

# Crosstalk and Impedance Measurements of PC Board Patterns

— HP 4194A Application Information —

Introduction

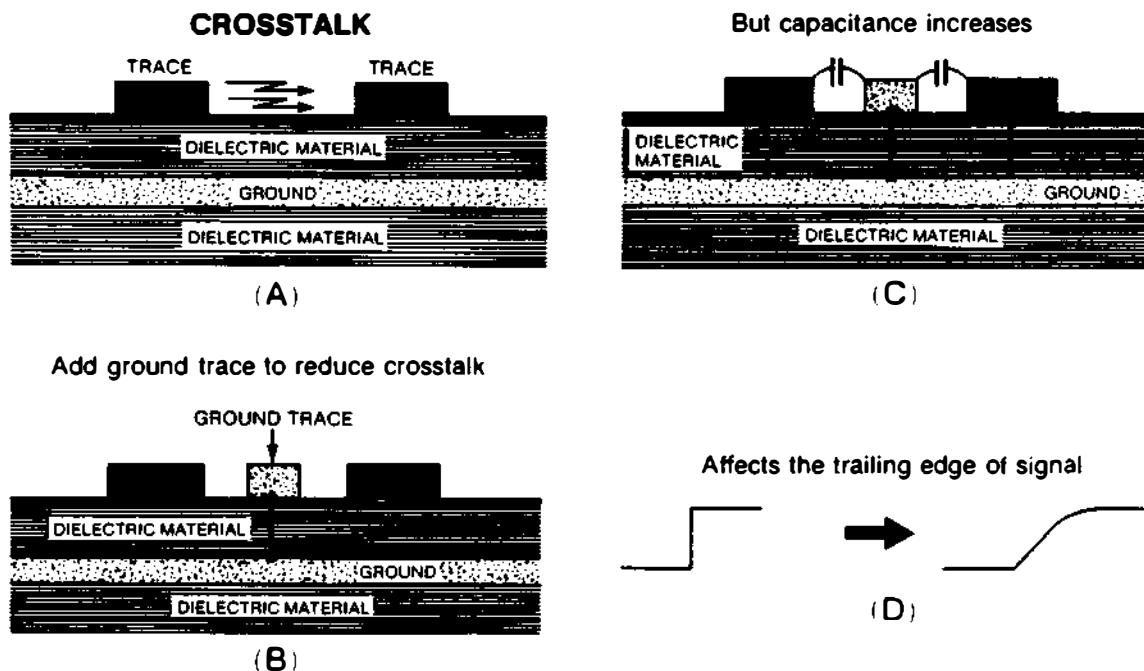
This application sheet describes how to use the HP 4194A Impedance/Gain-Phase Analyzer to measure impedance parameters ( $Z, C, G, L, R$ ), crosstalk, and the dielectric constant of PC boards. This information will be useful to PC board and circuit designers, PC board end users and material suppliers.

Problem

The demand to measure more PC board parameters has increased because of the complexity of today's boards and circuits. Electronic instruments and computers are utilizing higher density and multilayer PC boards. Device speeds have also increased, causing more concern about the signal timing characteristics.

Capacitance and crosstalk between traces increases as PC board's density and number of layers increase. A ground trace can be added between traces to reduce crosstalk, but the capacitance between the trace and ground will also increase. The trace-to-ground capacitance increases because the dielectric material in the PC board becomes thinner. A large capacitance between the trace and ground rounds off the edges of a signal (refer to Fig 1).

Figure 1 Capacitance and Crosstalk on a PC Board



## Impedance Measurements

PC board designers must be concerned about impedance. The HP 4194A Impedance/Gain-Phase Analyzer and HP 41941A/B Impedance Probe can measure various kinds of impedance parameters.

### 1) Characteristic Impedance

Refer to the Application Note 339-2.

### 2) Capacitance and conductance between traces or trace and ground, and trace inductance and resistance

Use the HP 41941A/B Impedance Probe to measure the impedance parameter on the PC board.

#### NOTE

The following should be used as guidelines for designing good PC board traces.

- 1) For high frequency analog and ECL circuits, the characteristic impedance ( $Z_0$ ) should be designed as follows;

$$Z_0 = \sqrt{\frac{L}{C}} \quad , \quad \begin{array}{l} L \text{ is the trace series inductance} \\ C \text{ is the trace-to-ground capacitance} \end{array}$$

- 2) For other digital circuits, the capacitance between traces and trace-to-ground must be minimized. The inductance and resistance of each trace must also be minimized.

## Crosstalk Measurement

The HP 4194A Impedance/Gain-Phase Analyzer can measure crosstalk between traces on a PC board using its gain-phase measurement function (10 Hz to 100 MHz). To measure crosstalk, make the connections shown in Figure 2b or 3b, depending upon the direction of the signals (Figure 2a and 3a). You should have good connections when measuring up to 100MHz. Solder cables and resistors to the PC board directly. Resistor leads should be as short as possible.

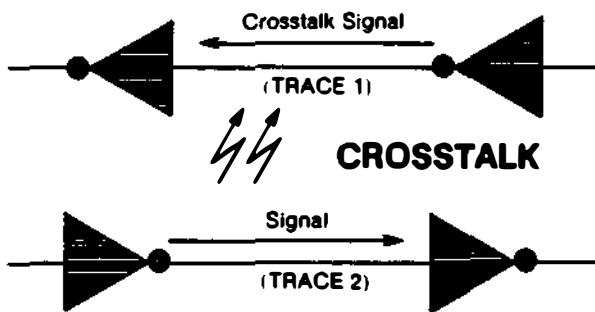


Figure 2a PC Board Signal & Crosstalk

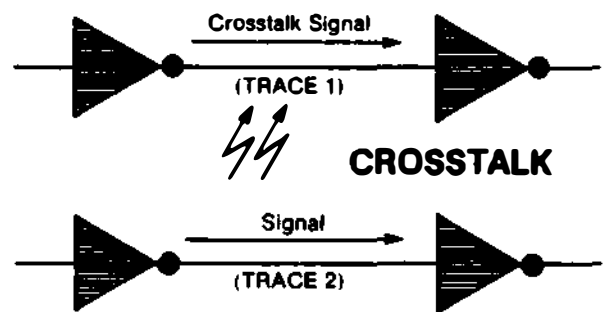


Figure 3a PC Board Signal & Crosstalk

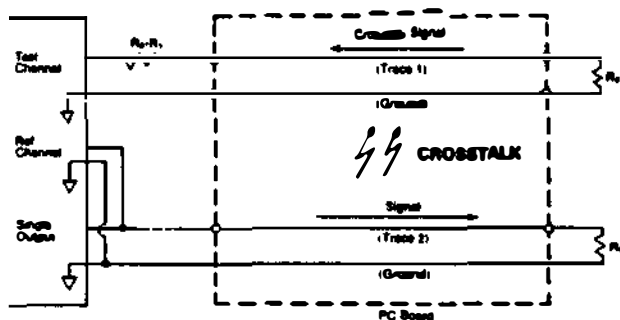


Figure 2b PC Board Crosstalk Measurement

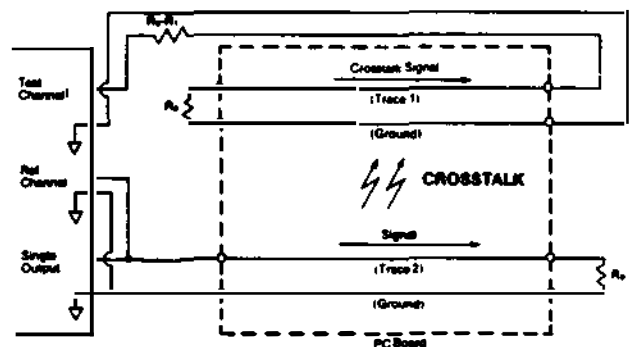


Figure 3b PC Board Crosstalk Measurement

where;

$R_0$ : characteristic impedance of PC board trace

$R_1$ : 50 ohms (4194A/41941A/B w/opt 350)  
75 ohms (4194A/41941A/B w/opt 375)

When the input impedance of an IC is much greater than the PC board trace characteristic impedance, and the IC output impedance is less than the PC board characteristic impedance, then there is another way to measure crosstalk. In this case, leave one end of both traces open and measure. Refer to Figure 4 for an example.

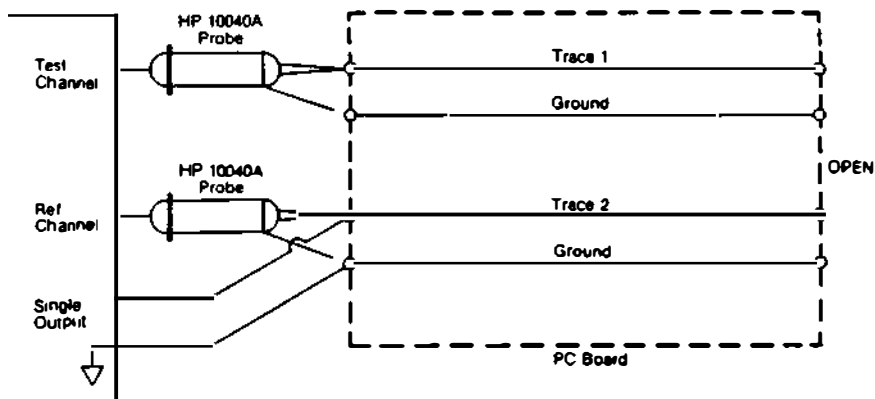


Figure 4 Crosstalk PC Board Measurement

### Dielectric Constant

The dielectric constant of PC board material is derived from capacitance measurement (refer to the dielectric constant equation in Figure 4). The HP 4194A can measure capacitance and calculate the dielectric constant using an Auto Sequence Program (an internal basic-like program that controls the HP 4194A operation without a computer). The HP 4194A can then display the dielectric constant vs frequency on its color CRT.

$$K \text{ sample} = \frac{d * C \text{ sample}}{A * E_0}$$

where;

K sample = Dielectric constant of the device

C sample = Capacitance value of the device (this is measured)

A = Area of electrode

d = Distance between the electrodes

E<sub>0</sub> = Permittivity of free space (8.854 X 10<sup>-12</sup>)

For more information, call your local HP sales office listed in the telephone directory white pages. Ask for the Electronic Instrument Department, or write to Hewlett-Packard U.S.A. - P.O. Box 10301, Palo Alto, CA 94303-0890 Europe - Hewlett-Packard S.A., P.O. Box 529, 1180 AM Amstelveen, The Netherlands Canada - 6877 Goreway Drive, Mississauga, L4V 1M8 Ontario Japan - Yokogawa-Hewlett-Packard Ltd., 3-29-21, Takaido-Higashi, Suginami-ku, Tokyo 168 Far East - Hewlett-Packard Asia Headquarters, 47/F China Resources Building, 26 Harbour Road, Wanchai Hong Kong Australasia - Hewlett-Packard Australia Ltd., 31-41 Joseph Street, Blackburn, Victoria 3130 Australia. Latin America - Hewlett-Packard Latin America Headquarters, 3495 Deer Creek Rd., Palo Alto, CA 94304. For all other areas, please write to: Hewlett-Packard Intercontinental Headquarters, 3495 Deer Creek Rd., Palo Alto, CA 94304