Advantages and Limitations of the PCB-Adapter PBA-3002A

high power pulse instruments

Advanced TLP/HMM/HBM Solutions

1 Introduction

Fig. 1 shows the PBA-3002A, which can be used for quick and easy measurements:

- pulsed IV-characteristic of discrete devices
- pulsed IV-characteristic of specific pin combinations on soldered ICs on a e.g. printed circuit board (PCB), in order to investigate which kind of ESD protection is integrated in the IC and correlation of standard TLP (100 ns pulse width, 10 ns rise time) with HBM (ANSI/ESDA/JEDEC JS-001)

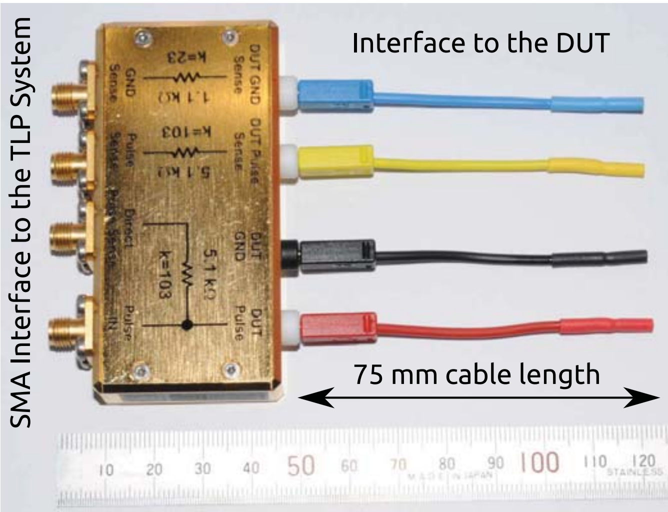

Figure 1: PCB adapter PBA-3002A

1.1 Interface to the DUT

The 4 lumped cables for device-under-test (DUT) connection are 75 mm long:

DUT Pulse (red): connect the DUT Pulse

DUT GND (black): connect the DUT GND

DUT Pulse Sense (yellow) - optional: sense the DUT pulse signal at the DUT with a separate channel for better waveform quality (optional)

DUT GND Sense (blue) - optional: sense the DUT GND signal at the DUT with a separate channel for better waveform quality (optional)

1.2 SMA Interface to the TLP System

The SMA interface to the TLP systems has 4 ports:

Pulse In Pulse signal coming from the high voltage pulse generator (TLP)

Direct Pulse Sense DUT voltage sensing output with integrated voltage divider 5.1 kΩ / 50 Ω which results in a voltage scaling factor of (5100 + 50)/50 = 103.

Pulse Sense (optional) if separate pulse sense channel is used. Integrated voltage divider 5.1 kΩ / 50 Ω which results in a voltage scaling factor of (5100 + 50)/50 = 103.

GND Sense (optional) if separate GND sense channel is used. Integrated voltage divider 1.1 kΩ / 50 Ω which results in a voltage scaling factor of (1100 + 50)/50 = 23.

1.3 Setup and Limitations

1.3.1 Direct Pulse Sense

The direct pulse sense setup shown in Fig. 2 is the most simple one.

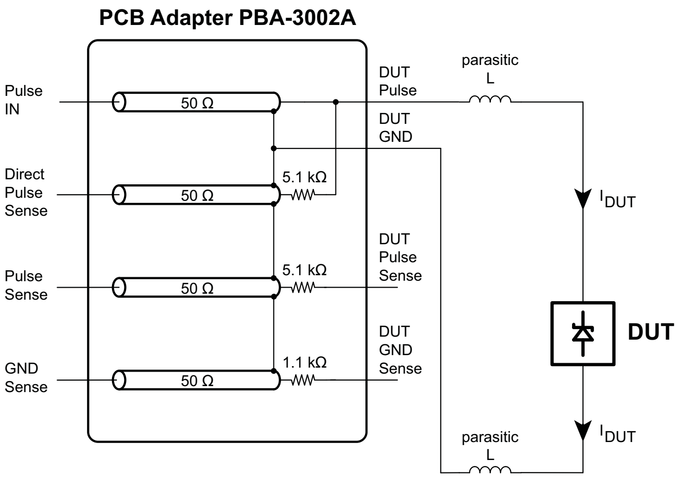

Figure 2: Direct pulse sense

$$V_{DUT} = 103 \cdot V_{\text{Direct Pulse Sense}} \qquad (1)$$

Advantage:

- only two cables necessary to connect the DUT

Disadvantage:

- parasitic inductance L of the DUT cable create additional voltage overshoot and ringing at the internal voltage sensing node which distort the “Direct Pulse Sense” signal

To evaluate the frequency response of the setup shown in Fig. 2 the PBA-3002A has been measured with a vector network analyzer as shown in Fig. 3. Please note also the port definition shown in this figure.

Fig. 4 shows the frequency response of pulse input to DUT (which is S21) in dB. It can be seen clearly in Fig. 4, that the frequency response of the pulse force line is limited to about

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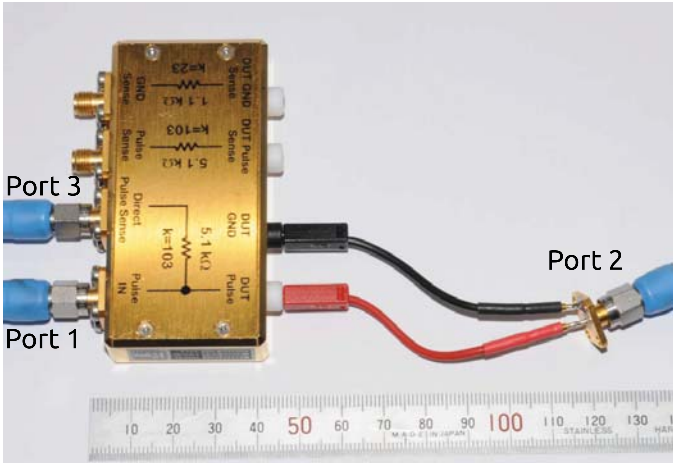

Figure 3: PBA-3002A measured with a vector network analyzer from 300 kHz to 9 GHz

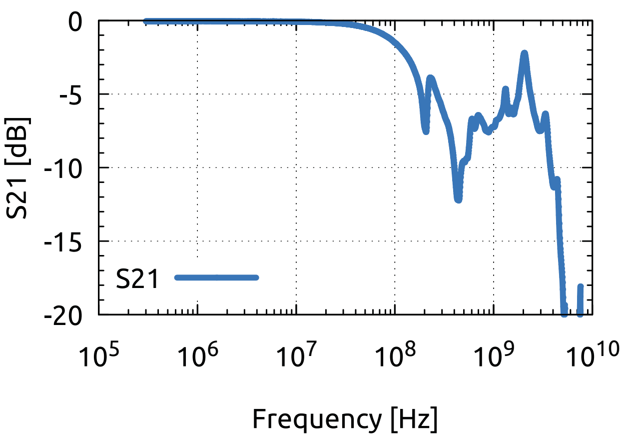

Figure 4: PBA-3002A frequency response of pulse input to DUT (S21) in dB

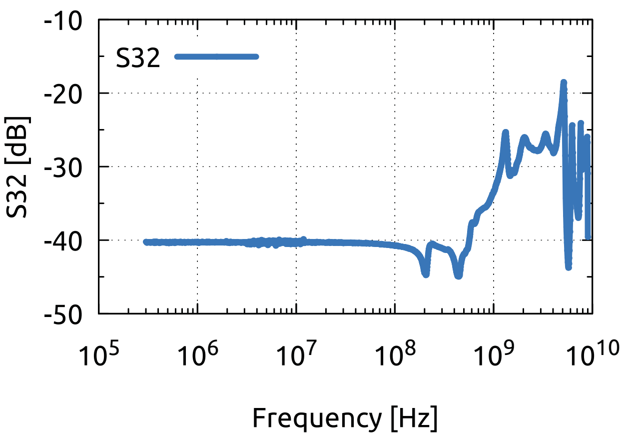

Figure 5: PBA-3002A frequency response of "Direct Pulse Sense" channel (which is S32) in dB

150 MHz because of the parasitic inductance of the 75 mm long lumped DUT cables.

The same basic behavior holds true for the "Direct Pulse Sense" channel. Fig. 5 shows the frequency response from DUT to the "Direct Pulse Sense" SMA output (which is S32) in dB. The nominal attenuation related to the scaling factor of 103 results to $20 \cdot \log_{10}(1/103) = -40.26$ dB. It can be seen that the frequency response of the "Direct Pulse Sense" channel starts to deviate at about 150 MHz onward because of the parasitic inductance of the 75 mm long lumped DUT cables.

1.3.2 Separate Pulse Sense

The separate pulse sense setup shown in Fig. 6 overcomes the parasitic inductance of the DUT pulse cable.

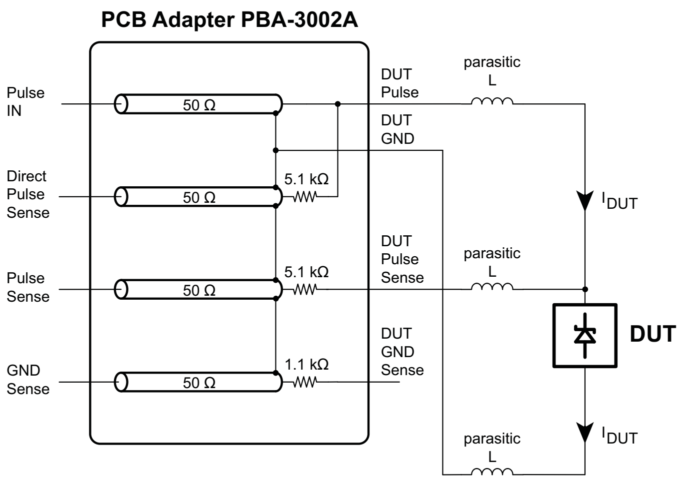

Figure 6: Separate pulse sense channel

$$V_{DUT} = 103 \cdot V_{\text{Pulse Sense}} \quad (2)$$

Advantage:

- more accurate DUT voltage measurement because avoiding parasitic voltage drop in the DUT pulse cable due to parasitic inductance L

Disadvantage:

- 3 DUT cables required

Similar limitations of the frequency response happen as discussed and shown in Sect. 1.3.1.

1.3.3 Separate Pulse Sense and GND

The separate pulse sense and GND sense setup shown in Fig. 7 overcomes the parasitic inductance of the DUT pulse and DUT GND cable.

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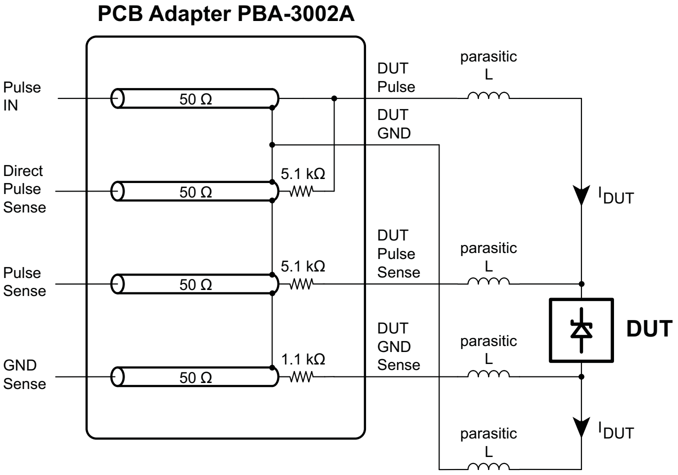

Figure 7: Separate pulse sense and GND sense channel

$$V_{DUT} = 103 \cdot V_{Pulse\ Sense} - 23 \cdot V_{GND\ Sense} \tag{3}$$

Advantage:

- more accurate DUT voltage measurement because avoiding parasitic voltage drop in the DUT pulse sense cable and DUT GND cable due to parasitic inductance *L*

Disadvantage:

- 4 DUT cables required

Similar limitations of the frequency response happen as discussed and shown in Sect. 1.3.1.

2 Time Domain Errors

Fig. 8 and Fig. 9 show potential time domain voltage measurement errors which may happen.

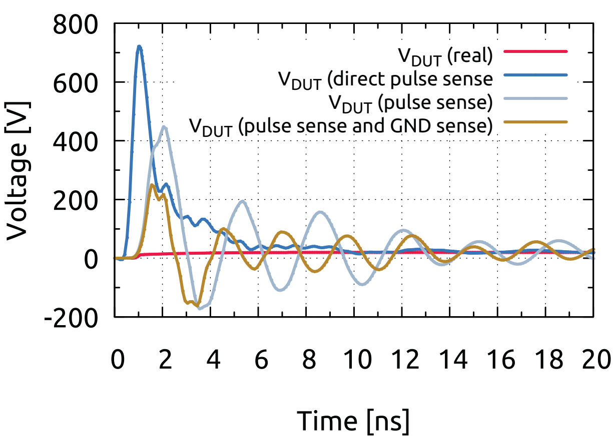

Figure 8: Time domain errors at 1 ns pulse rise time (example)

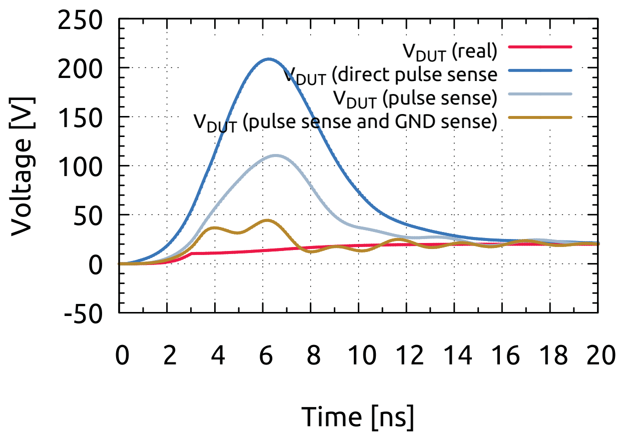

Figure 9: Time domain errors at 10 ns pulse rise time (example)

The figures compare all different methods with the real DUT voltage. The DUT is a diode with 10 V breakdown in reverse mode at 500 V TLP pulse voltage. It can be seen very clear that the “Direct Pulse Sense” method results in highest overshoot and ringing, compared to the “Pulse Sense” and “Pulse Sense and GND Sense” method. “Pulse Sense and GND Sense” shows lowest distortion, but has significant higher efforts in DUT connection, signal post-processing (Eqn. 3) and calibration. In all cases 1 ns pulse rise time results in much higher overshot than 10 ns.

3 Recommendations

- Use the PBA-3002A only for pulse rise times $\geq$ 10 ns.
- Don’t evaluate the first 20 ns because the measured voltage may be distorted by overshoots and ringing.
- To avoid large sampling errors in the oscilloscope due to high overshoots, the “Out-of-range detection” in the “Oscilloscope Adaptive Scaling” setting in the TLP software should be set to “Peal in avg. win”.
- Ringing and overshoot is strongly depending on the DUT impedance. Therefore investigation and validation is necessary in any case.
- If possible use the “Pulse Sense and GND Sense” method.
- The PBA-3002A is good temporary solution in some experimental situation.
- In general, the Picoprobe-based flex pitch solutions are the preferred methods, also for PCB probing: PHD-3001A, PHD-4001A, PHD-PPM10-H9, TPA-GFG, GF-A, PS-5026B