EMC Experiment Demonstration.

"Decoupling/bypass capacitor characteristics."

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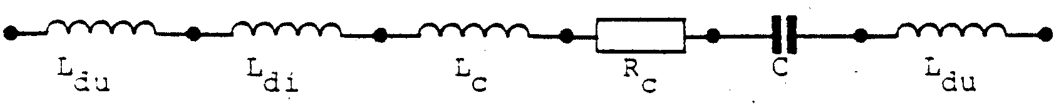
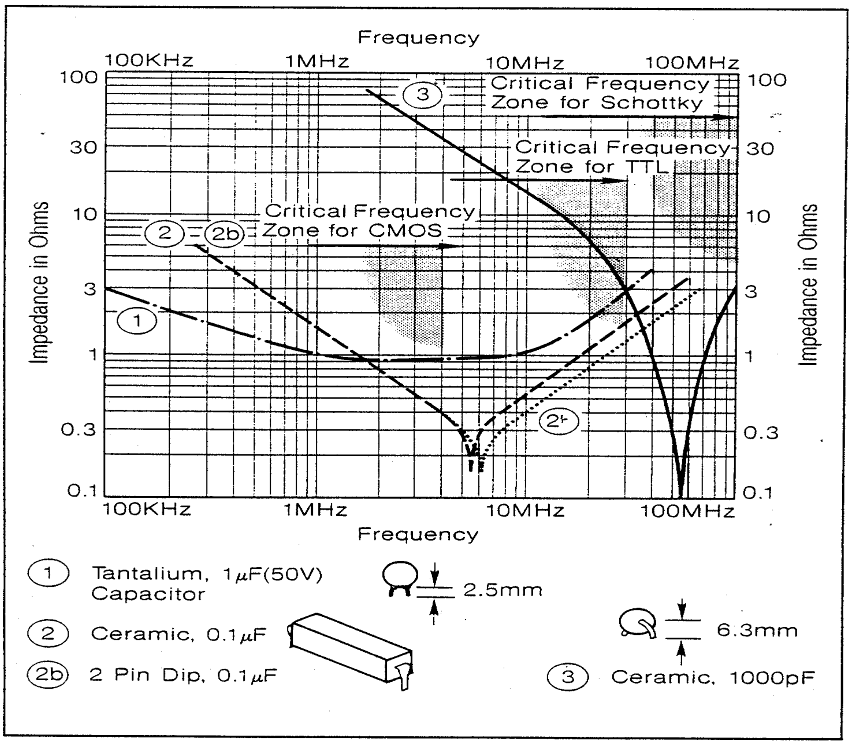
Measurement of insertion loss of various capacitor types using a spectrum analyser with tracking generator. (Or Component/Network Analyzer).
The self-resonant frequency and parallel resonance can be demonstrated with capacitors mounted in a shunt arrangement on test fixtures. The characteristics are evaluated between 50 Ohm source and 50 Ohm load.

In a shunt bypass/decoupling situation a capacitor has internal inductance and connecting lead inductance. The combination of capacitance and inductance will at some frequency become self-resonant. The capacitors then behave as capacitors below the self-resonant frequency and inductors above.

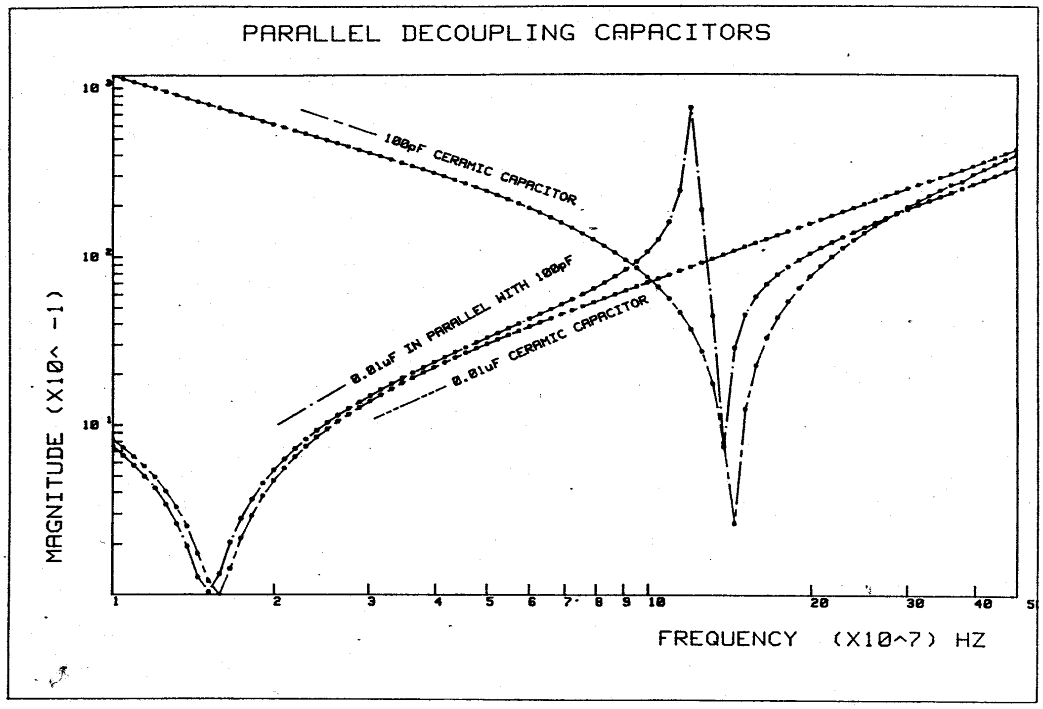


Ldu connecting lead partial self inductance.
Ldi internal conducting lead partial self inductance.
Lc construction inductance (distributed, but represented as single element).
Rc equivalent series resistance (due to skin-effect therefore frequency dependant).

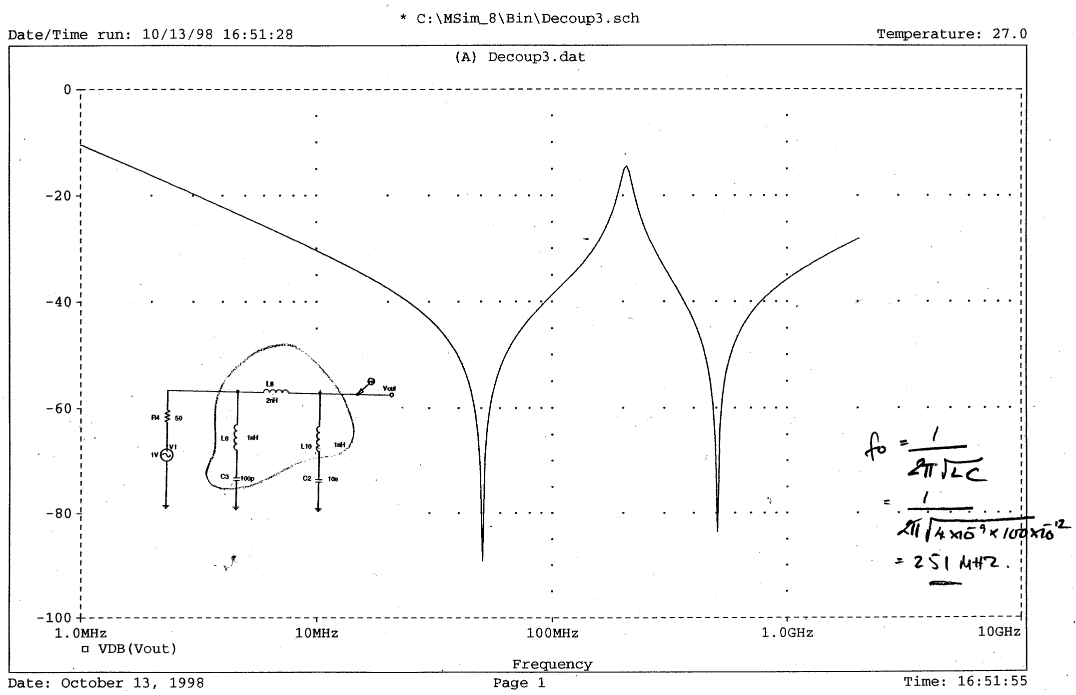


Impedance vs. Frequency of Some Typical PCB Mount Capacitors

There is a potential problem if both a low and high value bypass capacitor are used together in parallel, in an attempt to produce decoupling over a wide frequency range. Between the self-resonant frequencies of the two capacitors, a parallel resonance occurs where the impedance is larger than that of either capacitor.



Measured impedances of a 0.01 μF and a 100 pF ceramic capacitor individually and in parallel from 10 to 500 MHz.

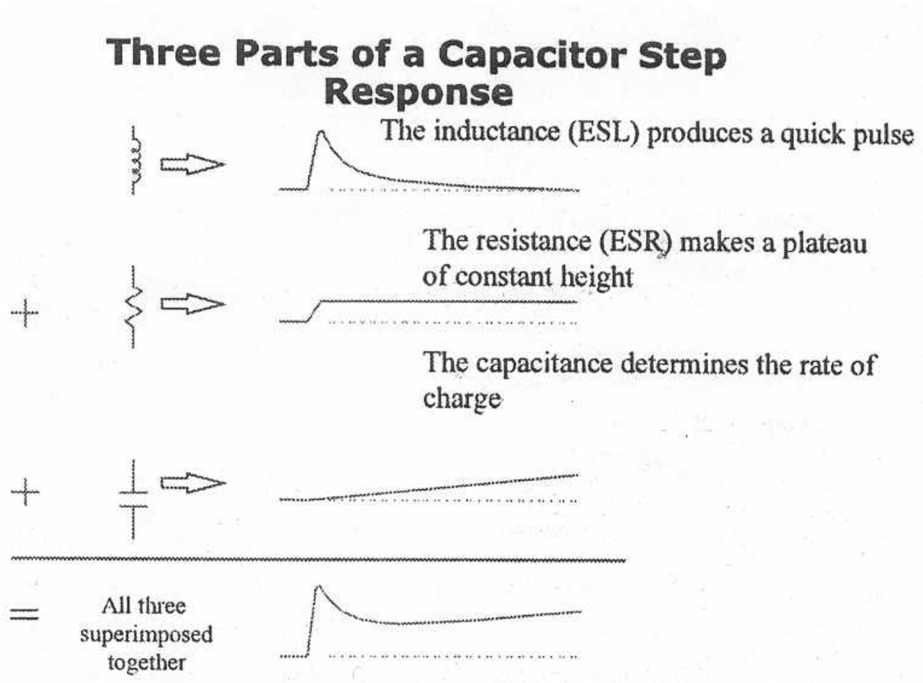


Spice simulation of parallel resonance associated with two bypass capacitors mounted in parallel (100pF and 10nF). The frequency of the parallel resonance will vary dependent on distance (inductance) between the capacitors.

Evaluating the inductance associated with bypass capacitors using Time Domain Reflectometry (TDR) and Time Domain Transmission (TDT).

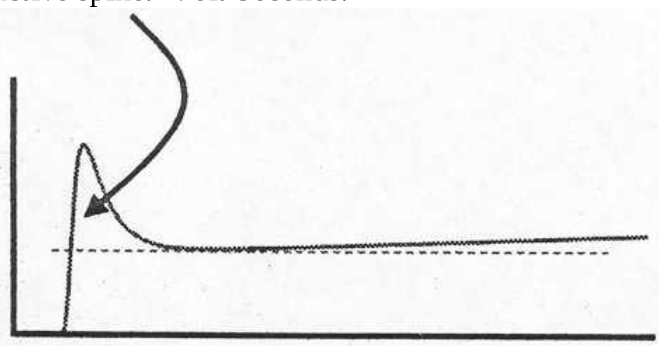
There is an interest in measuring the often very small value of inductance associated with a capacitor, without the reliance on the careful normalization that is required with a Network/Component Analyzer. If the component is mounted in a shunt arrangement across a test fixture, the capacitance may be determined from the TDR response. Additionally from the TDT response, the value of the components inductance may be determined from the area under the initial pulse observed. The measurement instruments Excess Reactance feature can calculate this area and hence inductance value.

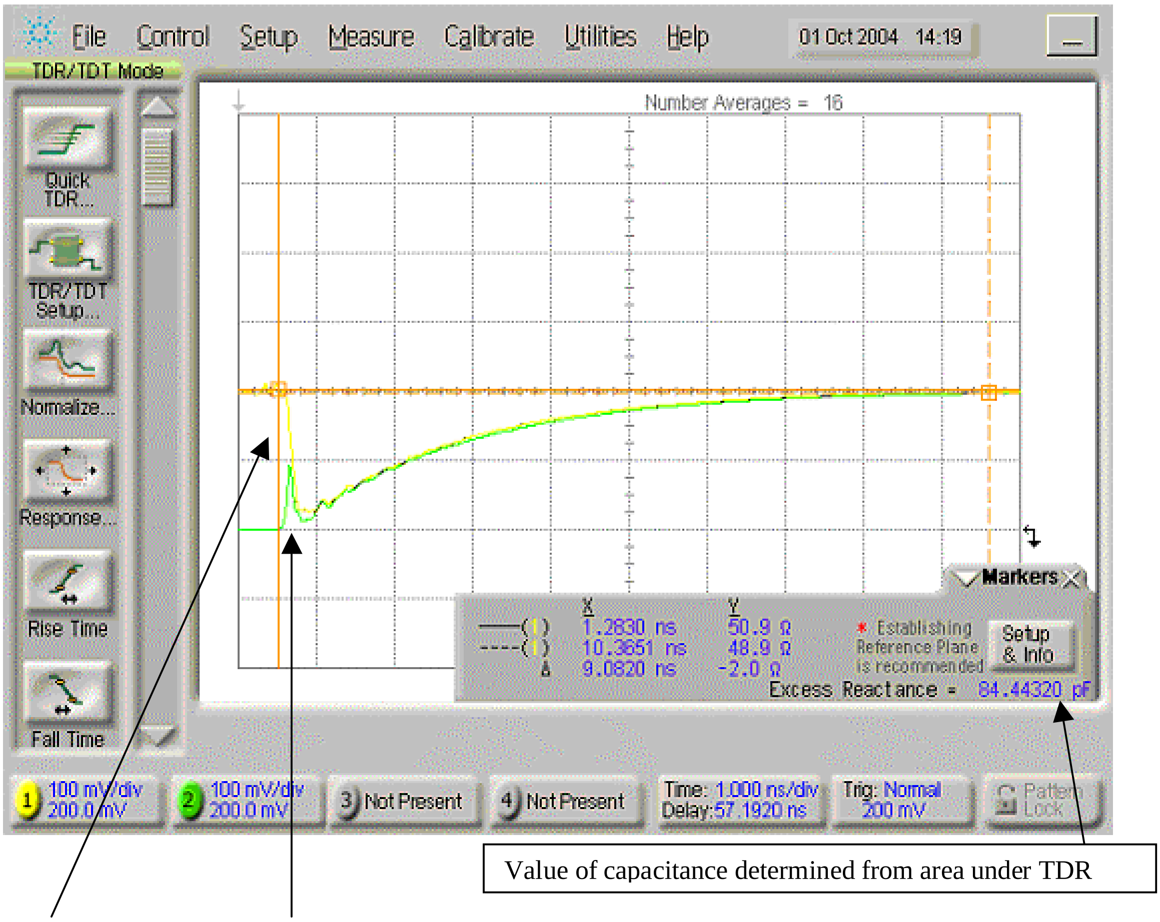
Composition and determination of inductance from area under TDT response.



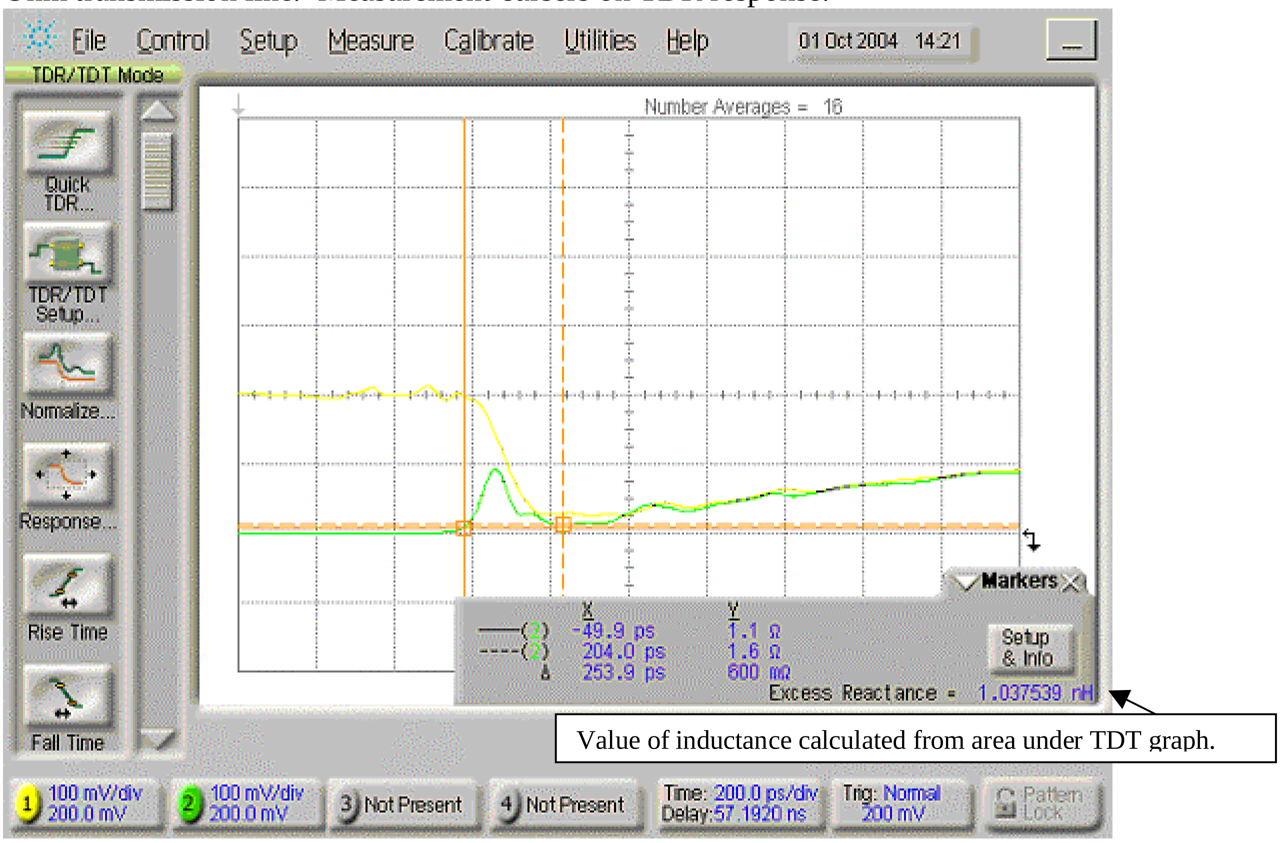
Rs	Source impedance (resistance) of measurement system and test jig. Ohms
V	Open circuit step voltage of test jig. Volts.
L	Inductance. Henries.
A	Area under inductive spike. Volt Seconds.

$$L = \frac{R_S A}{\Delta V}$$



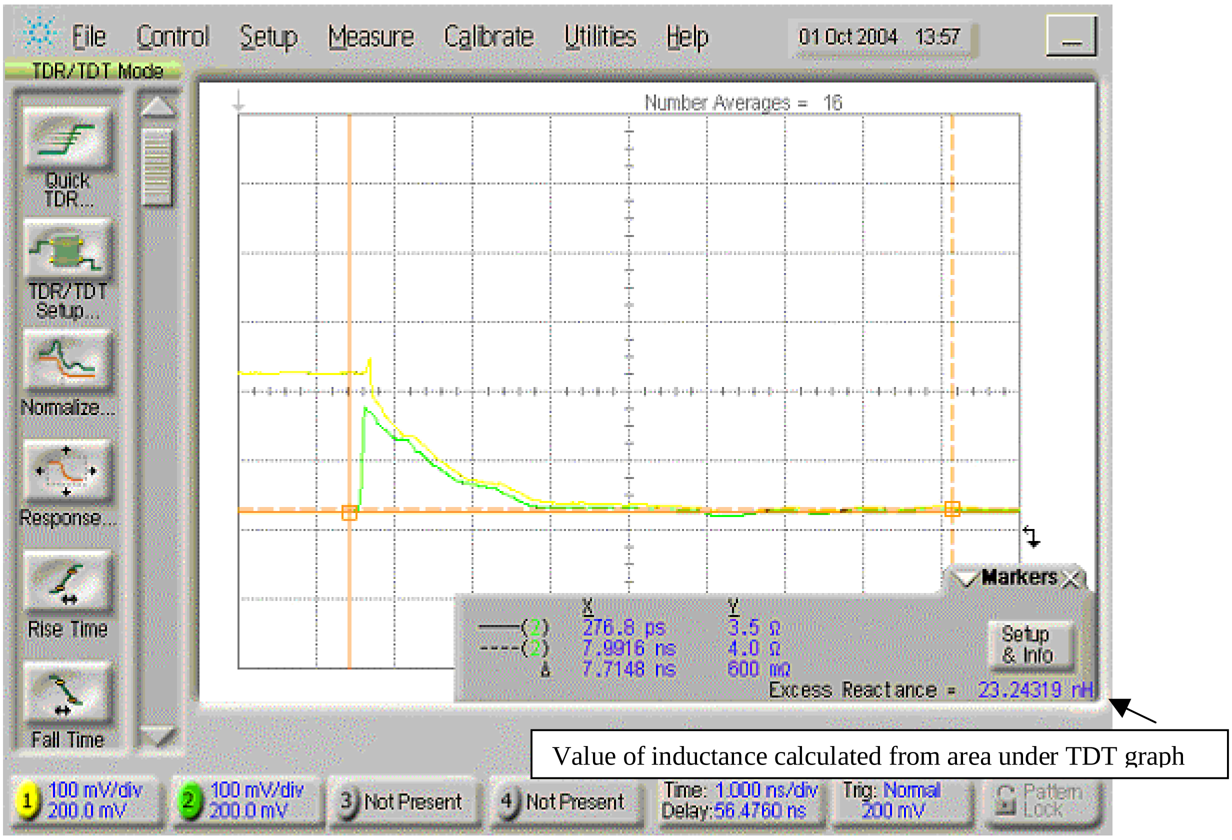


TDR (yellow) and TDT (green) initial pulse response of capacitor (82pF) across 50 Ohm transmission line. Measurement cursers on TDR response.



TDR and TDT (green) response of capacitor (82pF) across 50 Ohm transmission line, (with expanded horizontal time scale). Measurement cursers on TDT response.

The value of inductance associated with a bypass capacitor component is fairly small compared to the value of its mounting position inductance on a PCB. The total component and mounting inductance value, can be determined by probing at the IC supply pins and assessing the TDT response.



TDR (yellow) and TDT (green) response at the PCB IC DC supply pins with bypass capacitor (100nF) in position. Measurement cursers on TDT response.