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plug & play instruments
oscilloscopes

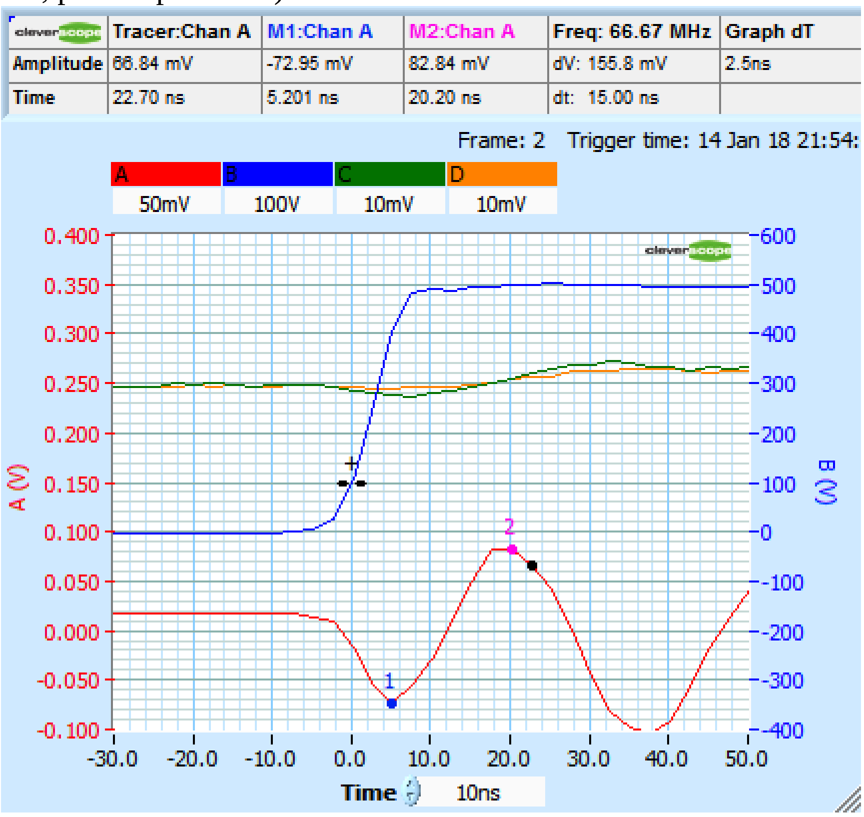
20 Mar 2018 v1.0

CS448 Scope probe common mode choke

Thinking behind using a common mode choke

The CS448 and 10x probe have a capacitance from the probe shield to real earth of about 12 pF. In addition the coaxial shield has an inductance proportional the loop area enclosed by the probe shield and return path. With a probe and cable organized as a circle this inductance amounts to about 1.4 uH, measured with my trusty Smart Tweezers. The series inductance and parallel capacitance will ring with a frequency of $f = \frac{1}{2\,\pi\sqrt{L\,C}}$ or f = 38.8 MHz.

With a 1x probe, we measure this oscillation in response to a step change (Chan A, red transitioning 500V in 6ns, probe tip shorted):



The oscillation period is about 2 x 15ns = 30ns, or f = 33 Mhz, so the inductance is a bit higher for this case (1.9uH), probably because the loop area is a bit bigger. The ring generates a differential end-to-end voltage along the length of the coax which is measured by the oscilloscope.

Reducing the ring

A standard way to reduce the amplitude of the ring in a parallel tank circuit is to add a resistive series component, so the ring voltage causes power dissipation. This can be achieved by noting that there are two current paths on the scope probe coaxial cable - current flowing on the inner surface which completes the return loop for current flowing down the coaxial inner, and current flowing on the outer surface which completes the return loop for currently flowing capacitively to ground from the Unit Under test (UUT), and returning via the channel ground capacitance and then back along the coax outer. The coax outer impedance can be changed by wrapping the coax around a common mode choke, as the outer current loop is not enclosed by the choke. The inner current will not be affected, as it is completely enclosed.

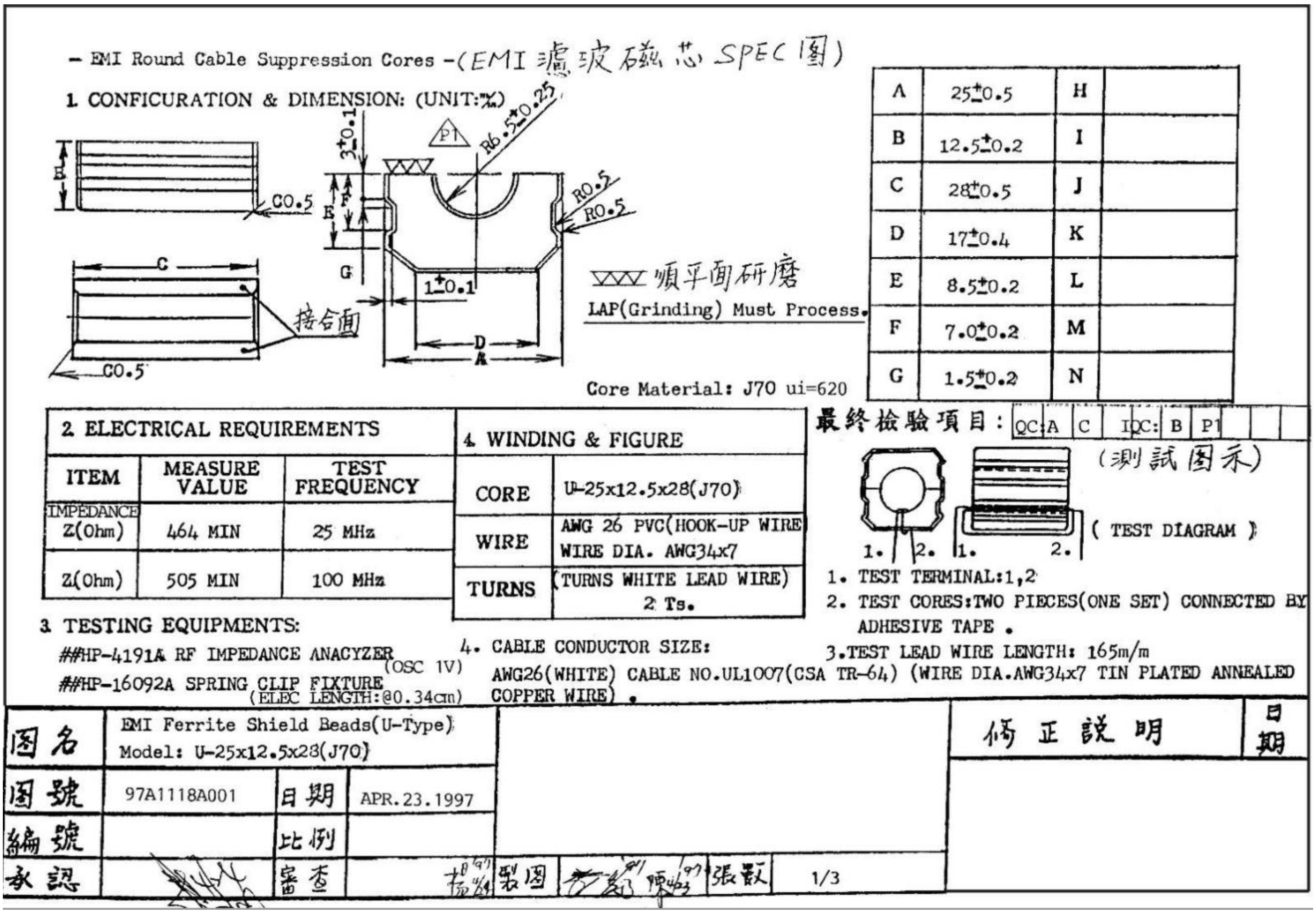
By using a lossy ferrite (ie one with a high resistive component), the ring will be damped. Cleverscope has been trying out various ferrites, and found that the highest loss ferrite is a Chinese origin 'J70' based ferrite for which the resistive impedance component dominates above 1 MHz. The loss factor increases rapidly above 1 MHz.

Summary of Ferrite Properties

Property	Symbol	Unit	Material			
			L8	J70	M7	S1★
Initial Permeability	μ_i		1500 ±20%	620 ±20%	160 ±20%	120 ±20%
Relative Loss Factor	$\tan\delta/u$	$\times 10^{-5}$	<2.8 @ 0.3MHz	<3.89 @ 0.7MHz	<44.6 @ 2MHz	<6.83 @ 1.5MHz
Saturation Flux Density	Bs	Gauss	2550	2500	2205	1625
Residual Flux Density	Br	Gauss	1225	1625	1700	1125
Coercive Force	Hc	Oe	0.225	0.725	1.04	1.275
Curie Temperature	Tc	^{o}C	>120	>150	>150	>200
Disaccommodation Factor	DF	$\times 10^{-3}$	11.8	14.4	1.89	11.7
Density	d	g/cm^3	>5.0	>4.8	>4.6	>4.3
Resistivity	ρ	$M\Omega$-cm	19	5.7	19	18

The ferrite is packaged as two halves of a full core in a plastic holder:

The core outline, and minimum impedance with 2 turns:



A	25±0.5	H	
B	12.5±0.2	I	
C	28±0.5	J	
D	17±0.4	K	
E	8.5±0.2	L	
F	7.0±0.2	M	
G	1.5±0.2	N	

2. ELECTRICAL REQUIREMENTS

ITEM	MEASURE VALUE	TEST FREQUENCY
IMPEDANCE Z(Ohm)	464 MIN	25 MHz
Z(Ohm)	505 MIN	100 MHz

4. WINDING & FIGURE

CORE	U-25x12.5x28(J70)
WIRE	AWG 26 PVC(HOOK-UP WIRE WIRE DIA. AWG34x7
TURNS	(TURNS WHITE LEAD WIRE) 2 Ts.

最終檢驗項目: QC: A C IQC: B P1

(測試圖示)

(TEST DIAGRAM)

1. 2. 1. 2.

1. TEST TERMINAL:1,2
2. TEST CORES:TWO PIECES(ONE SET) CONNECTED BY ADHESIVE TAPE .
3. TEST LEAD WIRE LENGTH: 165m/m

3. TESTING EQUIPMENTS:

##HP-4191A RF IMPEDANCE ANACYZER (OSC 1V)

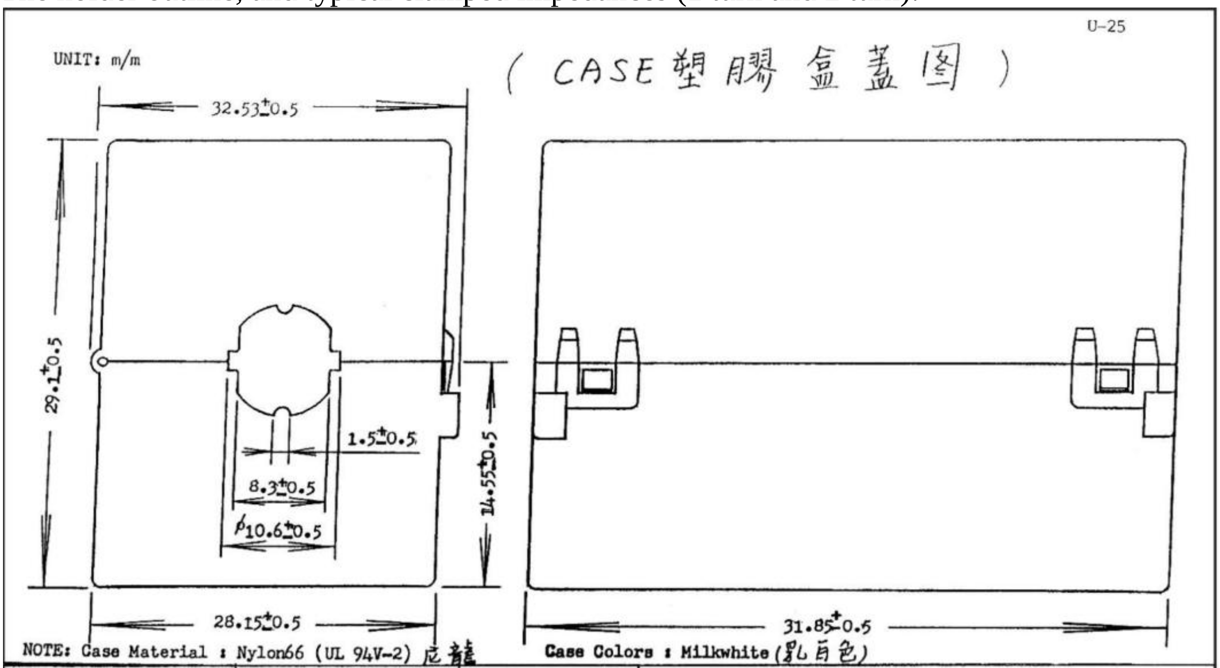
##HP-16092A SPRING CLIP FIXTURE (ELEC LENGTH:@0.34cm)

4. CABLE CONDUCTOR SIZE:
AWG26(WHITE) CABLE NO.UL1007(CSA TR-64) (WIRE DIA.AWG34x7 TIN PLATED ANNEALED COPPER WIRE) .

图名	EMI Ferrite Shield Beads(U-Type) Model: U-25x12.5x28(J70)				
图號	97A1118A001	日期	APR.23.1997		
編號		比例			
承認		審查	製图	張數	1/3

修正說明	日期

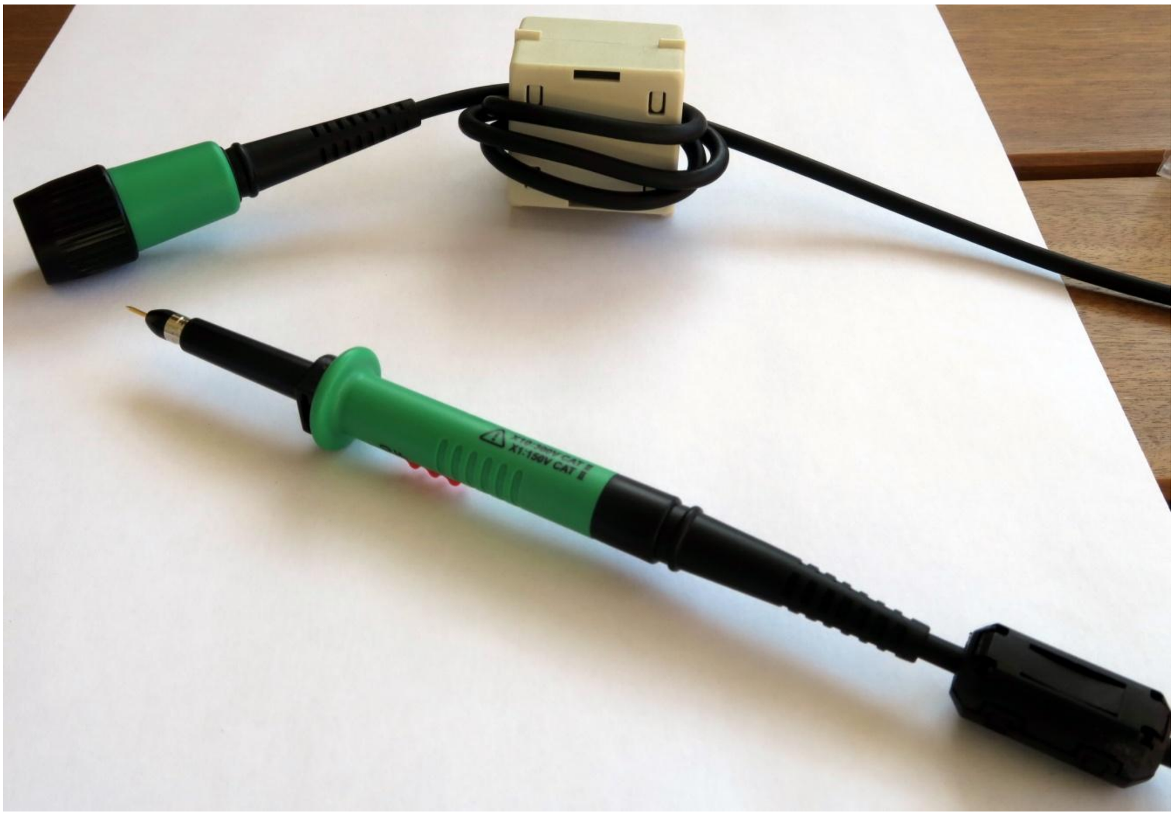
The holder outline, and typical clamped impedances (1 turn and 2 turn):



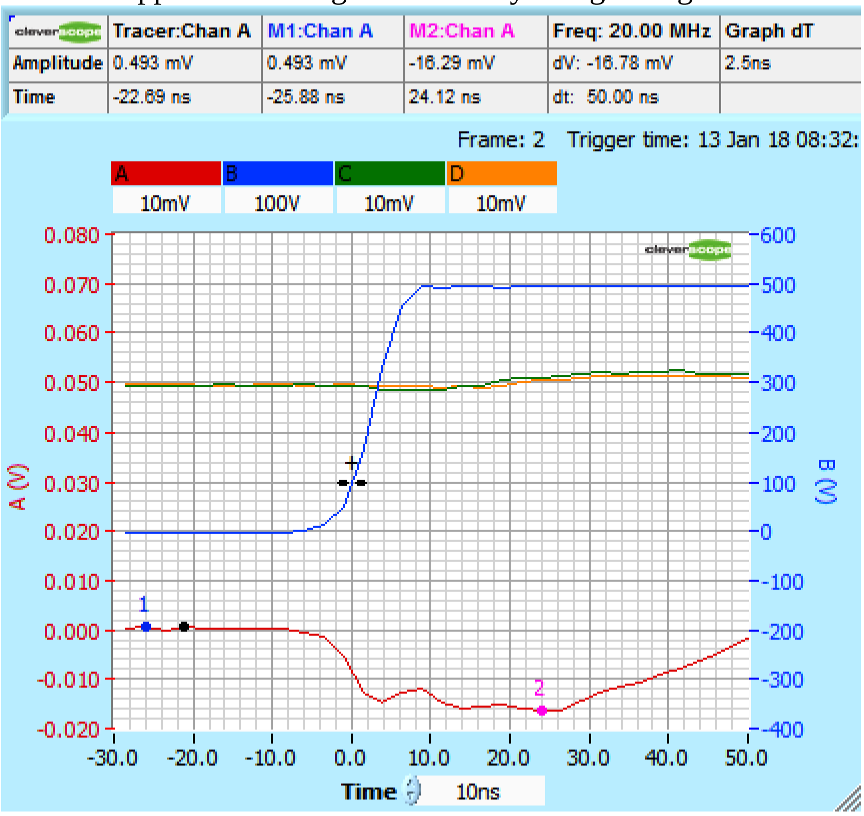
2.ELEC Z(Ohm) 1Ts. Typical Impedance @ 25MHZ	@ 100MHZ	Z(Ohm) 2Ts. Typical Impedance @ 25MHZ	@ 100MHZ	3. Applic CABLE ø m/m	4.NOTES:
163	267	658	729	~10.0	5.REV:

Actual Use

Cleverscope wrapped the probe coax 3 times around the core close to the BNC plug end (for convenience). Maximum efficiency is at the probe tip, but this is cumbersome. We have experimented with small cores at the probe tip, but not much is gained.



With this approach the ring is reduced by a large margin:



We recommend and will supply suitable common mode chokes.