STEREO IMPACT

PROBLEM REPORT
PR-3004
Waterman/Walpole
9/8/04

PR Numbers: 1xxx=UCB, 2xxx=Caltech/JPL, 3xxx=UMd, 4xxx=GSFC/SEP, 5xxx=GSFC/Mag, 6xxx=CESR, 7xxx=Keil, 8xxx=ESTEC, 9xxx=MPAe

Assembly : SIT	**SubAssembly : ATOF FM1**
Component/Part Number: ATOF (FM1)	**Serial Number:**
Originator: Waterman/Walpole	**Organization: UMd**
Phone : 301-405-4517	**Email : waterman@uleis.umd.edu**

Failure Occurred During (Check one √)

X Functional test ☐ Qualification test ☐ S/C Integration ☐ Launch operations

Environment when failure occurred:

X Ambient ☐ Vibration ☐ Shock ☐ Acoustic
☐ Thermal **X** Vacuum ☐ Thermal-Vacuum ☐ EMI/EMC

Problem Description

The Start count rate from Time of Flight Electronics went to zero while in test at Brookhaven.

Analyses Performed to Determine Cause

The SIT FM1 electronics, the FM1 HVPS and the prototype telescope - the flight telescope is still not ready, went to Brookhaven National Labs for accelerator calibration. At the end of the day, during the final run, there was a HV breakdown somewhere in the system. At the time it was not obvious where the discharge was, but we have since determined that there was discharge at the end on one of the high voltage wires out of the HVPS. There is a burn mark on the insulation under the shrink tubing which provides the strain relief for the pin at the end of the 3200v wire from the HVPS. It appears that air was trapped under the shrink tube and provided a discharge path between the end of the wire and the end of the HV wire shield, ~3cm back.

Why the breakdown occurred when it did, we are not certain. The vacuum we were working at was marginal (~1.1 E-5 Torr) but had been stable all day. We were not touching any cables or connections. Some time before the breakdown we did command an increase in voltage, but this was from a relatively low level to a level we had been running at for hours previously.

Unfortunately, the result in the breakdown was another instance of damaging the ATOF START and STOP inputs. Both channels are out.

Corrective Action/ Resolution

X Rework ☐ Repair ☐ Use As Is ☐ Scrap

On the flight board the start and stop signal electronics, Q1 (AT41435), (1N5711) D1, D2 and D3 was replaced with new parts. After repairing the wire ends on all the wires out of the HVPS, we have run the supply with the ETU electronics and the prototype telescope for over a week, raising and lowering the voltage, monitoring the control voltage into the supply and the HV coming out. We ran the supply for 3 days straight at a voltage higher than we plan to run in flight and monitored the HV Monitor output, using a data logger that takes data every second, instead of relying on the SIT housekeeping that reads out once per minute. The result was a straight line, with no spikes on it. We have found that replacing the Q1 and D1,D2,D3 components in a damaged channel restores it to full operation. Thresholds are ok and there is no sign of compromised performance. The Max-Planck-Institut (Lindau) conducted a stress analysis 9/13/2004 (see attached). From the test results it was confirmed that no further parts were compromised on the board.

Date Action Taken:_____9/10/2004_____ **Retest Results**:____Success, board level test. __

Corrective Action Required/Performed on other Units ☐ Serial Number(s): ____n/a___

Closure Approvals

Subsystem Lead:	_____	Date:_____
IMPACT Project Manager:	_____	Date _____
IMPACT QA:	_____	Date:_____
NASA IMPACT Instrument Manager:	_____	Date:_____

Analyses Performed to Determine Cause, Continued

Project: STEREO/IMPACT/SIT
Item: ATOF Board

ATOF HV Discharge Test with Reference Board

Prepared by: Klaus Heerlein
Revision: 1.0
Date: 2004/09/13

Table of Contents:

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1 Introduction

Due to several damages on the input transistors and protection diodes that occurred during testing with SIT sensor some measurements have been done at MPS to verify the ATOF board behavior to over voltages and discharges.

2 Test Setup

For the testing a ATOF reference board populated with commercial parts was used. To simulate defined discharges a capacitor of 56nF was charged by an external power supply and discharged by using a toggle switch. The resulting voltage spikes were measured by an oscilloscope. To verify damage to the input channel and its parts after each run, the overall performance of the channel was tested and the protection diodes were removed from the board and their resistive impedance was measured and compared to the measured reference values.
Due to some testing that was done before already it turned out that a discharge voltage of several hundreds of volt is necessary to damage the input channel of the ATOF board. Because of this knowledge the tests were made with voltages of -250V, +250V and +200V.

3 Measured Parts Reference Values

To have comparable reference values to detect damages to parts reference values were measured with a Fluke 87 III multimeter:

Status	**Part: Diode 1N5711 (commercial):**	**Measured Value:**
a	Diode test forward biased	0.356
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	924 KOhm

Status	**Input Resistance Start Channel**	**Measured Value:**
e		25.9 Ohm

Status	**Input Resistance at first stage transistor**	**Measured Value:**
f		1.057 kOhm

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4 Parts datasheet Absolute Maximum Values

Part	Minimum reverse breakdown voltage
1N5711	70V

Part	Emitter Base Voltage	Collector Base Voltage	Collector Emitter Voltage
At41435	1.5V	20V	12V

5 Test Runs

5.1 Discharge Test -250V at input channel

The charge capacitor was charged to -250V and the charge was applied to the input channel of the ATOF reference board by using the toggle switch.
The resulting voltage spikes were measured at the input of the channel, the input of first stage transistor and the input of 2nd stage transistor.
The screen dumps of the measured signal are shown below:

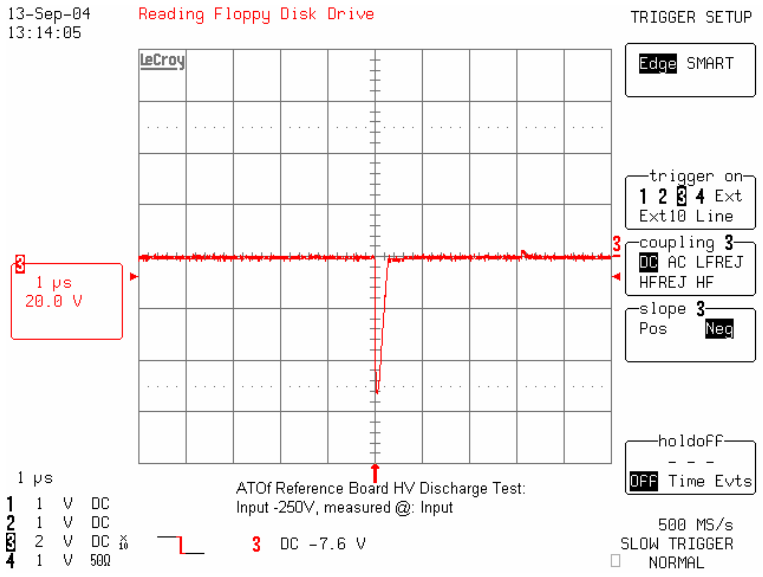

Figure 1: Measured discharge pulse at input when applying -250V charge to input

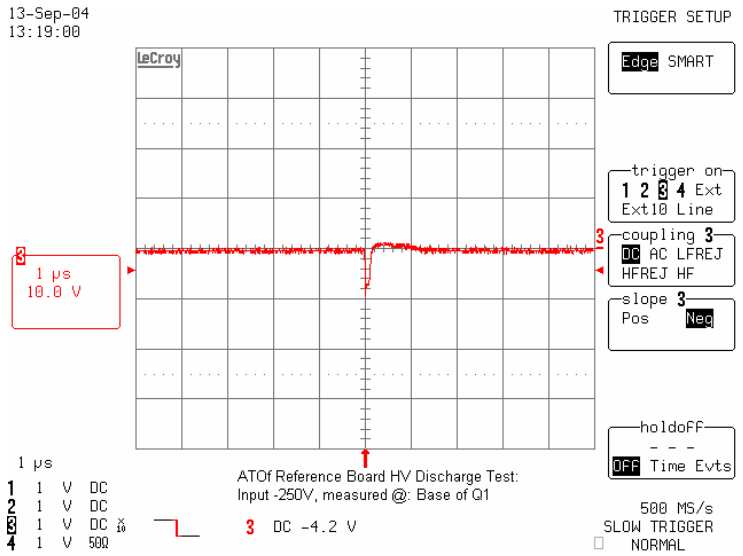

Figure 2: Measured discharge pulse at base of Q1 when applying -250V charge to input

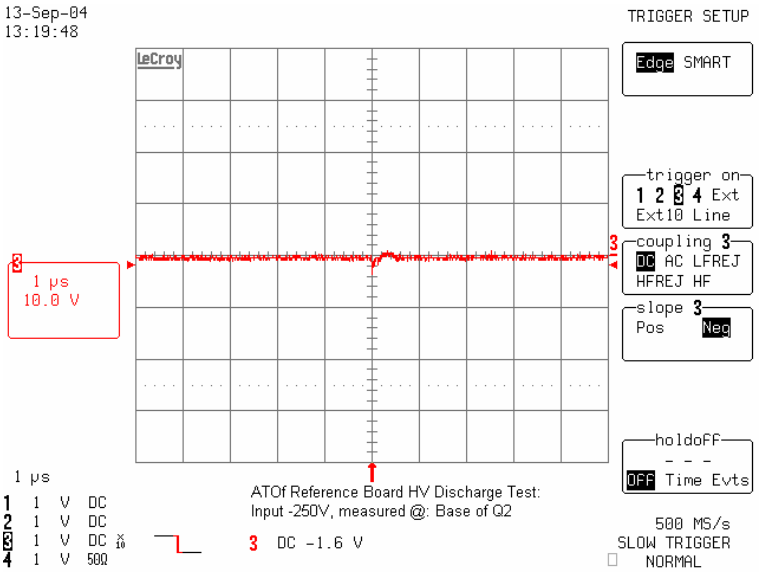

Figure 3: Measured discharge pulse at base of Q2 when applying -250V charge to input

After the measurement the protection diodes were removed from the board and their resistive .behavior was measured.

	D3	**Measured Value:**
a	Diode test forward biased	0.347
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	108 kOhm
d	resistance between Anode-Kathode forward biased	17 kOhm

	D2	**Measured Value:**
a	Diode test forward biased	0.332
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	64 kOhm

	D1	**Measured Value:**
a	Diode test forward biased	0.353
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	890 kOhm

Status	**Input Resistance Start Channel**	**Measured Value:**
e		25.9 Ohm

Status	**Input Resistance at first stage transistor**	**Measured Value:**
f		1.058 kOhm

Result: The Protection Diodes for the negative rail got some damage. They showed a (high impedance) resistive behavior even when reverse polarized after the test. The diode function still worked and the input transistors were still working as expected.
The complete channel was still performing nominally.

The two diodes D2 and D3 were replaced for the following tests.

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5.2 Discharge test +250V at input channel

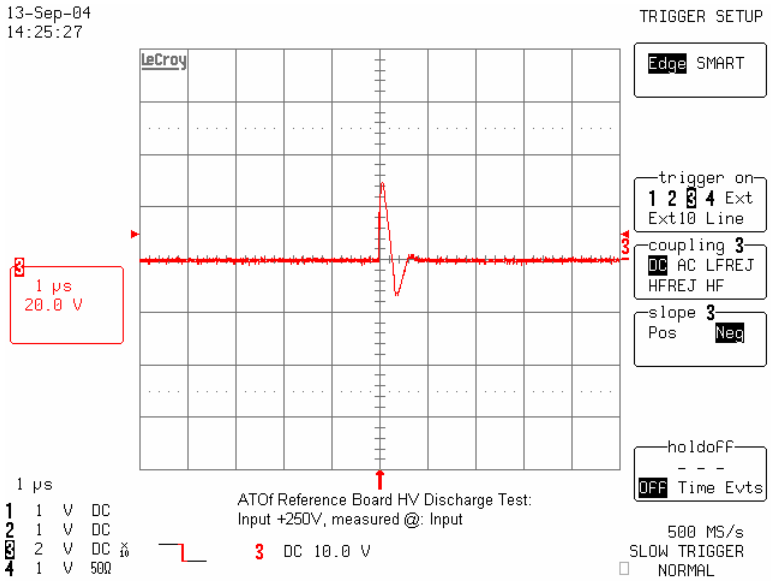

Figure 4: Measured discharge pulse at input when applying +250V charge to input

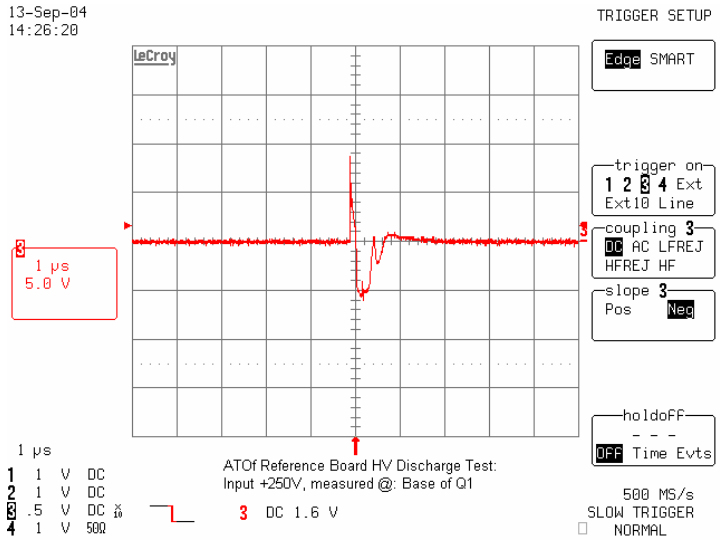

Figure 5: Measured discharge pulse at base of Q1 when applying +250V charge to input

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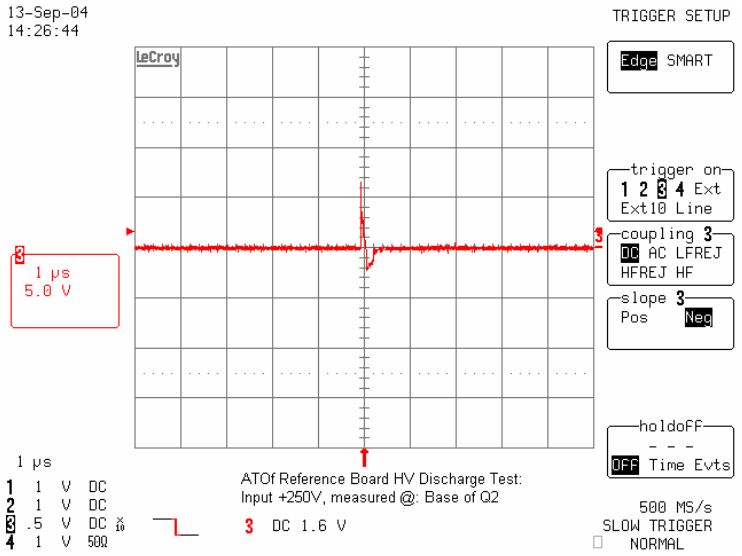

Figure 6: Measured discharge pulse at base of Q2 when applying +250V charge to input

	D3	**Measured Value:**
a	Diode test forward biased	0.351
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	807 kOhm
	D2	**Measured Value:**
a	Diode test forward biased	0.328
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	770 kOhm
	D1	**Measured Value:**
a	Diode test forward biased	0.348
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	61 kOhm

Status	**Input Resistance Start Channel**	**Measured Value:**
e		25.9 Ohm
Status	**Input Resistance at first stage transistor**	**Measured Value:**
f		1.058 kOhm

Result: The Protection Diode for the positive rail showed damage. A (high impedance) resistive behavior was measured when forward polarized. The diode function was still working. The input transistors still worked nominally and the complete channel performed still well.
The diode D1 was replaced for further tests.

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5.3 Discharge Test +200V at input channel (multiple times)

In this test the charge capacitor was charged to -+200V and again the charge was applied to the input channel of the ATOF reference board by using the toggle switch.
In difference to the tests before now the charge was applied about 50 times right after another. The resulting voltage spikes were measured once at the input of the channel, the input of first stage transistor and the input of 2nd stage transistor.
The screen dumps of the measured signal are again shown below:

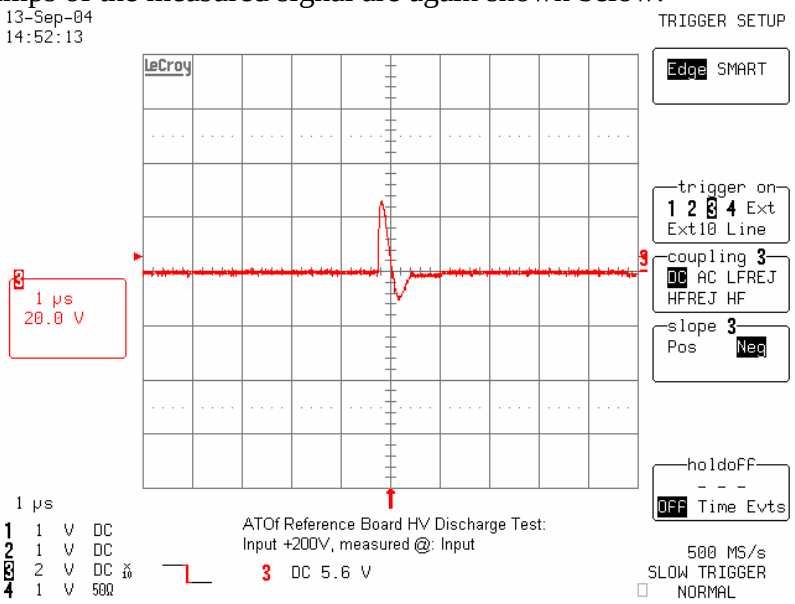

Figure 7: Measured discharge pulse at input when applying +200V charge to input

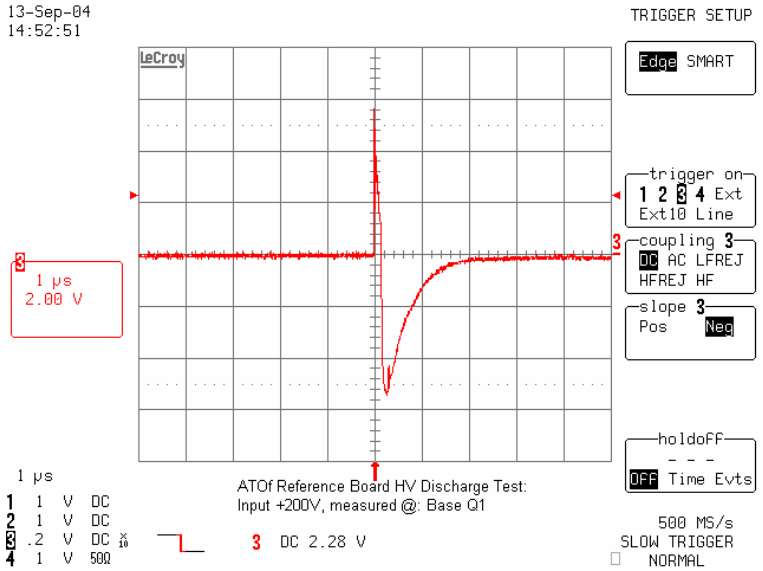

Figure 8: Measured discharge pulse at base of Q1 when applying +200V charge to input

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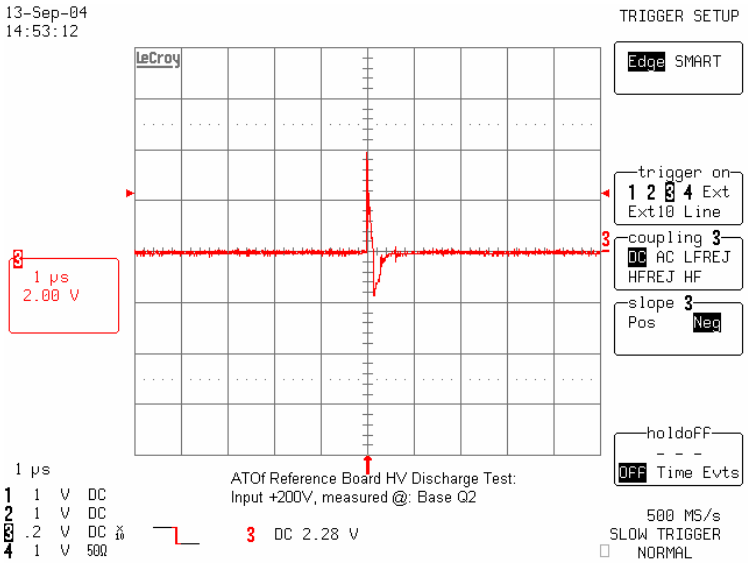

Figure 9: Measured discharge pulse at base of Q2 when applying +200V charge to input

	D3	**Measured Value:**
a	Diode test forward biased	0.351
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	840 kOhm
	D2	**Measured Value:**
a	Diode test forward biased	0.328
b	Diode Test reverse based	∞
c	resistance between Anode-Kathode reverse biased	∞
d	resistance between Anode-Kathode forward biased	760 kOhm
	D1	**Measured Value:**
a	Diode test forward biased	0.145
b	Diode Test reverse based	0.202
c	resistance between Anode-Kathode reverse biased	358 Ohm
d	resistance between Anode-Kathode forward biased	300 Ohm

Status	**Input Resistance Start Channel**	**Measured Value:**
e		25.9 Ohm

Status	**Input Resistance at first stage transistor**	**Measured Value:**
f		1.058 kOhm

Result: The Protection Diode for the positive rail had a complete failure (300 Ohm resistance in both directions). The negative rail protection diodes were still working and measured resistive values behaved like before. The input transistors were still working and the complete channel performed still nominally.
The diode D1 was again replaced.

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6 Conclusion

The ATOF board is a preamplifier for very low voltage signals in the range of up to 1000mV. The used input diodes obviously are able to protect the preamplifier for over voltages in the range of hundreds of volt but it has to be taken into account that these diodes are very low capacitance and low current ones and might not be capable to protect against big charges or much higher voltages.

It was verified that high voltage discharges in the order of >= 200V with a charge capacitance of 56nF can cause damage to the input channel of the ATOF board protection diodes. From the datasheet data the protection diodes can withstand reverse voltages of approximately 70V. For short time pulses (small charges) they will withstand higher voltages. At the tested setup voltage spikes in the range of less than 10V occurred at the input of the transistor Q1 even for input voltage of up to 250V. The second stage transistor gets much less charge as the first one because the main charge will be defeated in the first transistor and the protection diodes. During the complete test a failure of an input transistor never occurred. It seems that to destroy this transistor even higher voltages or higher charges are necessary. It is likely that if the protection diodes fail first the missing protection will allow higher voltage spikes to reach the transistor base and then can cause damage of the transistor when further over voltages occur.
During all performed tests there never happened a failure to the first transistor and it was measured that the second stage transistor always gets much less charge then the first one.

Although it is difficult to say and for sure dependent on the occurred charges and voltage it seems that except for the parts that are directly connected to the input no other parts have been compromised on the boards. This is confirmed by the result from this test and the approved well performance of the two FM boards that got repaired after the replacement of the damaged input stage parts.

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