5. Static measurements

5.1. Aim and method

Static measurements were taken in order to evaluate the output voltage variation range in relation to saw blade charge impedance Z under different conditions of usage. The resulting peak-to-peak voltage values were measured using an oscilloscope.
The output coupling was disconnected from the data processing circuit, except for the paragraph 1.5 measurements, to isolate the system from the compensation phenomenon.

5.2. Measurements without wood

Aim: to determine the output voltage range in relation to the type of human touch.

Condition	Voltage Vs V pp	Oscillo. N° in annex	Observations
No touch	2.39	1	Reference
Blade only touch, person on ground	1.53	2	Real operating condition
100pF capacitor between blade and frame	1.5	3	Capacitor and resistor equivalent to human touch Corresponding impedance module: 3.2kΩ
3.4 kΩ resistor between blade and frame	1.52	4	
Blade only touch, person insulated 30cm above ground	1.70	5	Worst condition under operation
Blade touch with insulated finger (thin plastic sheet)	1.92	6	Sideways touch with a glove
Touch with 200pF capacitor in series	1.92	7	Allows capacitive coupling of insulated contact with blade to be reproduced
Blade touch by insulated pinching	1.58	8	Unrealistic. But allows minimum value for a direct touch to be approached. Equivalent to man/blade capacitive coupling
Touch with 332pF capacitor in series	1.61	9	Allows capacitive coupling of insulated pinching contact with blade to be reproduced. Corresponding impedance module: 960 Ω
4.7 kΩ resistive touch	2.29	10	Corresponds to dry skin/blade contact
1 kΩ resistive touch	1.94	11	
100 Ω resistive touch	1.67	12	

Table 2: Output voltage in relation to human touch without wood in contact with blade[4]

The output voltage is reduced by 36%, when a person on the ground touches the blade, and by 29% when the person is raised to 30cm above the ground. However, the reduction remains significant for this worst condition from a detection during operation viewpoint.

Insulated touch constitutes capacitive coupling between the blade and the person and it integrates in series with the capacitance of the person. The resulting voltage variation is even smaller (20% reduction).

[4] corresponding oscillograms (N° 1 to 12) are annexed

When this capacitive coupling is increased by pinching hard the saw blade with several fingers, the voltage value corresponding to direct touch is reached. This situation is equivalent to a purely capacitive charge because it is formed by placing two capacitances in series (coupling + man). Pinching can therefore be replaced by a capacitance inserted in series with the capacitance of the person. The value of this capacitance that enables the voltage value corresponding to direct human touch to be reached is 332pF. The equivalent series impedance module (960Ω at 500kHz) is higher than the value of the series resistance (100Ω) that also enables one to approach the voltage value corresponding to direct human touch.
This shows that the type of charge (purely capacitive or capacitive + resistive) influences very significantly the capacitive coupling output voltage.

It should be recalled that the measurements with an insulated contact correspond to no accident situation and were performed only for experimental reasons.

5.3. Measurements with dry wood in contact with saw blade

Aim: to measure the variation in output voltage for different types of dry wood in contact with the saw blade both with and without human touch.

Measurements were taken with wood in contact with the blade with and without touching the blade. Blade contact with the dry wood hardly varies the output voltage and the results are essentially identical to those contained in the above paragraph. The piece of dry wood is in fact "transparent" from an electrical standpoint.

5.4. Measurements with moist wood in contact with saw blade

Aim: to measure the variation in output voltage for different types of moist wood in contact with the saw blade with and without human touch.

The pieces of moist wood used were those used in paragraph 5.3 above after immersion in water for 24 hours.

Condition	Voltage Vs Vpp	Oscillo. N° in annex	Observations
No touch	2.22	1	Reference
Blade touch without wood	1.36	2	"
Blade and frame touch	0.76	3	"
27%H MDF only in contact with blade	1.24	4	"
27%H MDF with blade touch	1.03	5	Real accident situation
Touch with 27%H MDF in contact with blade	1.24	6	Real operating situation Allows evaluation of influence of wood conductibility on system
Touch with 27%H MDF in contact with blade and frame touch	1.24	7	
21%H oak only in contact with blade	2.18	8	Reference
21%H oak with blade touch	1.47	9	Real accident situation
50%H Novopan only in contact with blade	1.37	10	Reference
50%H Novopan with blade touch	1.18	11	Real accident situation
24%H beech only in contact with blade	2.03	12	Reference
24%H beech with blade touch	1.46	13	Real accident situation

Table 3: Output voltage in relation to different types of moist wood with and without blade touch

The charges created by human touch and moist wood add up. There is no touch masking phenomenon due to output signal saturation.
Human touch of the moist wood in contact with the blade is equivalent to a resistive touch (cf. table 2). It provides no additional contribution to the reduction in output voltage Vs. This shows that possible untimely tripping only results from contact of the moist wood with the blade.

5.5. Measurements with two pieces of moist wood

Aim: to measure the variation in output voltage in relation to blade charges created by two pieces of moist wood (moisture content unknown).

Condition	Voltage Vs Vpp	Oscillo. N° in annex	Observations
1st MDF only in contact with 1 side of blade	1.73	1	Voltage dependent on single charge
2nd MDF only in contact with 1 side of blade	1.91	2	
1^{st} + 2nd MDF in contact each side of blade	1.57	3	Addition of two charges
Preceding 1st + 2nd MDFs in contact with each side of blade with blade touch	1.24	4	Addition of all charges

Table 4: Output voltage in relation to number of wood pieces in contact with blade

The results show that the charges add up and confirm the results given in paragraph 5.4 above.

5.6. Measurements with different size pieces of wood

Aim: to measure the variation in output voltage in relation to the size of pieces of wood with the same moisture content.

Condition	Voltage Vs Vpp	Oscillo. N° in annex	Observations
No touch	2.44	1	Reference
Large* MDF piece only in contact with blade lateral face (*540x80x45mm)	1.77	2	Voltage dependent on size of piece
Small* MDF piece only in contact with blade lateral face (*130x80x45mm)	1.72	3	
Medium* MDF piece only in contact with blade lateral face (*410x80x45mm)	1.72	4	
Small MDF piece only in contact with one half of blade lateral face	1.79	5	Influence of blade area in contact with wood for different sizes of piece
Medium MDF piece only in contact with one half of blade lateral face	1.79	6	

Table 5: Output voltage in relation to size of piece of wood in contact

The output voltage only depends on the area in contact with the blade for given moisture content and position of the piece of wood.

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5.7. "Green wood" static compensation

Aim: to measure the range of variation in input voltage Vd (Vdrive), saw blade voltage and output voltage Vs in relation to the charge on the blade.

The output coupling was connected to the data processing circuit for these measurements.

Condition	Voltage Vpp	Oscillo. N° in annex	Observations
Input voltage Vd; no touch	12.16	1	Reference
Blade voltage with no contact	3.16	2	
Output voltage Vs with no contact	2.25	3	
Input voltage Vd; blade in contact with dry fir	12.3	4	Normal working situation
Input voltage Vd; blade touch	18	5	Accident situation
Input voltage Vd; blade and frame touch	19.2	6	Maximum value in accident situation
Blade voltage with blade touch	2.37	7	Accident situation
Output voltage Vs with blade touch	2.23	8	

Table 6: input voltage compensation range in relation to charge on blade

Voltage Vd applied to the input coupling varies between 12.16 (no contact) and 19.2 V (maximum charge), whilst the output voltage Vs remains almost constant. In static mode, the "green wood" compensation completely masks the blade touch.

6. Dynamic measurements

6.1. Aim and method

The aim of these measurements is to evaluate the output voltage (Vs) variation rate when there is contact with the dangerous part of the saw blade (accident situation). The dummy blade was at rest and contact was made with the fastest possible finger approach speed because taking these measurements in a real situation was inconceivable. However, this approach speed could neither be measured nor repeated. In this case, we are concerned with obtaining the highest possible rate of decrease in contact impedance and reaching an impedance value as near as that corresponding to an accident situation. Here, this value is reached as soon as the dangerous part of the blade penetrates the thickness of the skin and comes into contact with flesh, which is significantly more conducting because of blood irrigation.
Skin penetration occurs very quickly and low impedance contact is established with the total capacitance of the human body.
In most cases, measurements were taken with the output coupling disconnected from the data processing circuit to isolate the system from "green wood" compensation. For some measurements, the output coupling was connected to the data processing circuit to obtain the tripping signal required for oscilloscope synchronization.

6.2. Blade touch in the absence of wood

The time taken for the output voltage to reach its minimum value in relation to dummy blade touch varies approximately between 80 and 300µs (oscillogram N° 1 to 8). These curves depend on the contact impedance variation rate and thus the approach speed. The latter varies from one touch to another, which explains the difference in values. The designer indicated a time of 50µs for a human finger touching the teeth of a real rotating blade, which corresponds approximately to a 30% reduction in output voltage.

Two deliberately gradual blade touches give values of 70 and 650ms (oscillogram N° 9 and 10). A quicker touch recorded with the same oscilloscope time scale (oscillogram N° 11) does not allow the voltage variation time to be evaluated. These results show that output voltage variation time can vary widely. However, in an accident situation, i.e. a case of sudden contact with the blade, the coupling output voltage variation time would decrease very significantly.
Another measurement was taken by tripping the oscilloscope with the tripping signal emitted by the data processing circuit (oscillogram N° 12). This measurement was taken with the output signal from the coupling connected to this same circuit according to figure 3. It gives a time of approximately 80µs.

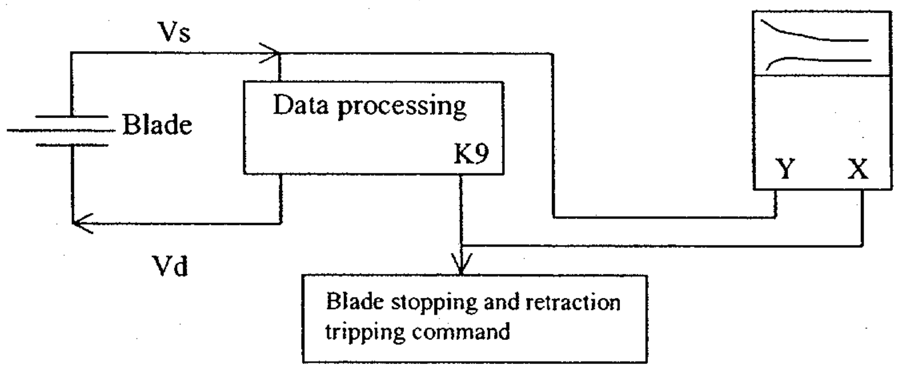


Figure 3: Oscilloscope tripping by blade stoppage triggering

These measurements provide results of the same order of magnitude as that indicated by the designer and obtained from real situation measurement.

6.3. Influence of output voltage (Vs) variation rate

Oscillograms N° 1 and 2 reveal the sensitivity of the data processing circuit to the detected voltage reduction rate. They do not directly concern the capacitive detection principle. The action of the compensation circuit is such that a reduction time of approximately 450ms causes no tripping, whilst a time approximately 15 times smaller does cause tripping. These measurements show the effective sensitivity to output voltage (Vs) variation rate of the data processing circuit, thereby avoiding the masking phenomenon due to "green wood" compensation referred to in paragraph 5.7.

6.4. Blade touch in the presence of moist wood

The objective of this measurement was to check that, when touching the blade, the coupling output voltage variation dynamics remain unchanged in the presence of moist wood in contact with the saw blade. This measurement corresponds to the capacity of the system to detect human touch even when the moist wood being sawn constitutes already a strong capacitive charge.
Output voltage reduction time and amplitude attenuation are of the same order of magnitude as when there is no wood present (approximately 100µs and 15% respectively).

Oscillograms N° 1 and 2 show the output voltage variation rate of the disconnected coupling, when the dummy blade has been touched. Oscillogram N° 3 illustrates that the variation time is very small for a low impedance contact represented by a screwdriver tip handled by a person. This confirms that the output voltage variation rate depends on the contact impedance. Oscillogram N°4 shows the output voltage variation rate and time for a touch with the output coupling connected to the data processing circuit. "Green wood" compensation does not influence the variation time.

7. Capacitive circuit failure modes

Capacitive detection circuit failure modes are easy to determine because its design is very simple. Failure modes can be short-circuits, disconnections and coupling capacitance variation.
Detection of faults occurring in the capacitive coupling circuit must be ensured by the data processing circuit.
For example, the circuit does not detect permanent short-circuiting of the input coupling before switching on. The result is a tripping failure if the blade is touched. This dangerous malfunction could result from an insulation fault between the input coupling electrode and the blade+shaft assembly. This failure mode can, however, be excluded depending on the adopted assembly constitution.

8. Complementary analysis

This did not concern the capacitive detection principle but involved more the prospects for improving the performance characteristics of the overall system.

- Electromagnetic interference immunity test

For the purpose of investigation, the saw + wired system was subjected to a radiated electromagnetic field according to IEC standard 61000-4-3, 10V/m level, corresponding to the degree of severity applied to industrial equipment. The system tripped at frequencies around 130 MHz. It was not considered useful to pursue this test due to the low immunity noted right from the start of interference application.

As stated in paragraph 3, the circuit is highly vulnerable to electrostatic discharges of human origin applied to the Vsense input circuit when the blade is touched.

Case of untimely tripping

Untimely tripping was obtained when one of the blade side faces was quickly approached by a piece of moist wood. This is not surprising in view of the previously obtained results. The piece of moist wood handled in these conditions constitutes a relatively large charge variation applied to the blade.
In a normal operating situation, the piece of wood would be approached more slowly and the area in contact with the blade would be significantly lower at the start of sawing, which would reduce the wood/blade capacitive coupling (cf. § 5.6) and allow the "green wood" compensation to react.
However, differed untimely tripping did occur during sawing tests using moist wood (cf. analysis performed by BIA).

Case of possible tripping failure

no case of tripping failure following blade touching was revealed during these measurements. However, this observation does not permit us to exclude this possibility resulting from failure of a capacitive circuit component (cf. § 7) or of the data processing circuit.

9. Similar existing detection devices

An American company is marketing a system based on the same principle but more specifically aimed at installations and certain machines. Tripping takes place when contact is made by a fixed metal "antenna" specially designed for the danger zone concerned.

10. Another existing circular saw blade stopping device

A brief demonstration of a device for stopping the rotation of a miter-box saw blade was given during a consumer television program. Despite the steps taken, it has not been possible to obtain a copy of the part of the program concerned or other more detailed technical information because, according to the inventor, this device is the subject of a patent application.

11. Conclusion

Detection by capacitive effect presented and analyzed in this document is based on the simple principle of a capacitive bridge reproducing variations in electrical characteristics due to saw blade touch. The soundness of the principle is founded on the fact that it does not suffer from the drawbacks inherent to proximity-based detectors because detection is based on man-blade contact, which presents invariable characteristics in an accident situation.

On the one hand, the minimum values of the man's electrical characteristics (tissue capacitance, conductivity) are identical from one individual to another and, on the other hand, the blade - man's capacitance contact establishment time is naturally very short. This principle has therefore not been designed to forestall an accident situation. However, it forms part of a larger system designed to reduce accident seriousness.

Capacitive detection does not affect the availability of the work equipment when using dry wood. Yet, no detection masking phenomenon was revealed. In response to untimely tripping resulting only from moist wood, the designer might be tempted to reinforce the "green wood" compensation phenomenon, which could lead to masking of an accident situation.

Detection of blade human touch is invariably ensured for accident situation representative cases.

This detection principle also has the advantage of being easily realizable if it is foreseen at design stage for the work equipment on which its installation is planned.

It can therefore be recommended for work equipment, for which "conventional" detectors cannot be used.

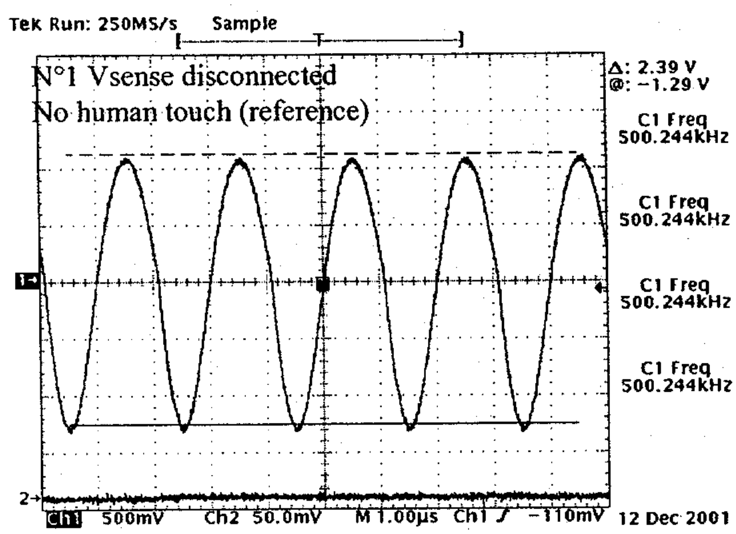
However, as stated above, this detection principle forms necessarily part of a more complex system, whose safety level assessment remains to be performed particularly in relation to electronic circuits.

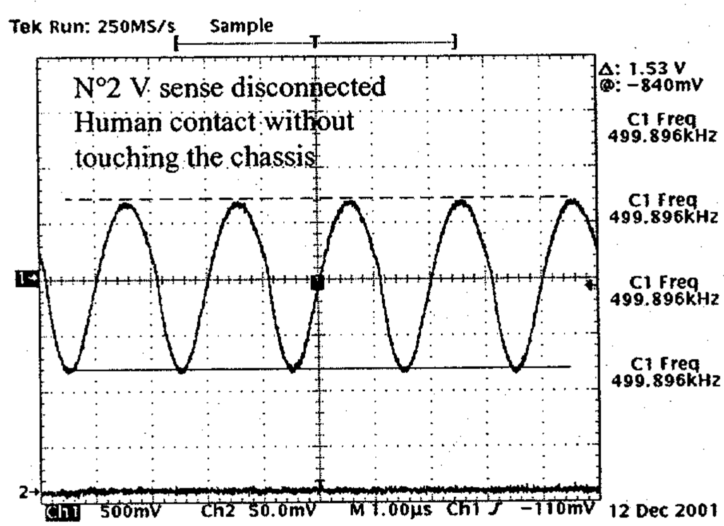
A brief examination shows that the data processing circuit has not been designed according to design rules covering operating safety (fault detection, architecture, etc.), although it does provide self-control functions. Neither is it capable of sustaining external influences (electrostatic discharges).

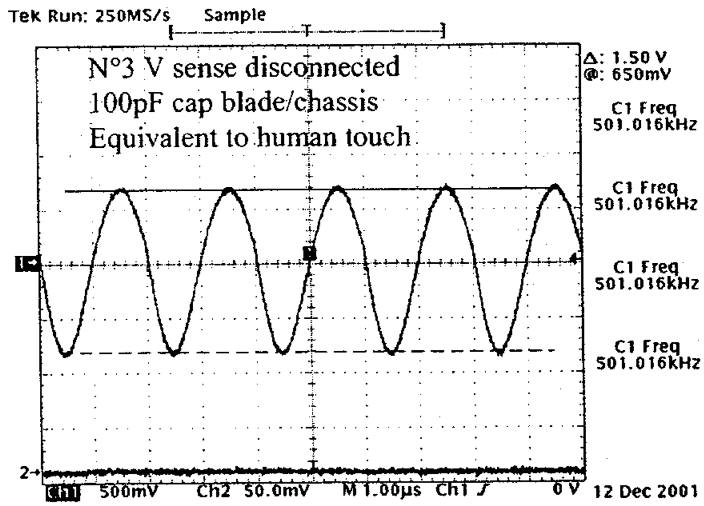
Despite the points remaining to be considered and improved, the capacitive detection principle forms part of a system, whose current performance characteristics are promising in terms of curtailing the seriousness of accidents occurring on types of woodworking machinery other than workbench circular saws.

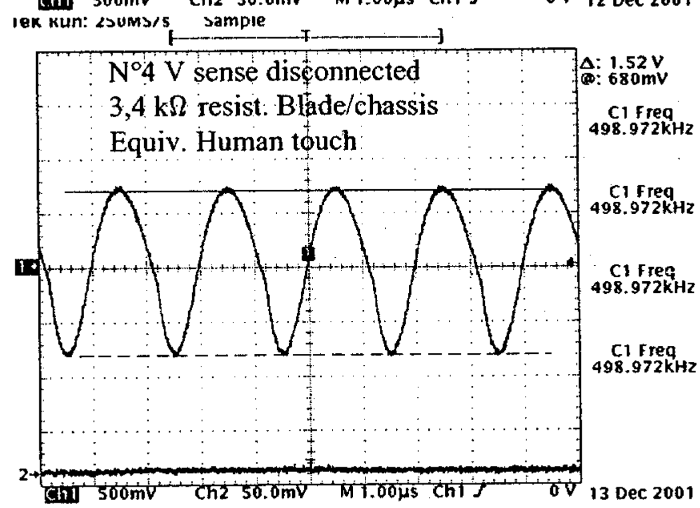
Annex

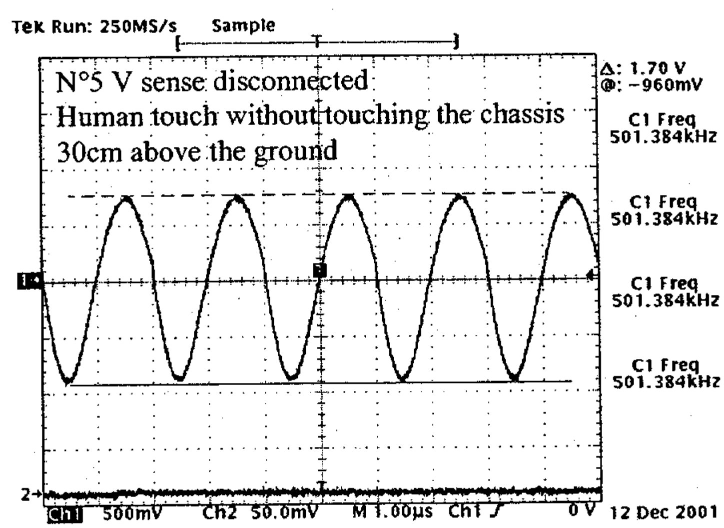
Static measurements without wood (cf. § 5.2, table 2)

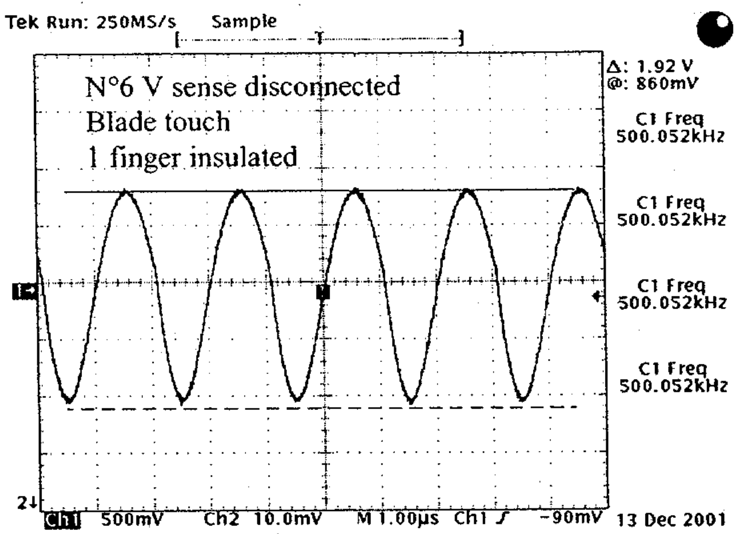


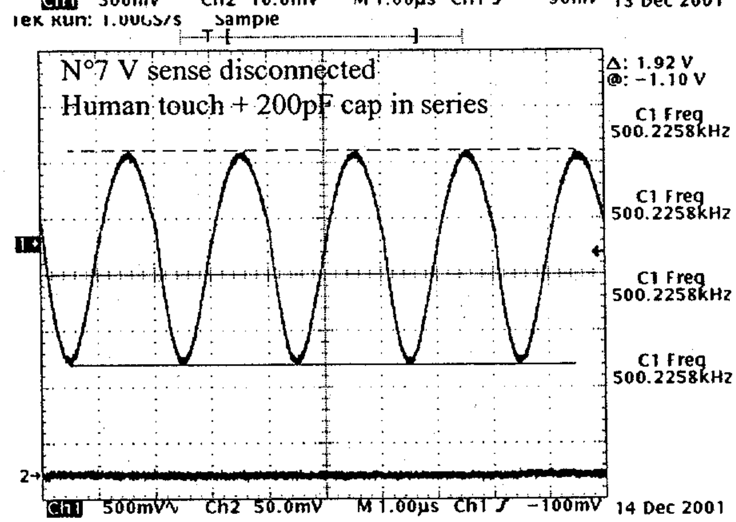


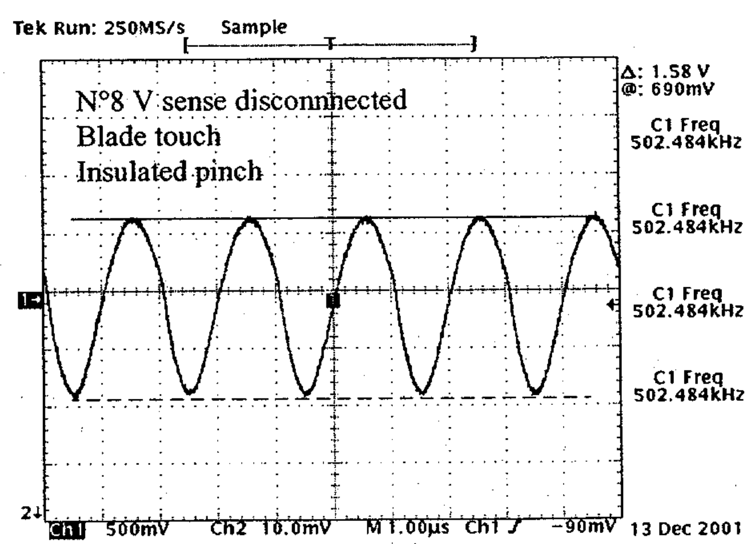

Tek Run: 250MS/s Sample
N°3 V sense disconnected
100pF cap blade/chassis
Equivalent to human touch
Δ: 1.50 V
@: 650mV
C1 Freq
501.016kHz
C1 Freq
501.016kHz
C1 Freq
501.016kHz
C1 Freq
501.016kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ 0 V
12 Dec 2001


Tek Run: 250MS/s Sample
N°4 V sense disconnected
3,4 kΩ resist. Blade/chassis
Equiv. Human touch
Δ: 1.52 V
@: 680mV
C1 Freq
498.972kHz
C1 Freq
498.972kHz
C1 Freq
498.972kHz
C1 Freq
498.972kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ 0 V
13 Dec 2001


Tek Run: 250MS/s Sample
N°5 V sense disconnected
Human touch without touching the chassis
30cm above the ground
Δ: 1.70 V
@: −960mV
C1 Freq
501.384kHz
C1 Freq
501.384kHz
C1 Freq
501.384kHz
C1 Freq
501.384kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ 0 V
12 Dec 2001


Tek Run: 250MS/s Sample
N°6 V sense disconnected
Blade touch
1 finger insulated
Δ: 1.92 V
@: 860mV
C1 Freq
500.052kHz
C1 Freq
500.052kHz
C1 Freq
500.052kHz
C1 Freq
500.052kHz
Ch1 500mV Ch2 10.0mV M 1.00µs Ch1 ∫ −90mV 13 Dec 2001


N°7 V sense disconnected
Human touch + 200pF cap in series
Δ: 1.92 V
@: −1.10 V
C1 Freq
500.2258kHz
C1 Freq
500.2258kHz
C1 Freq
500.2258kHz
C1 Freq
500.2258kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ −100mV 14 Dec 2001


Tek Run: 250MS/s Sample
N°8 V sense disconnected
Blade touch
Insulated pinch
Δ: 1.58 V
@: 690mV
C1 Freq
502.484kHz
C1 Freq
502.484kHz
C1 Freq
502.484kHz
C1 Freq
502.484kHz
Ch1 500mV Ch2 10.0mV M 1.00µs Ch1 ∫ −90mV 13 Dec 2001

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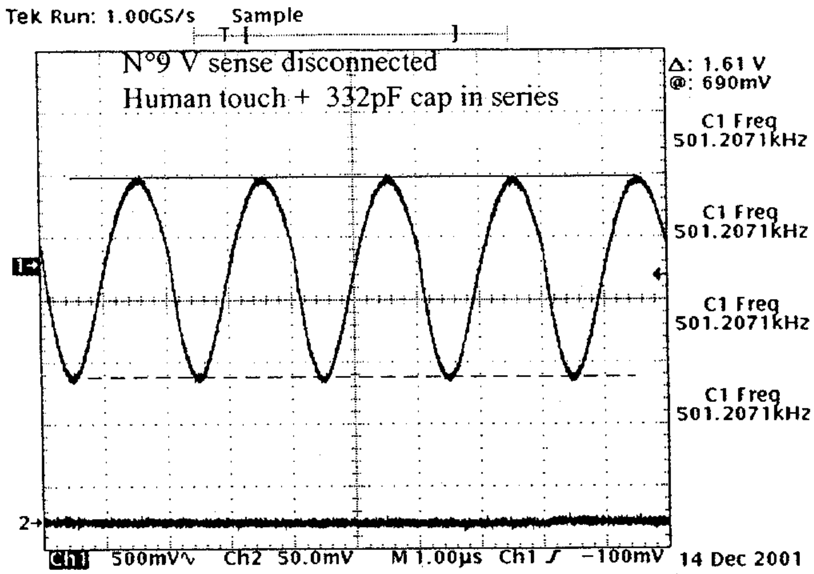
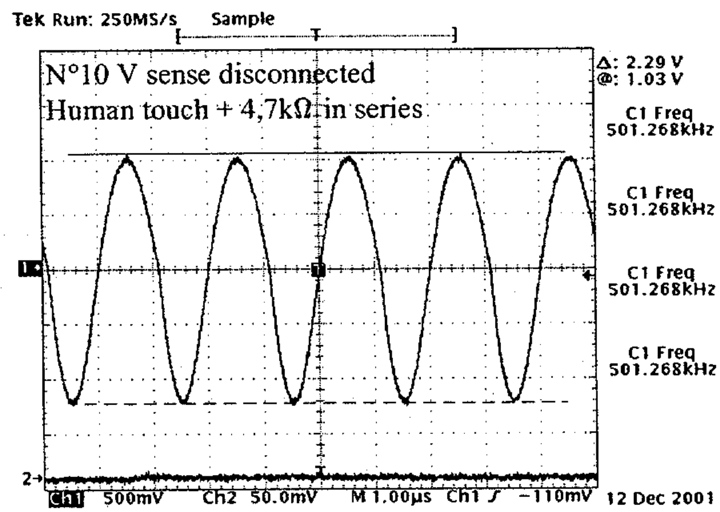
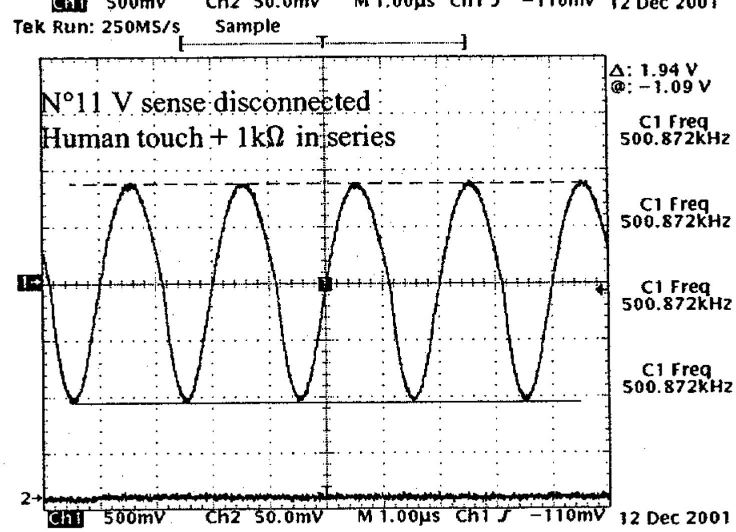

Tek Run: 1.00GS/s Sample
N°9 V sense disconnected
Human touch + 332pF cap in series
Δ: 1.61 V
@: 690mV
C1 Freq 501.2071kHz
C1 Freq 501.2071kHz
C1 Freq 501.2071kHz
C1 Freq 501.2071kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ −100mV 14 Dec 2001


Tek Run: 250MS/s Sample
N°10 V sense disconnected
Human touch + 4,7kΩ in series
Δ: 2.29 V
@: 1.03 V
C1 Freq 501.268kHz
C1 Freq 501.268kHz
C1 Freq 501.268kHz
C1 Freq 501.268kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ −110mV 12 Dec 2001


Tek Run: 250MS/s Sample
N°11 V sense disconnected
Human touch + 1kΩ in series
Δ: 1.94 V
@: −1.09 V
C1 Freq 500.872kHz
C1 Freq 500.872kHz
C1 Freq 500.872kHz
C1 Freq 500.872kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ −110mV 12 Dec 2001

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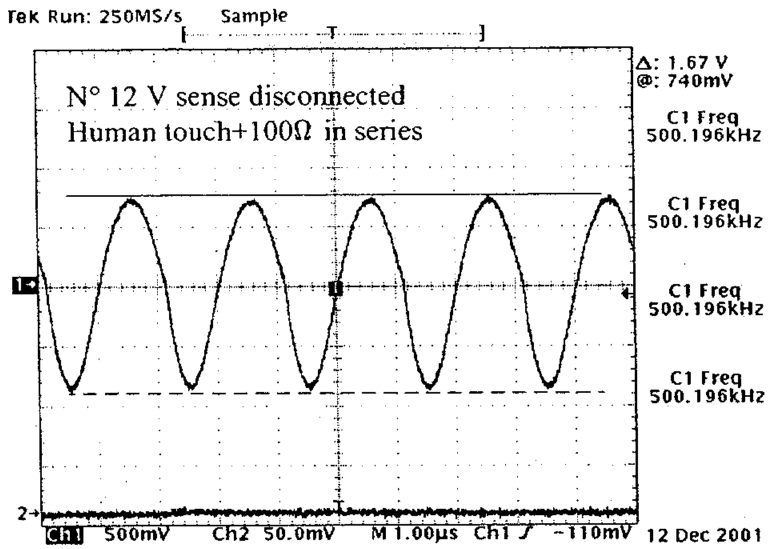
Tek Run: 250MS/s Sample
N° 12 V sense disconnected
Human touch+100Ω in series
Δ: 1.67 V
@: 740mV
C1 Freq
500.196kHz
C1 Freq
500.196kHz
C1 Freq
500.196kHz
C1 Freq
500.196kHz
Ch1 500mV Ch2 50.0mV M 1.00µs Ch1 ∫ -110mV
12 Dec 2001

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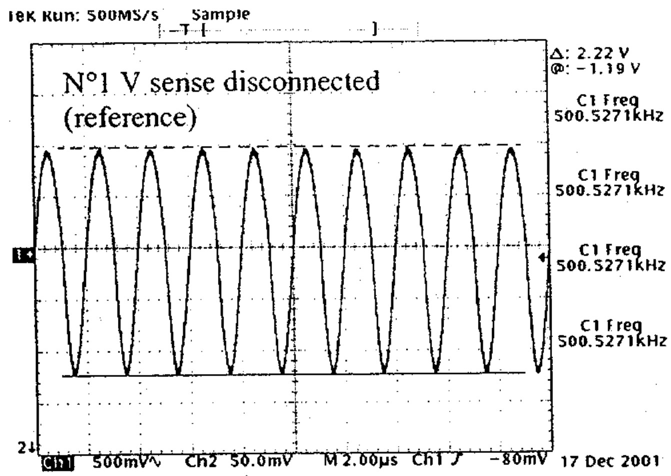
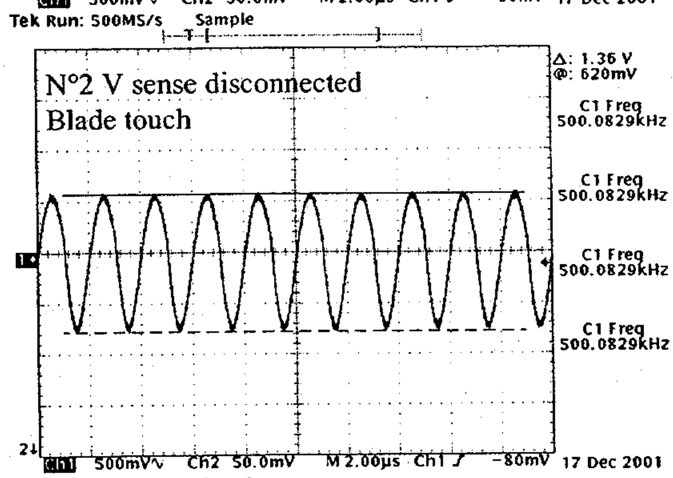
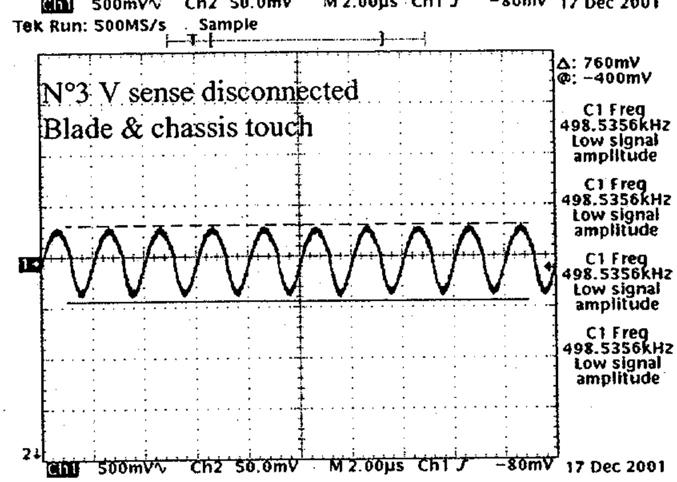
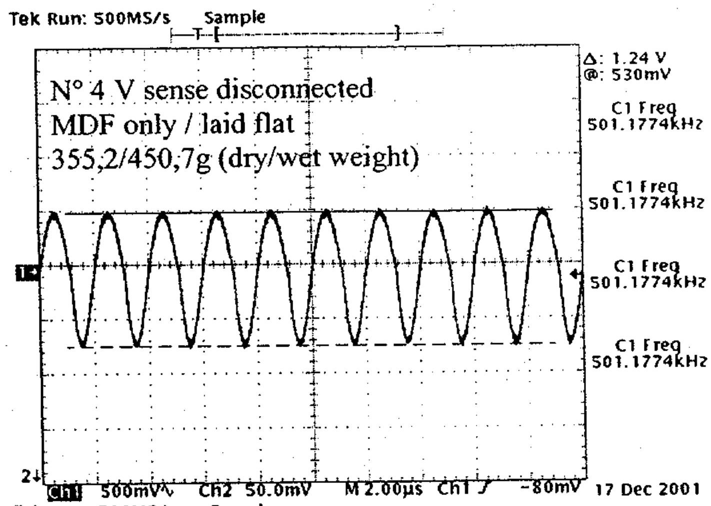
Measurements with wet wood contacting the blade (cf. §5.4, table 3)

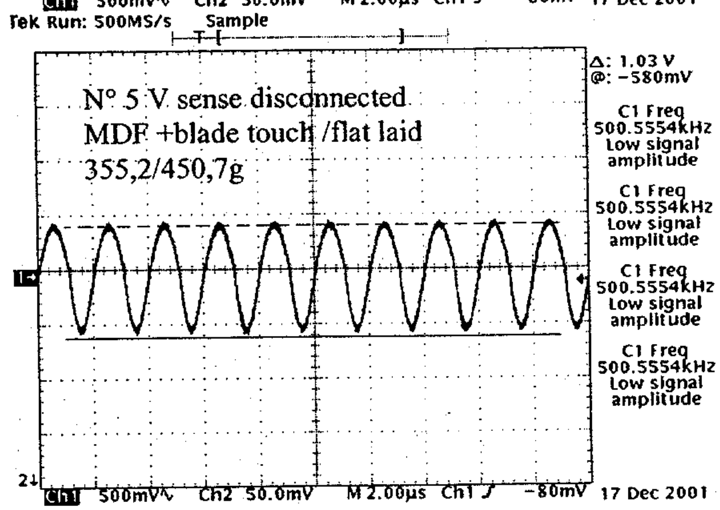


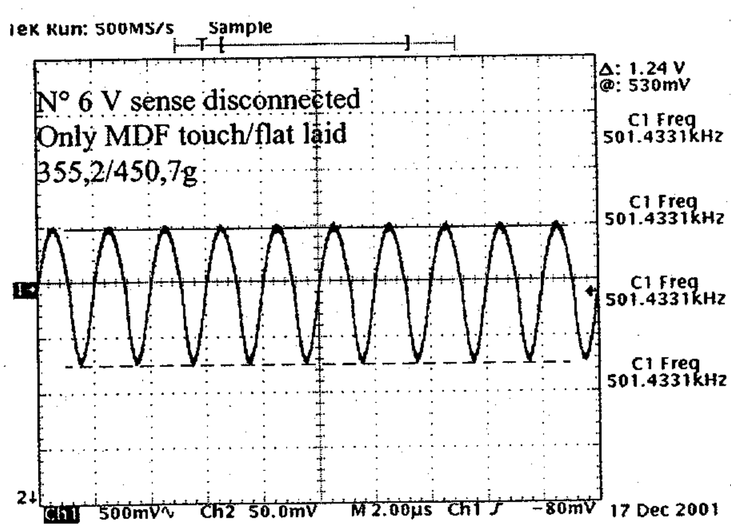


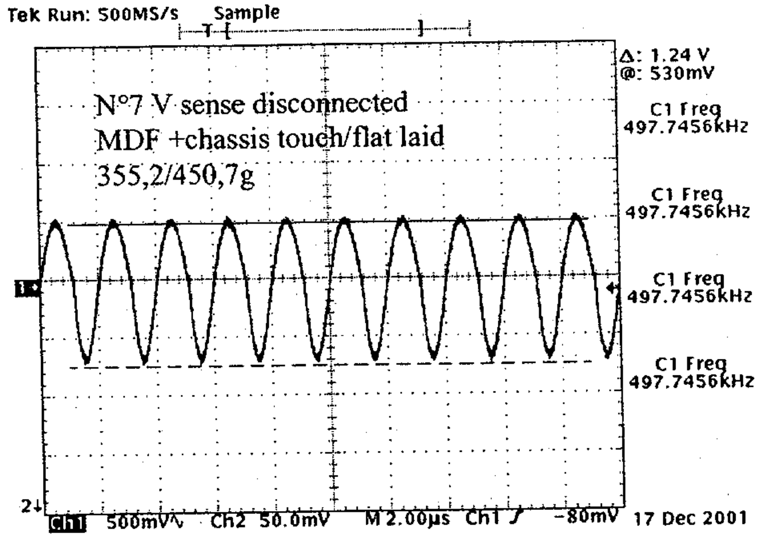


MDF

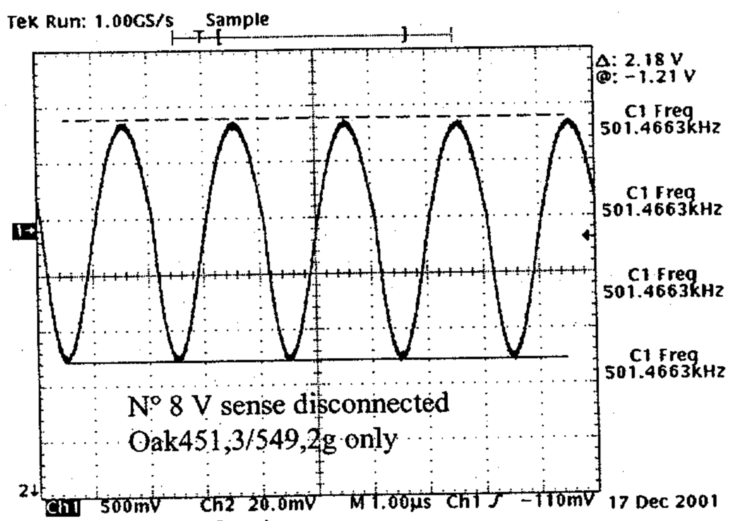

Tek Run: 500MS/s Sample
N° 4 V sense disconnected
MDF only / laid flat
355,2/450,7g (dry/wet weight)
Δ: 1.24 V
@: 530mV
C1 Freq
501.1774kHz
C1 Freq
501.1774kHz
C1 Freq
501.1774kHz
C1 Freq
501.1774kHz
Ch1 500mV Ch2 50.0mV M 2.00µs Ch1 -80mV 17 Dec 2001

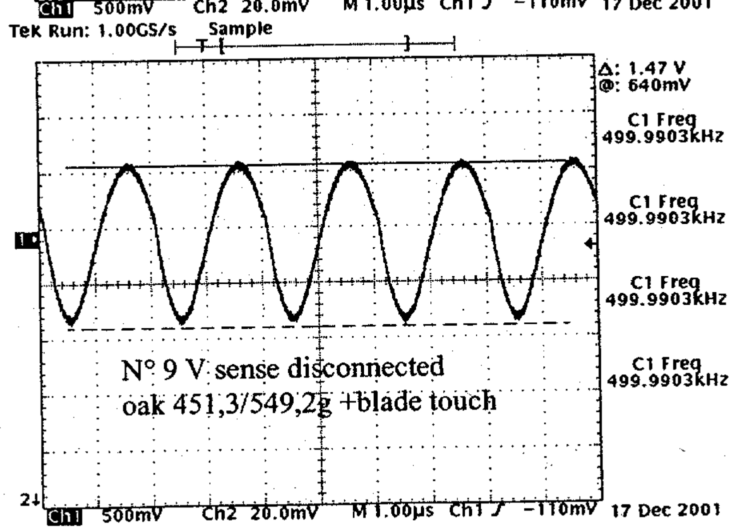

Tek Run: 500MS/s Sample
N° 5 V sense disconnected
MDF +blade touch /flat laid
355,2/450,7g
Δ: 1.03 V
@: -580mV
C1 Freq
500.5554kHz
Low signal
amplitude
C1 Freq
500.5554kHz
Low signal
amplitude
C1 Freq
500.5554kHz
Low signal
amplitude
C1 Freq
500.5554kHz
Low signal
amplitude
Ch1 500mV Ch2 50.0mV M 2.00µs Ch1 -80mV 17 Dec 2001


Tek Run: 500MS/s Sample
N° 6 V sense disconnected
Only MDF touch/flat laid
355,2/450,7g
Δ: 1.24 V
@: 530mV
C1 Freq
501.4331kHz
C1 Freq
501.4331kHz
C1 Freq
501.4331kHz
C1 Freq
501.4331kHz
Ch1 500mV Ch2 50.0mV M 2.00µs Ch1 -80mV 17 Dec 2001

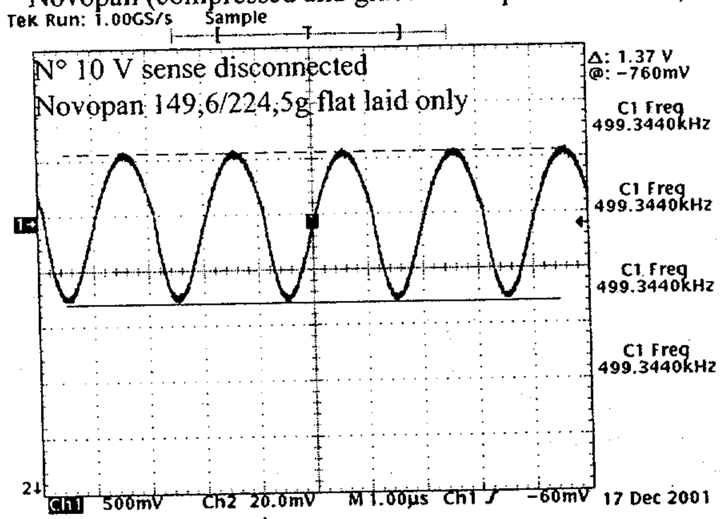

Tek Run: 500MS/s Sample
Δ: 1.24 V
@: 530mV
C1 Freq 497.7456kHz
C1 Freq 497.7456kHz
C1 Freq 497.7456kHz
C1 Freq 497.7456kHz
N°7 V sense disconnected
MDF +chassis touch/flat laid
355,2/450,7g
Ch1 500mV Ch2 50.0mV M 2.00µs Ch1 −80mV 17 Dec 2001

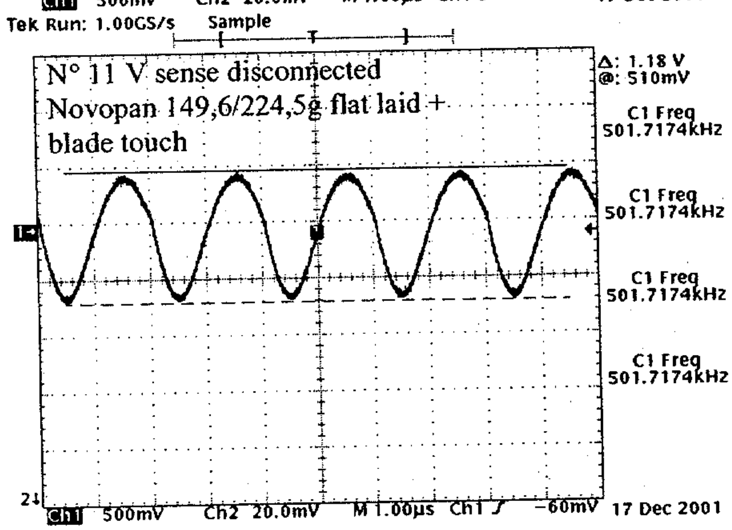
Oak


Tek Run: 1.00GS/s Sample
Δ: 2.18 V
@: −1.21 V
C1 Freq 501.4663kHz
C1 Freq 501.4663kHz
C1 Freq 501.4663kHz
C1 Freq 501.4663kHz
N° 8 V sense disconnected
Oak451,3/549,2g only
Ch1 500mV Ch2 20.0mV M 1.00µs Ch1 −110mV 17 Dec 2001

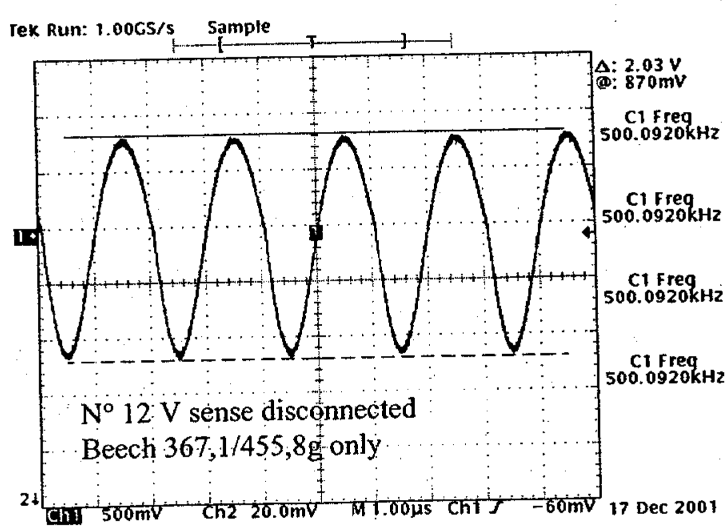

Tek Run: 1.00GS/s Sample
Δ: 1.47 V
@: 640mV
C1 Freq 499.9903kHz
C1 Freq 499.9903kHz
C1 Freq 499.9903kHz
C1 Freq 499.9903kHz
N° 9 V sense disconnected
oak 451,3/549,2g +blade touch
Ch1 500mV Ch2 20.0mV M 1.00µs Ch1 −110mV 17 Dec 2001

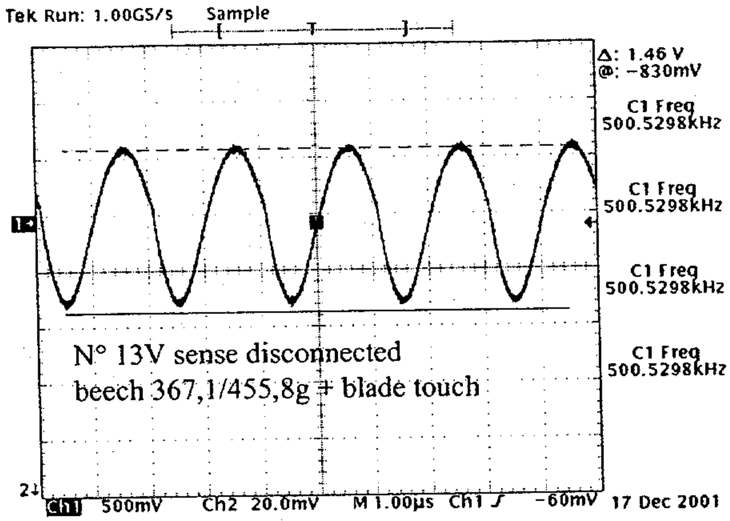
Novopan (compressed and glued wood particles board)





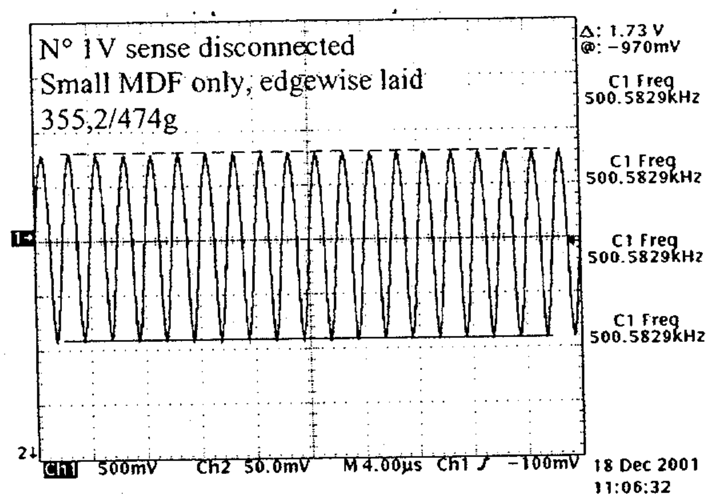
Beech

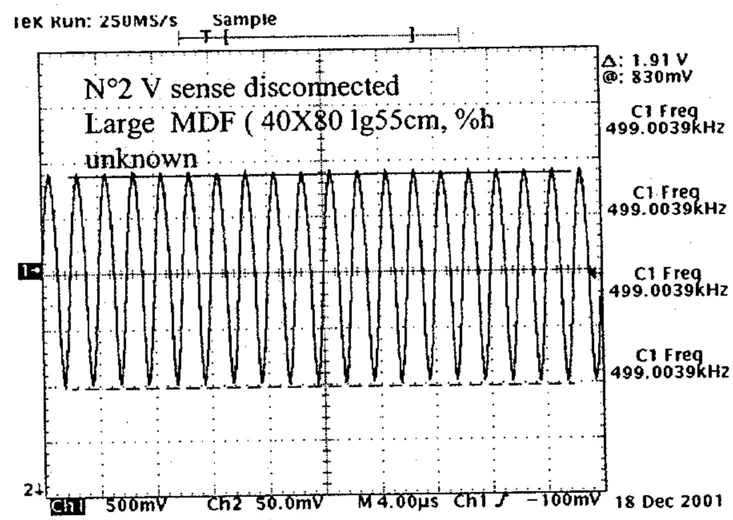


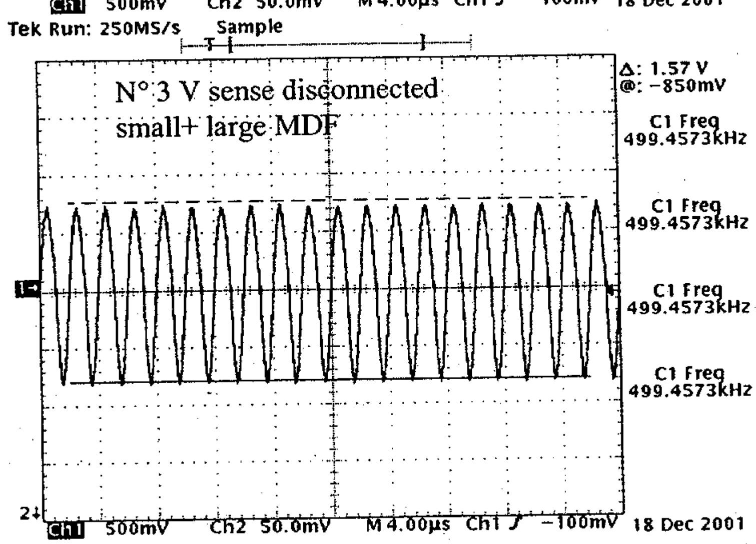

Tek Run: 1.00GS/s Sample
Δ: 1.46 V
@: −830mV
C1 Freq 500.5298kHz
C1 Freq 500.5298kHz
C1 Freq 500.5298kHz
C1 Freq 500.5298kHz
N° 13V sense disconnected
beech 367,1/455,8g + blade touch
Ch1 500mV Ch2 20.0mV M 1.00µs Ch1 ∫ −60mV 17 Dec 2001

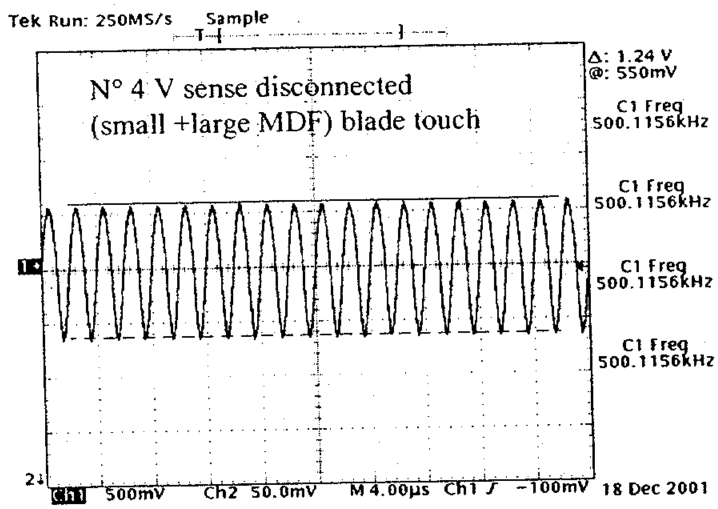
423

Measurements with two pieces of wet wood (cf. §5.5, table 4)



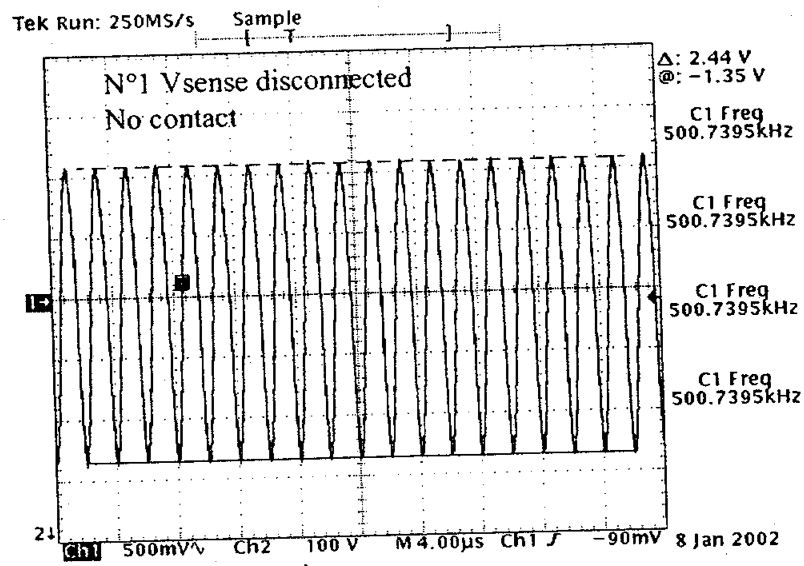


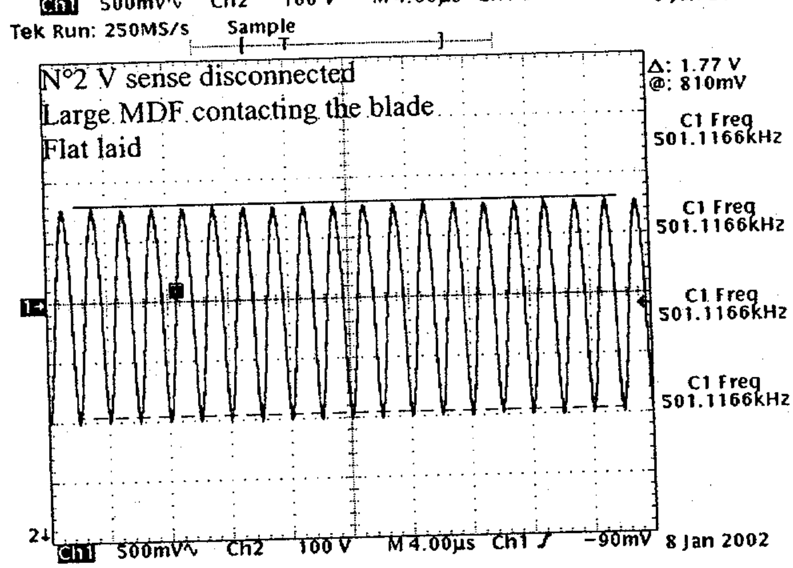


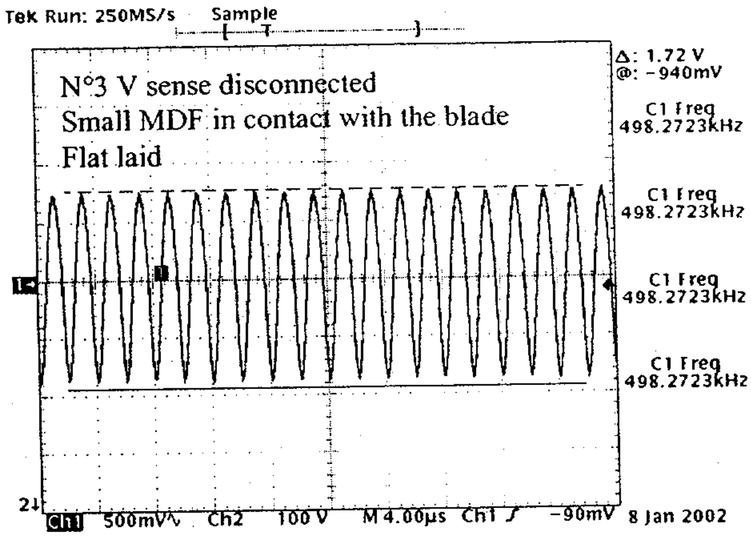

Tek Run: 250MS/s Sample
N° 4 V sense disconnected
(small +large MDF) blade touch
Δ: 1.24 V
@: 550mV
C1 Freq
500.1156kHz
C1 Freq
500.1156kHz
C1 Freq
500.1156kHz
C1 Freq
500.1156kHz
Ch1 500mV Ch2 50.0mV M 4.00µs Ch1 ∫ −100mV 18 Dec 2001

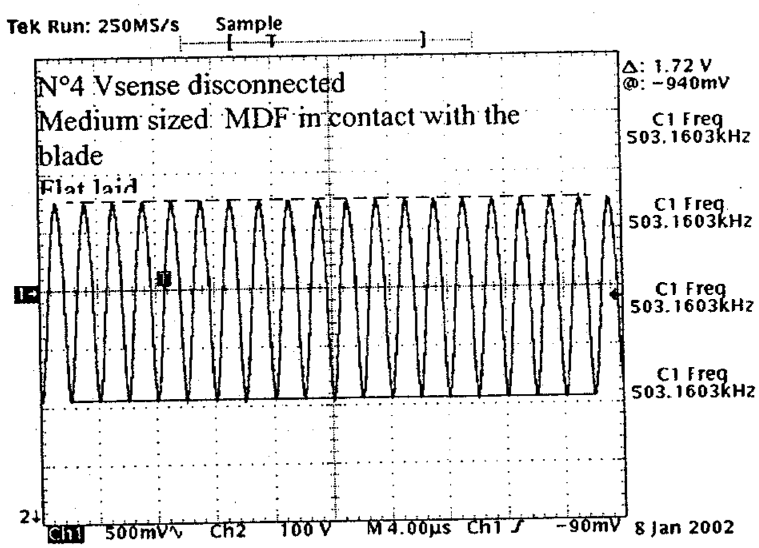
Measurements with different sized wet wood pieces (cf. §5.6 table 5)

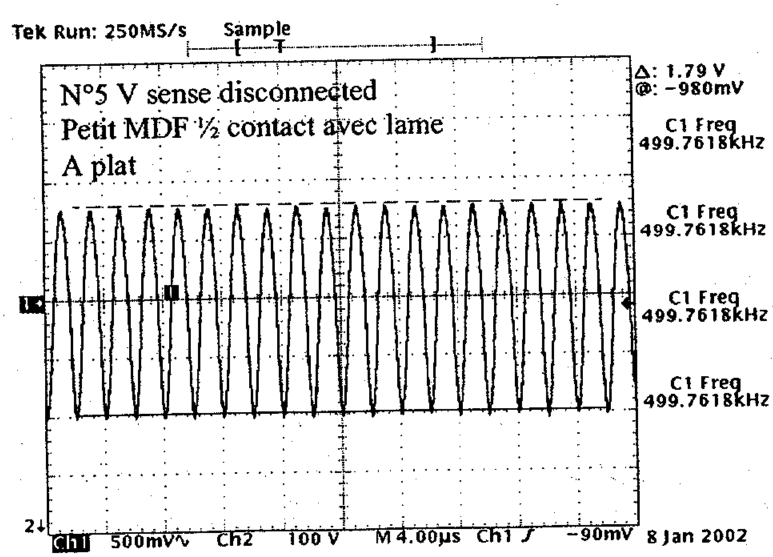
large MDF lgth. 540mm
small MDF lgth. 130mm
Medium sized MDF lgth. 410mm (Same %h for the three samples)



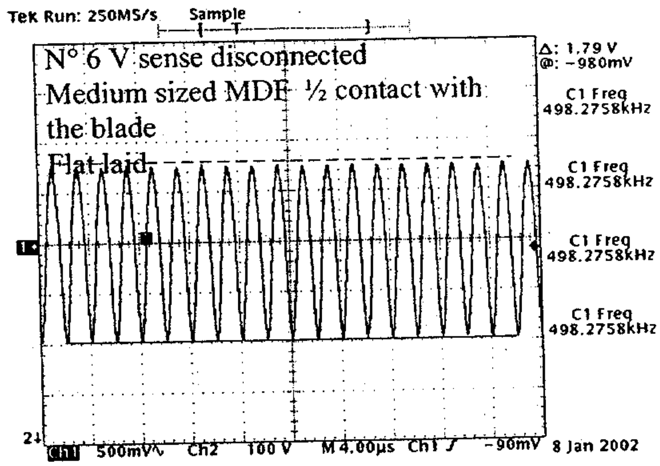



Tek Run: 250MS/s Sample
N°3 V sense disconnected
Small MDF in contact with the blade
Flat laid
Δ: 1.72 V
@: -940mV
C1 Freq 498.2723kHz
C1 Freq 498.2723kHz
C1 Freq 498.2723kHz
C1 Freq 498.2723kHz
Ch1 500mV∿ Ch2 100 V M 4.00µs Ch1 ∫ -90mV 8 Jan 2002


Tek Run: 250MS/s Sample
N°4 Vsense disconnected
Medium sized MDF in contact with the blade
Flat laid
Δ: 1.72 V
@: -940mV
C1 Freq 503.1603kHz
C1 Freq 503.1603kHz
C1 Freq 503.1603kHz
C1 Freq 503.1603kHz
Ch1 500mV∿ Ch2 100 V M 4.00µs Ch1 ∫ -90mV 8 Jan 2002


Tek Run: 250MS/s Sample
N°5 V sense disconnected
Petit MDF ½ contact avec lame
A plat
Δ: 1.79 V
@: -980mV
C1 Freq 499.7618kHz
C1 Freq 499.7618kHz
C1 Freq 499.7618kHz
C1 Freq 499.7618kHz
Ch1 500mV∿ Ch2 100 V M 4.00µs Ch1 ∫ -90mV 8 Jan 2002

427


Tek Run: 250MS/s Sample
N° 6 V sense disconnected
Medium sized MDF ½ contact with the blade
Flat laid
Δ: 1.79 V
@: -980mV
C1 Freq 498.2758kHz
C1 Freq 498.2758kHz
C1 Freq 498.2758kHz
C1 Freq 498.2758kHz
Ch1 500mV Ch2 100 V M 4.00μs Ch1 -90mV 8 Jan 2002

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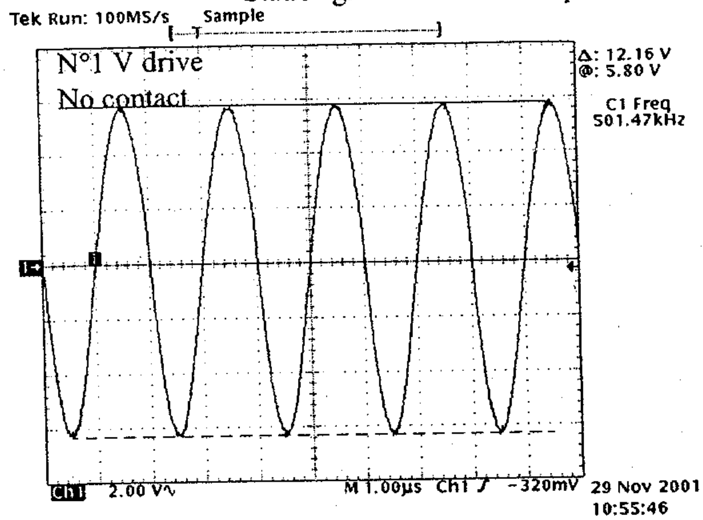
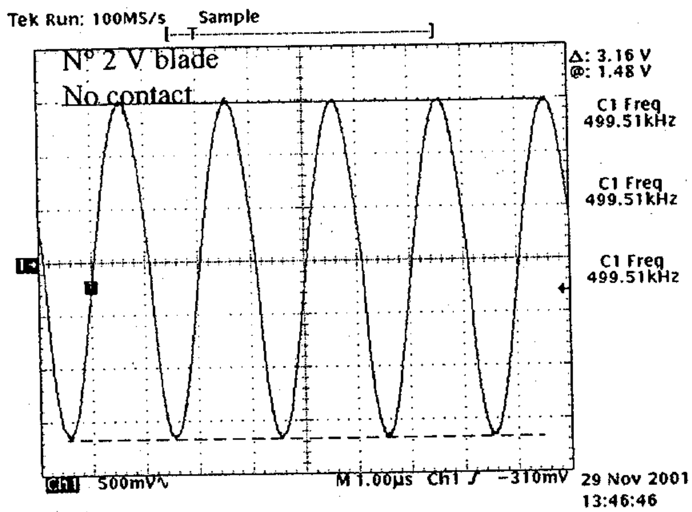
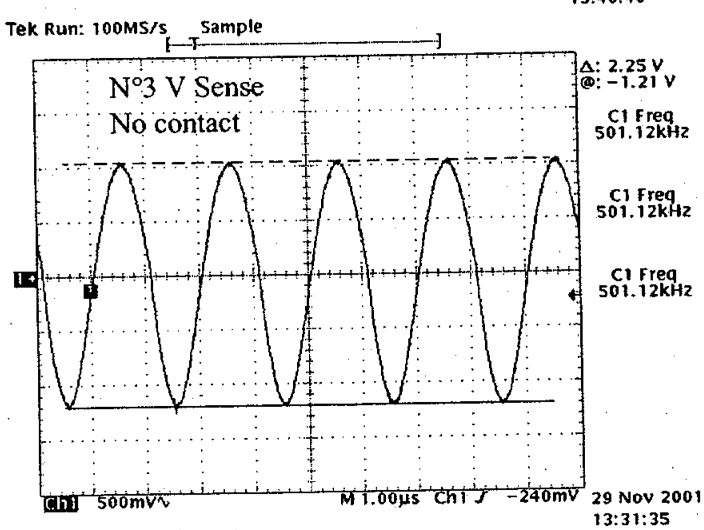
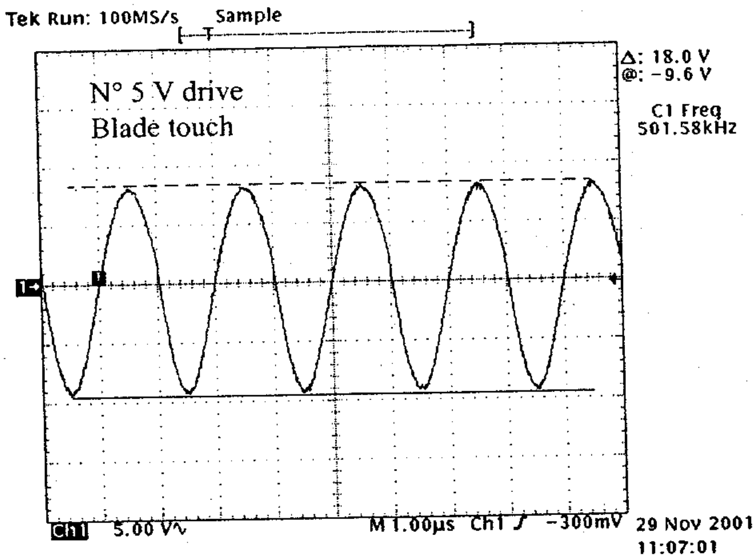
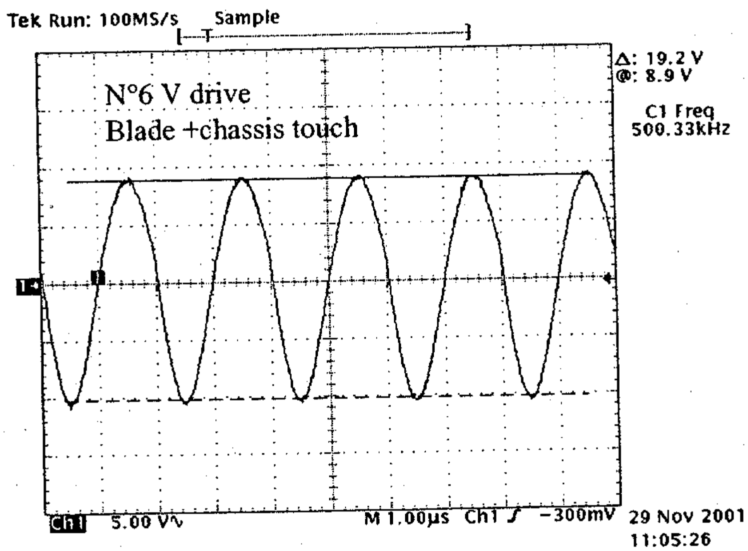
Static "green wwood" compensation " (cf.§5.7, table 6)

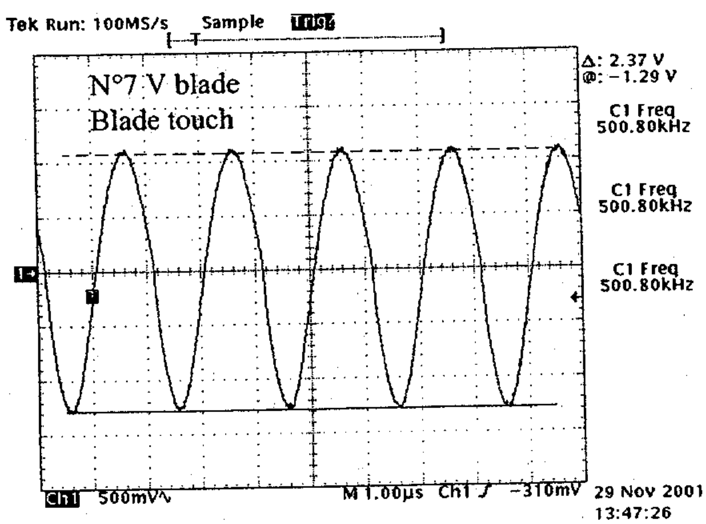


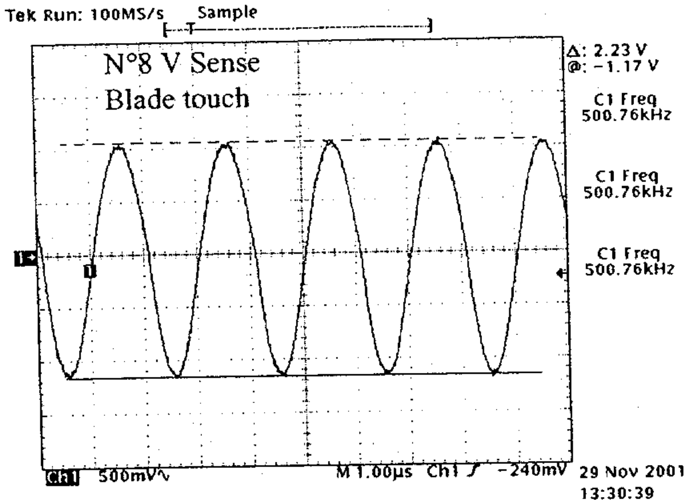




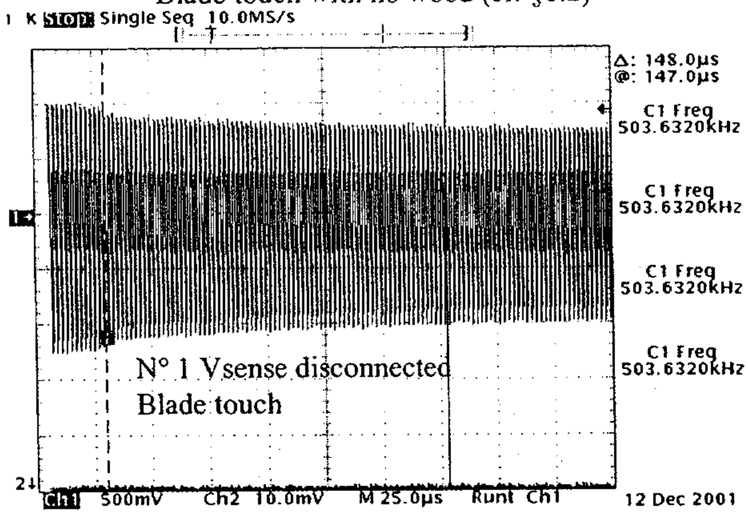

Tek Run: 100MS/s Sample
N° 5 V drive
Blade touch
Δ: 18.0 V
@: -9.6 V
C1 Freq
501.58kHz
Ch1 5.00 V
M 1.00μs Ch1 -300mV
29 Nov 2001
11:07:01

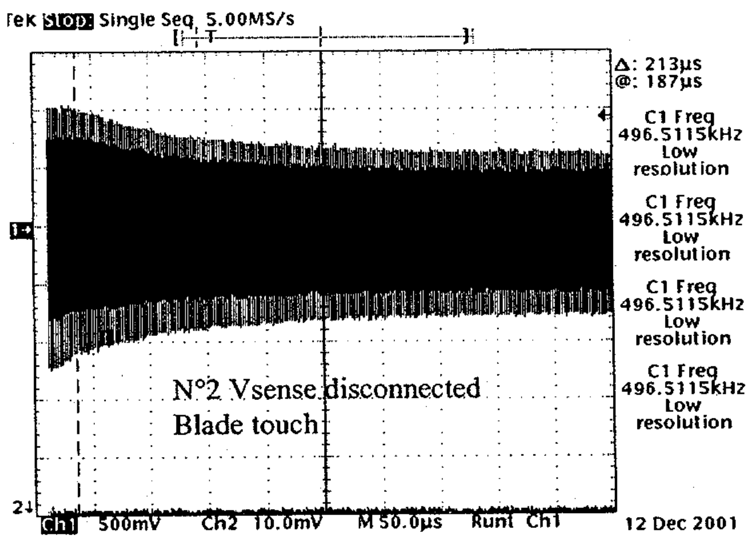

Tek Run: 100MS/s Sample
N°6 V drive
Blade +chassis touch
Δ: 19.2 V
@: 8.9 V
C1 Freq
500.33kHz
Ch1 5.00 V
M 1.00μs Ch1 -300mV
29 Nov 2001
11:05:26

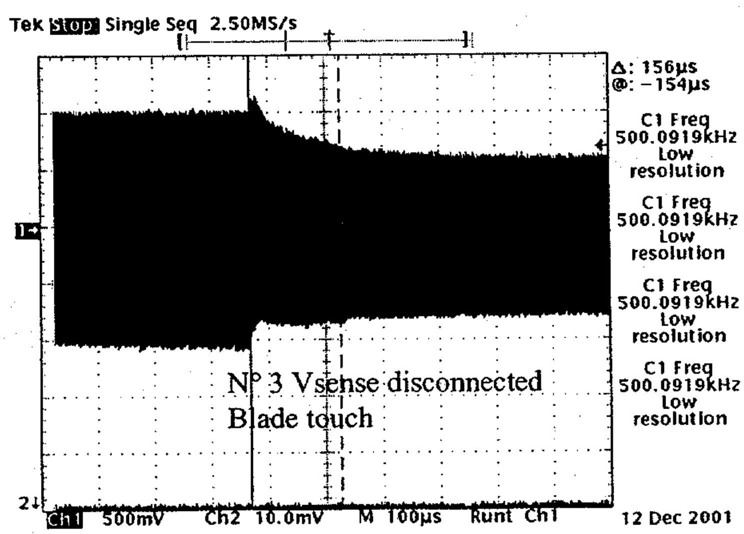

Tek Run: 100MS/s Sample Trig?
N°7 V blade
Blade touch
Δ: 2.37 V
@: -1.29 V
C1 Freq
500.80kHz
C1 Freq
500.80kHz
C1 Freq
500.80kHz
Ch1 500mV
M 1.00μs Ch1 -310mV
29 Nov 2001
13:47:26


Tek Run: 100MS/s Sample
N°8 V Sense
Blade touch
Δ: 2.23 V
@: -1.17 V
C1 Freq
500.76kHz
C1 Freq
500.76kHz
C1 Freq
500.76kHz
Ch1 500mV
M 1.00µs Ch1 -240mV
29 Nov 2001
13:30:39

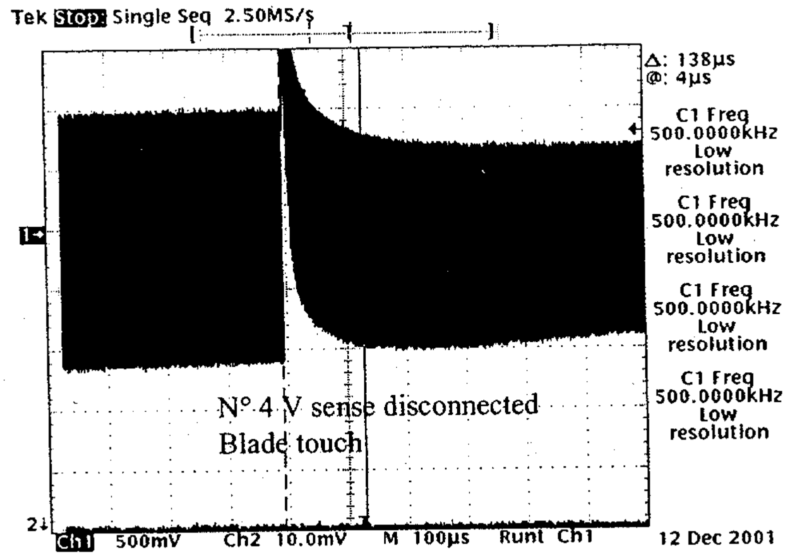
Blade touch with no wood (cf. §6.2)

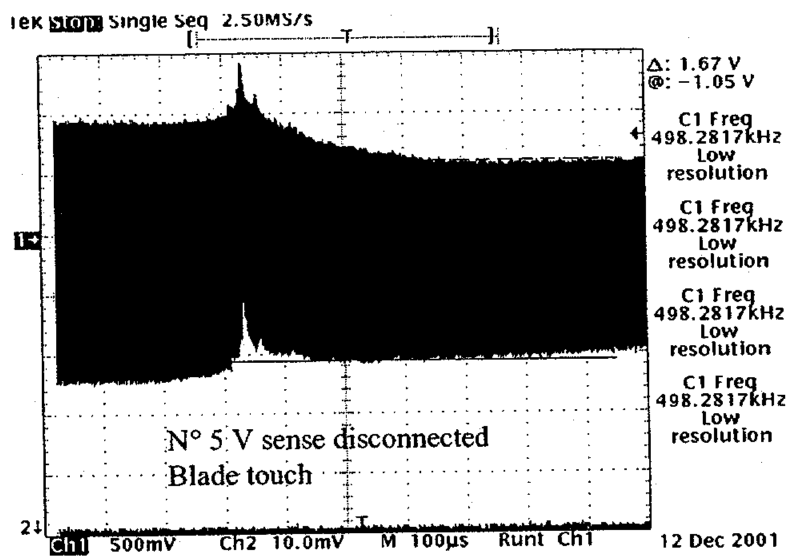


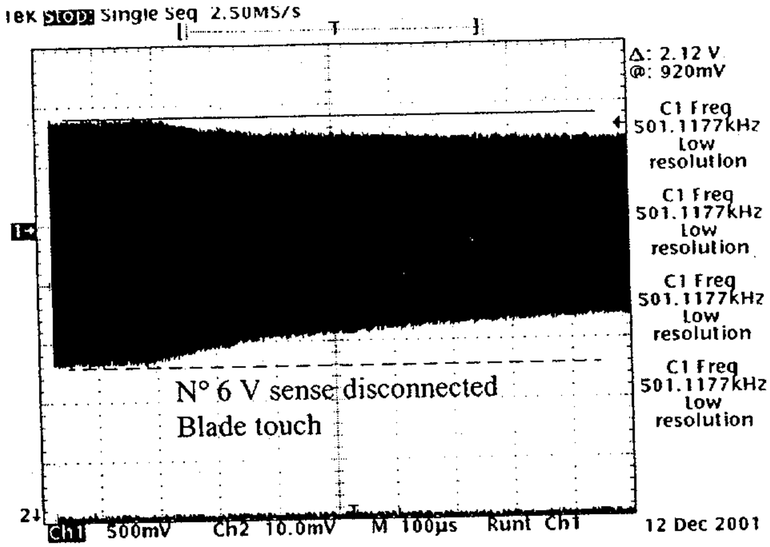


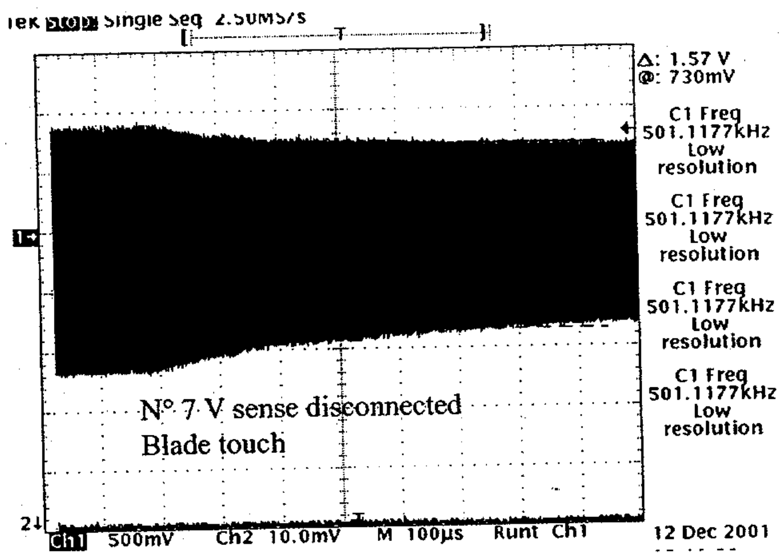


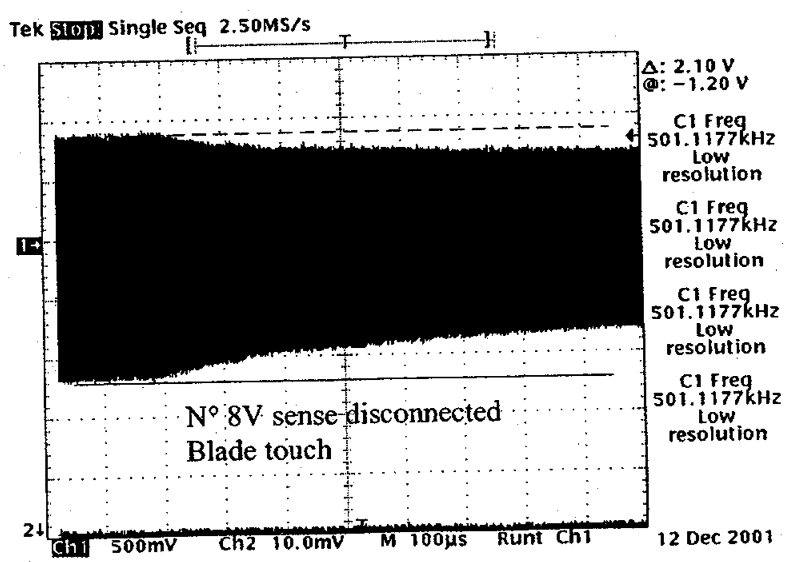
432

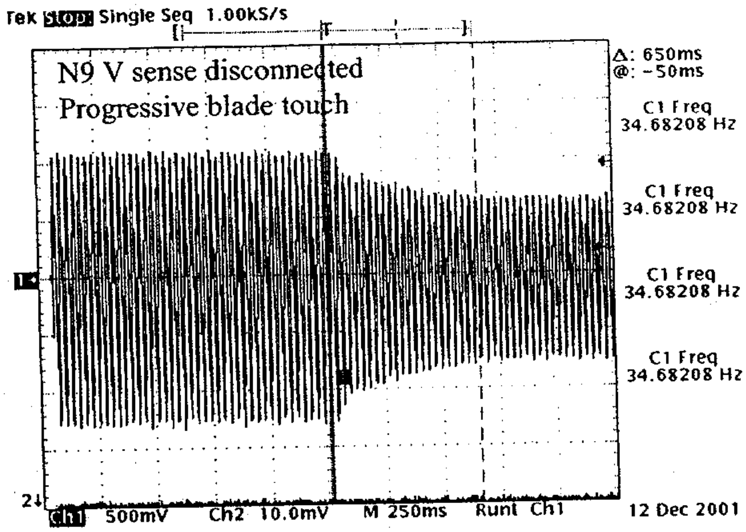

Tek Stop: Single Seq 2.50MS/s
Δ: 138µs
@: 4µs
C1 Freq
500.0000kHz
Low
resolution
C1 Freq
500.0000kHz
Low
resolution
C1 Freq
500.0000kHz
Low
resolution
C1 Freq
500.0000kHz
Low
resolution
N° 4 V sense disconnected
Blade touch
Ch1 500mV Ch2 10.0mV M 100µs Runt Ch1
12 Dec 2001

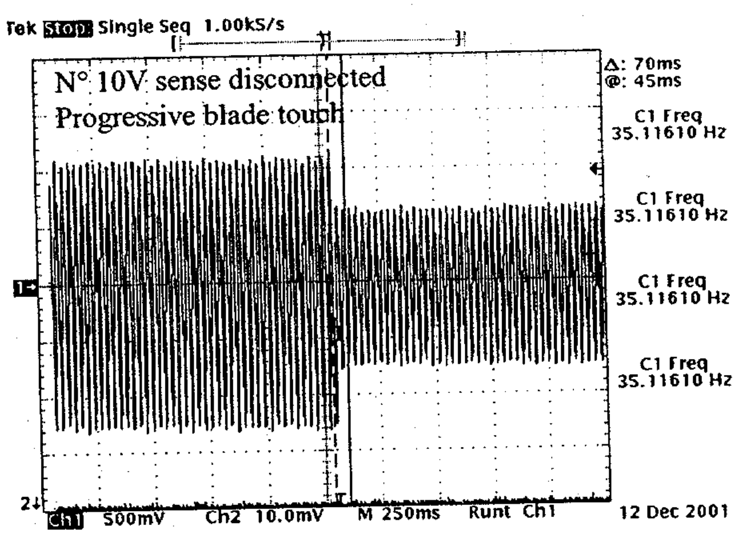

Tek Stop: Single Seq 2.50MS/s
Δ: 1.67 V
@: −1.05 V
C1 Freq
498.2817kHz
Low
resolution
C1 Freq
498.2817kHz
Low
resolution
C1 Freq
498.2817kHz
Low
resolution
C1 Freq
498.2817kHz
Low
resolution
N° 5 V sense disconnected
Blade touch
Ch1 500mV Ch2 10.0mV M 100µs Runt Ch1
12 Dec 2001

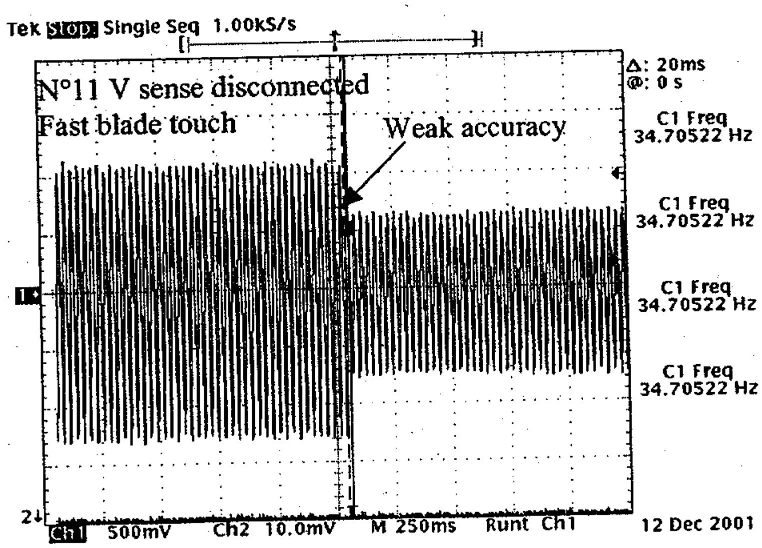

Tek Stop: Single Seq 2.50MS/s
Δ: 2.12 V
@: 920mV
C1 Freq
501.1177kHz
Low
resolution
N° 6 V sense disconnected
Blade touch
Ch1 500mV Ch2 10.0mV M 100µs Runt Ch1
12 Dec 2001


Tek Stop: Single Seq 2.50MS/s
Δ: 1.57 V
@: 730mV
C1 Freq
501.1177kHz
Low
resolution
N° 7 V sense disconnected
Blade touch
Ch1 500mV Ch2 10.0mV M 100µs Runt Ch1
12 Dec 2001


Tek Stop: Single Seq 2.50MS/s
Δ: 2.10 V
@: −1.20 V
C1 Freq
501.1177kHz
Low
resolution
N° 8V sense disconnected
Blade touch
Ch1 500mV Ch2 10.0mV M 100µs Runt Ch1
12 Dec 2001


Tek Stop: Single Seq 1.00kS/s
N9 V sense disconnected
Progressive blade touch
Δ: 650ms
@: -50ms
C1 Freq
34.68208 Hz
C1 Freq
34.68208 Hz
C1 Freq
34.68208 Hz
C1 Freq
34.68208 Hz
Ch1 500mV Ch2 10.0mV M 250ms Runt Ch1
12 Dec 2001


Tek Stop: Single Seq 1.00kS/s
N° 10V sense disconnected
Progressive blade touch
Δ: 70ms
@: 45ms
C1 Freq
35.11610 Hz
C1 Freq
35.11610 Hz
C1 Freq
35.11610 Hz
C1 Freq
35.11610 Hz
Ch1 500mV Ch2 10.0mV M 250ms Runt Ch1
12 Dec 2001


Tek Stop: Single Seq 1.00kS/s
N°11 V sense disconnected
Fast blade touch
Weak accuracy
Δ: 20ms
@: 0 s
C1 Freq
34.70522 Hz
C1 Freq
34.70522 Hz
C1 Freq
34.70522 Hz
C1 Freq
34.70522 Hz
Ch1 500mV Ch2 10.0mV M 250ms Runt Ch1
12 Dec 2001

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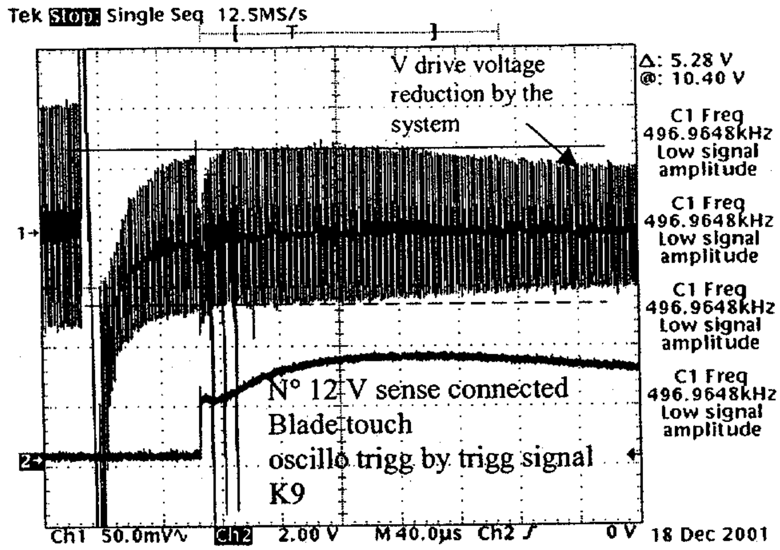
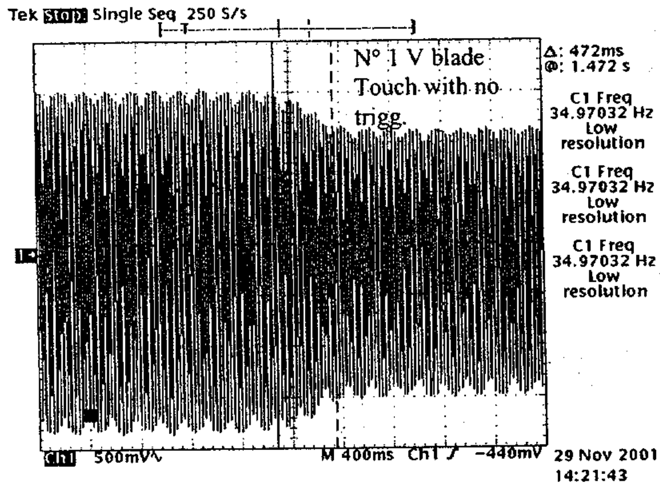
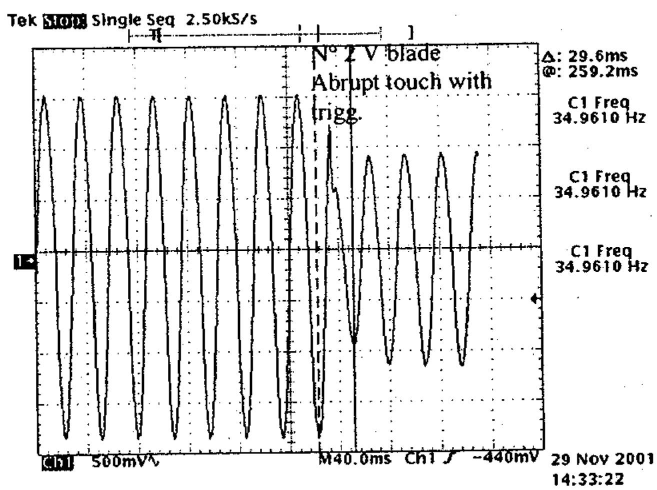

Tek Stop: Single Seq 12.5MS/s
V drive voltage reduction by the system
Δ: 5.28 V
@: 10.40 V
C1 Freq 496.9648kHz Low signal amplitude
C1 Freq 496.9648kHz Low signal amplitude
C1 Freq 496.9648kHz Low signal amplitude
C1 Freq 496.9648kHz Low signal amplitude
N° 12 V sense connected
Blade touch
oscillo trigg by trigg signal
K9
Ch1 50.0mV Ch2 2.00 V M 40.0µs Ch2 0 V 18 Dec 2001

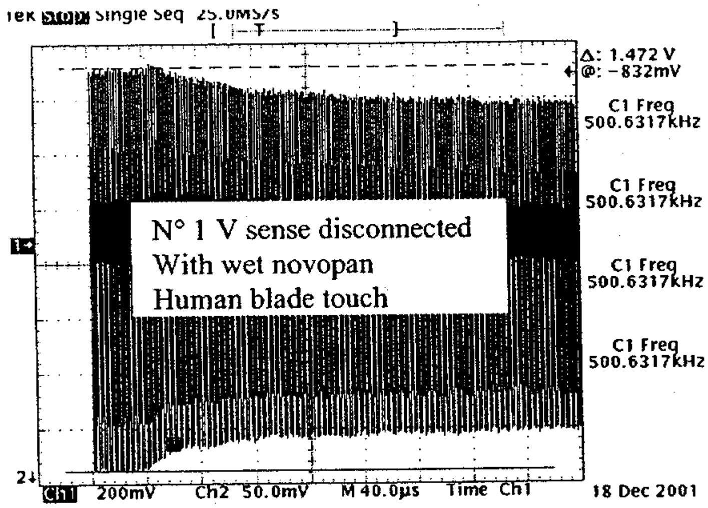
Influence of the variation speed of detected voltage (cf. §6.3)

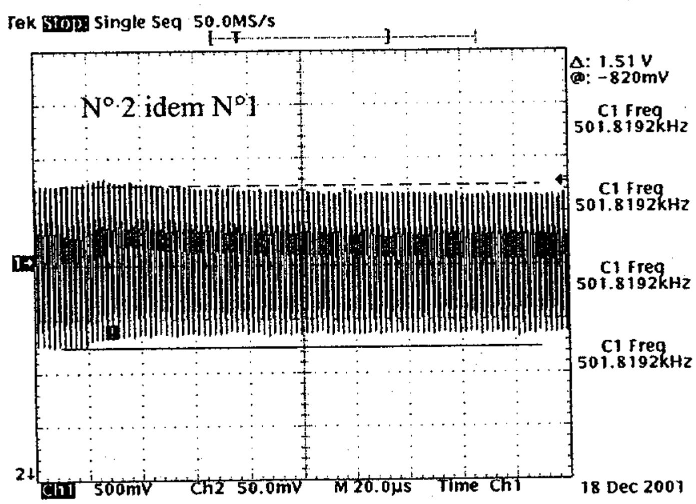


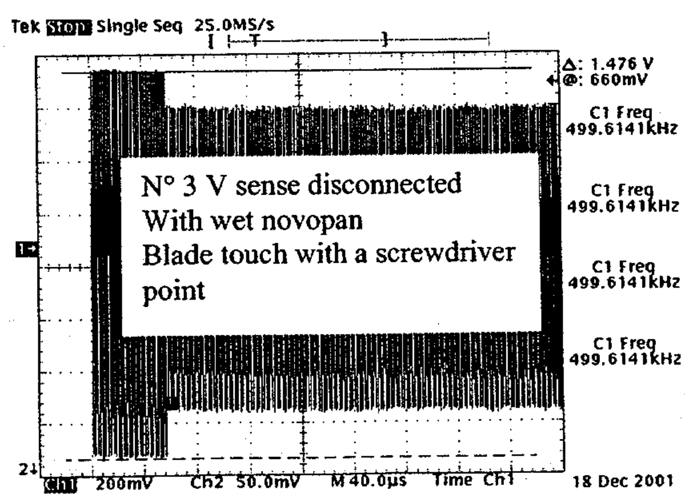


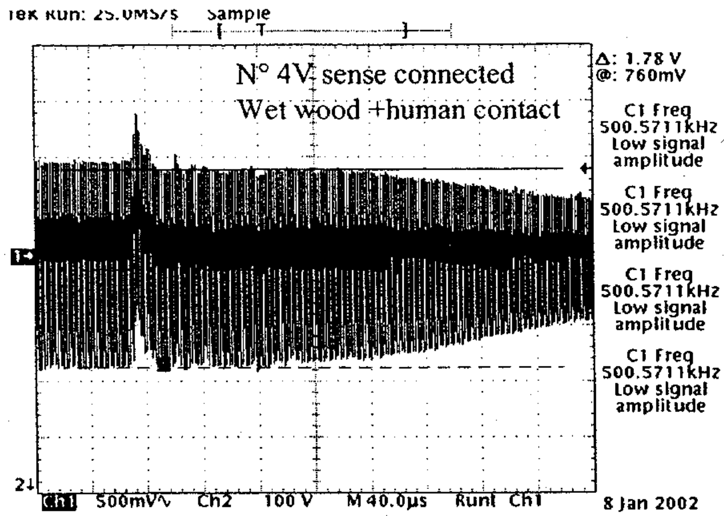
Note: Indicated frequency is not correct because of an aliasing phenomena of the oscilloscope. Only the magnitude remains significant

Blade touch with wet wood (cf. §6.4)








Tek Run: 25.0MS/s Sample
N° 4V sense connected
Wet wood +human contact
Δ: 1.78 V
@: 760mV
C1 Freq
500.5711kHz
Low signal
amplitude
C1 Freq
500.5711kHz
Low signal
amplitude
C1 Freq
500.5711kHz
Low signal
amplitude
C1 Freq
500.5711kHz
Low signal
amplitude
Ch1 500mV∿ Ch2 100 V M 40.0μs Runt Ch1
8 Jan 2002

June 2, 2003

David A Fanning
22409 S.W. Newland Road
Wilsonville, OR 97070
(503) 638-6102

Stephen Lemberg
Office of the General Counsel
U.S. Consumer Product Safety Commission
Washington, D.C. 20207

Re: Petition to Initiate Rulemaking for Table Saws

Dear Mr. Lemberg:

Thank you for your letter dated May 8, 2003, requesting an English translation of a report from the German safety agency BIA. Enclosed is a paper copy of that translation.

Also enclosed is one additional signature from an individual joining in the petition. We have created a Second Revised Index of Petitioners to include that individual, and a copy of that index is enclosed. The total number of petitioners is now 349.

Please let us know if you require any other information or items.

Sincerely,

David A. Fanning

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Interim Report

1 Description of Research Aim

Object of inspection is a novel safety system to reduce the consequences of injuries caused by circular saws and similar woodworking machines. The concept of the safety system is based in general on two functional units: capacitive detection of contact of the operator with the rotating tool; and halting of its hazardous motion in a fraction of a second.
This inspection especially focuses on the prediction of reliable detection for a variety of wood materials. Various wood materials and moisture content levels are considered. The design of the electronic system with respect to control categories has not been completely considered in this inspection, since the present system is a laboratory prototype. Next to a description of the detection characteristics, the reaction time of the braking system has been estimated to enable recommendations of the safety system for primary fields of applications.
In form of a first approximation, this interim report should serve as a basis to decide and plan on further investigations and endorsements.

2 System Description

This report is based on the documentation "SawStop, Descriptions of Safety Systems For Power Equipment, SawStop Inc., Wilsonville, Oregon 97070" (delivered in person to BIA on February 1, 2001) of the developers of the SawStop safety system, and on measurements conducted on a laboratory prototype that has been made available. This prototype consists of a circular table saw with a height-adjustable cutting blade, which is commercially available in the USA. This saw has been customized by the developers with capacitive sensors and signal processing electronics as well as with a braking mechanism to realize the safety concept.

2.1 Detection

Contact of the operator with the saw blade is detected with a capacitive sensing system. A sinusoidal AC voltage is transmitted by a coupling electrode through the metallic saw blade with insulated suspension to a de-coupling electrode (Figure 1, Image 1). Contact with the saw blade induces a damping of the amplitude of the transmitted signal. The amplitude of the input signal is regulated by control electronics to maintain a constant amplitude of the output signal (Figure 1, Image 2).

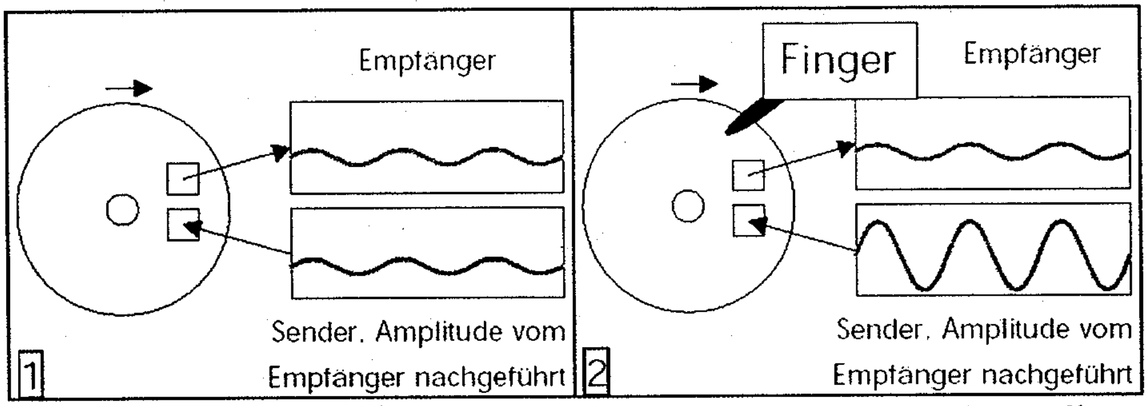


Figure 1 shows a diagram of the rotating saw blade with coupling and de-coupling electrodes. The amplitudes of the input and output signal are depicted in green and depend on the capacitive load at the saw blade. The amplitude of the input signal is regulated to ensure a constant output signal amplitude.

Contact of the electrically isolated saw blade with a work object or the operator induces a more or less severe electric shorting to ground (Figure 2). The severity of shorting not only depends on the conductive (Ohm) resistance between the saw blade and ground, but more importantly on the capacitive (blind) resistance. The capacitive conductivity is given by $2\pi fC$, and the frequency f of 500 kHz of the sinusoidal signal is very high. Therefore, a small capacitive load can dampen the amplitude severely. For example, assuming a 100 pF capacitance for the human body will correlate to a conductive resistance of about 3 kOhm.

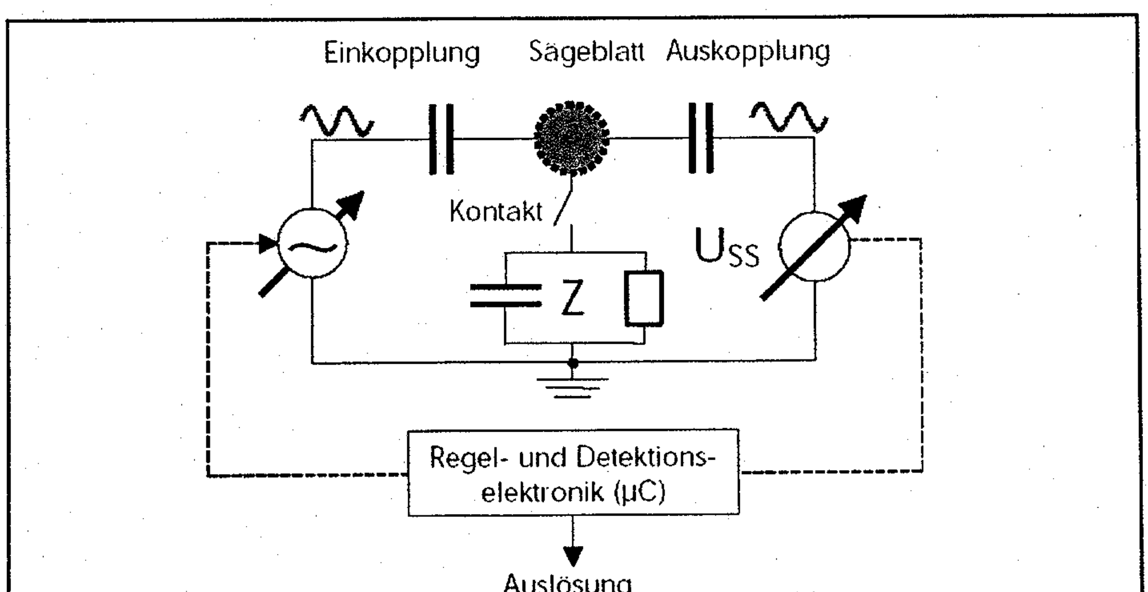


Figure 2 depicts the diagram of the electronic detection circuitry (µC: Micro-controller, U_{ss}: peak-to-peak voltage, z: complex resistance).

To detect contact of the operator with the saw blade, not only the magnitude of amplitude attenuation but also the rate of amplitude attenuation is analyzed (see also Figure 3). Slow rates of amplitude attenuation (milliseconds to seconds) are interpreted as changes in environment conditions, caused for example due to contact of the work object during cutting, changes in air humidity, or similar factors. Only severe amplitude attenuations which occur in a timeframe of well below one millisecond are interpreted as hazardous contact, and will trigger a halt of the saw blade. In general, the system is only triggered, when the rate of amplitude attenuation induced by contact with the saw blade is higher than the speed by which the control circuitry can up-regulate the amplitude of the input signal. The speed by which the control circuitry regulates the input signal amplitude is a variable parameter and can be adjusted to the apparent environment conditions.

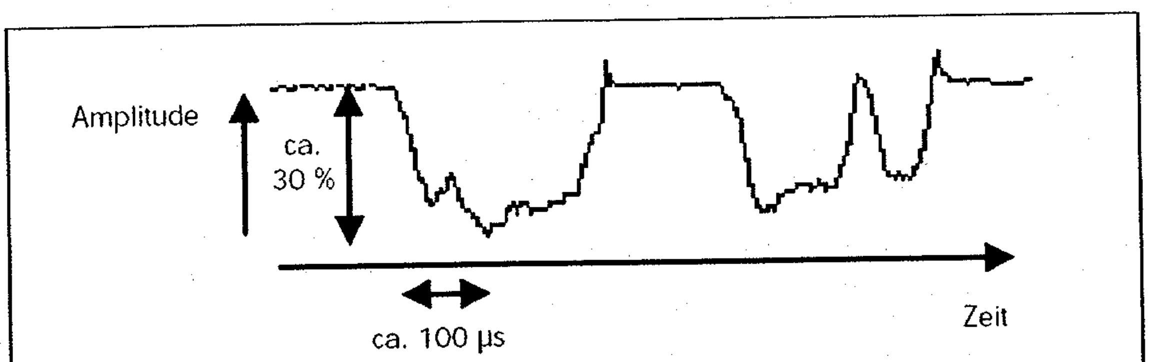


Figure 3 shows the principle of amplitude attenuation at the de-coupling electrode during contact of a simulated finger with the passing teeth of the saw blade.

2.2 Stopping of the Saw Blade

After detection of a contact with the saw blade, a central control electronics triggers a mechanical braking system. This system consist essentially of a brake pad, which is mounted below the saw blade. The brake pad is pushed by a strong steel spring towards the center of the saw blade, but remains retained during normal operation by a stainless-steel fuse-wire (Figure 4, Image 1). During triggering, the fuse-wire burns with a high energy pulse, delivered in an very short time, after which the brake pad is pressed toward the saw blade center into the teeth of the saw blade. The brake pad consists of a material, in which the saw blade gets stuck immediately, so that the blade stops very quickly (Figure 4, Image 2). The brake pad, spring, fuse wire, and trigger electronics components are combined in a brake module, which can completely be replaced with a new module after successful activation (Figure 5). The laboratory prototype provided for this inspection was furthermore equipped with a height-adjustable saw-blade. The existing mechanics for height-adjustment was expanded, so that the forces caused by a sudden stop of the saw blade will be converted into a momentum, which completely retracts the saw blade underneath the level of the saw table top (Figure 4, Image 3).

Therefore, the hazardous motion is effectively stopped, and the rotating tool is displaced away from the operator. Simultaneously to the mechanical stopping, the energy supplied to the motor which drives the saw blade over a transmission belt will be interrupted.

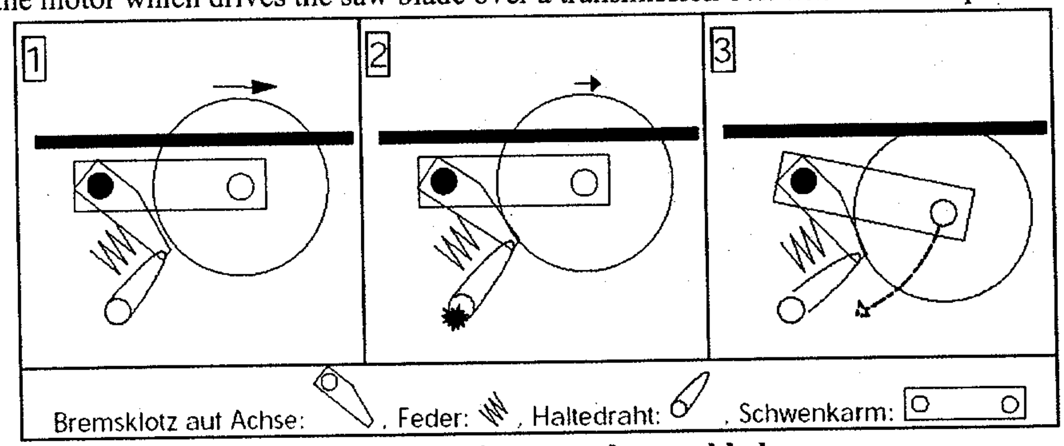


Figure 4 shows the concept to stop and retract the saw blade.

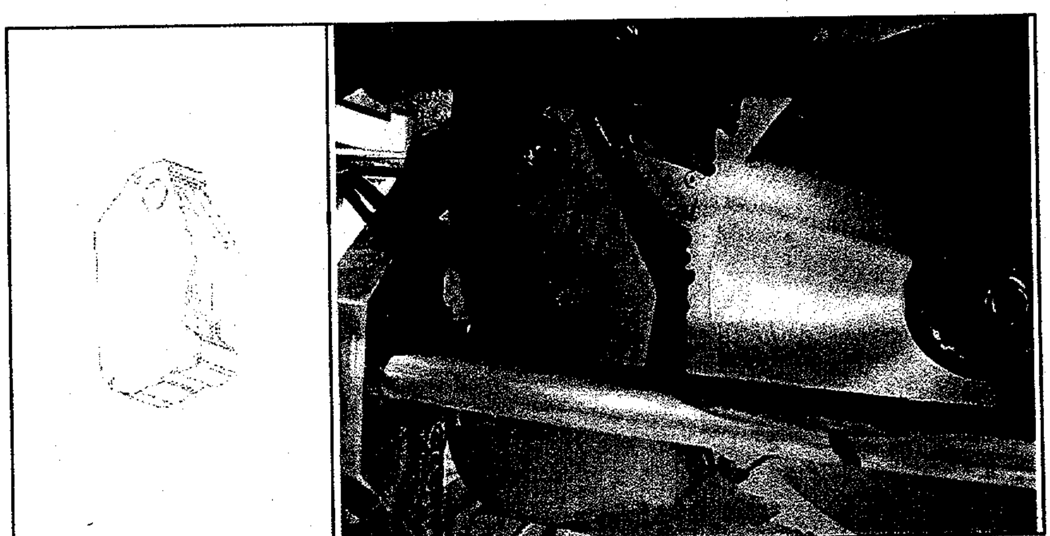


Figure 5 shows an exchangeable brake module as schematic, and after activation in association with the stopped and retracted saw blade.

2.3 Safety-related Electronics

A series of self-tests and control function are integrated into the complex control electronics, which controls the detection and differentiation of a hazardous situation as well as the stopping of the saw blade. These encompass start-up self-tests as well as continuous tests to monitor certain parts of the detection sensors and trigger electronics. A redundant, multi-channel version of the safety relevant components is not realized.

3 Performed Inspections

The reliability and availability of the safety system was evaluated in practice-oriented cutting trials on dry and damp wood under various environment conditions. Inspections focused on the aspect of detection. The reliability of the stopping mechanism was estimated by typical reaction times required for a complete stop of the saw blade.

3.1 Cutting Trials on Dry and Damp Wood

3.1.1 Description of the conducted measurements

To test the availability of the circular saw with activated safety system, cutting trials on 24 different wood types were conducted. These contained 10 solid wood types, three plywood types, seven particle boards, with and without laminated surfaces, as well as four MDF-boards. All wood samples were 20 cm by 40 cm in size, and were cut in longitudinal direction by translation along the parallel guide. The saw blade height was fixed at 5 cm above the level of the table surface, so that for each wood thickness (10.6 mm to 38.7 mm) each board was cut through its entire thickness. The capability of the saw to generate oblique cuts after tilting of the saw blade was not utilized. Each cut was conducted in presence of the conventional safety equipment, which included the cut-separator and a protective cover.

In the first test series, cutting trials were conduced on dry wood samples. The 24 wood samples have been stored for several years in a dry basement. Their residual moisture content was between 5% and 10%. For the subsequent test series on damp wood, 14 wood samples were selected and submersed for 12 hours in a water bath. Finally, the residual moisture content of all samples, the dry and wet stored samples, was measured with a Second-Hygrometer (Hygrotest 6500, Fa. Testoterm). The residual moisture content is defined as the ratio between the water content and the dry wood content, and can therefore assume values from 0% to over 100%. Since the measurement range of the employed Hygrometer was limited to 100%, higher measurement values were reduced to 100%. Directly after moisture content assessment, a second series of cutting trials was conducted with the now damp wood specimens to estimate the saw availability. The cutting requirements were identical to the cutting trials on dry wood specimens.

3.1.2 Measurement results

The following Table 1 lists for each of the 24 wood samples next to the wood type and thickness, the results of the cutting trials, and the measured residual moisture content. The cutting trials on dry wood samples were conducted on all 24 wood samples, and subsequently repeated on a selection of 14 damp wood samples. Since the residual moisture content was only measured after the 14 wood samples had been submersed in water, residual moisture content data under dry conditions was not available. However, residual moisture content is most likely in the range of the ten wood samples which remained dry, which is 5% to 10%. For additional information, the length of the cut was measured whenever the safety system triggered. Under consideration of the sample thickness and by approximation of the cut surface as trapezoid shape, the collateral contact surfaces between the saw blade and the wood sample was estimated.

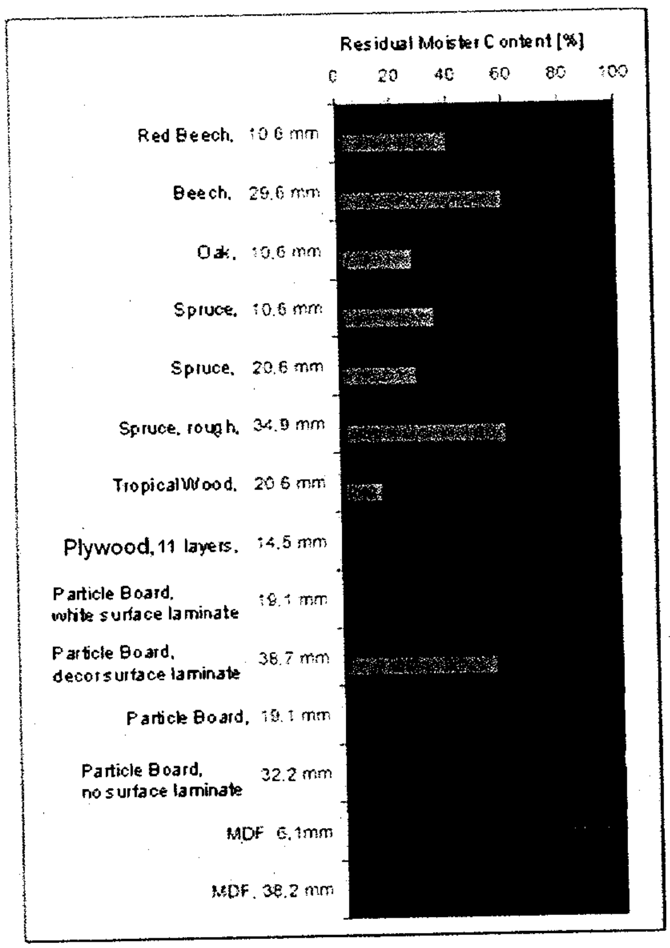
This area served as an approximate measure of the sensitivity of the trigger mechanism during cutting of very damp wood. The footnotes corresponding to the trigger events during cutting of damp beech wood and tropical wood samples resulted from the fact that due to the pronounced swelling of the wood samples no complete cuts could be achieved. Despite several cutting trials, the saw blade was slowed down due to jamming after a cut length of 11 to 30 cm. However, no trigger of the SawStop safety-system occurred.

No.	Wood type / Material	Thickness [mm]	Trigger Event dry	Trigger Event damp	Contact Area [cm2]	Residual moister content [%]
Solid Wood Samples						
1	Red Beech	10.6	no	no		39.5
2	Red Beech	10.6	no	- (1)		6.4
3	Beech	20.6	no	- (1)		7.9
4	Beech	29.6	no	no (2)		59.5
5	Oak	10.6	no	no		27
6	Oak	20.6	no	- (1)		8.7
8	Spruce	10.6	no	no		34.3
9	Spruce	20.6	no	no		27.8
11	Spruce, rough	34.9	no	no		60
12	Tropical wood	20.6	no	no (3)		15.3
Plywood						
13	Plywood, 5-layers	7	no	- (1)		6.9
14	Plywood, 11-layers	14.5	no	- (1)		9.8
15	Plywood, 11-layers	14.5	no	yes	4.2	100
Particle Board, laminated						
16	Particle Board, white lamina	10.5	no	- (1)		5
17	Particle Board, white lamina	19.1	no	yes	1.5	100
18	Particle Board, veneer	19	no	- (1)		6
19	Particle Board, decor lamina	38.7	no	no		55
Particle Board, not laminated						
20	Particle Board	19.1	no	yes	5.5	100
21	Particle Board	19.1	no	- (1)		6
22	Particle Board	32.2	no	yes	2.3	100
MDF-Boards						
23	MDF	6.1	no	- (1)		5.8
24	MDF	6.1	no	yes	1.2	100
25	MDF	25	no	- (1)		5,7
26	MDF	38.2	no	yes	2.5	55.1
(1)	These ten of the 24 wood samples were not cut in damp condition					
(2)	damp wood jammed in two cutting trials after 11 and 15 cm cutting length					
(3)	damp wood jammed in two cutting trials after 30 cm cutting length					

Table 1 depicts the results of the cutting trials on dry and damp wood samples.

3.1.3 Interpretation of Measurements

Under dry conditions, which correspond among all wood samples to a residual moisture content of 5% to 10%, no false trigger was encountered among any of the wood types and thicknesses, regardless of their composition and lamination. The system always remained available. A different picture emerged from the cutting trials on damp wood samples. The results of the 14 wood samples of Table 1 which were cut in damp condition, are illustrated in Graph 1.



Graph 1 demonstrates the triggering of the safety system during cutting of a variety of damp wood samples. The wood samples are sorted according to their composition and thickness, and are depicted with their residual moisture content. Red bars indicate wood samples which induced a false trigger. In addition, a number is provided at the tip of each red bar. It expresses the bilateral contact area in the cutting zone in cm² between the wood sample and the saw blade at the time of triggering.

Notably, none of the solid wood samples caused a false trigger, even if their residual moisture content reached up to 60%. After 12 hour storage in water, composite wood samples, namely plywood, particle boards, and MDF boards, had mostly a residual moisture content of over 100% and exhibited in general a false trigger within the first centimeters of cutting distance. The transition zone between these two extremes was marked by two composite wood samples: an approximately 4 cm thick particle board with décor laminate surface and a residual moisture content of 55% was cut without a false trigger, but an MDF board of similar thickness and moisture content caused a false trigger after a cutting distance of only a few centimeters.

3.2 Simulation of a Hazardous Condition with Rotating Saw Blade

3.2.1 Description of Measurements

To conduct a reliability test under realistic operating conditions, a hazardous conditions representative for cutting of wood was simulated. A fresh pig tail served as a finger extension, which was placed on the wood sample, and which was advanced into the cutting area (see Figure 6). For this test, wood sample number 13 (plywood, 5 layers, 7 mm thick) was used, which had been stored dry, and which had a residual moisture content of approximately 6.9%. As an electrical safety precaution, the operator was standing on an isolation pad during the cutting procedure. His hands were however in contact with the grounded table top of the saw.

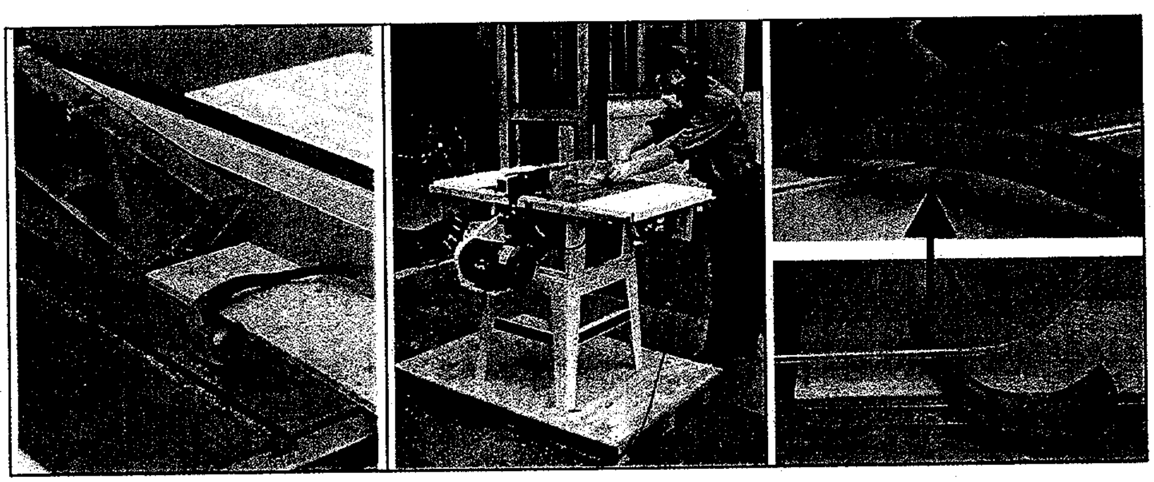


Figure 6 illustrates the simulation of a hazardous condition by the aid of a pig tail. On the left, the placement of the simulated finger with respect to the rotating saw blade is shown. In the middle, the cutting process just before triggering of the safety system can be seen. The two pictures on the right illustrate the subsequent state: the saw blade is retracted and the cut in the pig tail is barely visible.

3.2.2 Test Result

The safety mechanism triggered immediately upon contact with the pig tail, although the first centimeters of wood were cut without a false trigger. The resulting minimal incision was barely visible and less than one millimeter deep. However, it should be noted that the pig tail was held at the edge of the wood sample, and was able to flex backwards slightly.

3.2.3 Interpretation of Test Results

The observation suggests a reliable detection of the hazardous condition. However, this can only serve as an exemplary result, which remains to be tested in a comprehensive study under various operating conditions and under consideration of the exact functionality of the detection circuitry. It is however impressive, that the hazardous condition was recognized immediately at contact, while the false trigger in damp wood samples occurred only after more or less deep incisions.

3.3 Reaction time of the Braking System

3.3.1 Measurement Description

To estimate the reaction time of the braking system, a measurement setup with two inductive proximity switches was built, which allowed for time assessment with a storage oscilloscope.

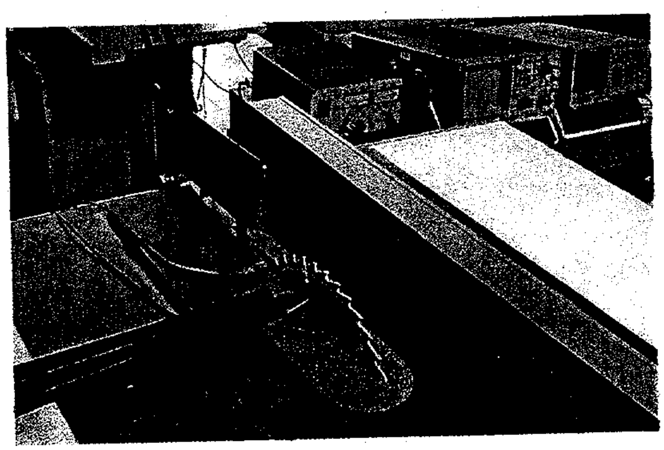


Figure 7 shows the measurement setup to determine the reaction time of the braking system.

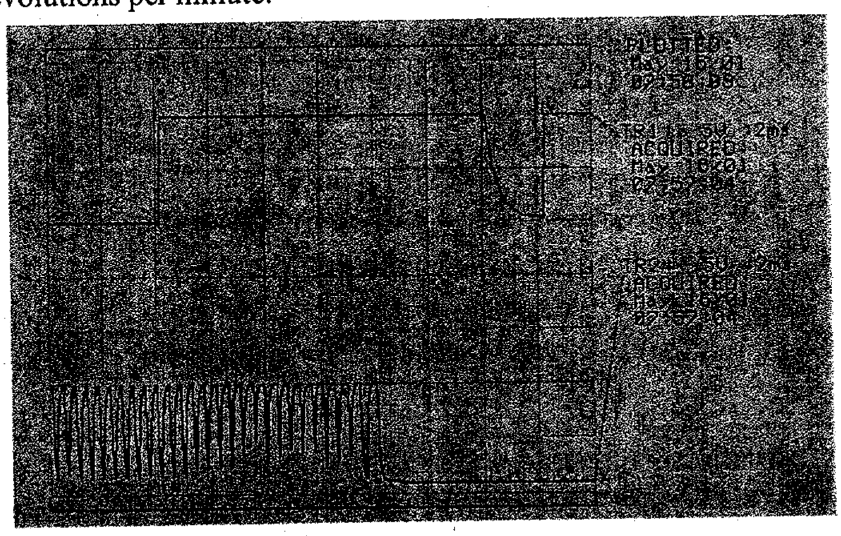
A sensor with metallic enclosure was rapidly advanced toward the side of the metallic saw blade. The sensor was mounted on an extension rod which was metallic and which was in contact with the hand of the operator. Due to this contact, the safety system is triggered at the instant, at which the sensor will contact the saw blade.

Since the inductive proximity switch reacts instantaneously on approximation of metal in the 1 mm detection range by switching its output signal from 0V to approximately 10V, the storage oscilloscope could be triggered with this signal (upper, black line in graph 2). A second proximity switch was mounted on the table top of the saw to monitor rotation. Its output signal indicates the transition of individual cutting teeth of the saw blade. Absence of a regular signal alternation depicts the combined braking and retraction of the saw blade. In either case it indicates the initiation of the hazard averting activity.

3.3.2 Measurement Results

The signals of the proximity sensors captured by the storage oscilloscope are shown in Graph 2. During the initial 4 milliseconds, the unrestrained motion of the saw blade can be seen. During this time frame, approximately nine saw teeth advanced past the revolution sensor. The blade had 60 teeth. The duration of a complete revolution was 40 x 4/9 ms, which corresponds to a motor frequency of approximately 56 Hz or rotation speed of 3375 revolutions per minute.

10 V
(5 V pro Skaleneinheit)



8 ms
(2 ms pro Skaleneinheit)

Graph 2 shows the oscilloscope recording of the reaction time of the braking system. The rising edge of the upper, black line depicts the time point of contact with the saw blade. The lower, blue line shows the transition of cutting teeth of the saw blade along a peripheral point.

The signal of the revolution sensor disappeared about eight milliseconds after triggering of the safety system, while already after 6 to 7 ms a decrease in rotation speed could be observed.

3.3.3 Interpretation of the Measurement Results

The function of the braking mechanism of the system is best assessed in terms of its reaction time. Based on the tests, the duration from the initial contact with the saw blade to the initiation of the hazard preventing motion can be estimated to be approximately 8 milliseconds. Estimating a measurement error of 20 to 50%, a maximal value of 12 ms can be assumed. It furthermore should be noted, that the braking time is dependent on the material of the braking pad and the saw blade, as well as on the number and profile of the cutting teeth.
EN 999 (Safety of Machines – Arrangement of safety equipment under consideration of the approximation velocity of body members) states 2.0 m/s as a guidance value for the maximal, short duration velocity of approximation. Under the assumption of such reflex motion, a reaction time of 12 ms corresponds to 24 mm travel distance. Under these assumptions, the reaction time of the SawStop-System appears to be too slow to ensure an effective protection. Assuming however a typical object feeding speed representative for wood processing, these assumed values can be reduced by approximately a factor of 10. Therefore, for motions that are fixed to the work object, an effective protection can be provided.

4 Summary

The conclusions of the present investigation are naturally confined to the regime representative for pilot studies. Regarding the first key question, if the sensing technology is applicable to a variety of wood samples and sizes, some conclusions can be drawn:

- Dry wood with a residual moisture content of less than 10% was cut in the cutting trials without false triggering, regardless of the wood type and composition. The system seems therefore to operate with high availability for cutting of dry wood.
- For very damp wood samples with over 50% residual moisture content, false triggering occurs depending on the type of wood. Solid wood samples show no complications, while wood composites consistently induced false triggering due to their large capacity for water absorption.

The reliable detection of a hazardous contact with the saw blade in absence of marked limitations on system availability seems to be possible for work on dry and slightly damp wood. Only very damp wood composites cause false triggering and can therefore only be cut after deactivation of the safety system, as is required for example for cutting of aluminum. However, for exact definition of the transition range a comprehensive study under consideration of dynamic effects and a detailed analysis of the detection system is required. As demonstrated in the simulation of a hazardous scenario, false triggering in very damp wood samples may lead to problems with system availability rather than with the reliability of the trigger mechanism in a hazardous situation.
The ability to classify the electronic circuitry with respect to control categories is limited based on the current state of laboratory tests. A series of proven safety principles such as self-tests already have been implemented, but a major portion of the control electronics

remains based on a single channel. Furthermore, the temporary deactivation of the safety system for cutting of metal seems to be insufficiently protected against failure and manipulation.
The results regarding the function of the sensing circuitry as well as the estimated 8 milliseconds reaction time of the system suggest the following applications:

- Wood working machines in moisture-protected indoor environments, in which various wood types with residual moisture contents of up to 25% are used,
- Machines, in which the typical feed rate is limited, for example due to the manner in which the work object is advanced, to not exceed 0.2 m/s,
- Machines with high potential for injuries, in which the achieved safety effect outweighs a potential reduction in system availability.

The evaluation of the SawStop Safety system is positive: reliable detection can be combined with high availability. However, next to the conclusions that it is a promising system, this crude analysis can only provide recommendations for a detailed study: for example, the exact determination of a false trigger threshold depending on the wood type and the residual moisture content, or the detailed testing of the dynamic detection system for potential blind spots. For evaluation of various influencing factors, such as the saw blade type, potential shielding and grounding effects, dirt, nails in wood etc., an exact understanding of the physical function and detection algorithms is mandatory. Also, the electromagnetic compliance in regard to interference susceptibility and interference induction remains to be tested. Meaningful would be the parallel investigation of a production-ready model, which has been advanced from the current laboratory prototype model, during long-term application in one the above mentioned fields. Furthermore, for such a model a classification of the system with respect to control categories will be possible.

i. A. Sachbearbeiter

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Dr. M. Schaeter Dipl.-Phys. M. Hauke

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I join in the preceding petition under 5 U.S.C. §553(e) and 15 U.S.C. §2058(i) to initiate rulemaking for table saws.

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Name: BRUCE ALAN EMMONS

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77.	DUSEL, Peter W.	119 Lake Road Ontario, NY 14519 585-231-8484	
78.	EBERT, Richard J.	3923 Murry Hill Court Murrysville, PA 15668 724-733-4757	
79.	EMMONS, Bruce A.	13409 Woody Point Road Charlotte, NC 28278 704-583-2551	
80.	ENGMAN, Douglas H.	5821 Newton Ave., S. Minneapolis, MN 55419 612-922-1593	
81.	EPSTEIN, Judy	3303 Dato Highland Park, IL 60035 847-432-4973	
82.	FALLON, David C.	6330 185th St. SW Lynnwood, WA 98036 425-774-5198	
83.	FANNING, David A.	4020 N.E. 171st Avenue Vancouver, WA 98682 360-944-7204	
84.	FERNANDEZ-VERAUD, Alesandro	1223 Dickinson Dr., Bldg. 48-E Coral Gables, FL 33146 305-284-5904	
85.	FEYLER, Richard	74 Summer Street Stoughton, MA 02072 781-341-1889	

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	Name	Address & Phone Number	Notes
86.	FILBRUN, Richard R.	280 Brubaker Drive New Carlisle, OH 45344 937-845-0211	
87.	FISHER, Adam D.	11 Media Lane Stoney Brook, NY 11790 631-751-6606	
88.	FOLEY, Jeffrey D.	10 Beech Street Barre, VT 05641 802-479-9797	
89.	FORD, Joseph D., Jr.	49 Warbler Lane W. Yarmouth, MA 02673 508-398-3544	
90.	FOSLIEN, Patrick	12500 18th Avenue N. Plymouth, MN 55441 612-644-1005	
91.	FOURNIER, Karl, M.D.	2400 Patterson St., Ste. 300 Nashville, TN 37203 615-342-6300	
92.	FRANCIS, William	P.O. Box 305 Stowe, VT 05672	Signature is on the page with Ralph Waddell.
93.	FRANTZ, Gary,M.D.	541 Edgewood Road Mansfield, OH 44907 419-756-3117	
94.	FREDKOVE, Joe	12020 Mayflower Circle Minnetonka, MN 55305 952-544-2785	
95.	FULMER, James David	19930 S.W. 59th Terrace Tualatin, OR 97062 503-885-1040	
96.	FUSSELL, Del D.	11455 N. Antelope Lane Parker, CO 80138 303-805-2663	
97.	GAMMAN, Steve	2318 N. 38th Street Seattle, WA 98103 206-547-1286	
98.	GANJE, Josh	1101 3rd Street SW Clear Lake, WI 54005 715-263-2113	

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	Name	Address & Phone Number	Notes
99.	GANS, Shannon	6650 Vista del Mar #2 Playa del Rey, CA 90293 310-823-2050	
100.	GASS, Stephen F.	22409 S.W. Newland Road Wilsonville, OR 97070 503-638-6102	
101.	GOCHOEL, Susan	5107 N. 39 Street Tacoma,WA 98407 206-498-4167	
102.	GOCHOEL, Brian C.	5107 N. 39 Street Tacoma, WA 98407 206-498-4167	
103.	GODBOUT, Ronald E.	2 Woodlawn Avenue Northfield, NH 03276 603-286-7741	
104.	GOLDEN, Daniel T.	641 Hillwood Court St. Paul, MN 55119 651-721-1519	
105.	GOLDSTEIN, Albert	3666 Middleton Drive Ann Arbor, MI 48105 734-662-4780	
106.	GOTTGFEB, Larry	160 Cooper Road West Berlin, NJ 08091 856-768-9600	
107.	GOUGH, Kerry M.	6212 Auburn Avenue Oakland, CA 94607 510-832-5800	
108.	GOUGH, Matthew	649 Canyon Drive Auburn, CA 95603 530-823-6024	
109.	GRANITZKI, Jeff	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
110.	GRANITZKI, Jesse	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
111.	GRATZNER, Matthew	4107 Redwood Avenue Los Angeles, CA 90066 310-578-9929	

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	Name	Address & Phone Number	Notes
112.	GREENWALD, Jessica	3835 S.W. 58th Court Miami, FL 33155 305-667-2418	
113.	GRETILLAT, Lon	14 Quarry Road Mason City, IA 50401 641-422-9962	
114.	GRIECO, Patrick	27 Niagara Street Toronto, ON M5V 1C2 Canada 416-979-8162	
115.	GROENKE, Kevin	89 Church Street S.E. 139 Rapson Hall Minneapolis, MN 55455 612-624-9093	
116.	GROW, Sara	8550 Evanston Ave. N. Seattle, WA 98103 206-320-5237	
117.	GUNTER, Peter	1625 Morris Avenue S. Benton, WA 98055 206-779-5917	
118.	HADACEK, Matthew W.	13281 Elizabeth Street Thornton, CO 80241 303-280-4683	
119.	HALES, Sherman R.	P.O. Box 1118 Magalia, CA 95954 530-873-0579	
120.	HALL, Tim	11912 Spring Drive St. Louis, MO 63131 314-997-2901	
121.	HALL, Amy K.	7407 W. Manchester Ave. #8 Los Angeles, CA 90045 310-410-9407	
122.	HANEY, Harry	1945 Wallinford Circle Sun Prairie, WI 53590 608-834-1057	
123.	HANSEN, Todd	5 Michael Blvd. #9 Whitby, ON L1N 5P4 Canada 905-430-7529	

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	Name	Address & Phone Number	Notes
124.	HARDS, Margaret M.	50 North Medical Drive Salt Lake City, UT 84132 801-581-2137	
125.	HARDY, Sarkis	2703 S. 10th Avenue Arcadia, CA 91006 626-447-9811	
126.	HARGER, Penelope	3047 12th Avenue W. Seattle, WA 98119 206-284-9236	
127.	HARRELSON, Susan M., Esq.	4220 Donovan Way North Las Vegas, NV 89030 702-642-7548	
128.	HASELBERGER, G. S.	9155 N.E. 21st Place Bellevue, WA 98004 425-246-6067	
129.	HASH, Jefforey	2551 Mt. View Road Vinton, VA 24179 540-767-2490, ext. 31	
130.	HAYDEN, Vicki	1404 Rack Street Cambridge, MD 21613 410-221-2300	
131.	HAYES, Bill	9731 Rougeview Drive Santa Ana, CA 92705 714-744-9416	
132.	HAYNES, Jennifer L.	7407 W. Manchester Ave. #8 Los Angeles, CA 90045 310-410-9407	
133.	HAYWARD, Kent	3920 Marathon Street #9 Los Angeles, CA 90029 323-665-4519	
134.	HENRY, Jackie	7525 32nd Avenue NW Seattle, WA 98117 206-320-8085	
135.	HEWITT, Thomas W.	343 Asilomar Pacific Grove, CA 93950 831-646-0246	
136.	HIX, James R.	2551 Mountain View Road Vinton, VA 24179 540-767-2490, ext. 28	

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	Name	Address & Phone Number	Notes
137.	HOFER, Richard E.	1941 Greenview Road Montoursville, PA 17754 570-433-0601	
138.	HOHN, Michael	8306 SW 181st Avenue Beaverton, OR 97007 503-848-8806	
139.	HOULE, Roger	34 Oxford Street W. Moose Jaw, SK S6H 2N1 Canada 306-694-0654	
140.	HOWELL, Ken	17501 S.E. 16th Circle Vancouver, WA 98683 360-892-7461	
141.	HUEBNER, Randall	18000 S.W. Bany Road Beaverton, OR 97007 503-591-5169	
142.	HUISINGA, R. E.	17425 N. 16th Dr. Phoenix, AZ 85023 602-452-4439	
143.	HULTGREN, Gregory D.	202 Ridgewood Avenue Minneapolis, MN 55403 612-870-9924	
144.	HUNTER, Ian	4107 Redwood Avenue Los Angeles, CA 90066 310-578-9929	
145.	HYSON, Donald E.	601 S. Church Street Winnebago, IL 61088 815-335-2966	
146.	IRVINE, Mark	5975 Sarah Orr Lane Cumming, GA 30040 678-566-0600 ext. 446	
147.	ISHAM, Timothy W.	151 Moore Street Bailey, CO 80421 303-816-2164	
148.	JACOBSEN, Kirk L.	990 N. Phoenix Road Medford, OR 97502 541-857-4226	

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	Name	Address & Phone Number	Notes
149.	JACOBSEN, Andrew	3420 Skillman Lane Petaluma, CA 94952 707-765-9385	
150.	JOCIUS, James M.	1005 Hiawatha Drive Elgin, IL 60120 847-741-5954	
151.	JONES, Jeffrey B.	603 S.E. 6th Street Battle Ground, WA 98604 360-723-5142	
152.	KALRA, Camellia	5905 Washburn Avenue S. Minneapolis, MN 55410 952-920-8252	
153.	KAPLAN, F. Thomas	7203 N. Charles St. Lutherville, MD 21093 410-825-3265	
154.	KASDAN, Morton, M.D.	P.O. Box 6048 Louisville, KY 40206 502-897-1601	
155.	KEATON, Alan L., M.D.	218 Rainbow Drive Livingston, TX 77399 541-953-3751	Submitted individual comments.
156.	KEESLING, Brooke	4107 Redwood Avenue Los Angeles, CA 90066 310-578-9929	
157.	KELLEY, William C.	606 20th Street East Tifton, GA 31794 229-382-2857	
158.	KELLIHER, Steve	4664 Baxter Road Cottage Grove, WI 53527 608-846-3010	
159.	KELLY, Michael	Swedish Hospital Providence Campus 500 - 17th Avenue Seattle, WA 98124 206-320-2404	
160.	KING, James T., J.D.	813 Patterson Avenue Glendale, CA 91202 818-242-1100	

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	Name	Address & Phone Number	Notes
161.	KJOME, Eric B.	492 Montrose Ave. Elmhurst, IL 60126 630-833-5153	
162.	KLUGE, Steven C.	29 Long Creek Drive Burnt Hills, NY 12027 518-399-0758	
163.	KLUGE, Tamara	29 Long Creek Drive Burnt Hills, NY 12027 518-385-9755	
164.	KNAPP, Terry S.	1299 N. Orchard, Ste. 110 Boise, ID 83706 208-336-0801	Submitted individual comments.
165.	KNEBEL, Kyle C.	1107 S. Burnside Avenue Los Angeles, CA 90019 323-936-1037	
166.	KNEBEL, William E.	32108 Beachmeadow Lane Westlake Village, CA 91361 818-889-8010	
167.	KURSTEN, Henri	4410 Budd Road Lockport, NY 14094 716-434-0994	
168.	KWAK, Anita L.	2329 Halbeck SW Seattle, WA 98116 206-937-1791	Submitted individual comments.
169.	LAFFERTY, William B., Esq.	512 Lakeshore Drive Atlanta, GA 30307 404-378-7253	
170.	LANDGRAF, Donald R.	409 Hillcrest Drive Waterloo, IL 62298 618-939-7714	
171.	LANGILLE, Aletta	15 Douglas Court W. Brooks, AB T1R 0B6 Canada 403-362-4007	
172.	LARU, Kevin S.	720 Cleveland Avenue Racine, WI 53405	
173.	LaRUE, David R.	7609 Baimbridge Downers Grove, IL 60516 630-810-9543	

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	Name	Address & Phone Number	Notes
174.	LAU, Shirley	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9139	From UL Int'l Ltd.
175.	LAURO, Paul M.	259 Anzio Rd., #B Ft. Lee, VA 23801 804-734-0075	Submitted individual comments.
176.	LEACH, Robert S.	1551 Irene Street Bethlehem, PA 18017 610-758-3288	
177.	LeFEVRE, Brian	12149 E. Exposition Drive Aurora, CO 80012 303-344-3903	
178.	LEIDIG, Peter, P.T.	22310 34th Place W. Brier, WA 98036 206-320-3273	
179.	LEONARD, Lawrence M., M.D.	26 Amerescoggin Road Falmouth, ME 04105 207-781-2426	
180.	LIDDLE, Curtis B.	51 Jordan Road Plymouth, MA 02360 508-747-0109	
181.	LIN, Jacky	No. 78, Yuang Feng Road Taiping, Taichung Taiwan, ROC 886-4-22700258	
182.	LINDSTROM, Mark	305 Sunnyvale Lane Minnetonka, MN 55305 612-359-1341	
183.	LITWIN, Ralph	72 Dean Road Mendham, NJ 07945 973-543-9779	
184.	LLOYD, Michael D.	4226 Pillsbury Avenue S. Minneapolis, MN 55409 612-822-6308	
185.	LOCKWOOD, C.K.	10508 N.E. 36th Avenue Vancouver, WA 98686 360-546-3329	

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	Name	Address & Phone Number	Notes
186.	LOVE, Carl	11170 S.W. Fairfield Street Beaverton, OR 97005 503-671-9461	
187.	LUDKE, Harry	4721 Bennett Road Cuyler, NY 13158 607-842-6781	
188.	LUDWIG, Robert	9 Rose Lane Chappaqua, NY 10514 914-666-6692	
189.	MACHER, Robert J.	777 River Hills Drive Fenton, MO 63026 314-968-3222	
190.	MacINTOSH, Randy	50 Riverstar Circle Sacramento, CA 95831 916-427-2556	
191.	MAN, Fung Wing	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9589	From UL Int'l Ltd.
192.	MANCINELLI, Troy	427 River Isle Court Longwood, FL 32779 407-786-4938	
193.	MANSHIP, James L.	9029 Jeffery Avenue South Cottage Grove, MN 55016 651-458-3241	
194.	MARENICK, Robert M.	912 Gristmill Drive Rock Hill, SC 29732 803-366-8727	
195.	MAROTTA, David	1562 Rugby Circle Thousand Oaks, CA 91360 805-374-2052	
196.	MARSELLOS, Richard E.	5173 Ute Road, Box 411 Indian Hills, CO 80454 303-697-5894	
197.	MARTI, M. Felix	66 Bluestem Ridgway, CO 81432 970-626-4169	

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	Name	Address & Phone Number	Notes
198.	MASTERS, Celeste	7600 W. Manchester Playa del Rey, CA 90293 310-827-8518	
199.	McADAMS, Richard S.	8550 Evanston Ave. N. Seattle, WA 98103 206-320-5237	
200.	McCANDLESS, Stuart C.	5 Cozy Hollow Road Danbury, CT 06811 203-791-3500	
201.	McCORMICK, Kathy	2318 N. 38th Seattle, WA 98103 206-547-1286	
202.	McDADE, Thomas W., Jr.	6925 S.E. 34th Street Mercer Island, WA 98040 206-232-0249	
203.	McDANIEL, Patricia A.	3723 Highway One Rehoboth Beach, DE 19971 302-227-5754	
204.	McGOEY, Vince	660 Corrigan Crescent Peterborough, ON Canada 705-743-3982	
205.	MERRIMAN, Paul	2432 St. Croix Circle Marietta, GA 30062 770-518-4702	Submitted individual comments.
206.	MERRITT, Kip	4020 N. 85th Street Scottsdale, AZ 85251 480-990-2290	
207.	MILLER, Bob	5180 Commerce Dr., Ste. X Murray, UT 84107 801-262-8888	
208.	MILLER, Corwyn	108 Parkland Way Brooks, AB T1R 0M4 Canada 403-362-4558	
209.	MILLER, Eric W.	280 Brubaker Drive New Carlisle, OH 45344 937-845-0211	

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	Name	Address & Phone Number	Notes
210.	MILLER, Melissa	801 Pine Street Seattle, WA 98101 206-284-5527	
211.	MILLER, Ronald L.	95-1025 Hakala Street Mililani, HI 96789 808-626-2590	
212.	MINNEY, Kurtis C.	2002 Crestmont Street Norman, OK 73069 405-366-7562	
213.	MIYANO, John	9701 44th Avenue NE Seattle, WA 98115 206-985-8439	
214.	MOFFETT, Scott	111 S. 13th Street Nashville, TN 37206 615-226-8182	
215.	MOLEDOR, John	2684 Shaffer Road Atwater, OH 44201 330-628-9626	
216.	MONTGOMERY, Matt	2020 Fox Hunt Drive Troy, VA 22974 434-296-5097	
217.	MORETZ, Sarah	514 Ebenezer Avenue Rock Hill, SC 29730 803-417-0595	
218.	MORGAN, Chris H.	1102 Ellard Drive Hickory Creek, TX 76210 972-977-8705	
219.	MORRIS, Chad	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
220.	MOSKAU, Mike	920 Loveland Street Golden, CO 80401 303-279-0294	
221.	MOTA, Raymond N.	3026 Patricia Court Santa Maria, CA 93455 805-938-3185	
222.	MUNRO, Alick	1330 Delese Circle Reno, NV 89511 775-851-1518	

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	Name	Address & Phone Number	Notes
223.	NABORS, Jane	13109 NE Vinemaple Road Brush Prairie, WA 98606 360-892-1614	
224.	NANCOLLAS, Michael, M.D.	475 Irving Avenue, Suite 418 Syracuse, NY 13210 315-426-0190	
225.	NELSON, Timothy M.	1306 Meadows Lane Greenwood, MO 64034 816-537-8891	
226.	NEWLAND, Doug	P.O. Box 753 Northfield, MN 55057 612-298-3068	
227.	NEWMAN, Donald W.	7200 Treeridge Drive Cincinnati, OH 45244 573-231-7922	
228.	NIEBERGALL, John	24033 S.W. Cascara Terrace Sherwood, OR 97140 503-625-4107	
229.	NIELSON, Charlie	557 E. 3200 N. North Ogden, UT 84414 801-782-1892	
230.	NORMAN, Doris	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
231.	NOVOTNY, James A.	Livingston High School Livingston, NJ 07039 973-535-8000	
232.	NYSTUEN, Leslie, M.D., MSPH	234 Concord Avenue #1 Cambridge, MA 02138 617-492-8567	
233.	OBERMEYER, Thomas	1501 Hennepin Avenue Minneapolis, MN 55403 612-359-1523	
234.	ODOM, William R.	700 Iowa Avenue Whitefish, MT 59937 406-863-4890	

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	Name	Address & Phone Number	Notes
235.	OKERSTRÖM, John E.	15 Allan Dale Court Werribee, Victoria 3030 Australia 03-9741-2038	
236.	OLSON, Elder J.	103 Blasingame Street St. Simons Island, GA 31522 912-638-2731	
237.	OVARD, David	615 E. Whitehall Meridian, ID 83642 208-363-1583	
238.	OVERSTREET, William H.	not given	
239.	PAPE, James G.	4 Duchess Avenue S. Burlington, VT 05403 802-651-7021	
240.	PARKER, John C.	908 Highland Ave., Ste. #1 Kenai, AK 99611 907-283-3007	
241.	PATTON, George	205 Creek Drive Glassboro, NJ 08028 856-256-1663	
242.	PEFFER, Bryan	15836 Hyland Pointe Court Apple Valley, MN 55124 952-953-4719	
243.	PERCY, Ty	6604 N.E. 163rd Avenue Vancouver, WA 98682 360-883-0516	
244.	PIERCE, Thomas H.	39 Laurelwood Lawrenceville, NJ 08648 609-896-8106	
245.	PLUMMER, Jeanne	49745 N.W. Schmidlin Lane Buxton, OR 97109 503-324-7586	
246.	PORTER, Bill	2117 N.E. Kim Lane Bend, OR 97701 541-388-3892	Submitted individual comments.
247.	POTTER, Robert P.	1324 So. Vermont Avenue Davenport, IA 52802 563-323-0382	

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	Name	Address & Phone Number	Notes
248.	POTTS, David W.	7819 S.E. 105th Avenue Portland, OR 97266 503-520-7005	
249.	POULIN, Earl	3924 Terrace Street Kansas City, MO 64111 816-753-4121	
250.	POWELL, Benjamin O.	1128 Barstow Avenue #6 Clovis, CA 93612 559-324-7179	
251.	POWERS, Roger N.	926 Trevino Road Southport, NC 28461 910-845-2178	
252.	PRICE, Robert O.	2192 Shady Run Road Vinton, VA 24179 540-890-6887	
253.	PURDUE, Patrick	14284 Neptune Road Seminole, FL 33776 727-517-9112	
254.	QUINN, John	4635 Bridle Trail Santa Rosa, CA 95409 707-537-8691	
255.	RAMIREZ, Ricardo A.	1705 Corpus Christi Street Laredo, TX 78040 956-726-4817	
256.	RAY, Larry A.	1409 North Fifth Street Red Oak, IA 51566 712-623-4086	
257.	REBER, Cheryl	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
258.	REED, Gerald, Dr.	10 Crescent Drive Glencoe, IL 60022 847-835-7053	
259.	REED, John	24700 McBean Parkway Valencia, CA 91355 661-255-1050	

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	Name	Address & Phone Number	Notes
260.	REGEHR, Ralph	867 McLeod Avenue Winnipeg, MB R2G 0Y4 Canada 204-668-0079	
261.	REYNOLDS, Joseph	99 Grow Avenue Montrose, PA 18801 570-278-1179	
262.	REYNOLDS, William E.	412 Englewood Drive Lufkin, TX 75901 936-639-9725	Submitted individual comments.
263.	RICHMAN, Jonathan, M.D.	1 Atwell Road Cooperstown, NY 13326 607-547-3468	Submitted individual comments.
264.	RICHTER, Christel	330 Oak Grove St., #M15 Minneapolis, MN 55403 612-813-0632	
265.	RIVERS, Richard "Brent"	2325 Woodcrest Drive Smyrna, GA 30082 770-805-0733	
266.	ROBB, Jill A.	P.O. Box 675550 15563 La Madreselva Rancho Santa Fe, CA 92067 858-756-2078	
267.	ROBERTS, Simeon B., Jr.	7015 Brooklyn Blvd. Brooklyn Park #306 Minneapolis, MN 55429 763-503-4702	
268.	ROIRDON, Ray	Box 9726 Seattle, WA 98109 206-284-5527	
269.	ROLAND, William A.	3627 Leeville Road Mt. Juliet, TN 37122 615-449-6646	
270.	RÖSELER, Kurt	64560 Highway 30 Deer Island, OR 97054 503-366-1472	
271.	ROSEN, Paul	226 N. Rouse Street Mundelein, IL 60060 847-566-2805	

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	Name	Address & Phone Number	Notes
272.	ROSENBERGER, Jack B.	2286 Encino Loop San Antonio, TX 78259 210-337-1234	
273.	ROSENTHAL, Andrew H.	1500 E. Medical Center Dr. 2130 Taubaum Ann Arbor, MI 48109 734-936-5895	
274.	ROYER, Christopher	8245 Carriage Oaks Way Antelope, CA 95843 916-729-1325	
275.	SCARIN, William J.	401 Washington Blvd. #10 Mundelein, IL 60060 847-566-6979	
276.	SCHNEIDER, Scott	22045 Del Valle Street Woodland Hills, CA 91364 818-999-9017	
277.	SCHUEFER, Casey	3055 Remington Drive West Linn, OR 97068 503-723-5004	
278.	SEVERANCE, Richard	12147 Parade Avenue N. Stillwater, MN 55082 651-733-6875	
279.	SHAW, Gloria E.	182 E. Walnut Avenue Realto, CA 92376 909-820-7700	
280.	SHAW, John R.	241 Rifle Range Road Sparta, NC 28675 336-372-8001	
281.	SIMPSON, Wendy	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
282.	SINCLAIR, David	11705 N.W. 26th Avenue Vancouver, WA 98685 360-576-6323	
283.	SINK, Pak Hiu	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9514	From UL Int'l Ltd.

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	Name	Address & Phone Number	Notes
284.	SKLIVAS, Howard	600 Denbury Avenue Ottawa, ON K2A 2P1 Canada 613-722-2724	
285.	SLAUGHTER, Robert G.	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
286.	SLOAN, Scott	519 West 36th Street New York, NY 10018 212-279-0790	
287.	SMITH, Donald L.	809 Spring St. NE, Apt. 406 Minneapolis, MN 55413 612-789-5135	
288.	SMITH, James F., COHN-S, CSP, CPEA	P.O. Box 5108, MS12-04 Denver, CO 80217 303-978-3324	
289.	SMITH, Tommi K.	Tennessee State University 3500 John Merritt Blvd. Nashville, TN 37209 615-963-5683	
290.	SNEDEKER, Orland D.	P.O. Box 92 Bunker Hill, IL 62014 618-585-4466	
291.	SNYDER, Thomas	9573 Cedar Mist Cove West Cordara, TN 38016 901-382-0874	
292.	SOPCHAK, Andrew M.	5003 Derringer Drive Jamesville, NY 13078 315-469-5752	
293.	SPENCER, Michael J.	179 Pine Hill Crive West Berlin, VT 05663 802-485-6442	
294.	STEIDER, Donald L.	60427 CR 21 Goshen, IN 46528 574-534-6276	
295.	STEINGRAEBER, John J.	1085 Hague Avenue St. Paul, MN 55104 651-645-2968	

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	Name	Address & Phone Number	Notes
296.	STEPHENS, Ramona K.	11564 Steeldust Court Rathdrum, ID 83858 208-773-7807	
297.	STEPHENSON, David R.	248 Remps Road Libby, MT 59923 406-293-9772	
298.	STRAIN, Kirk L.	2959 Walden Road Fayetteville, NC 28303 910-822-5277	
299.	STRZEMBOSZ, Andre, M.D.	P.O. Box 270207 St. Louis, MO 63127 314-945-1059	
300.	SUNDBY, Ray	195 W. Elm St. Louisville, CO 80027 303-666-6840	
301.	SUTTON, Bret J.	3005 S. College Street Seattle, WA 98144 206-723-9044	
302.	SVEHLA, Michael R., Jr.	9222 Virginia Court Orland Park, IL 60462 708-757-5200	
303.	SWARTZ, Timothy H.	P.O. Box 491 Northfield Falls, VT 05664 802-485-4760	Signature is on the page with Thomas W. Yacawyen.
304.	SWIERCZ, John R.	742 Cobb Avenue Placentia, CA 92870 714-572-9504	
305.	SWINTON, Stephen F., Sr.	15 Horton Drive Watervliet, NY 12189 518-271-8355	
306.	TATMAN, Craig A.	5957 Lyndale Avenue N. Brooklyn Center, MN 55430 763-560-6396	
307.	TEDESCO, Allen	202 Park Road Parsippany, NJ 07054 201-513-3234	
308.	TETZLAFF, James	3448 N. Narragansett Chicago, IL 60634 847-295-4664	

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	Name	Address & Phone Number	Notes
309.	THIELING, Stan	129 Firecrest Drive Brandon, MS 39042 601-825-8723	
310.	TIBBETTS, Gary	106 Jimney Drive Westford, MA 01866 978-692-1950	
311.	TONG, Marco	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9146	From UL Int'l Ltd.
312.	TONJUM, Randy	1517 11th Avenue Minneapolis, MN 55404 612-343-7084	
313.	TOUHY, James E.	911 Cedarcrest Drive Schaumburg, IL 60193 847-895-0401	
314.	TRAFTON, Tom	1942 Kirkland Avenue San Jose, CA 95125 408-279-8905	
315.	TRAVERS, Kevin	10 North Niantic Road Charlestown, RI 02813 401-364-0427	
316.	TUKROOK, Juanita	1910 11th Avenue S. Minneapolis, MN 55404 651-637-1284	
317.	TUMA, Jeanne M.	4240 Fulton Avenue #311 Studio City, CA 91604 818-981-8862	
318.	UFFER, Philip	724 Milford Mill Road Pikesville, MD 21208 410-602-1762	
319.	URQUHART, James R.	104 Village Common Fishkill, NY 12524 845-896-9683	
320.	VAILLANCOURT, Brian	58 Juniper Drive Goffstown, NH 03045	

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	Name	Address & Phone Number	Notes
321.	VAN ZEE, Pieter J.	1149 N.W. Alder Creek Corvallis, OR 97330 541-715-8658	
322.	VAN DERWERKEN, Joseph B., Sr.	19 Brenda Drive Hudson Falls, NY 12839 518-747-7816	
323.	VISAGE, Robert Melvin	410 Virginia Avenue Baltimore, MD 21221	
324.	VIVIANI, John L., II	13151 Pavilion Lane Fairfax, VA 22033 703-817-0575	
325.	WADDELL, Ralph	7 Highland Ave Randolph, VT 05060	
326.	WAGNER, Karl	719 Dove Path Lane Colonial Heights, VA 23834	
327.	WALKER, Brett	50 North Medical Drive Salt Lake City, UT 84132 801-585-2677	
328.	WALL, John	706 Garvey Hill Northfield, VT 05663 802-485-9871	Signature is on the page with Jeffrey D. Foley.
329.	WALLACE, Robert	735 Fairview Ave., SE Salem, OR 97302 503-364-8361	
330.	WALTZ, Samantha Ducloux	37 Walking Woods Drive Lake Oswego, OR 97035 503-699-3377	
331.	WARD, Nelson	2530 Blaisdal Ave., Apt. 302 Minneapolis, MN 55404 612-870-4767	
332.	WEINBERG, Larry	53 Campus Club Drive Cuilderland, NY 12084 518-869-1680	
333.	WERNER, Kent R.	258 Country Way Scituate, MA 02066 781-545-0114	
334.	WHEAT, Annie-Laurie	220 Driftwood Lane Rock Hill, SC 29732 803-323-2397	

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	Name	Address & Phone Number	Notes
335.	WHITE, James F.	188 Timmons Road Chapin, SC 29036 803-732-6751	
336.	WHITE, Jared	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
337.	WHITE, Lonny	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
338.	WHITE, Sanford	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
339.	WHITE, Vicki	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
340.	WIERS, Eric E.	507 Pumpkin Hill Road Ledyard, CT 06339 860-572-8608	
341.	WILCOX, Robin	7426 Keen Way N Seattle, WA 98103 206-525-9583	
342.	WIND, Ted, Jr.	1827 Fillmore Avenue, NE Minneapolis, MN 55418 612-722-0952	
343.	WINSON, Si B.	311 Pointer Pl. Arlington, TX 76002 817-466-4085	
344.	WRIGHT, David S.	49 Laurel Ridge Greenville, SC 29609 864-246-4066	
345.	WRIGHT, Warren	4264 Mountain Drive San Bernardino, CA 92407	
346.	YACAWYEN, Thomas W.	1170 Rte. 12 South Northfield, VT 05663 802-485-4206	
347.	YEGHIAYAN, Arra	Lincoln Hill Windham, NH 03087 617-687-0511	

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	Name	Address & Phone Number	Notes
348.	ZAHURAK, John K.	4337 S. Pinerest Way Boise, ID 83716 208-426-9073	
349.	ZAWISLAK, John	1088 Tradition Club Drive Pawley's Island, SC 29585 843-421-6143	