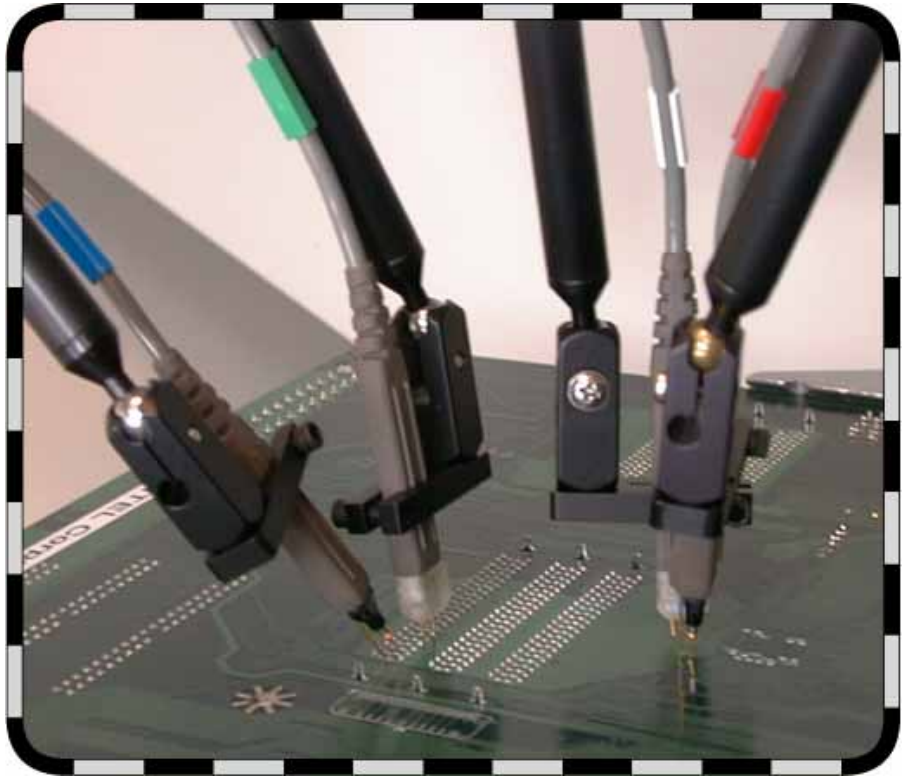
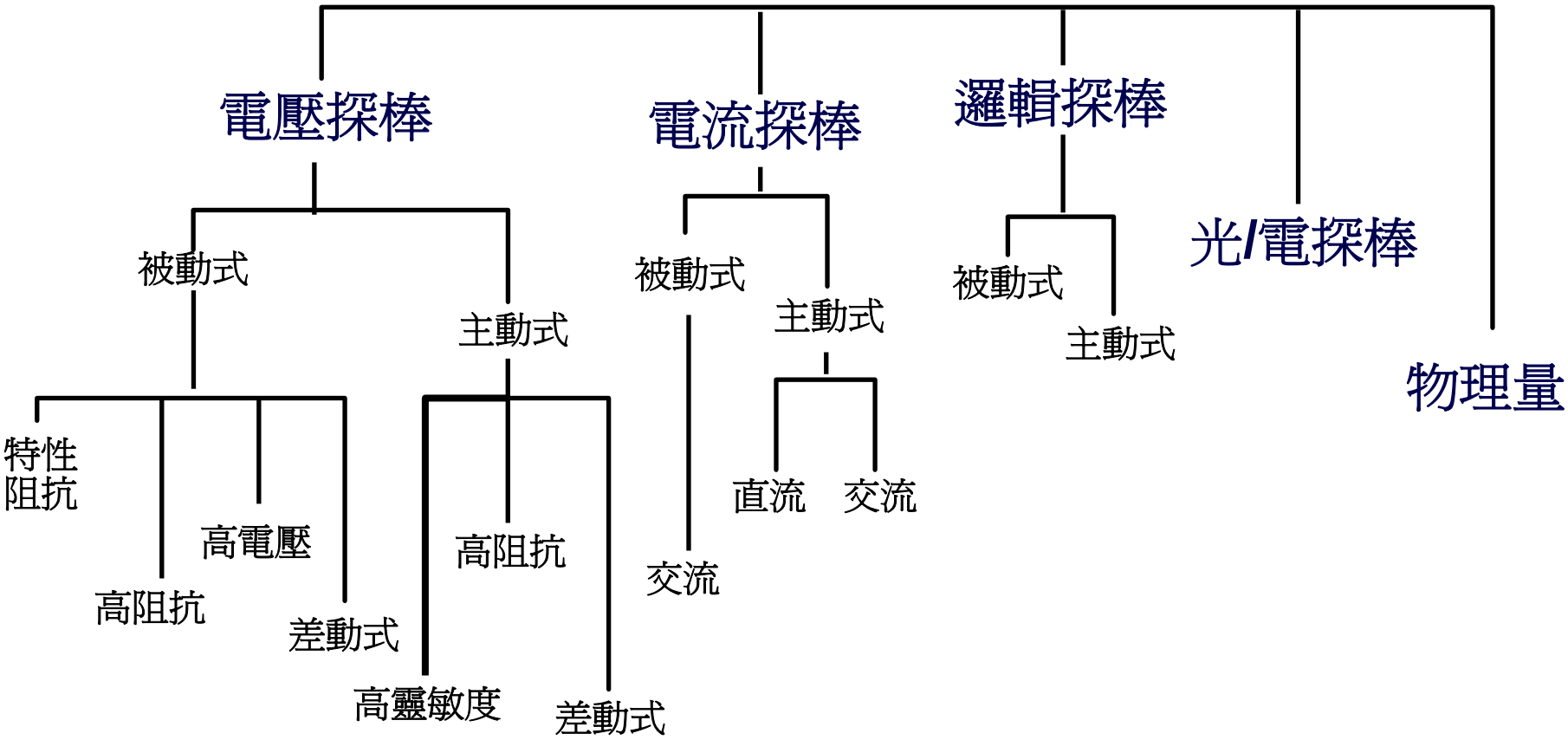
探棒的原理及種類

- 示波器功能的延伸
- 影響量測的準確性
- 不同的應用，搭配不同的探棒



探棒的種類

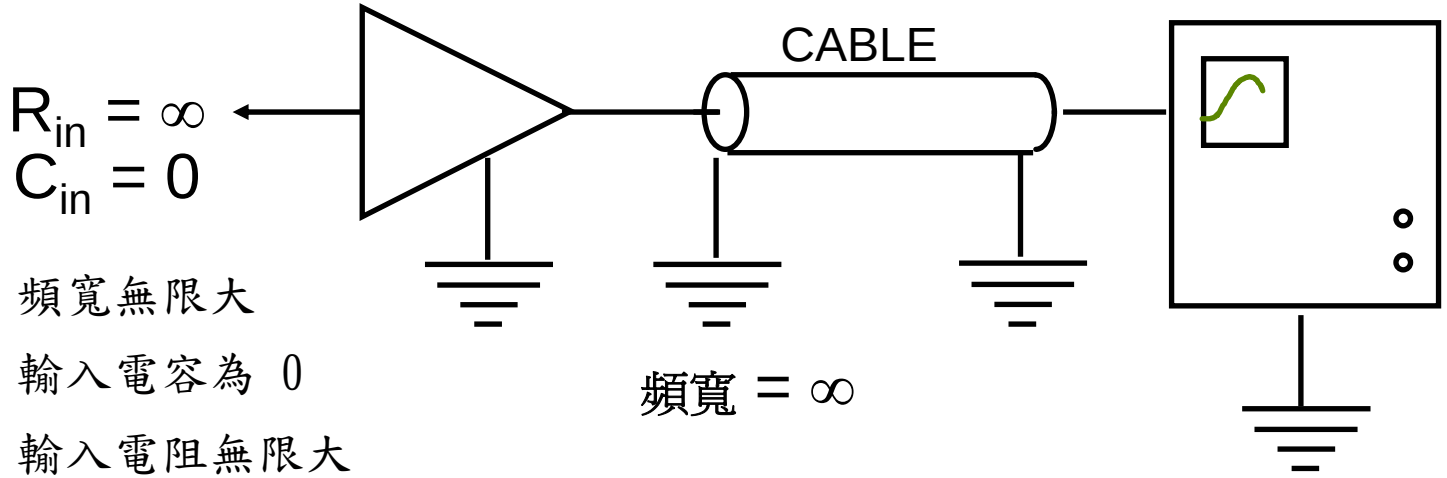

電壓探棒
被動式
特性阻抗
高阻抗
高電壓
差動式
主動式
高阻抗
高靈敏度
差動式
電流探棒
被動式
交流
主動式
直流
交流
邏輯探棒
被動式
主動式
光/電探棒
物理量

探棒如何影響測量精確度

- 要得到適當的測量結果，測量附件必須跟儀錶及待測物(DUT) 密切配合。須考量的項目包括 ：
  - 被量測的訊號形式(電壓、電流、邏輯、其他)
  - 訊號頻率內容(DC, Hz, kHz, MHz)
  - 訊號源阻抗(電阻、電容、電感)
  - 實體連接考量(DUT及儀錶)
  - 儀錶輸入阻抗 (50 ohm, 1M ohm, 其他)
  - 儀錶頻寬或上升時間

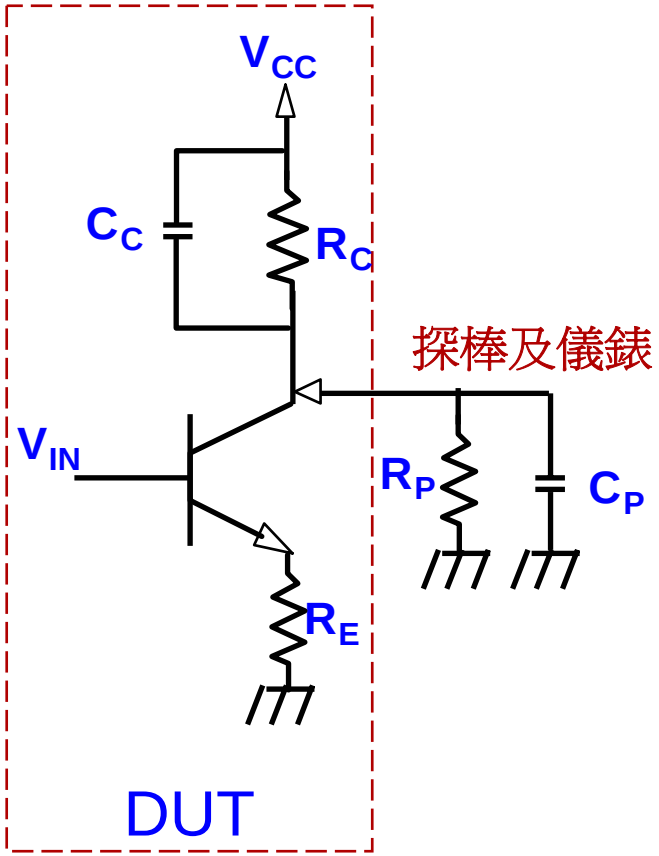
理想電壓探棒

- 理想的電壓探棒模型
  - 理想的探棒是沒有負載效應，也就是不會對測量造成任何影響



  - 頻寬無限大
  - 輸入電容為 0
  - 輸入電阻無限大
  - 動態範圍無限大(Dynamic Range)
  - 1:1衰減
  - 無延遲
  - 無相位偏移(Phase Shift)
  - 機械結構適合測量應用

探棒如何影響測量系統



NOTE: V_{CC} 爲交流接地

- 不具探棒及儀錶

$$\text{Gain} = \frac{-R_C}{R_E}$$

$$f_0 = \frac{1}{2\pi R_C C_C}$$

- 具探棒及儀錶

$$\text{Gain} = \frac{-(R_C \| R_P)}{R_E}$$

$$f_0 = \frac{1}{2\pi (R_C \| R_P)(C_C + C_P)}$$

探棒頻寬 v.s.系統頻寬

- 示波器的量測中，探棒是必備的，所以探棒頻寬亦會影響測量結果，其上升時間影響公式如下：

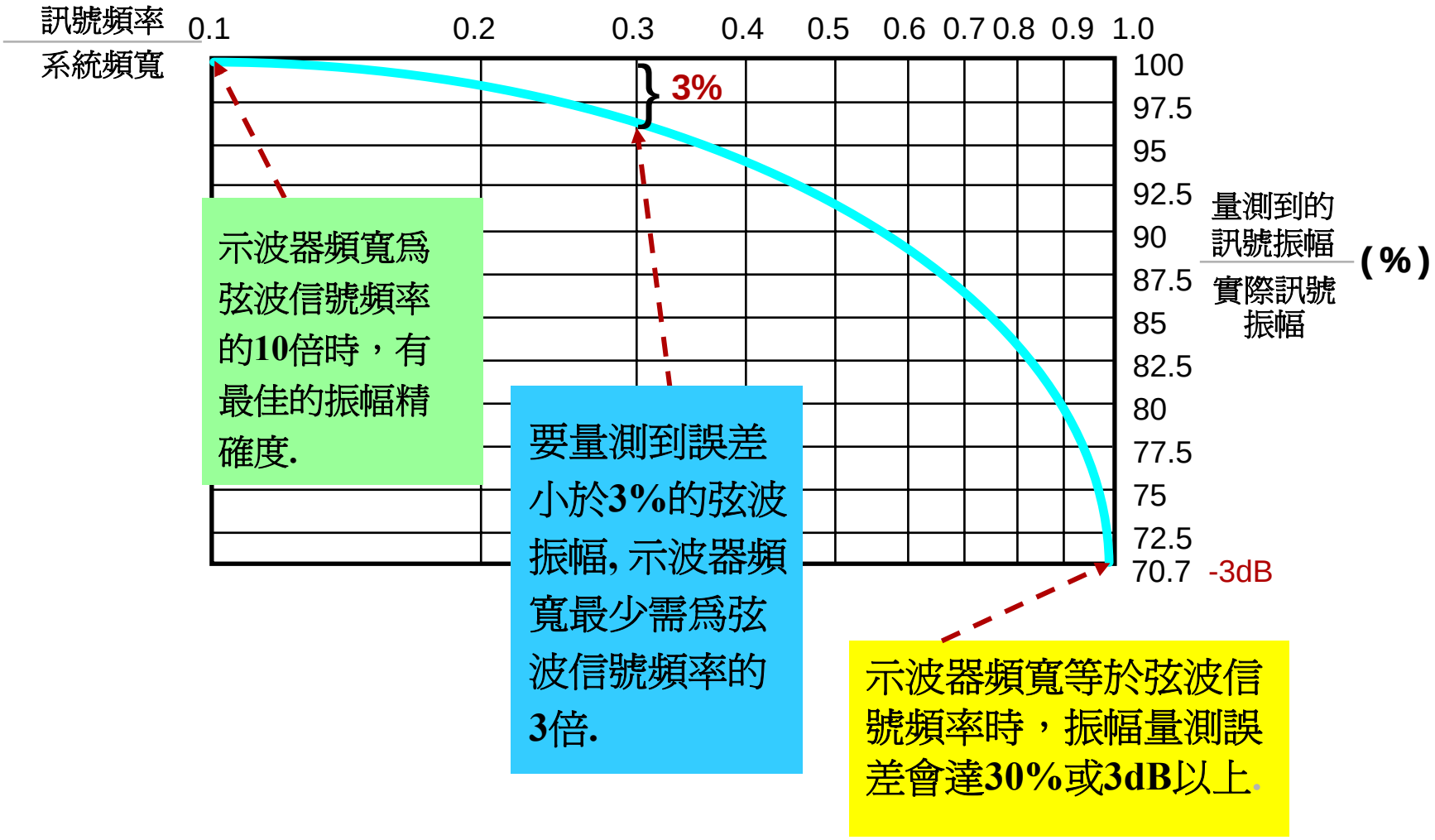
$$量測值_{上升時間} = \sqrt{(訊號_{上升時間})^2 + (示波器_{上升時間})^2 + (探棒_{上升時間})^2}$$

- 由於頻寬和上升時間成倒數關係故其頻寬公式如下：

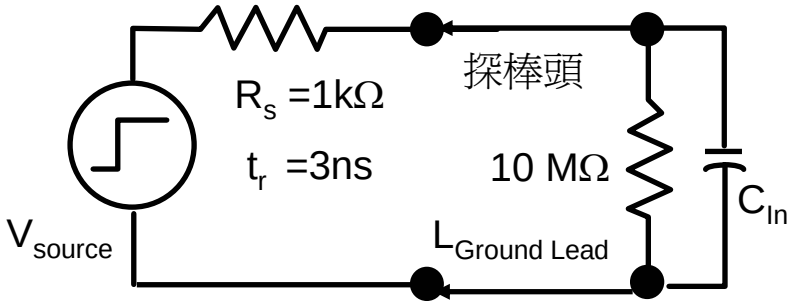
$$\frac{1}{量測頻寬} = \sqrt{\left(\frac{1}{訊號頻寬}\right)^2 + \left(\frac{1}{示波器頻寬}\right)^2 + \left(\frac{1}{探棒頻寬}\right)^2}$$

- 由此式也可看出，示波器及探棒的頻寬越寬，則對量測頻寬的影響越小，也就是說量測頻寬越接近訊號頻寬

系統頻寬 v.s.正弦波振幅



探棒輸入電容及訊號源阻抗

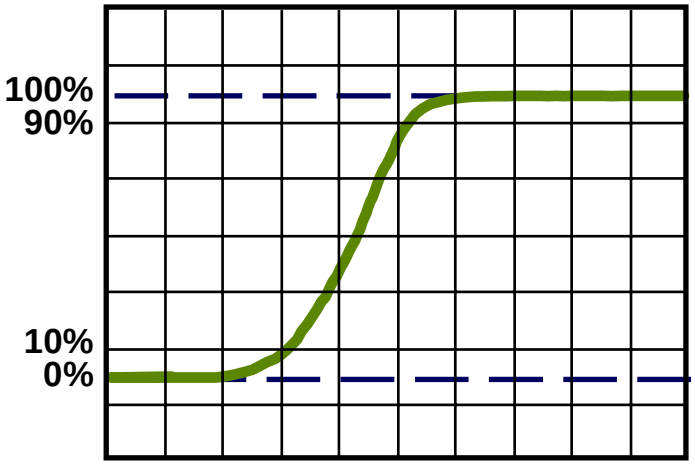


$t_r \simeq 2.2 (R_s * C_{in})$

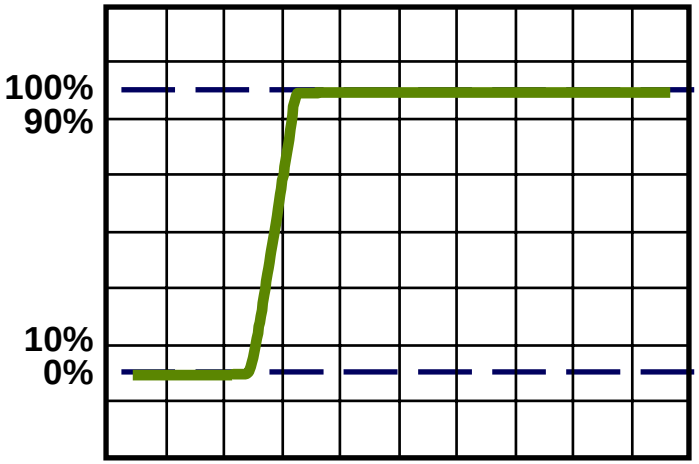
電容負載C_{in}使上升時間t_r增加

C_{in}= 100pF ≃ 220 ns(1X 探棒)

C_{in}= 10pF ≃ 22 ns(10X 探棒)



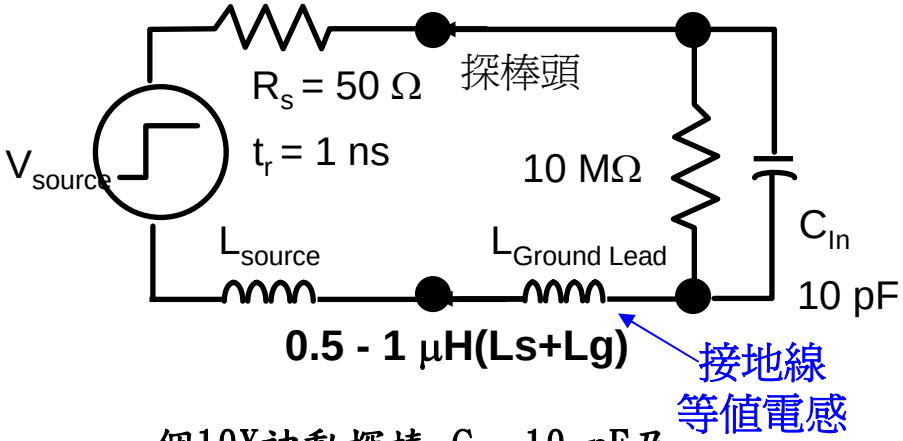
- 1X 被動探棒的上升時間波形



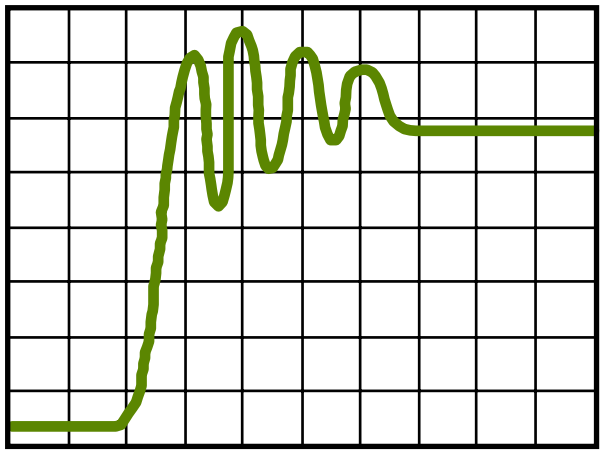
- 10X 被動探棒的上升時間波形

探棒接地線的電感效應

- 電感效應造成阻抗不匹配，頻寬越寬影響越大
- 接地線的長短會影響電感效應的大小，結果會產生脈波訊號的漣波



一個10X被動探棒 C_{in}=10 pF及
6“接地線的等效線路



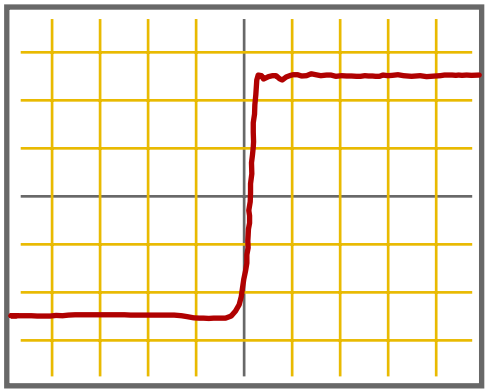
左側等效線路的探棒所造成的漣波

典型6“接地線探棒
所造成的的漣波頻率

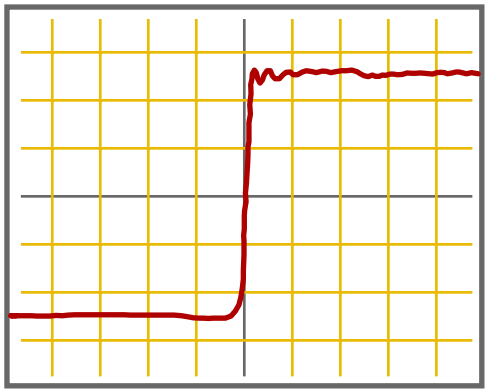
$$= \frac{1}{2\pi\sqrt{LC}} =$$

50 - 70 MHz 或 **t_r = 7 - 5 ns**

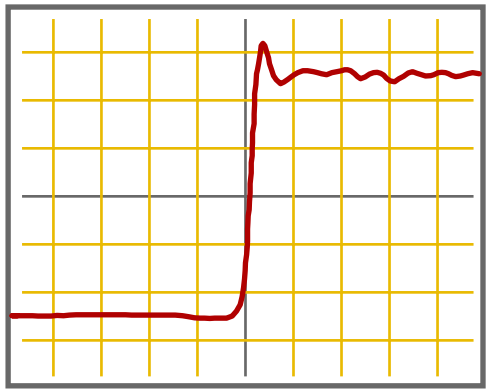
探棒接地線的電感效應



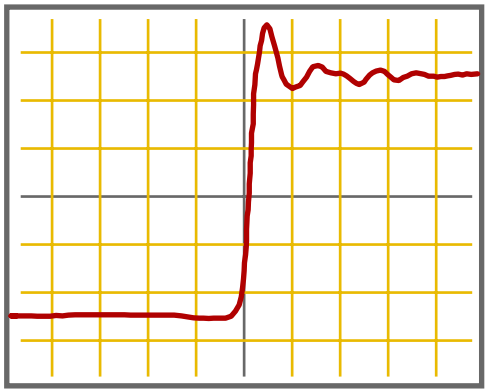
電纜線直接連接



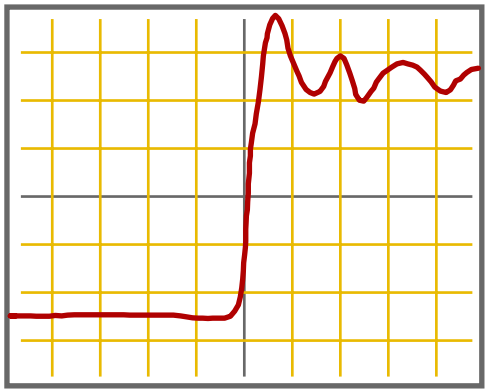
BNC 探棒頭連接



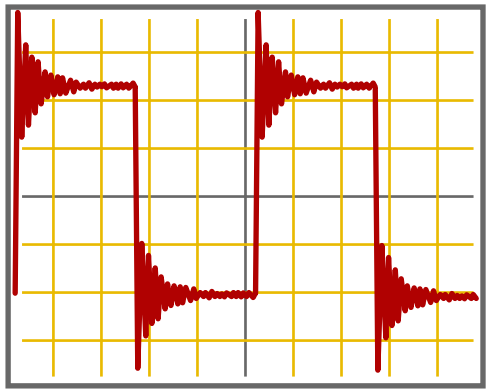
1” 接地線



3” 低阻抗接地線



6” 接地線



未接接地線

探棒傳輸延遲

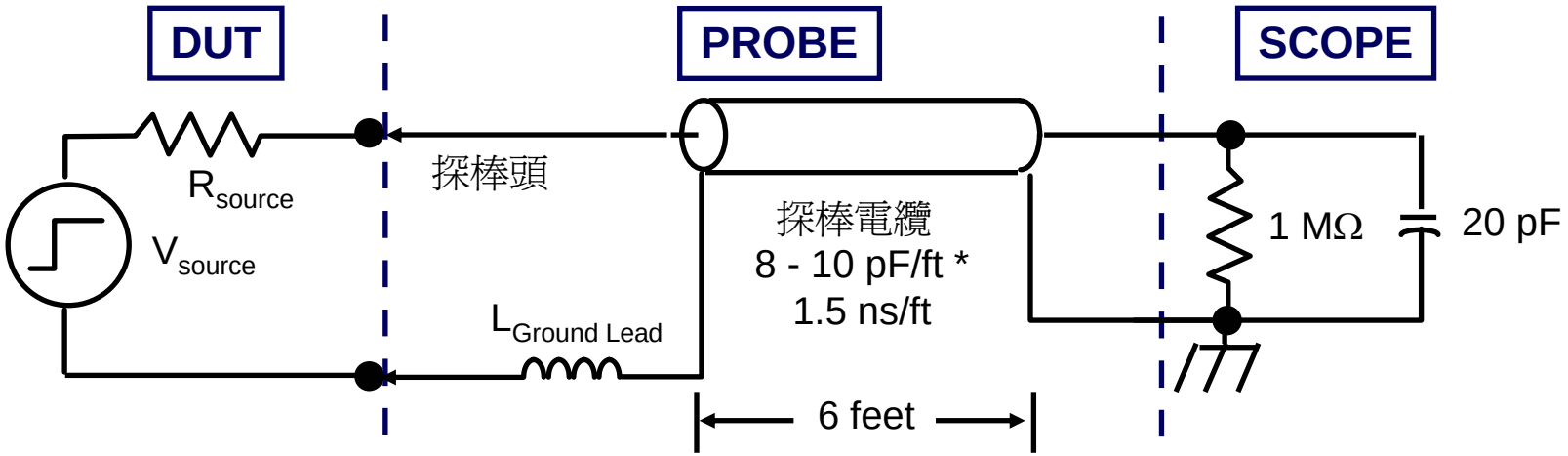
測量時序、功率、及延遲時重要的考量

- 典型的探棒延遲範圍在 4 ns 到 8 ns
- 不同的探棒會造成不同的延遲，需用示波器“deskew”的功能來消除探棒的延遲
- 同型探棒間的延遲應越小越好，典型的應在 200 ps 之內

電壓探棒典型的規格

型式	頻寬	上升時間	輸入電容	輸入電阻
1X 被動探棒	15 MHz	23 ns	100 pF	1 MΩ
10X被動探棒	100 MHz - 500 MHz	3.5 ns - 700 ps	13 pF - 8 pF	10 MΩ
Z0被動探棒	3 GHz - 9 GHz	120 ps - 40 ps	1 pF - 0.15 pF	50 Ω
主動探棒	500 MHz - 16 GHz	700 ps - 25 ps	2 pF - 0.2 pF	10 MΩ - 100KΩ

1X 電壓探棒 -- 被動式



優點 ：

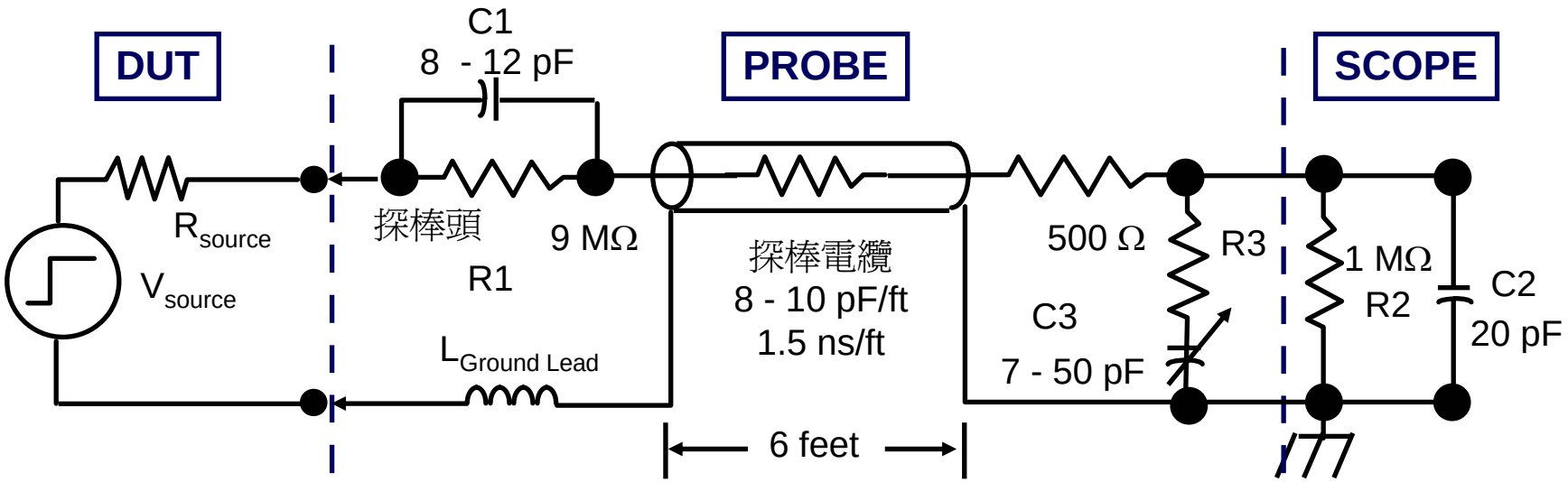
- 1X 沒有衰減
- 價格便宜

缺點 ：

- 高反射量
- 輸入電容太大
- 低頻寬

* 典型 50ohm電纜約有30 pF/ft 的電容量

10X 電壓探棒 -- 被動式



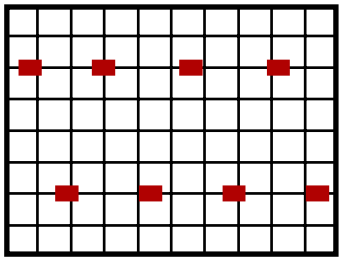
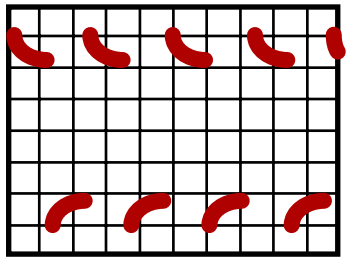
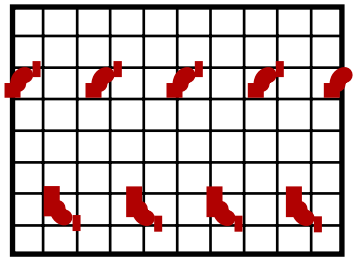
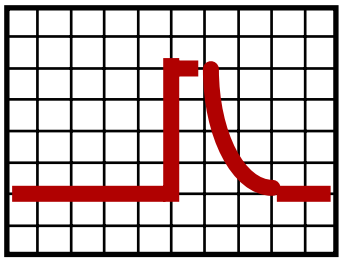
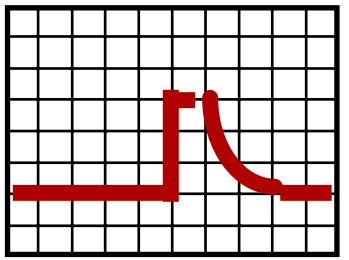
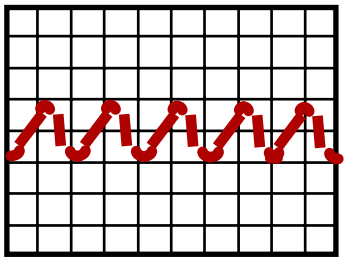
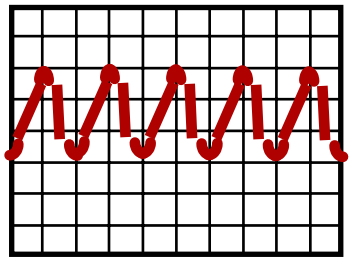
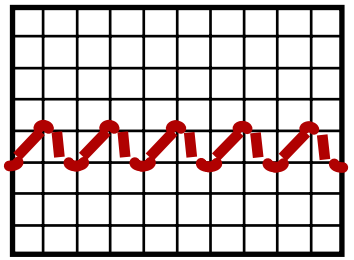
優點 ：

- 高輸入電阻
- 寬動態範圍
- 價格合理
- 機械結構堅固
- 比1X 探棒的輸入電容低

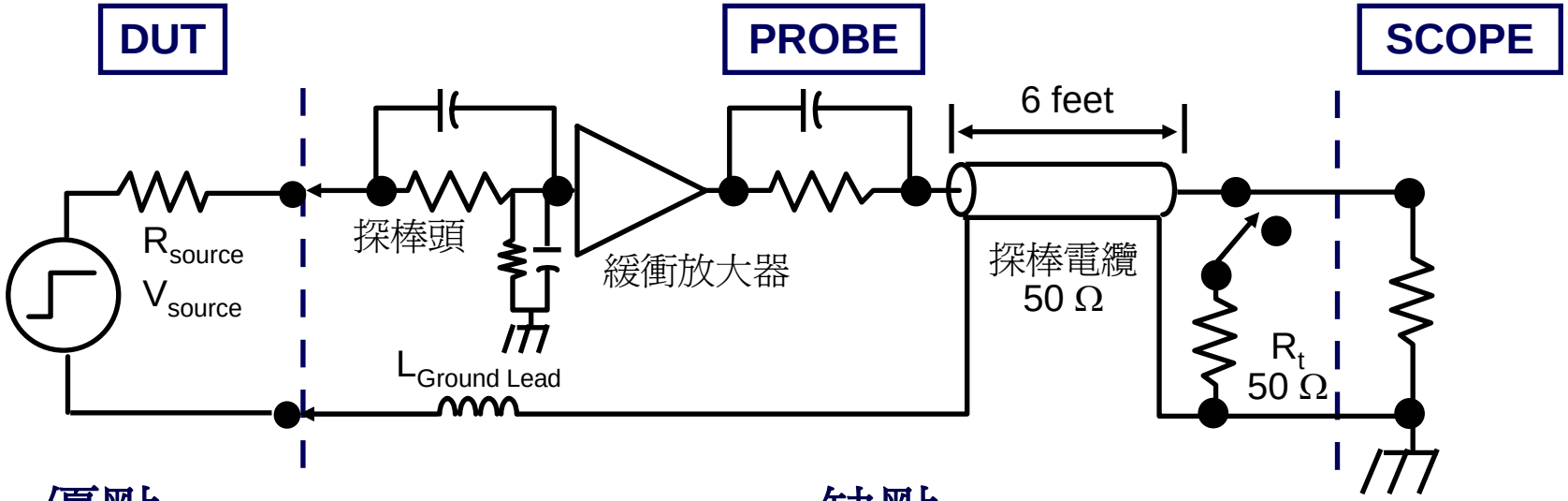
缺點：

- 輸入電容仍太高
- 跟**50 Ω**系統不相容
- 必須補償

被動探棒的低頻(LF)補償

正確補償	過補償	補償不足
		
1 ms/div	1 ms/div	1 ms/div
		
1us/div	1us/div	1us/div
		
50 kHz	50 kHz	50 kHz

10X 電壓探棒-- 主動式



優點：

- 低輸入電容
- 高輸入電阻
- 加上終端電阻跟**50 Ω**及1M Ω系統相容
- 無須補償

缺點：

- 高價位
- 動態範圍有限
- 機械結構較不堅固
- 須額外的電源

Single-Ended
Active ‘FET’ Probes

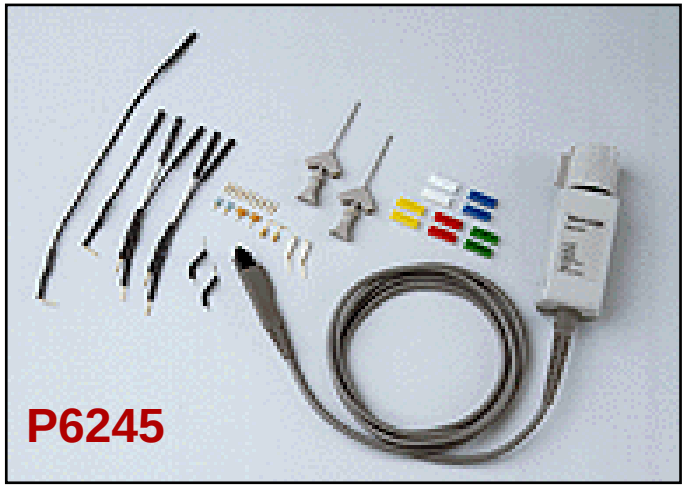
P6243 / P6245 / P6249 / P7240 / P7260 Active Probes

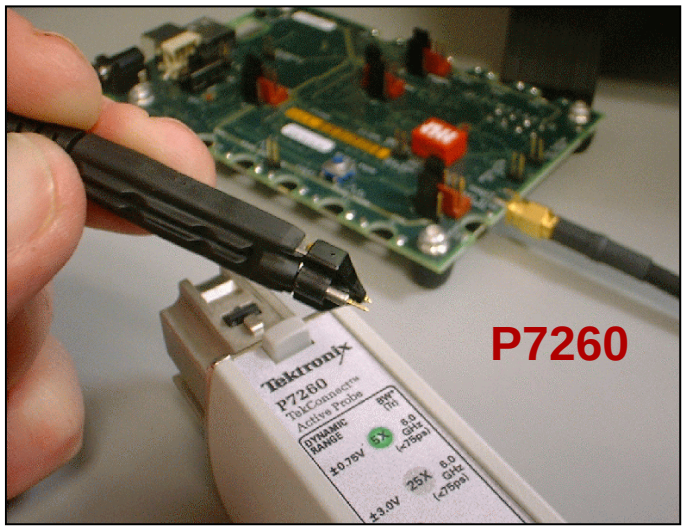
Applications:

- High-speed Digital Design, Component Design/Characterization, Manufacturing Engineering Test, Education, Research

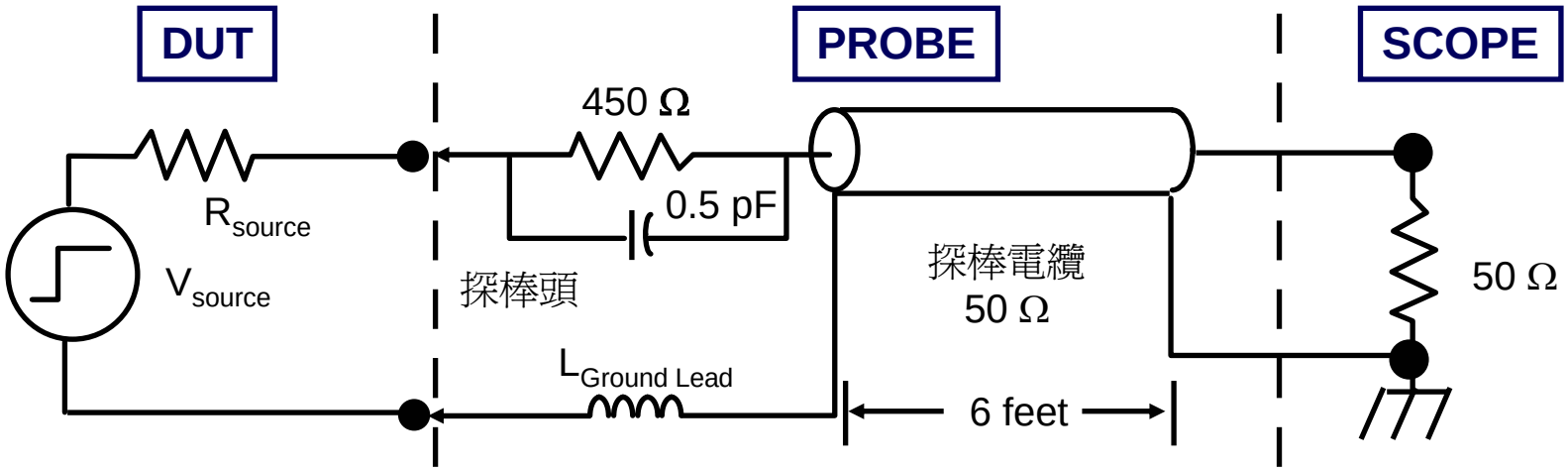
Potential Customers:

- Digital System Design Engineers
  Manufacturing Engineers/Technicians
  R&D Specialists/Engineers/Technicians
- Component Characterization - Engineers





50 Ω 10X 電壓探棒-- 被動式



優點：

- 低輸入電容
- 寬動態範圍
- 加上終端電阻跟**50 Ω**及1M Ω系統相容
- 無須補償

缺點：

- 低輸入電阻
- 必須有**50 Ω**的終端

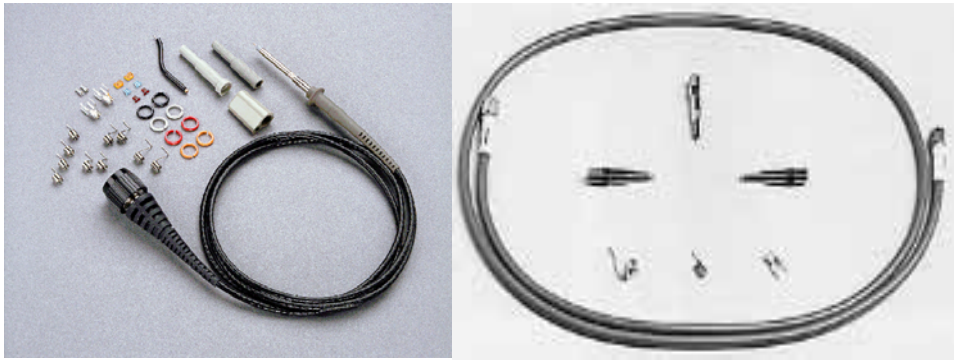
Low Capacitance Zo Passive Probes

P6158 Low Capacitance Probe

- Use with TDS400/ TDS500/ TDS600/ TDS700/ TDS3000 Series

P6150 Low Capacitance Probe

- Use with TDS8000, CSA8000, TDS800, CSA800, 11800 series

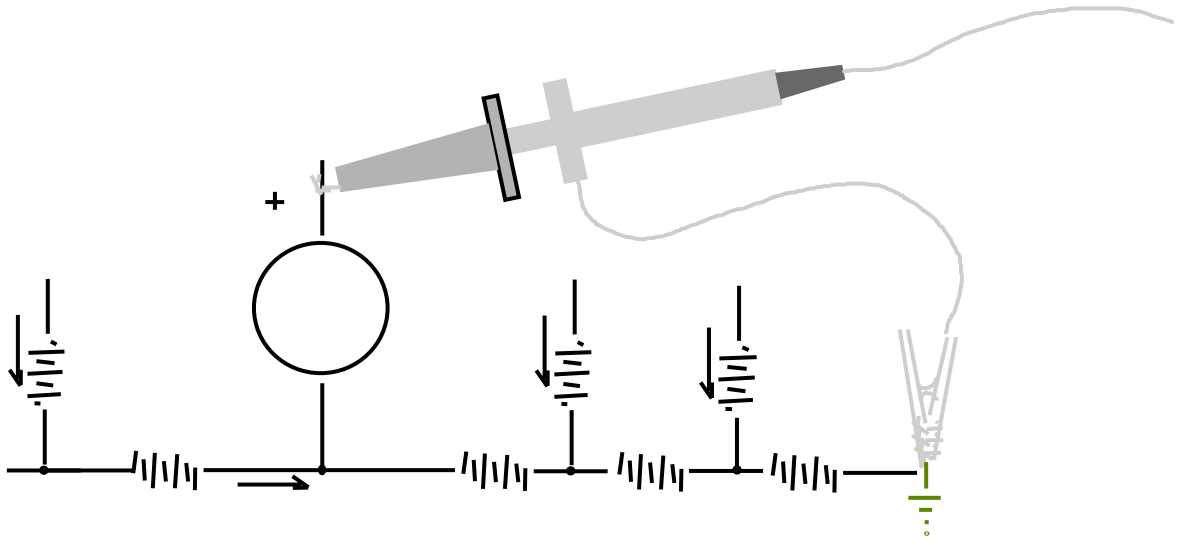


Banner Specifications:	P6158	P6150
Bandwidth:	DC- 3 GHz	DC- 9 GHz / 3 GHz
Attenuation:	20X	10X / 1X
Loading:	1 kΩ / 1.5 pF	500Ω / 0.15 pF 50Ω / NA
Maximum Input Voltage:	22 V_{RMS}	12.5 V_{RMS}
Probe Head Size:	Compact (3.5mm) Compatible with a Wide Range of Accessories	4mm
Interface:	TEKPROBE® I	SMA

何時使用差動式電壓探棒

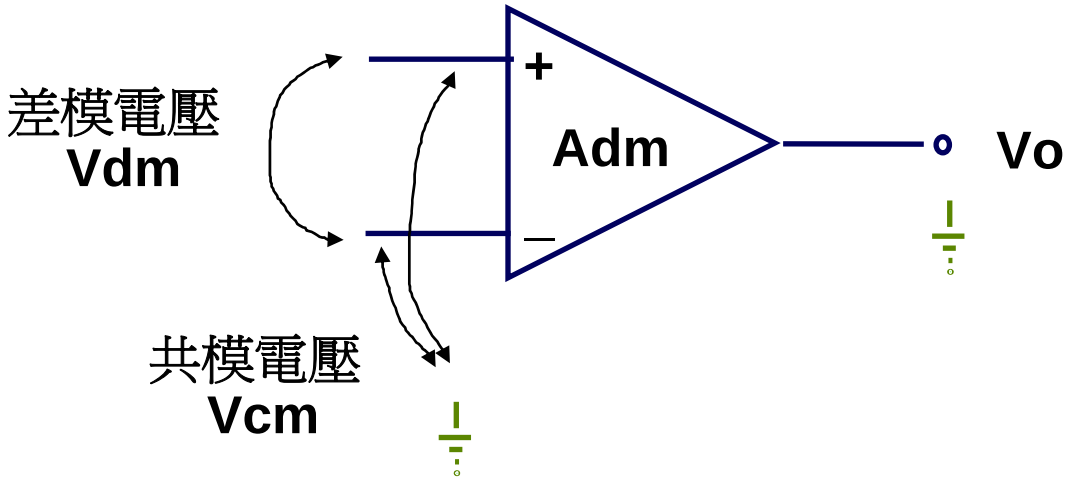
- 不以地點為參考點
  - 浮動點(Floating)測量
  - 平衡(Balanced)訊號

- 地點並不是很好的參考點時
  - 低振幅 (<10 mV)：地點雜訊大於訊號振幅
  - 高速度 (t_r < 2ns)：地點離訊號點太遠



共模及差模

- 共模(Common Mode)電壓 Vcm 及共模增益 Acm：
  - 兩個輸入端對地的電壓差為 Vcm，經過差動放大器後的增益為 Acm
- 差模(Differential Mode)電壓 Vdm 及差模增益 Adm：
  - 兩個輸入端間的電壓差為 Vdm，經過差動放大器後的增益為 Adm



共模互斥比(CMRR)

- CMRR(Common Mode Rejection Ratio)：

  差模增益 **Adm**跟共模增益 **Acm**的比值，即

  CMRR =Adm/Acm

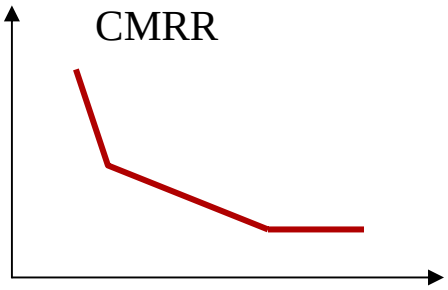
  或

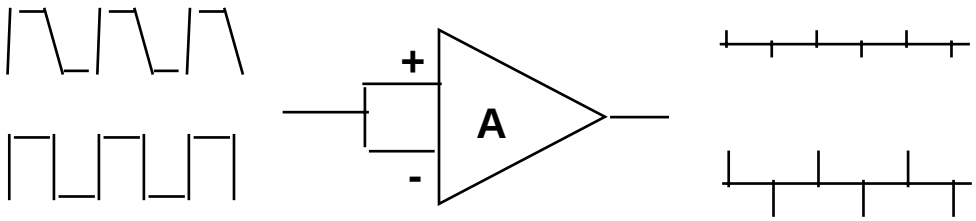
  dB(CMRR) = 20log(Adm/Acm)

  若**Acm** 趨近於零，則**CMRR趨近無限大** ，代表一理想的差動放大器
  所以針對差動式探棒而言**CMRR**值越大越好

CMRR的規格

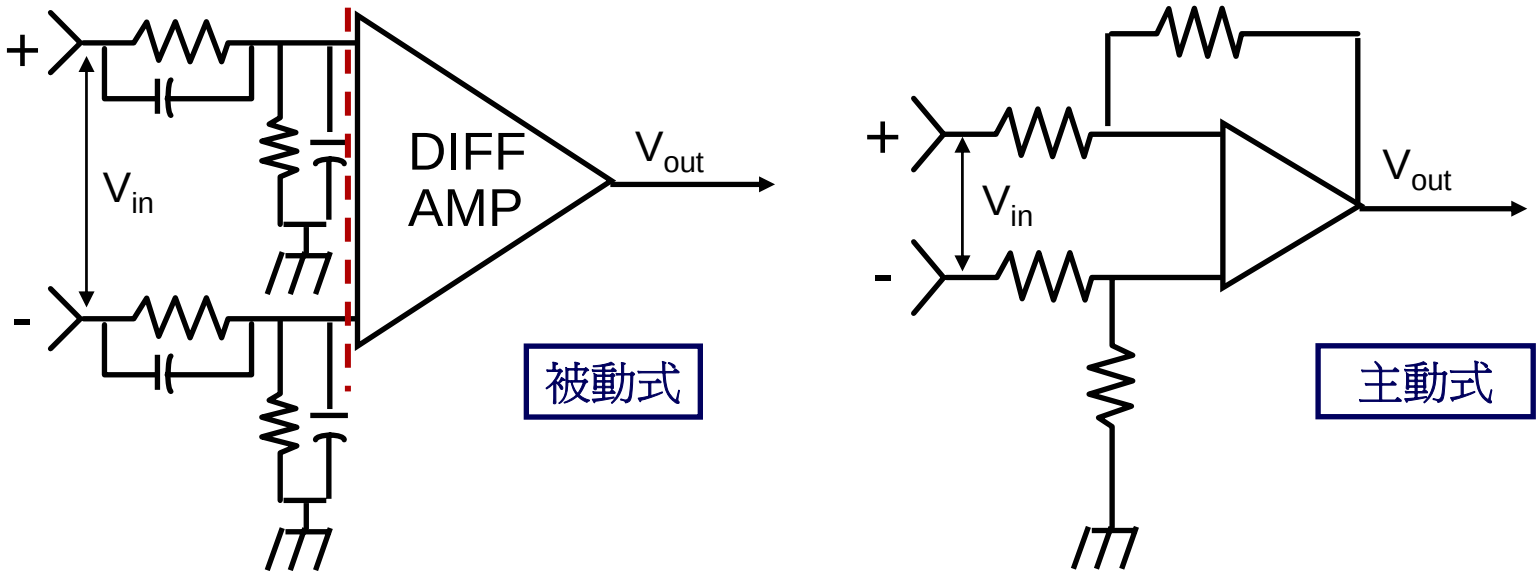
- CMRR值越大越好一般在60dB(1000:1)附近
- 隨著頻率增加CMRR會逐漸減小





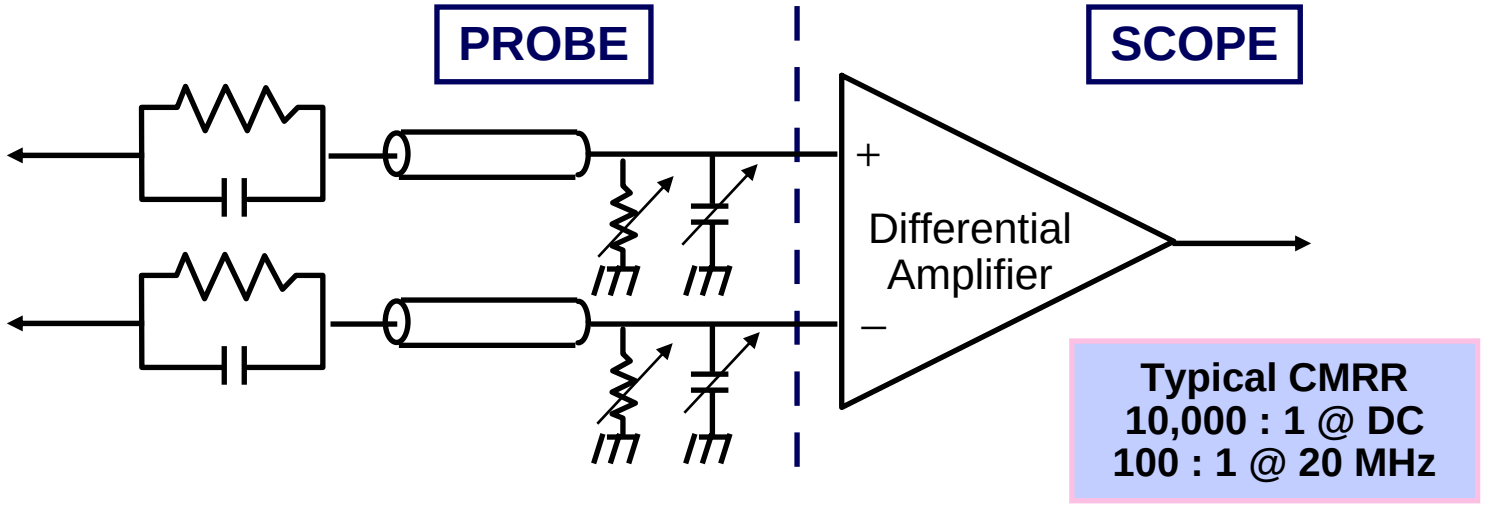
越快的邊緣會產生更多的共模電壓

電壓探棒-- 差動式



- 被動差動式探棒必須將兩支探棒的延遲、衰減、及補償，做精準的調校.
- 假如沒有做精準的調校，CMRR將會嚴重的下降.
- 主動差動式探棒由於具OP放大器做緩衝，因此不須要做這些調校.

電壓探棒-- 被動差動式



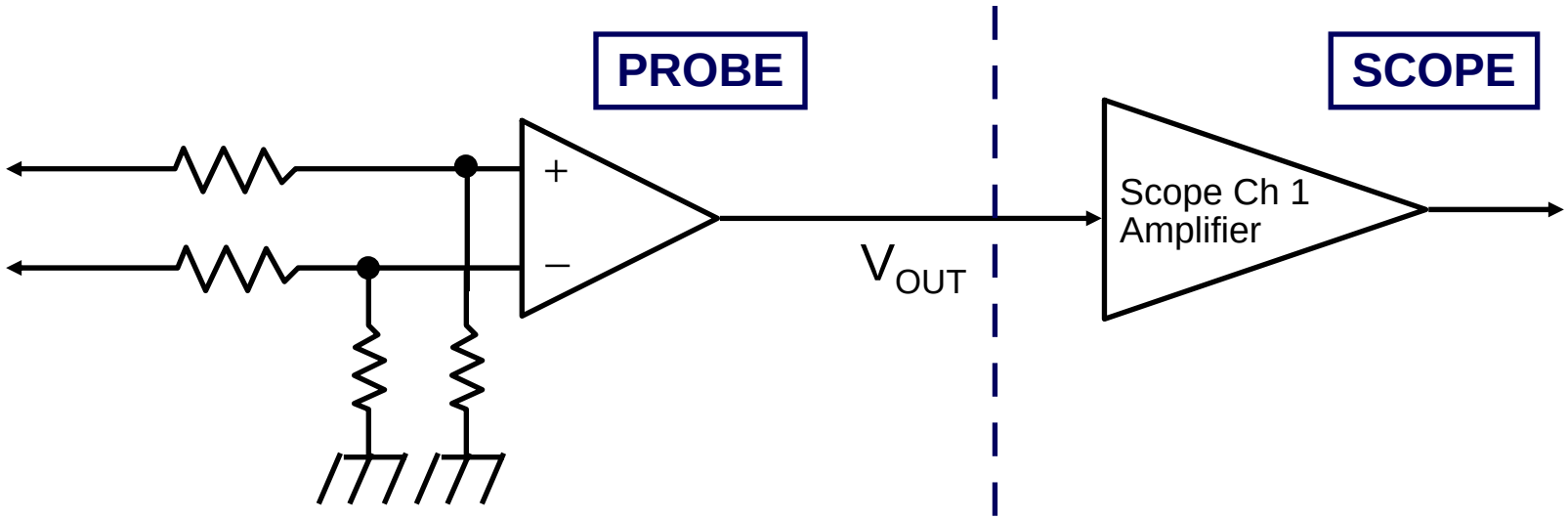
優點：

- 比被動式探棒的**CMRR**高
- 寬動態範圍
- 機械結構堅固
- 兩支探棒可以作較遠的分離

缺點：

- 須要兩個不同的輸入
- 跟**50 Ω**系統不相容
- 須補償

電壓探棒-- 主動差動式



優點：

- 低輸入電容
- 比被動差動式探棒的**CMRR**高
- 跟**50 Ω**及**1M Ω**單端**(Single-ended)**系統相容
- 探棒頭非常小

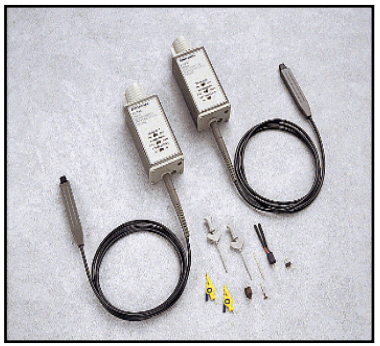
缺點：

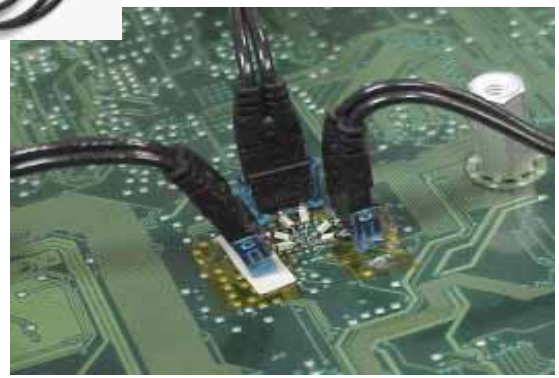
- 高價位
- 有限的動態範圍
- 須額外的電源

Active Differential Probes
TekProbe BNC

P6246 / P6247 / P6248 / P7330
P7350 / P7350SMA / P7360 / P7380
P7380 SMA / P7313 / P7313 SMA
Active Differential Probes

- Use with TDS400 & higher scopes
- Or use with 1103 Power Supply





P7313 Benner Specification

•Bandwidth	> 12.5 GHz (Typical)
•Rise Time	< 40 ps (10/90%) (Guaranteed)
•Rise Time	< 25 ps (20/80%) (Typical)
•Attenuation	5X or 25X, user selectable
•Differential Input Range	± 0.625V (5X) / ± 2.0V (25X)
•Common Mode Input Range	+4.0V to –3.0V
•Offset Voltage Range	+4.0V to –3.0V
•DC Input Resistance	100 KΩ
•AC Loading (Differential Zmin)	> 250 ohms out to 12.5 GHz
•CMRR	>50dB to 1MHz
	>35dB to 1GHz
	>20dB to 6 GHz
	>15dB to 12.5 GHz
•Non-Destructive Input Range	± 15 V
•Interface	TekConnect™
•Cable Length	1.2m

Introducing
Industry Leading

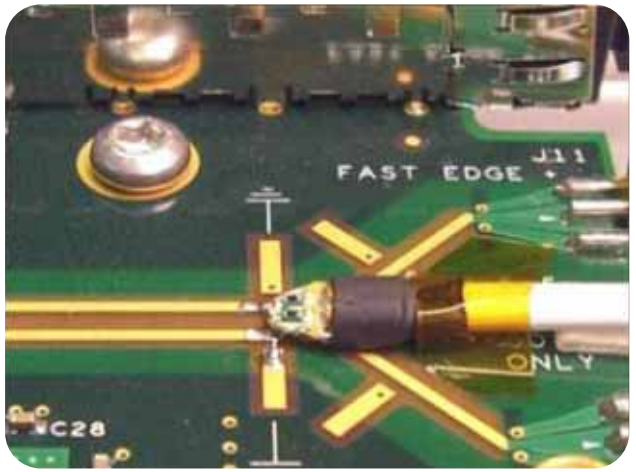
P7500 TriMode Differential Probes

Uncompromised Performance, Analysis, and Signal Access for Challenging Multi-Lane Serial Data Technologies

Addressing High-Speed Serial Data Challenges

Tektronix enables engineers to overcome their testing challenges

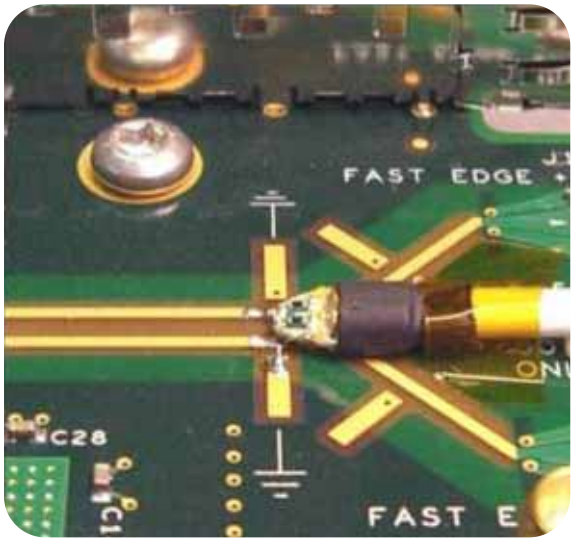
Signal access to test points
- –Efficient and accurate probing



Validating signal integrity
- –Best in class performance solutions
- –Tools to improve analysis and insight

Industry-Leading Probing Solution

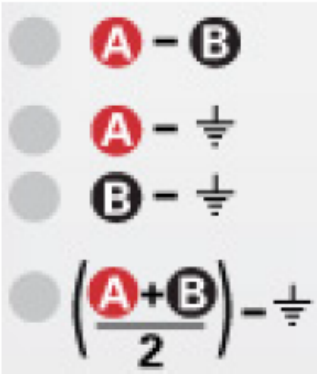
- ***New*** P7500 Series TriMode™ Differential Probes
  - Enables single-ended, differential and common-mode measurements with a *single* probe connection
  - 13GHz, 16GHz (analog) bandwidth probes are first two models of new family

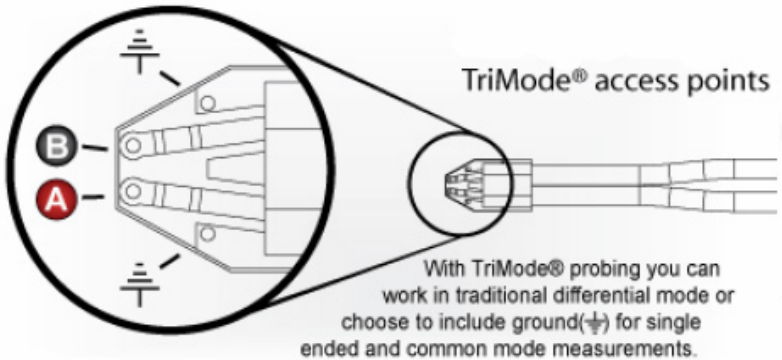


- Ideal for high speed serial standards which require multiple measurements at test points
  - PCI Express 2.0
  - SATA Gen 3
  - 8GFC/10GFC
  - 10GbE

TriMode Probe

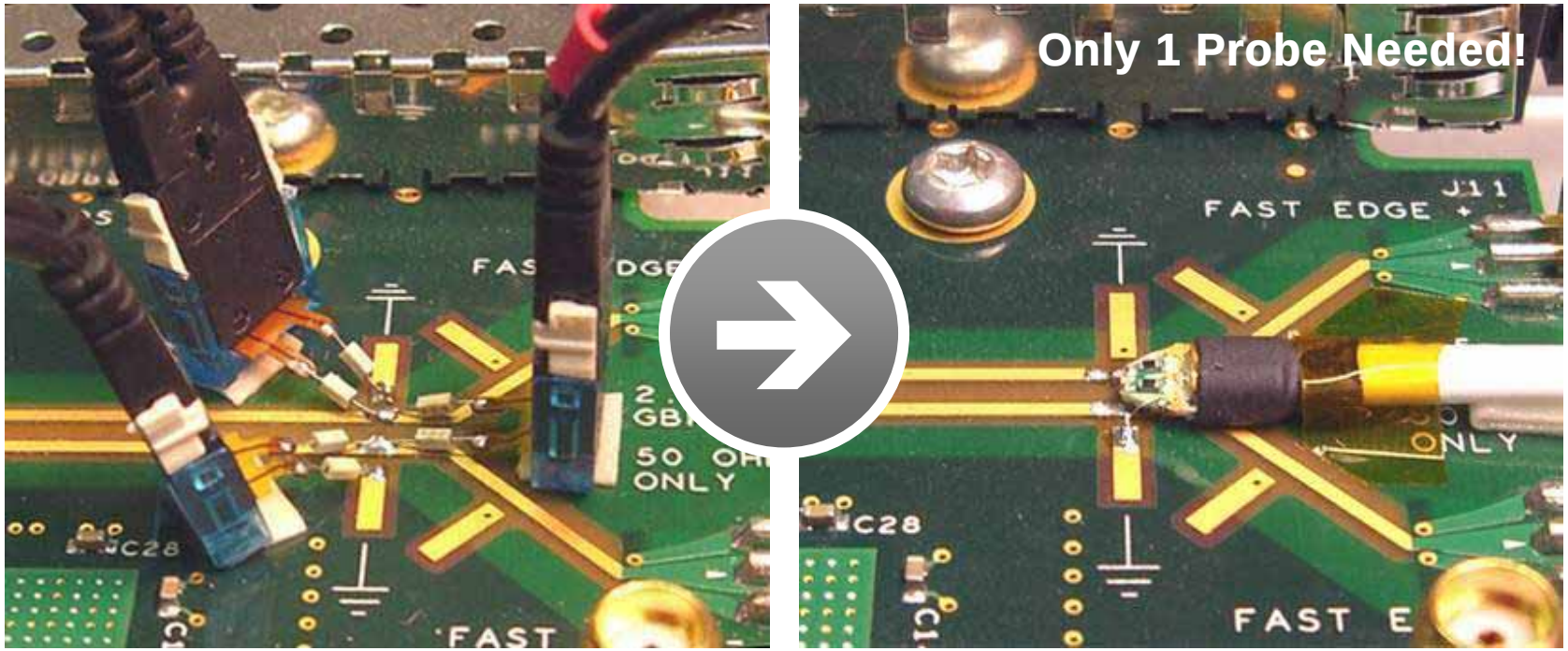
- TriMode, with a single probe-DUT connection, allows:
  - Traditional differential measurements: V+ to V-
  - Independent single ended measurements on either input
    - V+ with respect to ground
    - V- with respect to ground
  - Direct common mode measurements: (V+) + (V-)/2 with respect to ground
- Serial Data standards such as PCI Express, Serial ATA, etc require both differential and maximum permissible common mode voltage limit measurements. Requires two separate probes – Until Now!





P7500 Series

Addressing DUT Access Challenges



Before TriMode Probing

1 Probe for Differential

2 Probes for SE and Common Mode

Or

1 Probe Soldered and Re-soldered 3 times

2 Probes for Common Mode

After TriMode Probing

1 Probe and 1 setup for

Differential, SE and Common Mode

Tektronix®

Innovative Design for Efficient, Accurate Probing

- Sleek probe body with small connectors
- Miniature solder probe tips
  - Can be soldered to the plus, minus, *and* ground of a differential signal to enable TriMode probing
  - Long cables to access hard-to-reach test points
- Precision probing module
  - Small form factor permits access to fine pitch devices
  - Simple variable spacing adjustment
  - Can be hand-held or fixtured
  - Angle of approach adjustment

Summary: *New* DSA70000 Digital Serial Analyzers and *New* Tektronix P7500 TriMode Probes

Best-In-Class Performance

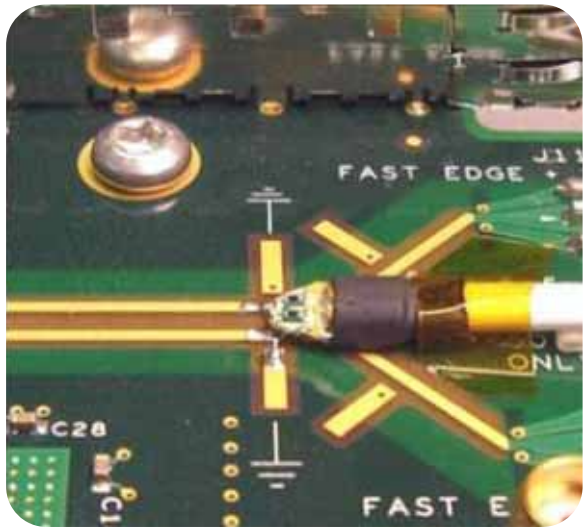
- Fastest real-time oscilloscope
- High performance on all four channels, simultaneously

Extensive Analysis and Insight

- Comprehensive real-time serial data analysis toolset
- Unmatched triggering performance and flexibility

Industry-Leading Probing

- Innovative TriMode probing
- Small form factor improves access to fine pitch devices

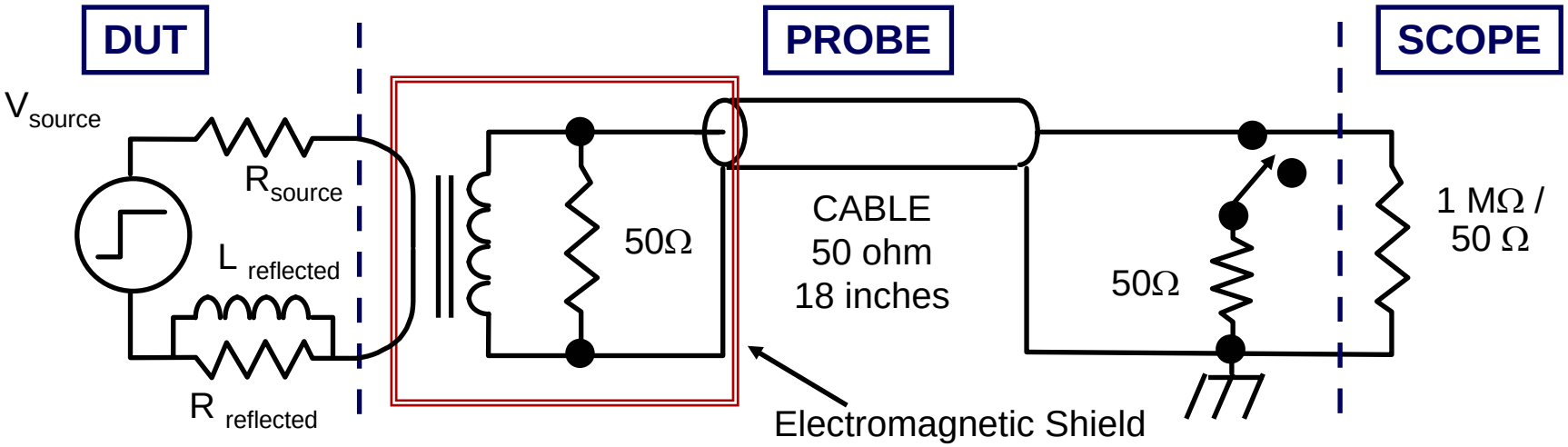


Complete Solution for High-Speed Serial Data

電流探棒的特性

- 探棒的交流反應，依據變壓器的動作，將電流轉為電壓
- 直流測試，須在變壓器上加一霍爾效應 (Hall Effect)感應器
- 兩種型式可用 ：
  - 固定核心(Fixed Core) - 須要打開導體(conductor)來連接
  - 分離核心(Split Core) - 允許直接附在導體上(clipping around)
- 以極低的嵌入阻抗(L reflected & R reflected)，使 DUT的電容性負載達到最小
- 提供電子絕緣，允許無參考地點量測

電流探棒-- 被動式



優點：

- 寬的 **AC** 頻寬
- 價格不貴
- 提供電子絕緣
- 低 **DUT** 負載
  ($R_{reflected}$ 典型 **1 to 2 Ω**
  $L_{reflected}$ 典型 **5 μH)**

缺點：

- 只能測量 **AC**
- 固定核心須要打開導體連接
- 直流電會使核心飽和

Fixed Core Current Probes

CT Series Family Products (CT6, CT1 and CT2)

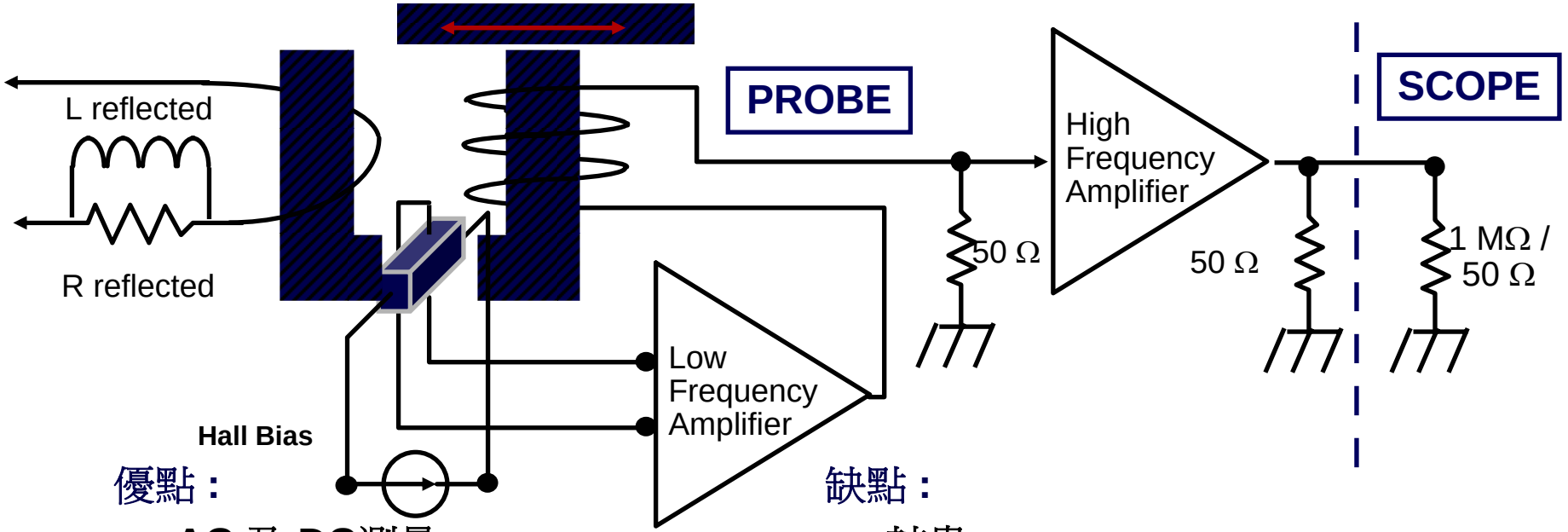
- Fixed Core Current Probes can be used with all Tektronix and Non-Tektronix Oscilloscopes

Specifications:	CT6	CT1	CT2
Bandwidth Typical:	250kHz to 2GHz	25kHz to 1GHz	1.2kHz to 200MHz
Max. Cont.Current (RMS):	120mA	450mA	2.5A
Max. Pk Pulse Current (A)	6A	12A	36A
Insertion Impedance (@ 10MHz):	1.1Ω	< 1Ω	0.1Ω
(@ 100MHz):	1.3Ω	2Ω	0.5Ω
(@ 1GHz):	11.9Ω	-	-
Max. Conductor Diam.:	#20 wire	#14 wire	#16 wire

Customers:

- Design Engineers; Manufacturing Test Engineers

電流探棒-- 主動式



優點：

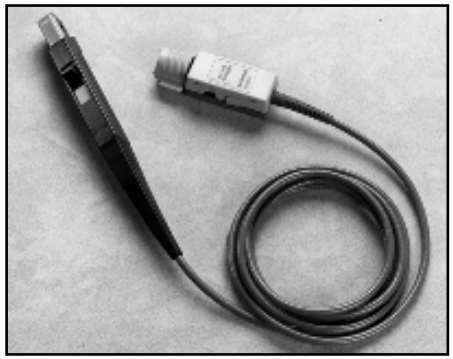
- **AC** 及 **DC**測量
- 跟**50 Ω**及1M **Ω**單端(**Single-ended)**系統相容
- 提供電子絕緣
- 低 **DUT** 負載
  (**$R_{reflected}$** 典型 **<< 1 Ω**
  $L_{reflected}$ 典型 **< 5 μH)**

缺點：

- 較貴
- 機械結構較不堅固
- 體積較大
- 須額外的電源

Current Probes – TCP202 TEKPROBE II Interface

TCP202



TCP202 DC Coupled Current Probe

- Use with TDS400/500/600/700 Series
  Easy To Use, “Plug and Play”
  Direct Current Readout when used with the TDS Series scopes

Banner Specifications:

- Bandwidth (probe only): DC to 50 MHz
- Insertion Impedance: 0.1Ω @ 1 MHz
- Current Continuous/Peak Pulse: 15 / 50 Amps
- Max. Conductor Diameter: 3.8 mm (0.15 in.)
- Safety Certifications: UL, CSA, IEC
- Interface: TekProbe II

Applications:

- Floating Measurements, Power Inverters, Switching Power Supply Design, TV/VCR Service/Repair, Motor Drive Controller Design, Power Semiconductors (i.e., IGBT’s Power MOSFET's, Thyristors), Battery Power Consumption

TCP300/TCP400 Current Probe System

- TCPA300 Amplifier
  - Uses the following probes:
    - TCP312 - 30A / 100MHz
    - TCP305 - 50A / 50MHz
    - TCP303 - 150A / 15MHz

- TCPA400 Amplifier
  - Uses the following probe:
    - TCP404XL - 750A / 2MHz
      (derated w/duty cycle; 500A continuous)

TDS7000B Series Scope

New TekConnect™ Probe Interface

- The Next Generation Intelligent Interface
- Why TekConnect?
  - Increased Communication Between Interconnections (up to 18 GHz)
    - TEKPROBE BNC and TEKPROBE SMA provide signaling capability between the probe and the oscilloscope sending data stored in the EEPROM which the host instrument uses to set up scale factor, offset, probe type, etc. TekConnect not only preserves this signaling interface, but provides additional enhancements:
      - » Intelligent Power Supply Switching providing power management for the instrument and accessories.
      - » Power Outputs remain open until a TekConnect device is detected.
      - » New TekConnect Probes have the pins mounted in the instrument not the probe ensuring no lateral forces applied to the pins when the probe is not connected.

TekConnect – TCA Series Adapters

TekConnect Adapters
For SMA, N, and BNC Interconnects
TCA-SMA / TCA-N / TCA-BNC / TCA75

- Use with TekConnect Scope Series
  TDS6000 / TDS7000 / CSA7000
  DPO70000 / DSA70000

50Ω "N"

50Ω "SMA"

50Ω "TPA-BNC"

For DPO7000 Series

50Ω "BNC"

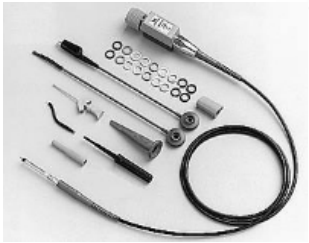
75Ω "BNC"

Banner Specifications:	TCA-SMA	TCA-BNC	TCA-N	TCA75
Bandwidth:	DC - 18 GHz	DC - 4 GHz	DC - 12 GHz	DC-4GHz
Bandwidth w/Scope:	DC - 4 GHz	DC - 4 GHz	DC - 4 GHz	DC-4GHz
Input Impedance:	50 Ω	50 Ω	50 Ω	75 Ω
VSWR (Plug-In Only):	1.23:1 @ 18 GHz	1.11:1 @ 4 GHz	1.19:1 @ 12 GHz	1.11:1 @ 4 GHz
VSWR (w/TDS7404):	1.09:1 @ 18 GHz	1.11:1 @ 4 GHz	1.11:1 @ 12 GHz	1.11:1 @ 4 GHz
Linear Dynamic Range:	<---------- TDS TekConnet Scope Input Rating ---------- >			
Attenuation:	1X	1X	1X	2.46X (AutoScaling)

TCA-1MEG High Impedance Buffer Amplifier

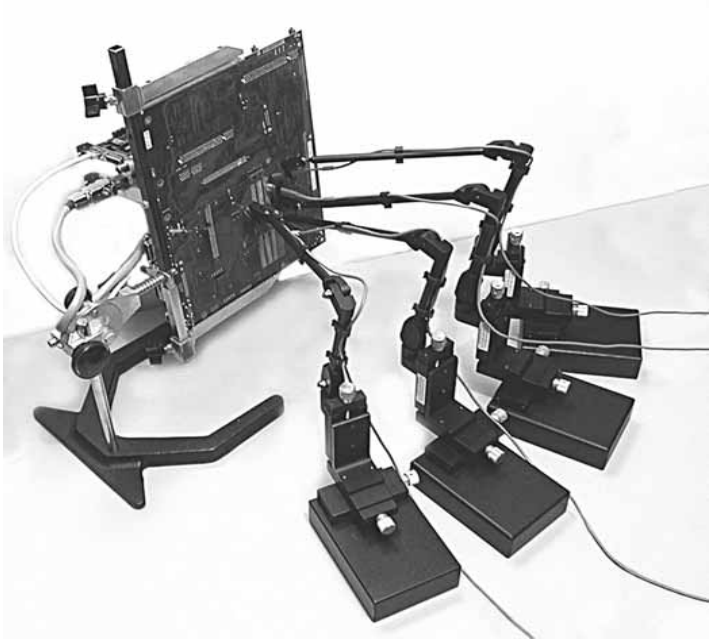
- Input Resistance – **1 Meg Ω**
- Input Capacitance – **10 pF**
- Bandwidth – **500 MHz**
  w/ >1.5 GHz TekConnect™ Host Instruments

- Bandwidth Limit – **20 MHz / 100 MHz**
- Input Coupling – **AC / DC / GND**

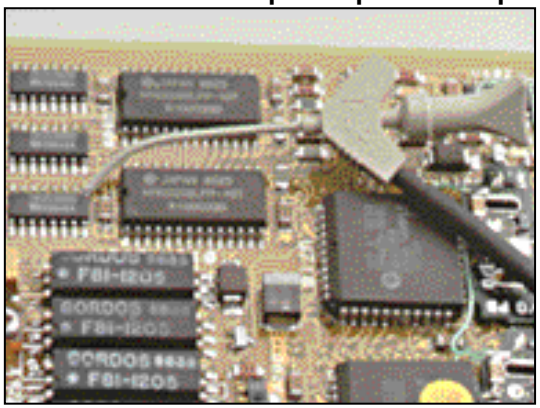


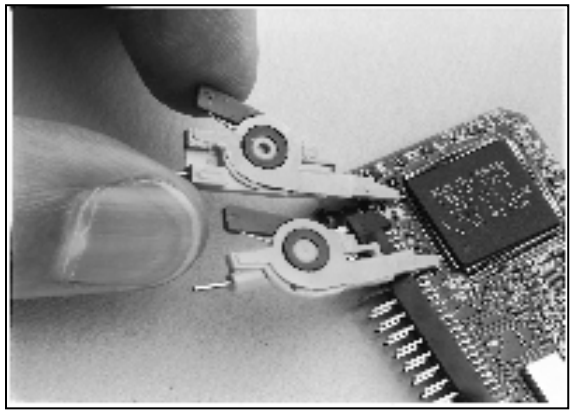
- Sensitivity – **TekConnect Host Instrument Minimum to 10V / Div Maximum**
- Interface Type – **TEKPROBE BNC Level I & II (50 Ω devices not supported)**
- Includes: P6139A Passive Voltage Probe, Manual, Upgrade CD's
- 1 MΩ path in series –
  - retains capability to easily return the oscilloscope back to its premium low VSWR 50-ohm environment
  - extends useful tool set

Hands-Free Probing Accessories



SMG50 SMT KlipChip™ Adapter

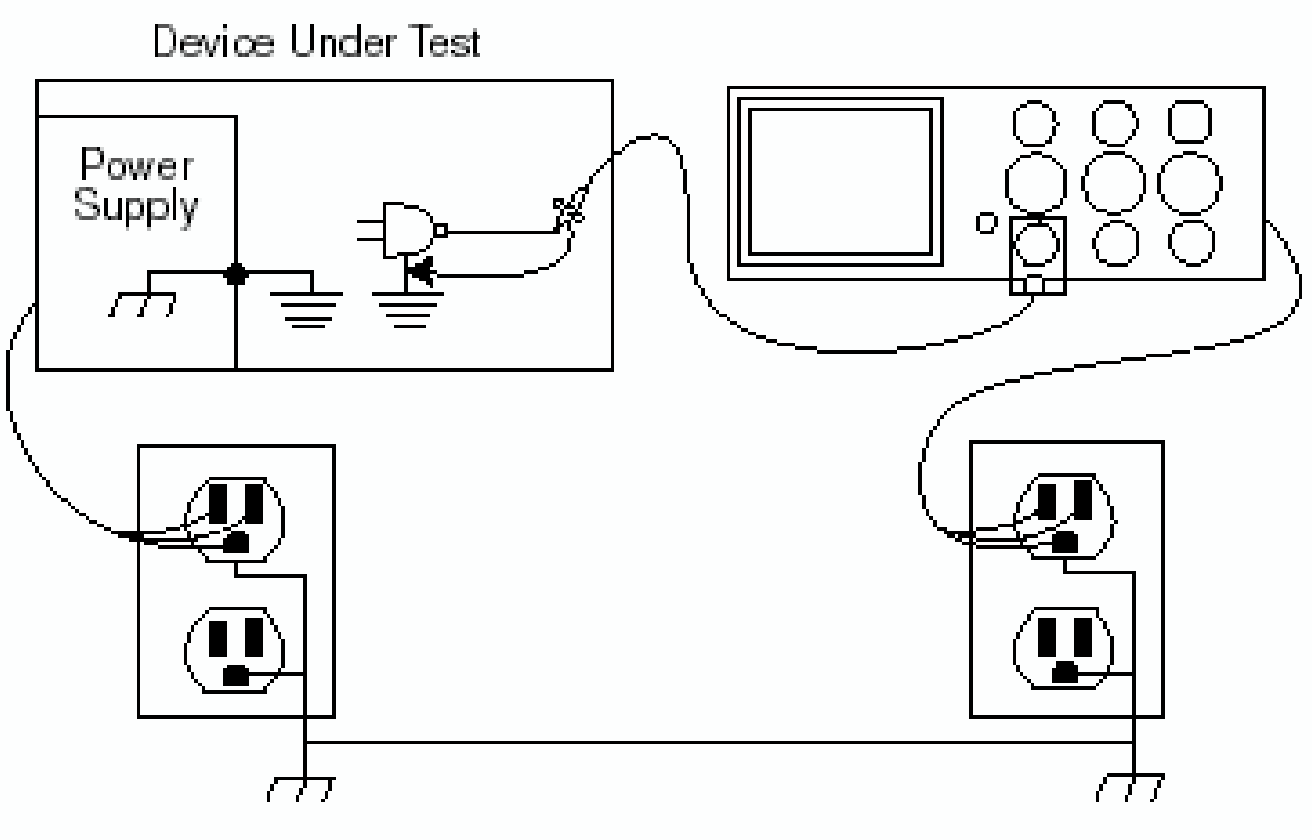




SMK4 Micro KlipChip™ Adapter

~10+ GHz
w/ P7380HHA

Complete Ground Circuit



Noise = Ground loop noise injection + Inductive pickup through the probe cable or ground lead

結論

- 探棒一定有負載
- 被動探棒一定要做補償
- 系統頻寬包括示波器、探棒及待測訊號
- 精確的測量量測工具的系統頻寬最好是待測訊號的3到5倍
- 盡可能使用低輸入電容及短地線
- 使用適當的連接方式接觸測試點