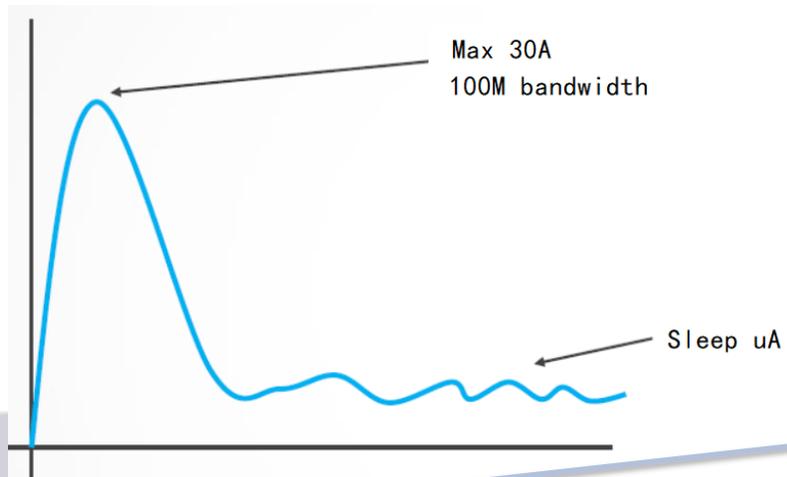


On



CX1105A 取样电阻的选取 ?

Shunt R	Range	Current range	Noise (rms) @20 MHz NBW	Noise (rms) @2.5 kHz NBW
2.5 mΩ	2.5 V	1000 A	440 mA	80 mA
	1 V	400 A	440 mA	80 mA
	250 mV	100 A	18 mA	1.2 mA
	100 mV	40 A	9.6 mA	0.52 mA
5 mΩ	25 mV	10 A	8 mA	0.16 mA
	2.5 V	500 A	220 mA	40 mA
	1 V	200 A	220 mA	40 mA
	250 mV	50 A	9 mA	0.6 mA
50 mΩ	100 mV	20 A	4.8 mA	0.26 mA
	25 mV	5 A	4 mA	0.08 mA
	2.5 V	50 A	22 mA	4 mA
	1 V	20 A	22 mA	4 mA
100 mΩ	250 mV	5 A	900 μA	60 μA
	100 mV	2 A	480 μA	26 μA
	25 mV	500 mA	400 μA	8 μA
	2.5 V	25 A	11 mA	2 mA
1 Ω	1 V	10 A	11 mA	2 mA
	250 mV	2.5 A	450 μA	30 μA
	100 mV	1 A	240 μA	13 μA
	25 mV	250 mA	200 μA	4 μA
	2.5 V	2.5 A	1.1 mA	0.2 mA



取样电阻 : 50mΩ

2.5V量程, 测量 50A

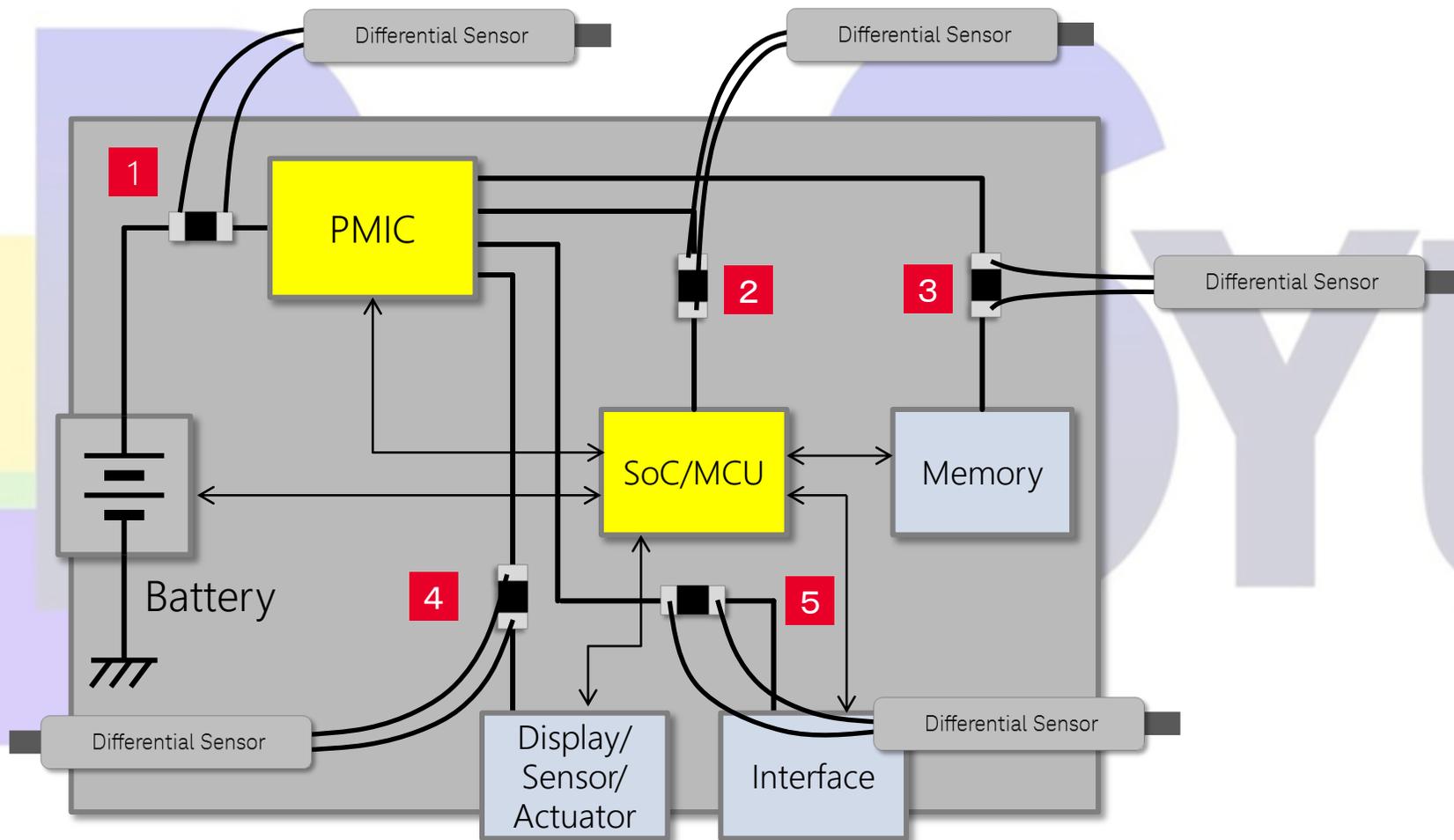
← Max. 30A with wider bandwidth

← Low current meas. with 2.5 kHz bandwidth

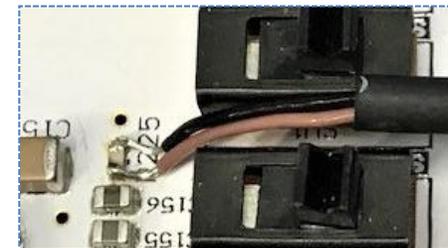
25mV量程, 测量 10uA



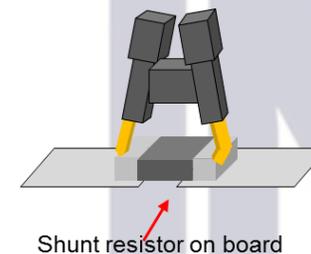
CX1105A方便电路的调试和分布式电流测量



某客户评估板测试样例



焊接引线



插针引线

CX3300分析功能之1——丰富的测量功能

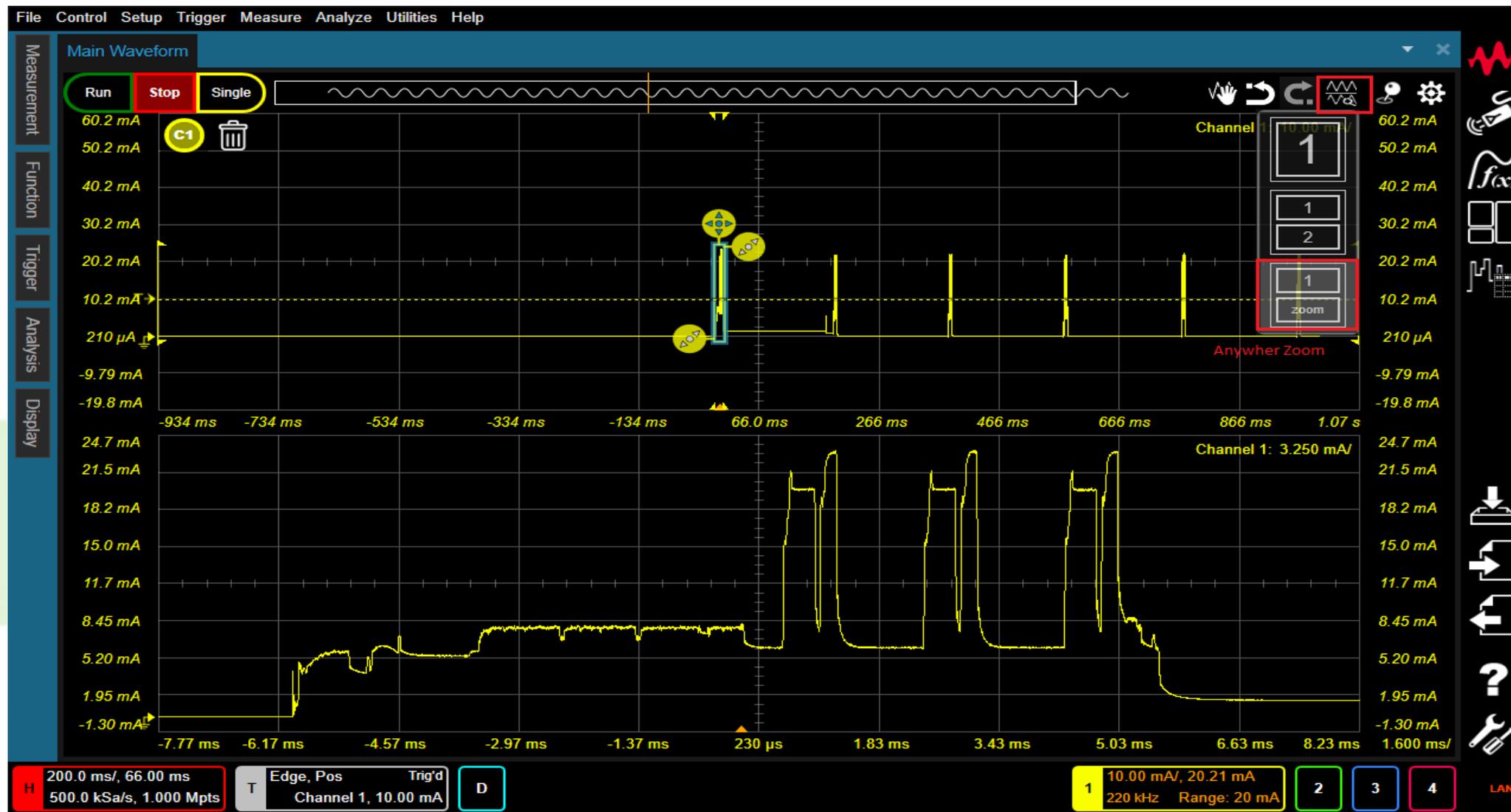
The screenshot displays the Keysight CX3300 oscilloscope software interface, highlighting its rich measurement capabilities. The interface is organized into several panels:

- Measurement Panel:** Features tabs for Time, Vertical, and Mixed. It includes icons for Rise time, Fall time, + width, - width, Period, Frequency, Duty cycle, T min, T max, and Slow rate.
- Function Panel:** Offers Math and Filter options, with icons for Smooth and other mathematical functions.
- Analysis Panel:** Contains icons for Area, Histogram, CCDF, FFT, Spectrum, Memory, Profiler, and XY.
- Display Panel:** Includes Markers, Annotations, Persistence, Plot Axis, and Waveform Memories. It also features grid settings for Auto, Linear, Log, and Invert, with options for X1 and Y1, X1, Y1 and Y2, and Show All.

Yellow boxes highlight specific features: the 'Area' icon in the Analysis panel, the 'Memory' icon in the Analysis panel, the 'OFF' button in the Display panel, and the 'X1, Y1 and Y2' grid option in the Display panel.

IN

CX3300分析功能之2——任意区域放大



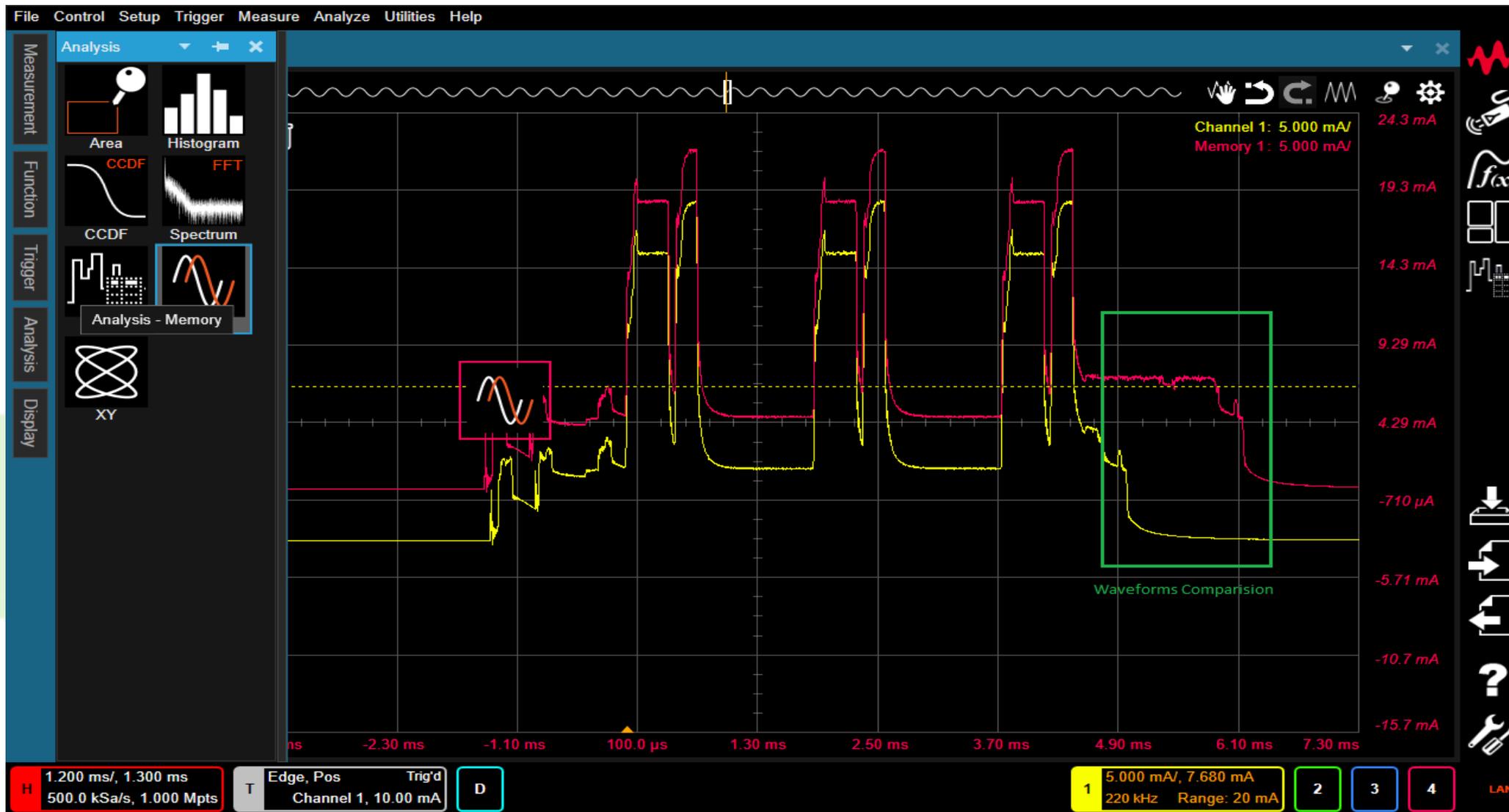
N

CX3300分析功能之3——区域测量光标



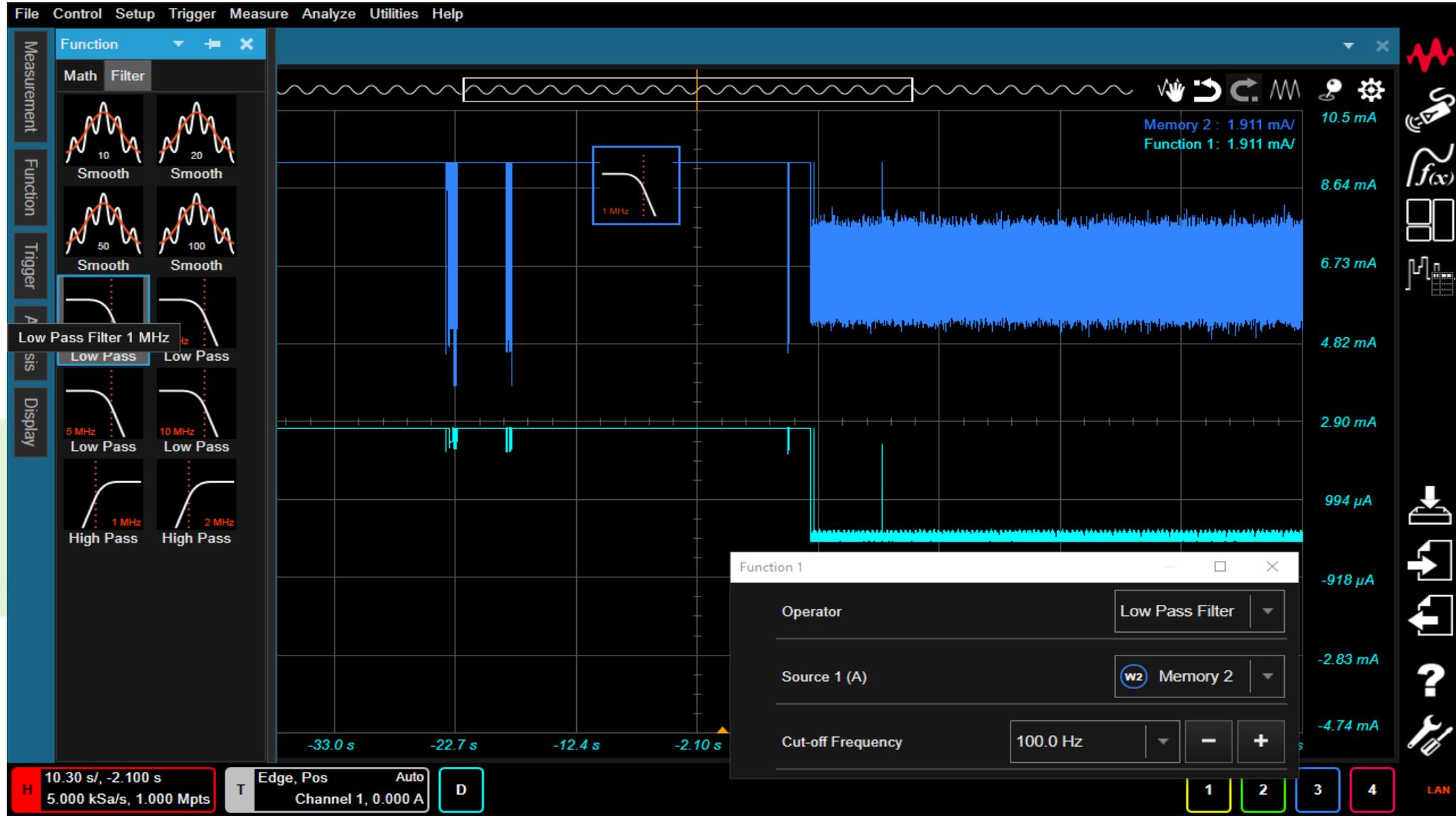
洽詢專線: 02-2278-9886

CX3300分析功能之4——波形存储和比较



N

CX3300分析功能之5——滤波和平滑



CX3300分析功能之6——触发及波形自动存储



File Control Setup Trigger Measure Analyze Utilities Help

Main Waveform

Run Stop Single

Load

File Selection

Look In... C:\Users\Administrator\Desktop\Shanghai Telecom NB_IoT20 Back Up

Name	Size	Type	Modified
cx3300_0.cxcomp	185.37 MB	CXCOMP File	4/24/2018 11:13:26 AM
cx3300_1.cxcomp	185.37 MB	CXCOMP File	4/24/2018 11:15:28 AM
cx3300_2.cxcomp	185.37 MB	CXCOMP File	4/24/2018 11:18:36 AM
cx3300_3.cxcomp	185.37 MB	CXCOMP File	4/24/2018 11:20:36 AM

File Type - Composite

Composite (Setup and Waveforms)

Model CX3324A
 Serial MY56160177
 Revision 2.0.1811.17985
 Sampling Rate 200.0 kSa/s
 Memory Depth 24.00 Mpts
 Channel 1 CX1101A
 Channel 2 CX1102A
 Channel 3 CX1102A-2
 Channel 4 CX1151A

Hardware configuration is incompatible

Preview

Run after loading Load

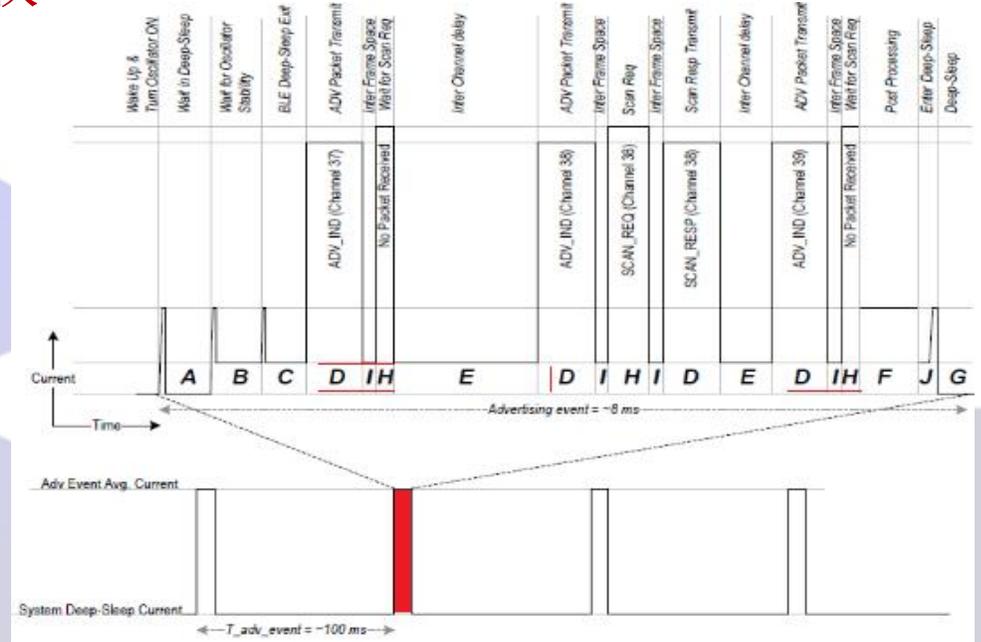
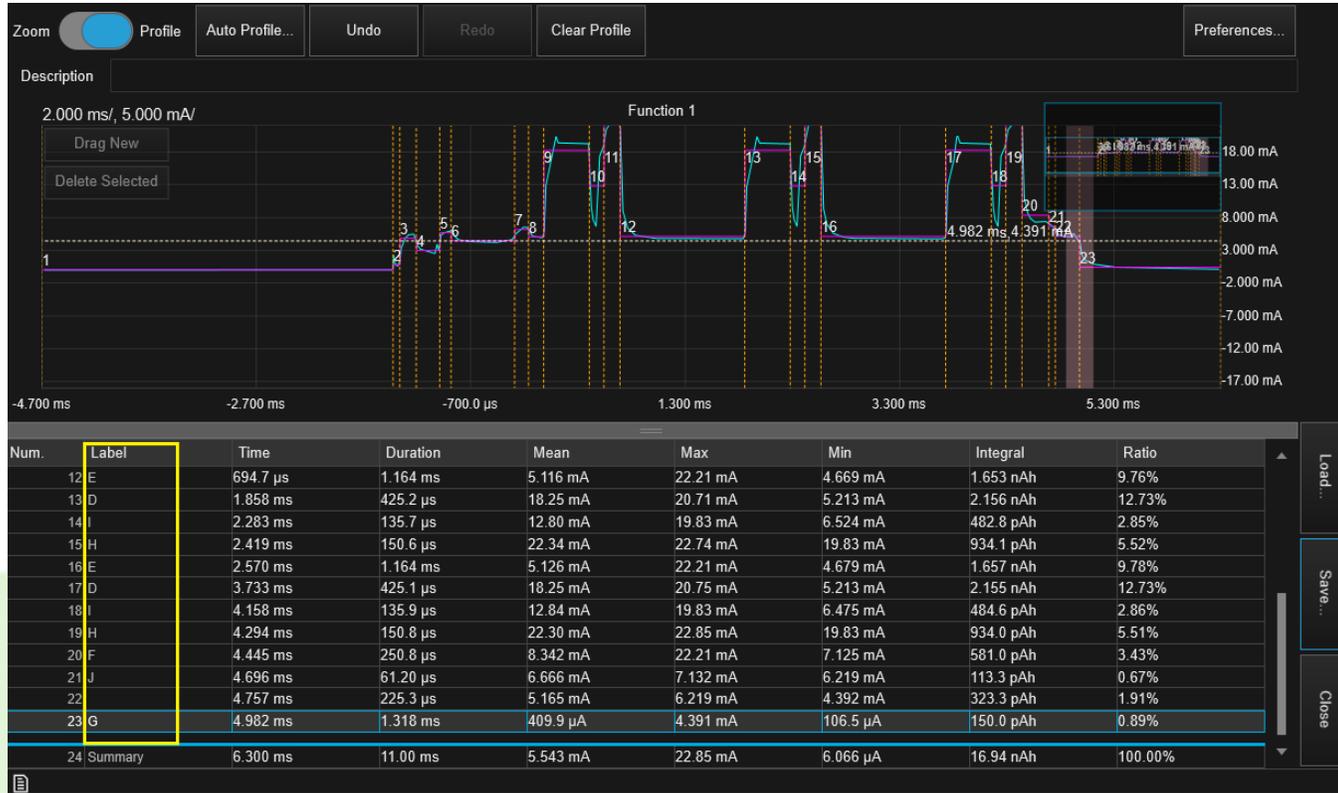
Auto Save : 0

C:\Users\Administrator\Documents\Keysight\Cx3300\Waveforms

H 6.700 s/, -18.50 s 1.000 GSa/s, 20.00 kpts T Edge, Pos Auto Channel 1, -187.0 mA D 250.0 mA/, -91.00 mA 89 MHz Range: 1 A 2.000 V/, -730.0 mV DC 170 MHz Range: 8 V 3 4 LAN

JIN

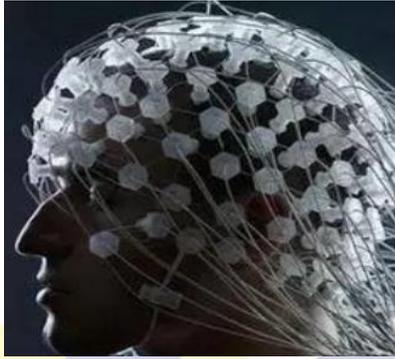
CX3300分析功能之7——自动功率特征提取



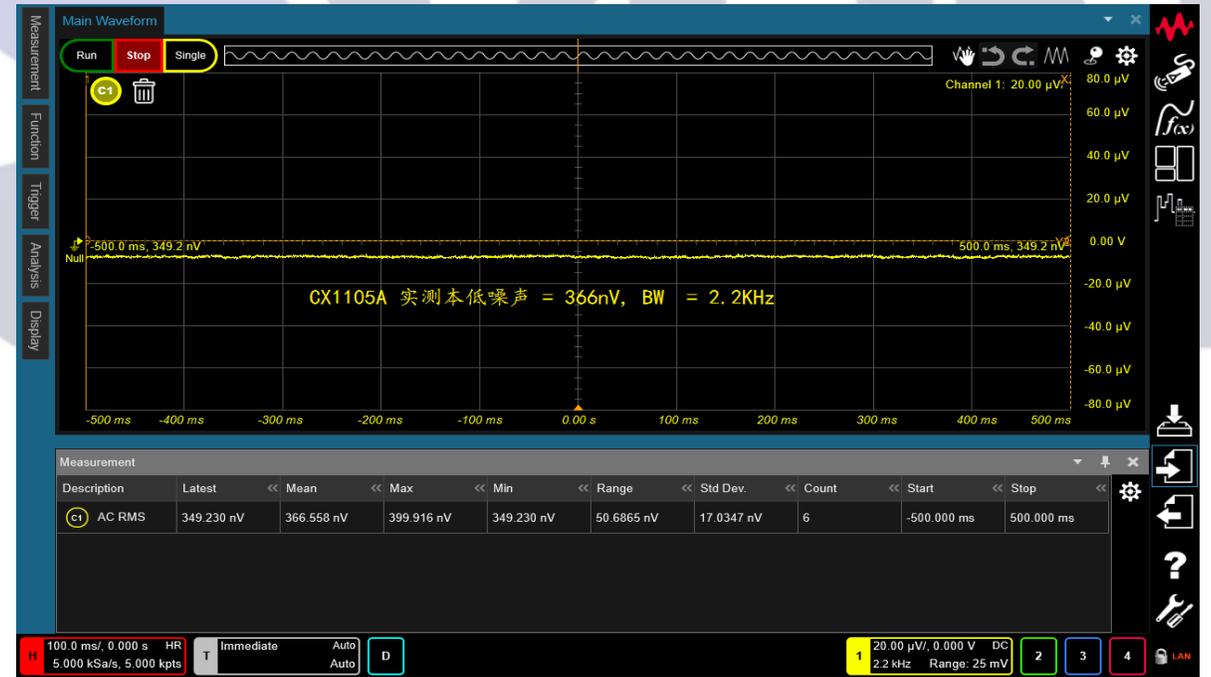
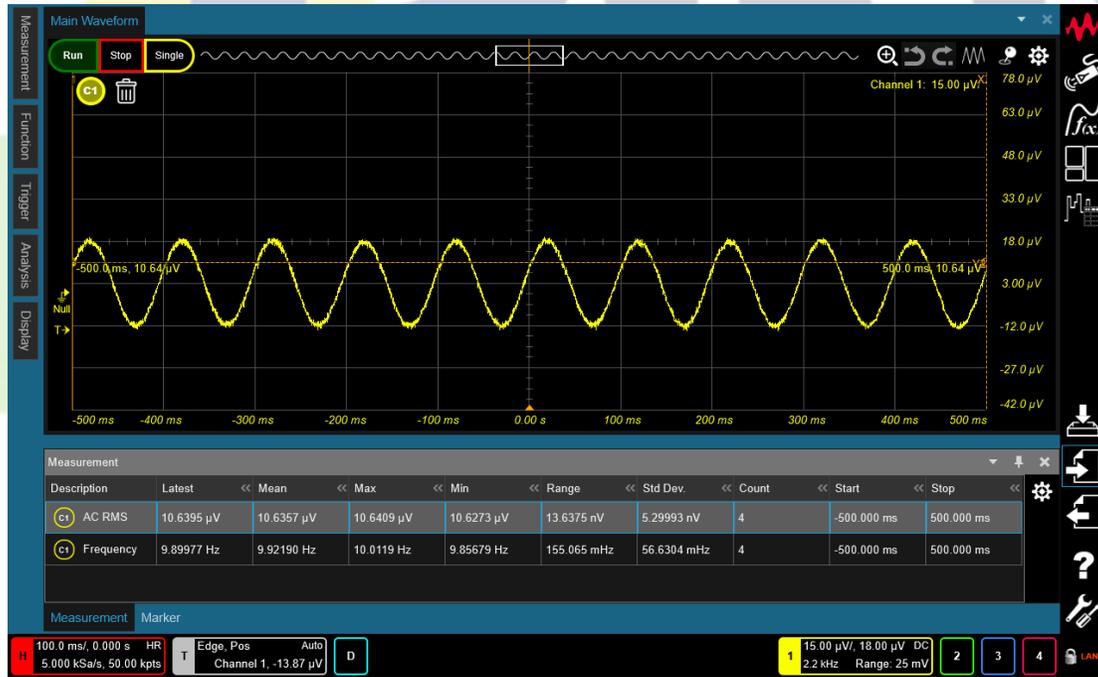
Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1	G	-4.700 ms	3.278 ms	19.16 µA	641.5 µA	6.066 µA	17.45 pAh	0.103013039201076
2		-1.422 ms	61.55 µs	779.7 µA	2.632 mA	117.9 µA	13.33 pAh	0.078713455716623
3	A	-1.361 ms	154.8 µs	4.836 mA	5.748 mA	645.3 µA	207.9 pAh	1.22762067801367
4		-1.206 ms	218.5 µs	2.977 mA	4.392 mA	2.413 mA	180.7 pAh	1.0666769895589
5	B	-987.5 µs	106.2 µs	5.680 mA	6.268 mA	3.386 mA	167.6 pAh	0.989469479427403
6		-881.3 µs	592.7 µs	4.476 mA	6.219 mA	4.167 mA	736.9 pAh	4.35109436548513
7	C	-288.7 µs	130.5 µs	6.177 mA	6.829 mA	5.213 mA	224.0 pAh	1.3223285277801
8		-158.1 µs	140.5 µs	5.071 mA	6.219 mA	4.823 mA	197.9 pAh	1.16859763198462
9	D	-17.65 µs	425.9 µs	18.24 mA	20.71 mA	5.214 mA	2.157 nAh	12.735953517051
10	I	408.2 µs	136.4 µs	12.81 mA	19.83 mA	6.488 mA	485.5 pAh	2.86650906108633
11	H	544.6 µs	150.0 µs	22.17 mA	22.69 mA	19.83 mA	923.8 pAh	5.45444247378647
12	E	694.7 µs	1.164 ms	5.116 mA	22.21 mA	4.669 mA	1.653 nAh	9.76268333608989
13	D	1.858 ms	425.2 µs	18.25 mA	20.71 mA	5.213 mA	2.156 nAh	12.729655531646
14	I	2.283 ms	135.7 µs	12.80 mA	19.83 mA	6.524 mA	482.8 pAh	2.85046907654618
15	H	2.419 ms	150.6 µs	22.34 mA	22.74 mA	19.83 mA	934.1 pAh	5.51547373406242
16	E	2.570 ms	1.164 ms	5.126 mA	22.21 mA	4.679 mA	1.657 nAh	9.78142481519876
17	D	3.733 ms	425.1 µs	18.25 mA	20.75 mA	5.213 mA	2.155 nAh	12.7253801158914
18	I	4.158 ms	135.9 µs	12.84 mA	19.83 mA	6.475 mA	484.6 pAh	2.86142344191701
19	H	4.294 ms	150.8 µs	22.30 mA	22.85 mA	19.83 mA	934.0 pAh	5.51482501259325
20	F	4.445 ms	250.8 µs	8.342 mA	22.21 mA	7.125 mA	581.0 pAh	3.43066259796706
21	J	4.696 ms	61.20 µs	6.666 mA	7.132 mA	6.219 mA	113.3 pAh	0.669089236464189
22		4.757 ms	225.3 µs	5.165 mA	6.219 mA	4.392 mA	323.3 pAh	1.908671886809
23	G	4.982 ms	1.318 ms	409.9 µA	4.391 mA	106.5 µA	150.0 pAh	0.885821995723497
24	Summary	6.300 ms	11.00 ms	5.543 mA	22.85 mA	6.066 µA	16.94 nAh	100

CX3300他们在这样用.....

脑电波传感器检测



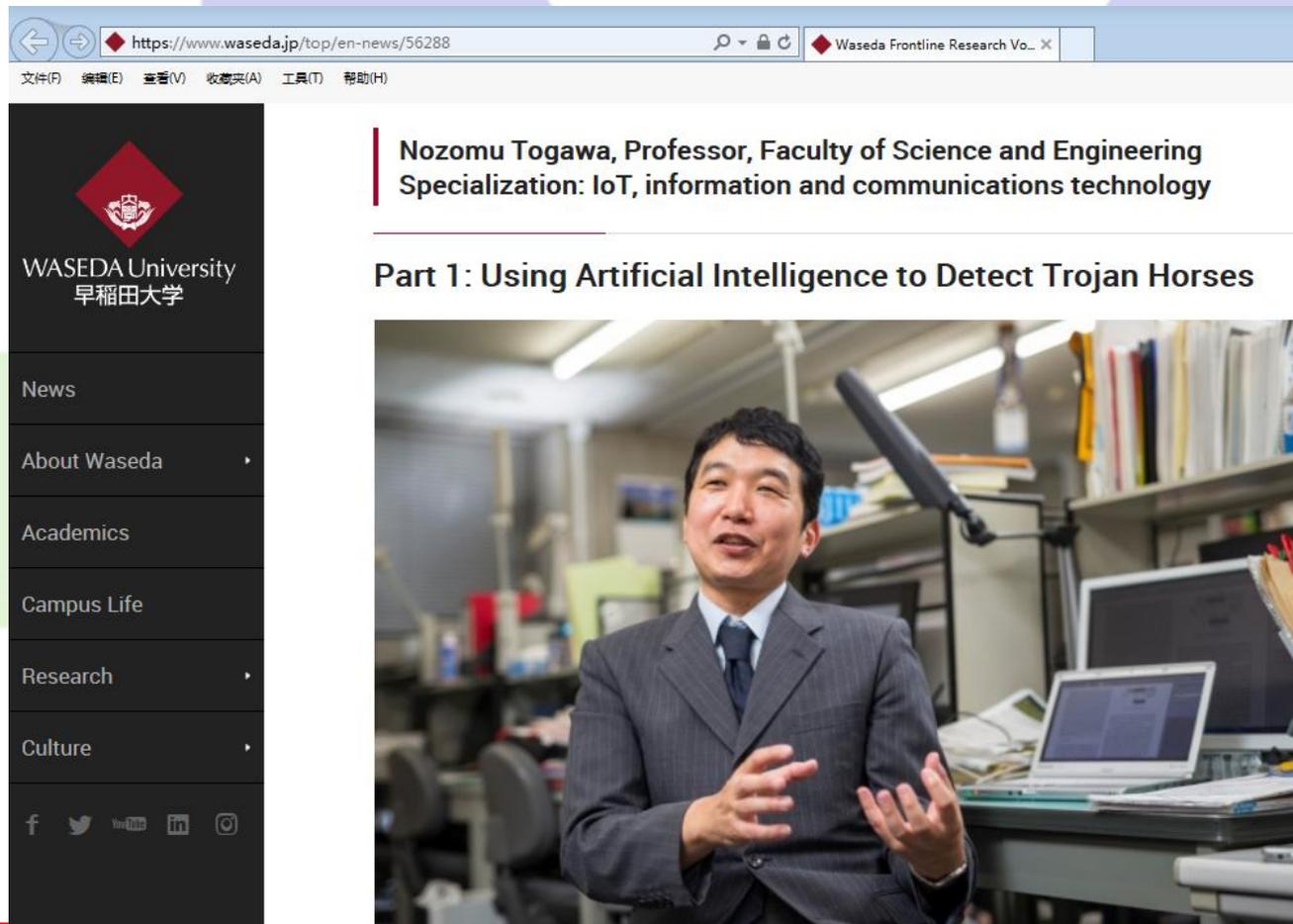
实测uV级别刺激电压信号数据：
信号幅度 (RMS) : 10.639uV
CX3300 + CX1105A本底噪声
(BW = 2.2KHz) : 366nV



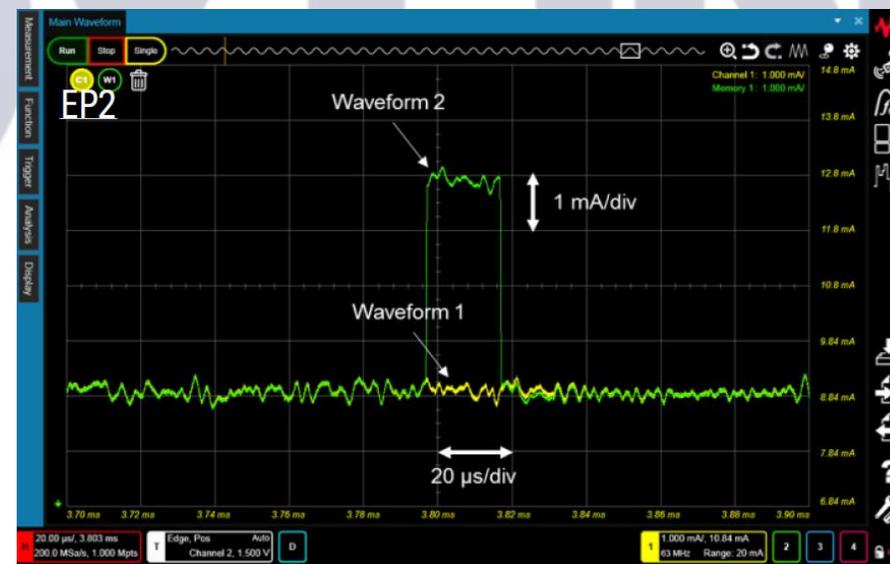
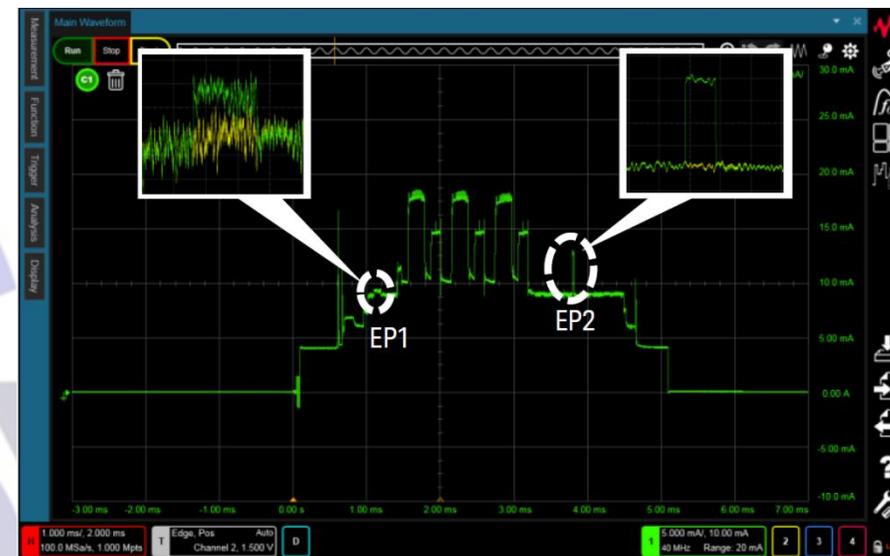
CX3300他们在这样用.....

早稻田大学，Nozomu Togawa教授，关于人工智能设备木马检测的研究：

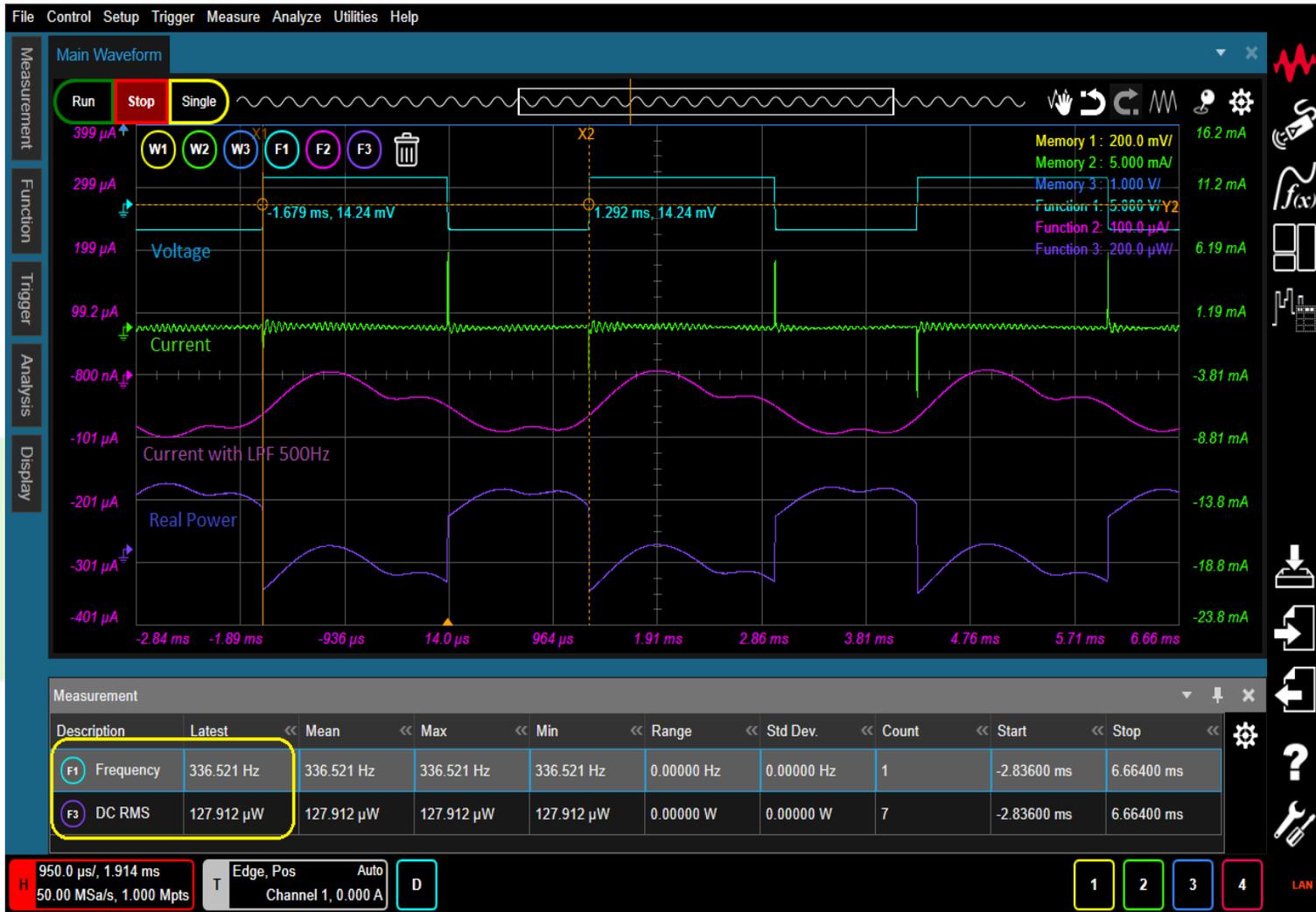
<https://www.waseda.jp/top/en-news/56288>



人工智能木马检测

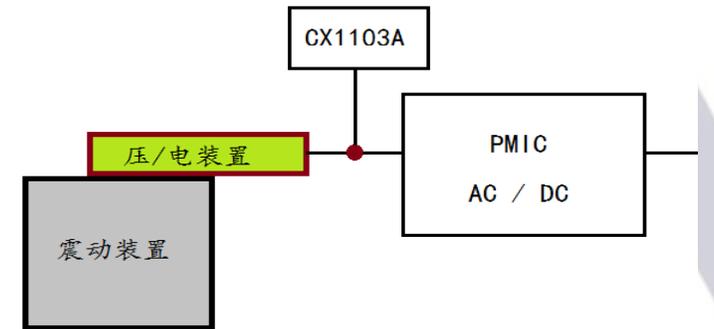


CX3300他们在这样用.....



微弱震动或无线RF能量收集

该装置电路的测试数据：
 主频率：336/52 Hz
 平均功率(RMS)：127uW
 峰值电流：5.24mA
 次频率：18.67KHz



无线广播RF能量收集

CX3300他们在这样用.....

学术界应用摘要

CX3324A - Google 学术...

Google 学术搜索 CX3324A

文章 找到约 16 条结果 (用时0.07秒)

时间不限
2019以来
2018以来
2015以来
自定义范围...

按相关性排序
按日期排序

不限语言
中文网页
简体中文网页

包括专利
 包含引用

创建快讯

Accurate error bit mode analysis of STT-MRAM chip with a novel current measurement module implemented to gigabit class memory test system
R Tamura, I Mori, N Watanabe... - 2018 Non-Volatile ... - 2018 - ieeexplore.ieee.org
... The developed current module and the device current waveform analyzer (Keysight Technologies CX3324A) are serially connected to pseudo-DUT ... The pulse current is simultaneously measured by the current measurement module and CX3324A. Fig ...
☆ 00 相关文章

Evaluation of drain current decrease by AC gate bias stress in commercially available SiC MOSFETs
M Sometani, Y Iwahashi, M Okamoto... - ... Devices and IC's ..., 2017 - ieeexplore.ieee.org
... Fig. 1. Schematic image of the novel measurement setup employing a device current waveform analyzer (Keysight CX3324A). Pulse generator Device current waveform analyzer (Keysight CX3324S) V D S G VDD Differential probe ...
☆ 00 相关文章

Three channel high dynamic current measurement system for low power systems
S Heller, I Nematollahi, S Koeble... - Journal of Physics ..., 2018 - iopscience.iop.org
... the energy demand. References [1] CX3324A/CX3324 Device Current Waveform Analyzer, datasheet, Keysight, 2017. [2] MSP430FR59xx Mixed-Signal Microcontrollers, datasheet, Texas Instruments, 2017. Figure 4. Output ...
☆ 00 被引用次数: 1 相关文章 所有 2 个版本

	Title	Link	Country	Company
1	Evaluation of drain current decrease by AC gate bias stress in commercially available SiC MOSFETs ——SiC MOSFETs器件漏电流-Gate端交流压力测试	http://ieeexplore.ieee.org/abstract/document/7989987/	Japan	National Institute of Advanced Industrial Science and Technology
2	Multiscale Co-Design Analysis of Energy, Latency, Area, and Accuracy of a ReRAM Analog Neural Training Accelerator —— ReRAM Analog 训练神经网络加速器在能量、延迟、区域及准确度的分析	https://arxiv.org/ftp/arxiv/papers/1707/1707.09852.pdf	U.S.	Sandia National Laboratories
3	Opto-Electronic Sensor Network Powered over Fiber for Harsh Industrial Applications ——新型光电传感器通过光纤供电在工业环境下的应用研究	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7995068	Germany	Budelmann Elektronik GmbH
4	Impact of Linearity and Write Noise in Analog Resistive Memory Devices in a Neural Algorithm Accelerator ——ReRAM 器件在神经网络算法加速器下的线性与写入噪声的影响	https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8103657	U.S.	Sandia National Laboratories
5	Development of an Evaluation Platform and Performance Experimentation of Flex Power FPGA Device ——Flex Power FPGA器件验证平台和性能实验的开发	https://www.jstage.jst.go.jp/article/transinf/E101/D/2/E101-D-2017BCP00037.pdf	Japan	National Institute of Advanced Industrial Science and Technology
6	Analysis of Lateral Thermal Coupling for GaN MMIC Technologies ——GaN MMIC器件热传导路径研究	https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8409464&tag=1	Sweden	Chalmers University
7	Energy/Reliability Trade-off of LoRa Communications over Fading Channels ——多径环境下LoRa 通信系统的功耗与可靠性评估	https://hal.archives-ouvertes.fr/hal-01816574/document	France	Univ Rennes
8	Accurate evaluation of fast threshold voltage shift for SiC MOS devices under various gate bias stress conditions —— SiC MOS器件在不同Gate偏置条件下快速门限电压切换精确度评估	http://iopscience.iop.org/article/10.7567/JAP.57.04FA07/pdf	Japan	National Institute of Advanced Industrial Science and Technology
9	Synaptic Barristor Based on Phase-Engineered 2D Heterostructures	https://onlinelibrary.wiley.com/doi/abs/10.1002/adma.201801447	Korea	KIST
10	Study of a low-power remote sensor node based on LoRa —— LoRa 网络中低功耗远程传感器的研究	https://webthesis.biblio.polito.it/7628/1/resi.pdf	Italy	POLITECNICO DI TORINO
11	Smart IoT Sensor With LwM2M Management ——智能IoT传感器LwM2M管理	http://wiki.hevs.ch/virt/images/e/ed/Smart_IoT_Sensor_With_LwM2M.pdf	Switzerland	University of Applied Sciences Western Switzerland
12	Compensation of Thermal Effects by Dynamic Bias in Low Noise Amplifiers ——利用动态偏置对低噪声放大器LNA进行热补偿	http://publications.lib.chalmers.se/records/fulltext/252232/252232.pdf	Sweden	Chalmers University of Technology
13	Artificial synapses emulated through a light mediated organic-inorganic hybrid transistor ——透过光媒有机-无机混合晶体管对人工神经元的评估	https://scholar.google.com/journal?hl=ja&as_sdt=0%2C5&q=CX3324A&btnG=	China	Institute for Advanced Study, Shenzhen University
14	A 13.56 MHz CMOS High-Efficiency Active Rectifier With Dynamically Controllable Comparator for Biomedical Wireless Power Transfer Systems ——基于13.56M CMOS 实现的高效无线功率传输WPT系统	https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8456497	Taiwan	Chang Gung University
15	Adaptive Source-FEC Coding for Energy-Efficient Surveillance Video Over Wireless Networks ——通过无线网络实现的能效监控视频的主动FEC编码	https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8226843	China	Beijing University

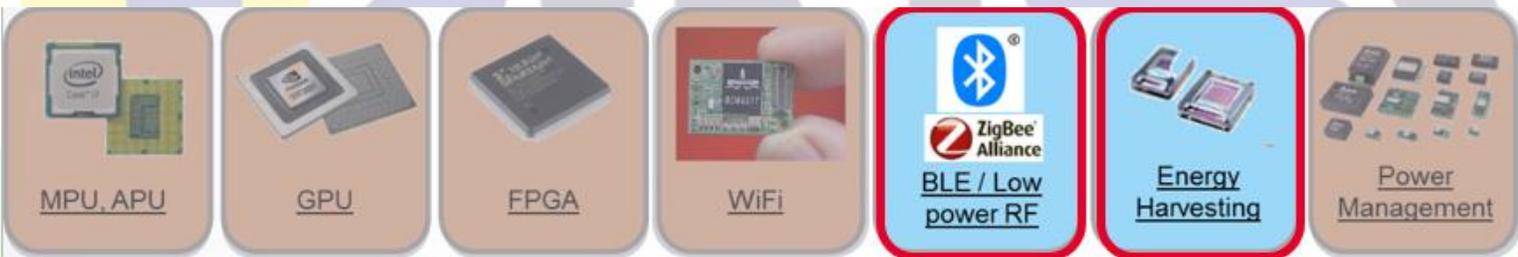
Google Scholar, 论文搜索 关键字 "CX3324A"

- Sic MOSFET
- ReRAM
- Opto-Electronic Sensor
- FPGA
- Gan MMIC
- Lora
- LNA
- Artificial Synapses
- Wireless Power Transfer
- Adaptive FEC Coding

建议使用CX3300.....



NVM存储材料、传感器、Wafer、低功耗处理器MCU



GPU、MPU、APU、FPGA高峰值电流的处理器，BLE/WiFi/LoRa等模



穿戴、医疗、AR/VR、智能手机、汽车电子产品



- ✓ 1GSa/s采样，200MHz带宽
- ✓ 14/16比特分辨率
- ✓ 电流范围100A至150pA
- ✓ 低至150pA电流噪声
- ✓ 低至400nV电压噪声

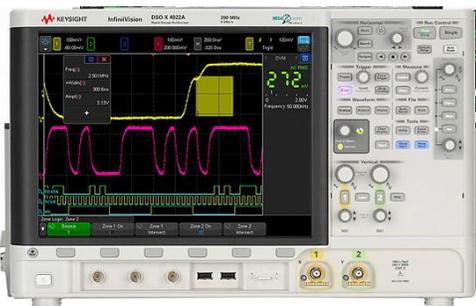
你最佳的电流测试方案？



B2900 SMU源表



B2980 皮安表



示波器



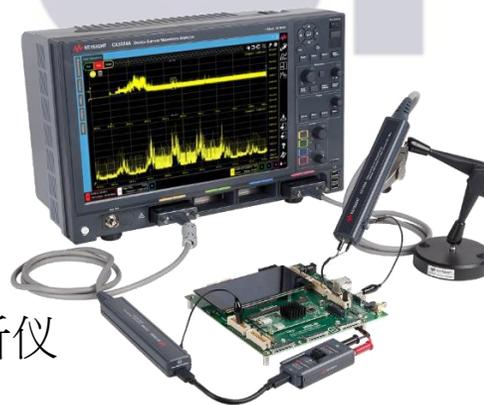
万用表



N6705C 直流源分析仪



功率分析仪PA2200



CX3300 器件
电流波形分析仪



Keysight 精密電流測量與 CX3300 器件電流波形分析儀

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www.pinsyun.com.tw

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