3.7.2.2 TDR PLOTS TUTORIALS

This chapter is intended to give you some ideas on how electronic components look like in the time domain.

INTRODUCTION

The characterization of parasitic devices can be done in the time domain or in the frequency domain. But time domain may be smarter, since the parasitic devices show-up with respect to their physical location. In the frequency domain, using s-parameters, we always have an overlay of curves that 'turn to the right' for capacitors, inductors or delay lines.

> Note: For frequencies below 3GHz, a simple parasitic device schematic is often sufficient (two delay lines or capacitors at port1 and port2 and a cross-coupling capacitor, no inductors).

Using time domain, it is best using a time domain reflectometer (TDR) like the hp54xxx series oscilloscopes with a TDR plug-in on channel_1. A voltage step of typically 200mV is triggered by IC-CAP on channel_1 and the back reflections are then measured by channel_1 also. Using other channels of the TDR, one could also measure the cross-coupling from one port of the test object to another.

TDR measurements are best for the modeling of geometrically large or spread structures.
As an example, we consider the modeling of the test fixture:
This can be done using delay lines, inductors (positive spikes in the back-reflected signal) and/or capacitors (negative spikes). Changes in the amplitude of the reflected signal are modeled using parallel (negative amplitude step) or series resistors (positive amplitude step). After the the measured curve has been fitted, the parameters of the test fixture parasitics are known and the 'inner' transistor can be de-embedded from S-parameter NWA measurements using Y-, Z- and/or S-matrix manipulations.

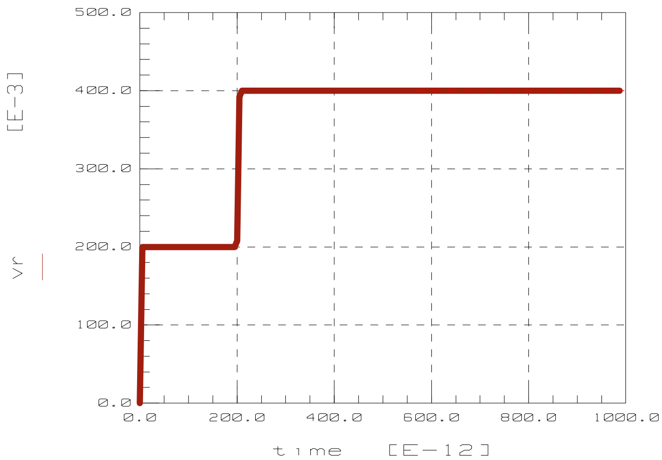
EXPECTED REFLECTOGRAMS OF TYPICAL PARASITIC COMPONENTS

IC_CAP file: tdr_plots.mdl

The following plots are intended to help you with the development of equivalent circuits from reflectograms.

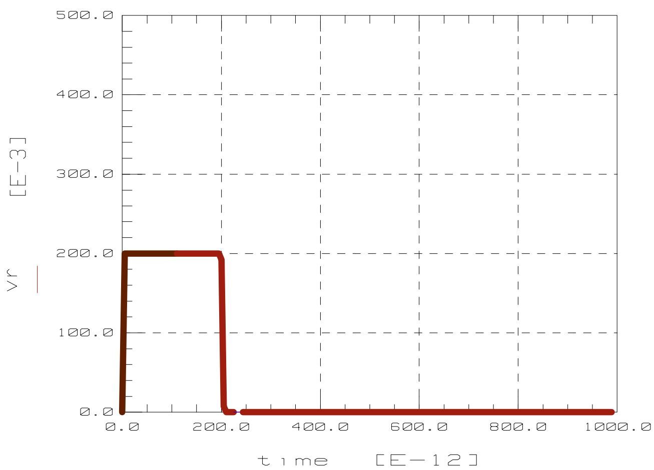
OPEN 50 OHM LINE

```
o----------------o
    t1=100ps

o----------------o
```



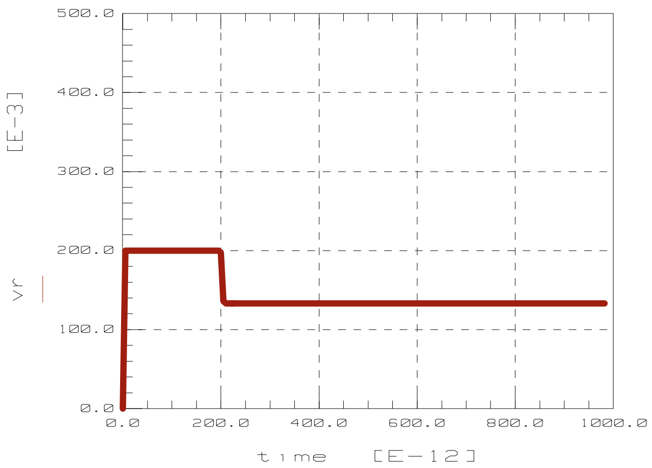
SHORTENED 50 OHM LINE

```
o----------------o-
    t1=100ps       |
                   |
o----------------o-
```



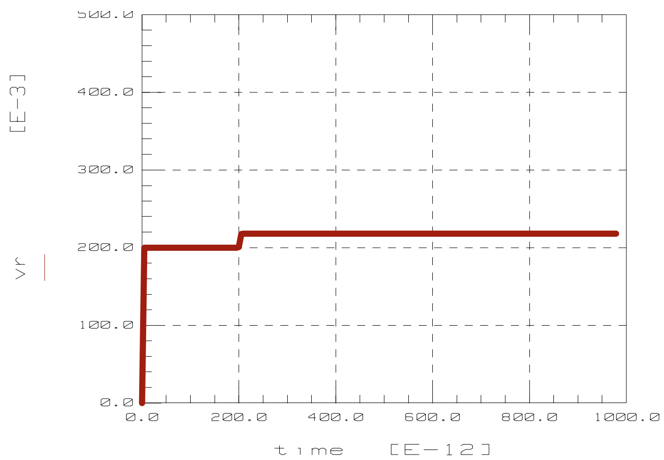
50 OHM RESISTOR BETWEEN TWO 50 OHM LINES

```
o---------------o-----o-----o---------------o
                      ┴
                     | |50 Ohm
     t1=100ps        |_|       t2= infinite
                      |
o---------------o-----o-----o---------------o
```



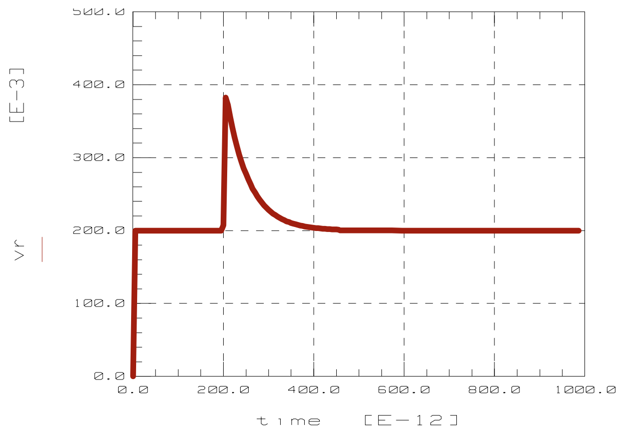
10 OHM RESISTOR IN SERIES TO TWO 50 OHM LINES

```
                           ___
o---------------o---|___|---o--------------o
                    10 Ohm
      t1=100ps                t2=infinite

o---------------o-----------o--------------o
```



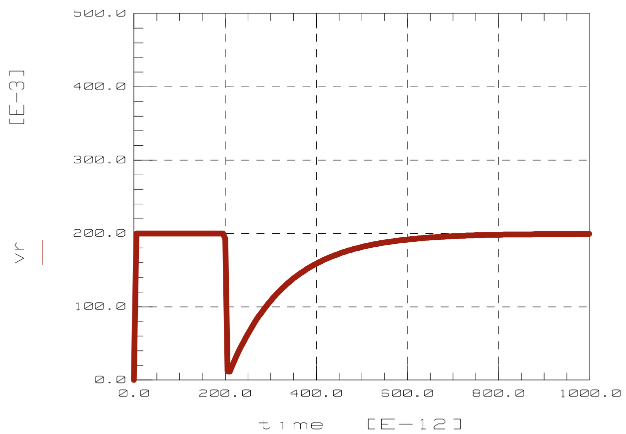
5nH INDUCTOR IN SERIES WITH TO TWO 50 OHM LINES

```
o----------------o---/\/\/---o--------------o
                      5 nH
   t1=100ps                     t2=infinite

o----------------o-----------o--------------o
```



5pF CAPACITOR BETWEEN TWO 50 OHM LINES

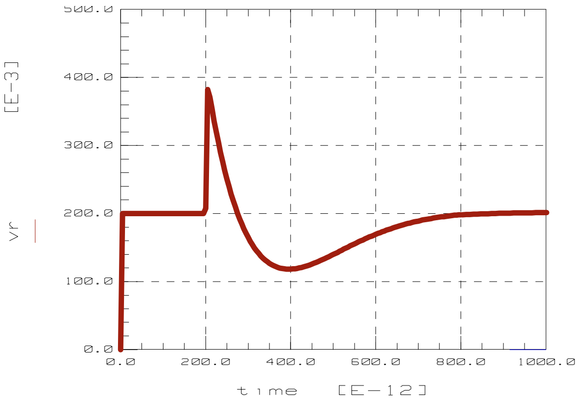
```
o----------------o--0--o--------------o
                    |
  t1=100ps         ---    t2=infinite
                   ---
                    | 5 pF
o----------------o--0--o--------------o
```



5nH INDUCTOR AND 5pF CAPACITOR BETWEEN TWO 50 OHM LINES

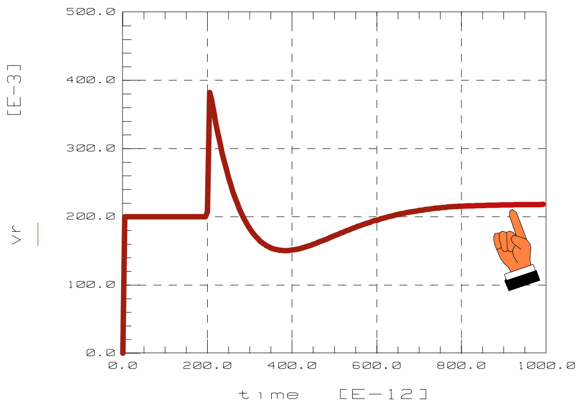
delay time: t_1=100ps

```
o---------------o--/\/\/---o--o-------------o
                    5nH     |
       t1                  ---    t2=infinite
                           ---
                            | 5 pF
o---------------o----------o--o-------------o
```



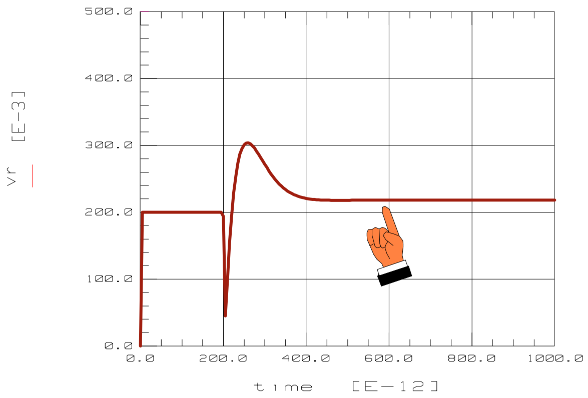
5nH INDUCTOR, 10 Ohm RESISTOR AND 5pF CAPACITOR BETWEEN TWO 50 OHM LINES

```
                                  ___
o---------------o--/\/\/--|___|--o--o-------------o
                    5nH    10 Ohm |
    t1=100ps                     ---    t2=infinite
                                 ---
                                  | 5 pF
o---------------o----------------o--o-------------o
```



5pF CAPACITOR, 5nH INDUCTOR AND 10 Ohm RESISTOR BETWEEN TWO 50 OHM LINES

```
                                           ___
o----------------o---o---/\/\/---|___|---o--------------o
                     |    5nH      10 Ohm
    t1=100ps        ---                         t2=infinite
                    ---
                     | 5 pF
o----------------o---o------------------o--------------o
```



<u>A note on mutual inductors and TDR measurements:</u>

Parallel strip lines, coupling across with mutual inductors (even with high coupling factors), are usually not much affecting the TDR measurement of the single strip line. But they can affect the corresponding S-parameter measurements heavily! So, for their modeling, either a THRU measurement of the cross-coupled signal using the oscilloscope input of the TDR will be necessary or additional measurements using a network analyzer.

<u>A note on the skin effect and TDR measurements:</u>

The skin effect shows-up in TDR measurements with a declining slope of the step response. See the chapter 'Modeling the Skin Effect' under 'Modeling Utilities' in the chapter 'Device Modeling' at the end of the book.

