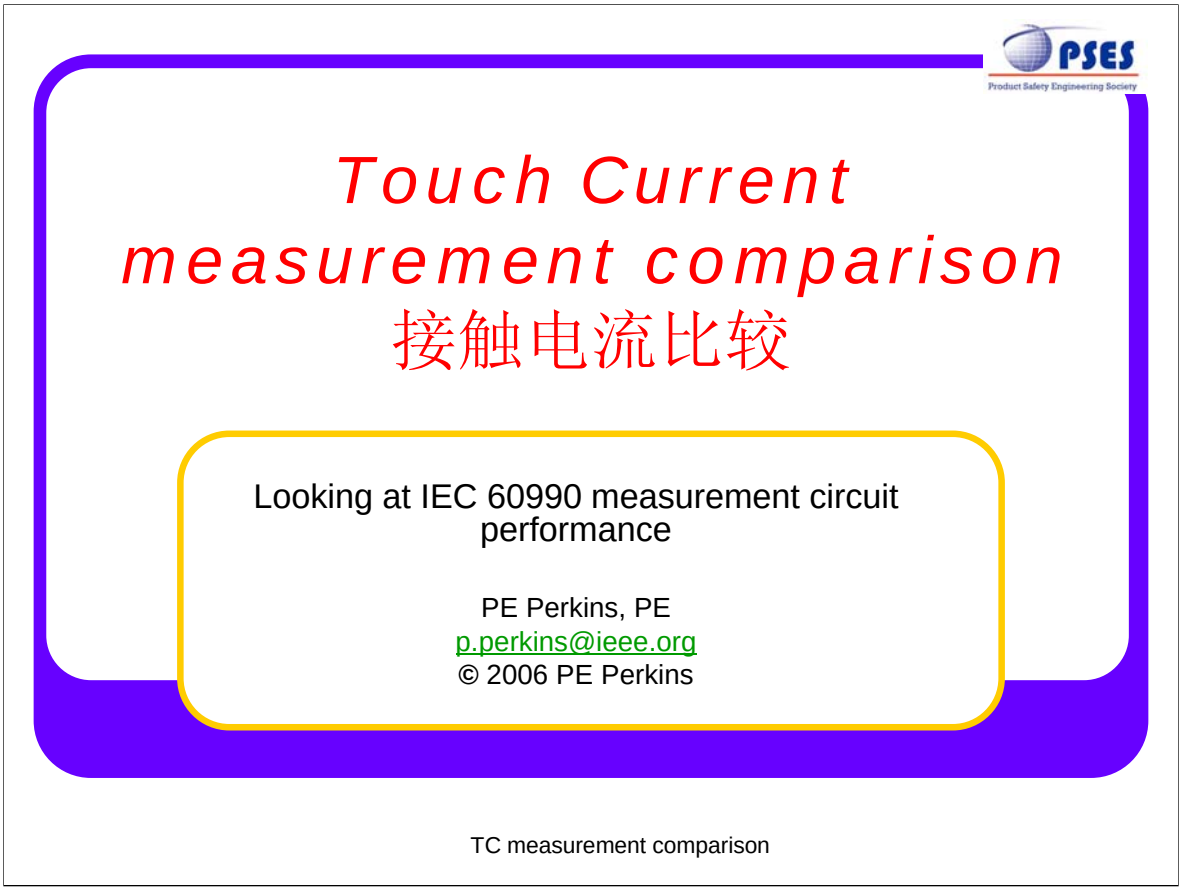


Touch Current measurement comparison

Looking at IEC 60990 measurement circuit performance

Abstract:摘要

This paper will examine in some detail the performance of the IEC 60990 circuits considering specific conditions or waveforms.

本文对IEC60990中电流的具体波形和状态进行详细的检查

Conditions of electric burn (eBurn) plus Touch Current response by these circuits will be shown.

同时讨论接触电流导致的电灼伤

The examples are intended to show a range of waveforms and their calculated response.

并举例说明波形的范围和计算方法

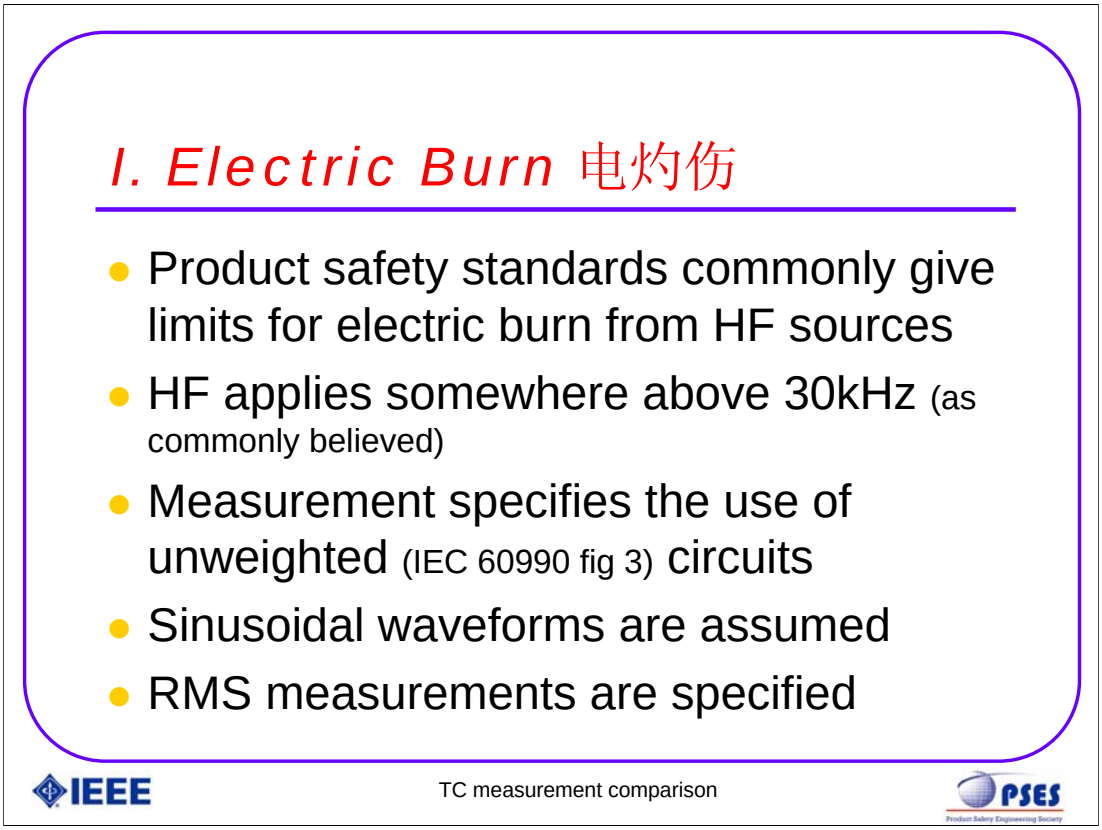
The discussion is divided into two parts. Electric burn (eBurn) then Touch Current comparisons across the two circuits – startle-reaction circuit and let-go circuit.

讨论分两部分：电灼伤，对通过受惊跳电流和释放电流的接触电流的比较

These results will be compared to a TC waveform to show a comparison to modern electronic equipment.

将对现代电子设备的接触电流的波形进行比较

This paper continues to confirm the need for peak measurements for TC waveforms from electronic equipment.

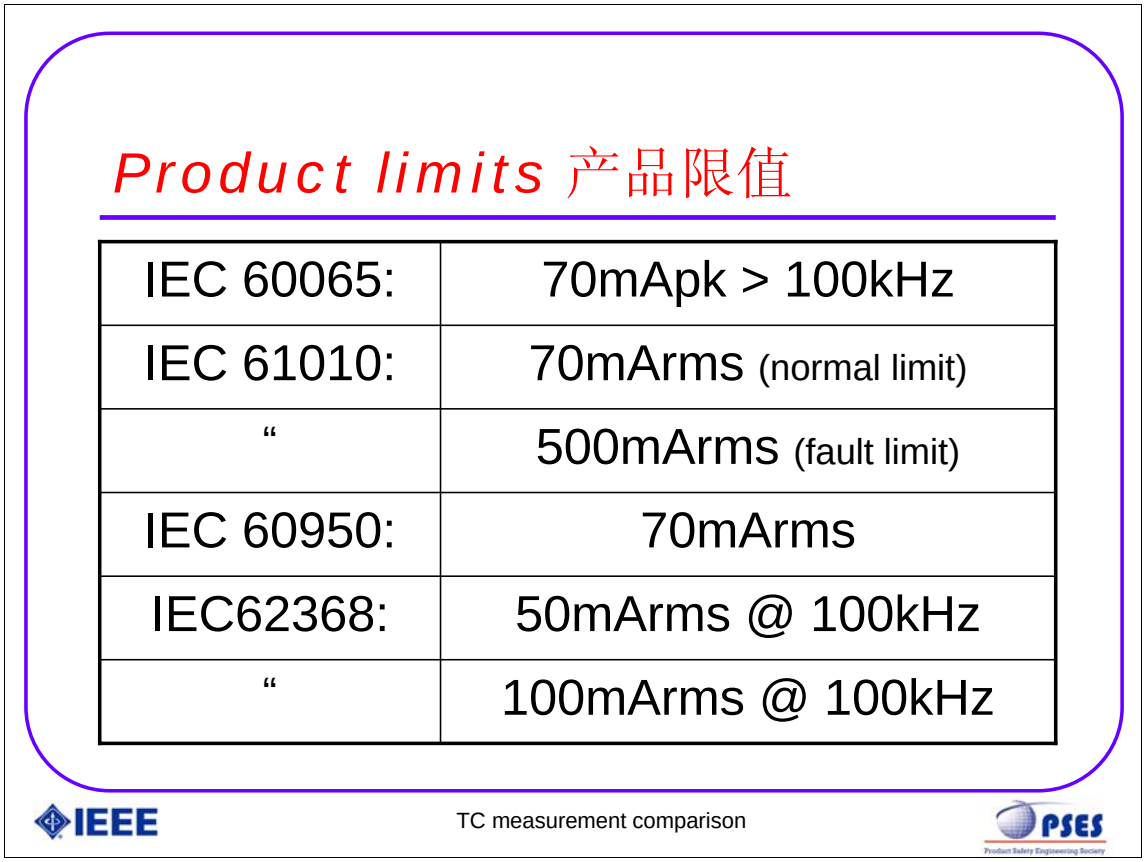


The purpose of a eBurn specification is to limit the burn to a person touching such a circuit.

电灼伤释义的目的是限制像接触电流产生的对人体的伤害

Earlier workers have been concerned with contact with HF circuits – wires, screwheads or connectors – which would primarily be finger contacts. Contact with wires – either end-on (wire diameter) or along the wire (very narrow width by 3 to 10 mm long) – is a very small area. Larger finger contacts in the range of 3mm to 10mm across seem to be the right order of magnitude. For a circle or a square contact this area is in the range of 7 to 100 mm^2; more generally this is on the order of 10's of mm^2.

A small black burn spot from a quick contact with a small wire diameter is very acceptable; a narrow line burn seems similarly acceptable. Larger burns, e.g. from a screw connector or the like, is more of a problem. Even larger area contact & burn can be available on a circuit board. A dinner plate sized reddened area eBurn doesn't seem acceptable. Large carbonized areas are not acceptable



Product Limits:产品限值

IEC 60065 specifies 70mApk AC using the unweighted TC measuring network. This applies to frequencies above 100kHz.

IEC60065中定义了在未加权的接触电流测试网络中，100kHz以上峰值为70mApk AC

IEC 61010 specifies 70mArms normal limit and 500mArms fault limit which relates to possibles burns at higher frequency.

IEC61010中描述了70mA（有效值）正常限值和500mA（有效值）的故障限值，该限值将有可能在较高的频率时产生灼伤

IEC 60950 specifies for LCC: 0.7mApk < 1kHz; 0.7*freq(kHz) ≤ 70ma (cl 2.4.2).

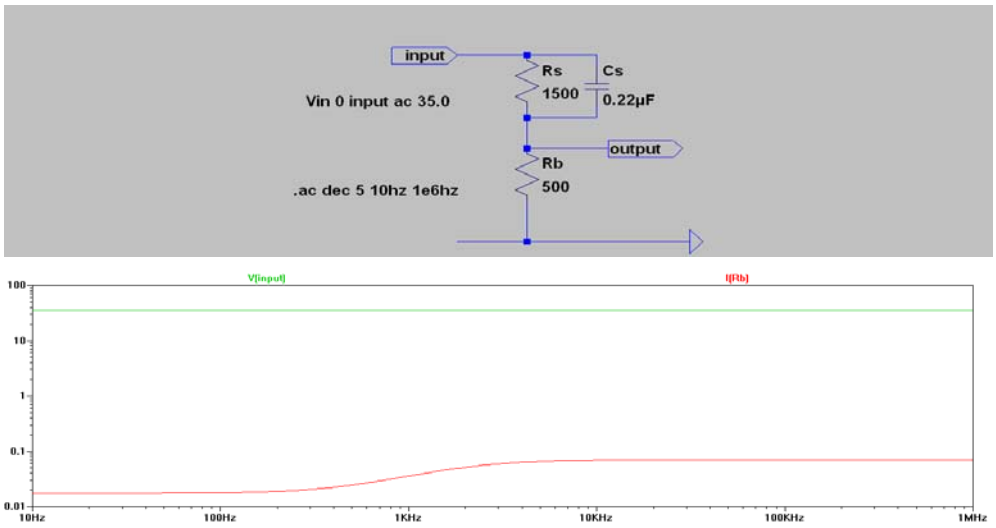
IEC60950对限流电路的定义： 0.7mApk < 1kHz; 0.7*freq(kHz) ≤ 70ma (cl 2.4.2).

IEC 62368 specifies ac (1kHz up to 100kHz) current: ES1 limit ≤ 0.5mArms x f in kHz [= 50mArms at 100kHz] and ES2 limit ≤ 5mArms + 0.95 x f in kHz [= 100mA at 100 kHz].

IEC 62368中定义交流电（ 1kHz～100kHz）：ES1限值≤ 0.5mArms x f in kHz [= 50mArms at 100kHz] ；ES2限值≤ 5mArms + 0.95 x f in kHz [= 100mA at 100 kHz].

Unweighted measurement circuit

IEC 60990, fig 3 未加权测量电路



IEEE

TC measurement comparison

PSES

The unweighted measurement circuit is also a basic part of each weighted measurement circuit shown in IEC 60990.

未加权测试电路是加权测试电路的一部分

This fundamental body model circuit has been used for the last 50 years or so in electric shock evaluations.

在电击评估中，模拟人体电路已经被采用了近50年

This example shows the increase in current with frequency due to the bypass capacitor. This increase is about a factor of 4 from LF to HF and the transition occurs in the region of about 0.5 kHz to 5 kHz or so.

例子中可以看出由于旁路电容带来的电流的增加，这个变化是从低频到高频中产生的，变化区域在0.5 kHz到5 kHz.

This example shown 70mArms HF current.

例子显示了高频电流70mA（有效值）

The shape of the curve is the same for any sinusoidal input signal; the LF & HF current values change as the input changes.

对于任一正弦波输入信号，其曲线的图形都是一样的，高频低频值随着输入的变化发生改变

eBurn data summary
电灼伤数据总结

Current /product std	LF current	HF current
IEC 60065	12.5mArms	50mArms
IEC 60950	17.5mArms	70mArms
IEC 61010	17.5mArms, 126mArms	70mArms, 500mArms
IEC 62368	12.5mArms, 25mArms	50mArms, 100mArms

IEEE TC measurement comparison PSES

This table summarizes the calculated results of the several eBurn limits given in the standards discussed.

图表中给出了几组电灼伤限值的计算结果

Remember that IEC 60065 specified a peak limit but, since eBurn only applies to sinusoidal waveforms, this has been converted to rms values for this analysis.

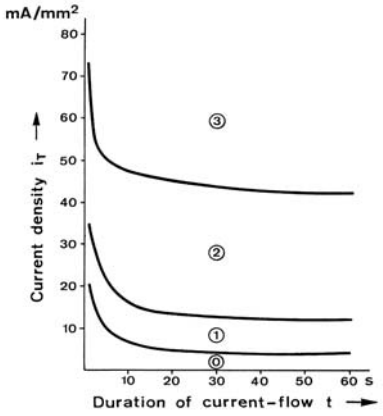
记住IEC60065中定义了峰值限值，但是电灼伤只适用于正弦波，所以分析时要转换为有效值。

The Low Frequency values are noted as they provide a basis for starting the discussion which is frequency dependant, as was shown.

频率不同时，为了方便论证，图表中列出了低频值

Skin eBurn data 皮肤灼伤数据

- **Reddening the skin** occurs at about 20mA/mm2 in a second or so – the shortest time a person can pull away by reaction. For finger contact of 100mm2 = 2000mA (2 Amps)
- **Leaving current marks** occurs at about 35ma/mm2 – 3500mA (3.5 Amps).
- **Carbonization of the skin** occurs at about 75 mA/mm2 – 7500mA (7.5 Amps). Longer term effects, 10's of seconds, are lower.



IEEE TC measurement comparison PSES

It is generally understood that a short term RF burn reddening the skin occurs at about 20mA/mm2 in a second or so – the shortest time a person can pull away by reaction. For a finger contact of 100 mm2 this is 2000mA (2 Amps) – a large current to which to subject a person.

总体来说，在20mA/mm2停留一秒钟左右，RF灼伤会使人体皮肤发红，一秒钟也是人能做出反应的最短时间。一个人手指接触100 mm2，电流为2000mA.

Leaving current marks occurs at about 35ma/mm2 – 3500mA (3.5 Amps).

Carbonization of the skin occurs at about 75 mA/mm2 – 7500mA (7.5 Amps). Longer term effects, 10's of seconds, are lower.

皮肤碳化—75 mA/mm2 – 7500mA (7.5 Amps).

The data from IEC 60479-1 does not show a frequency dependence for eBurn.

eBurn currents vs. area
电灼伤电流与接触面积的对比

Area, mm2	20 mA/mm2, mArms	35 mA/mm2, mArms	75 mA/mm2, mArms
7	140	245	575
10	200	350	750
20	400	700	1500
50	1000	1750	3750
100	2000	3500	7500

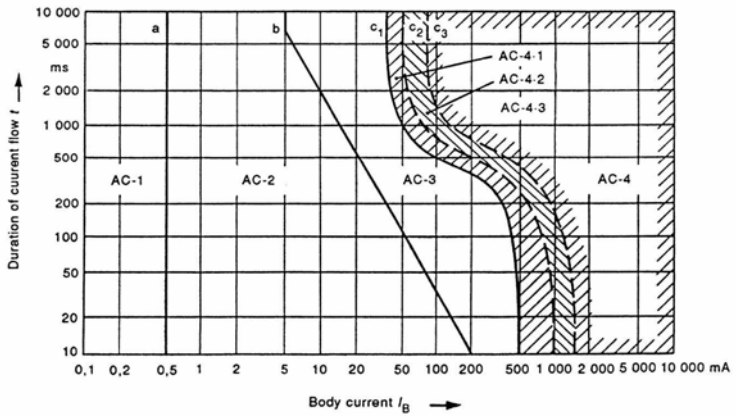
Combining the data from the current density curve with the contact areas expected provides the table of expected currents.

Note that the highest value considered here is 7.5 Amps over a 10cm by 10cm area.

LF AC duration vs. body current

(IEC 60479-1, fig 20)

低频交流持续时间与人体电流的对比



The LF currents calculated ranged from 12.5 mA to 126 mA.

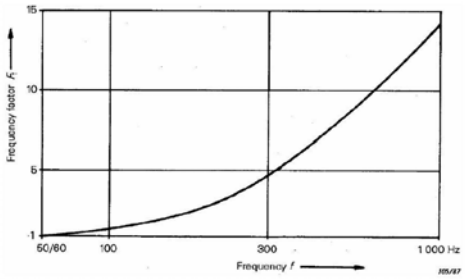
低频电流计算范围从12.5mA到126 mA

This shows that a one second contact at 50mA will produce ventricular fibrillation (VF).

一秒钟50 mA的触电会导致人体心室颤动

Frequency Factor for Ventricular Fibrillation
心室纤维性颤动的频率因数

- Freq factor for VF;
- waveforms > heart cycle,
- longitudinal thru the body
- (IEC 60479-2, Fig 3)



The frequency curve for VF in IEC 60479 is shown here. This curve can be extended to HF as has been done for the similar curves in IEC 60990.

上图是IEC60479中心室颤动（VF）的频率曲线，该曲线可以延展到HF曲线，与IEC60990中的曲线类似。

The current shown above is about 8.5x higher than the threshold for let-go at the same frequency. This means that slightly below this value one would be protected from VF but would not be able to let-go of the circuit.

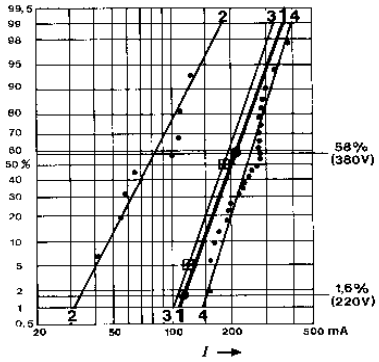
该曲线8.5X，高于惊跳电流在同一频率的门槛值。

No frequency compensating circuit has been developed in IEC 60990 for this curve since it is expected that products would not drive performance up against this limit.

为了防止产品使用过程中超过此限值，无频率补偿电路在IEC60990中已经得到完善

Comparative VF statistics
心室纤维性颤动统计比较

- 0.5% VF @ 100mA
- IEC 60479-1, fig 19



IEEE TC measurement comparison PSES

Certainly one would not want to put a person into VF upon contact with any eBurn current. Curve C1 (the 5% VF curve, protecting 95% of the population) would be the absolute upper limit without any margin for safety.

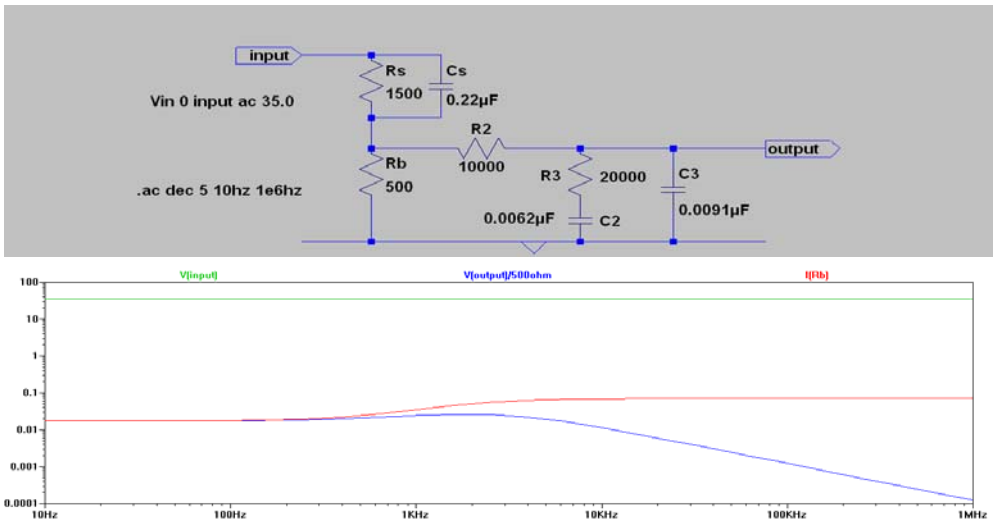
曲线C1是电灼伤电流绝对安全限值

The 1984 version of IEC 60479 had a footnote: 'The point 500mA/100ms corresponds to a fibrillation probability in the order of 0.14%'. (This note appears to be the basis for choosing 500mA as a limit.) This note has not been carried forward in the revision of the standard.

The latest version of the standard provides a comparative curve of Fibrillation data which provides a curve calculated from line voltage and frequency accidents showing 0.5% VF at 100mA.

最新版标准提供了对于房颤数据的比较，在100mA时，发颤发生为0.5%

eBurn from let-go weighted circuit
来自加权释放电路的电灼伤



IEEE TC measurement comparison PSES

The purpose of a eBurn specification is to limit the burn to a person touching such a circuit; but burns are not the only effect that needs to be considered. Coming in contact with such a circuit could lead to inability to let-go at levels well below those that would set off VF. Inability to let-go is defined by the b-curve body current levels of IEC 60479 'conventional time/current zones of effects of ac currents'.

规定电灼伤目的是限制人接触到这样电路而被灼伤，但是灼伤不是需要被考虑的唯一出发点。与这样的电路接触会导致不能摆脱导致心室纤维性颤动。b曲线表示是在交流电下，通过人体电流的曲线。

From this point forward we will examine these traditional eBurn values along with determining the frequency at which they fall below the let-go curve, curve b.

从这个角度向前看，我们检查传统的电灼伤值连同它们降到释放曲线下的频率，曲线-b

Using this frequency as a lower limit assures that any contact with the circuit will not result in inability to let-go (including its effect at high frequency).

用这个频率作为下限可以保证接触这个电流不会导致不能摆脱（包括在高频下）

eBurn data summary

plus let-go frequency limit

电灼伤数据总结 加上释放频率限值

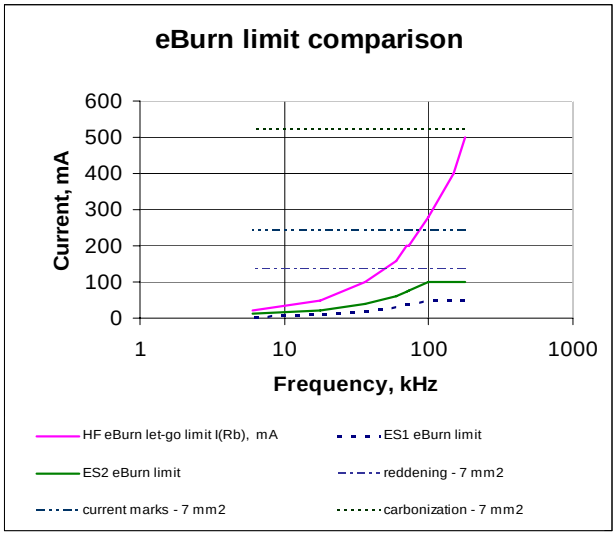
Current /product std	LF current	HF current	Let-go freq
IEC 60065	12.5mArms	50mArms	> 22kHz
IEC 60950	17.5mArms	70mArms	> 25 kHz
IEC 61010	17.5mArms, 126mArms	70mArms, 500mArms	> 25kHz, > 180Khz
IEC 62368	12.5mArms, 25mArms	50mArms, 100mArms	> 22kHz > 36kHz

IEEE TC measurement comparison PSES

Here we summarize the results of these calculation adding the let-go lower limit frequency.

这里我们总结一下，加上释放频率下限值

eBurn current comparison
电灼伤电流总结



IEEE TC measurement comparison PSES

The plot shown summarizes the eBurn 5mA let-go point calculated above.

上面这个图总结电灼伤释放电流限值为5mA

Skin effects (reddening, current marks and carbonization) lines are shown for a small contact area.

趋肤效应（变红，波纹和碳化）线为小的接触区域内

Operating below (and to the right of) the curve always insures being below curve b insure let-go from allowable eBurn currents.

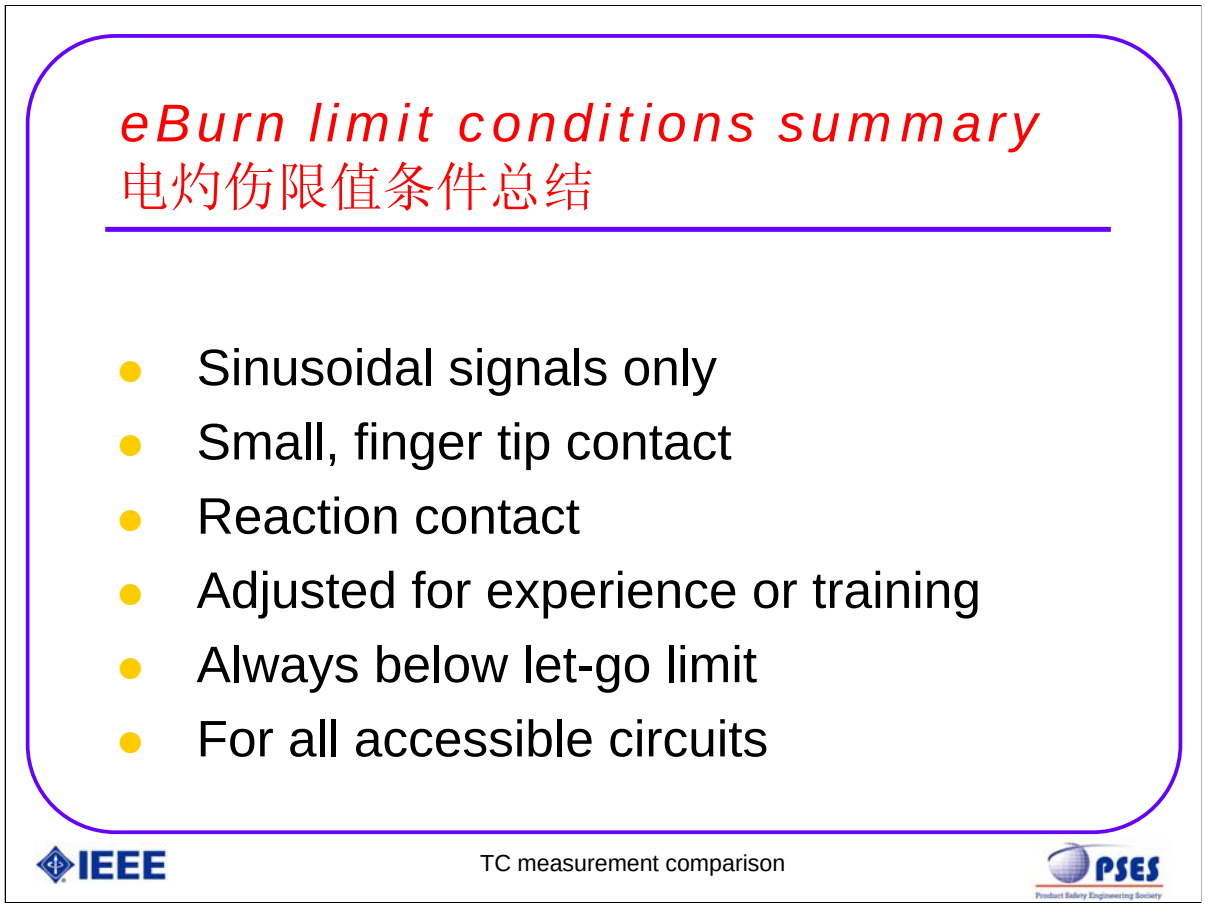
在曲线下面（右面）操作，可确保低于曲线b，确保可以摆脱适当的电灼伤电流

Operating above (and to the left of) the curve is forbidden under these conditions.

严禁在曲线上面（左面）的条件下操作。

Each of these effects must be taken into account in setting a limit.

每一种效应都必须被考虑规定限值。



The eBurn limit only applies to sinusoidal signals.

电灼伤电流仅适用正弦信号。

The area of contact should be limited to small, finger tip contact to HF circuits.

接触面积要限制小，指尖接触高频电路

The time of contact should be specified as being limited to reaction (< 1 sec).

接触时间要规定就像限制反应时间一样（<1s）

The allowable limit should be specified for each type of person covered in the standard (ordinary normal user, supervised user or trained serviceman).

允许的限值应该对于标准里的每一种人详细说明

Why would we subject ordinary users to an eBurn?

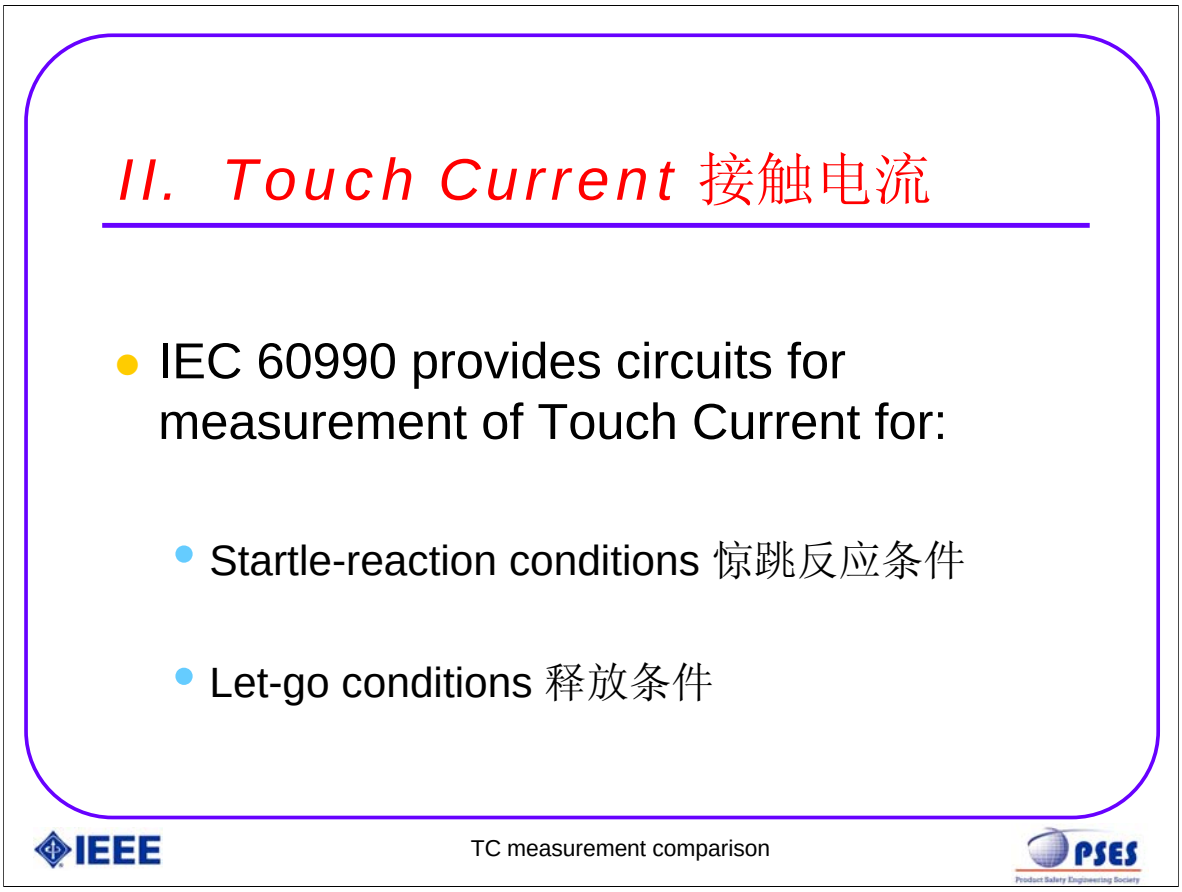
为什么我们主要说普通人的电灼伤呢？

The allowable limit should ensure that the hazard never exceeds the let-go limit vs. frequency curve above.

允许的限制要确保危险不会超过释放限值频率曲线以上

These requirements should apply to accessible circuits which can be contacted at both poles. This includes all grounded secondary circuits and any isolated circuits where both contacts are easily available to touch.

这些要求适用于两级之间易触及电路。包括所有的接地次级电路和任何一个容易接触的隔离电路



IEC 60990 provides 2 Touch Current measurement circuits which meet the frequency factor curves of IEC 60479 under the following conditions.

IEC60990规定2个接触电流测量电路，电路满足IEC60479的频率因数曲线条件

A circuit weighted for startle-reaction (formerly called perception-reaction) – fig 4

加权惊跳反应电路（以前叫感知反应）——图4

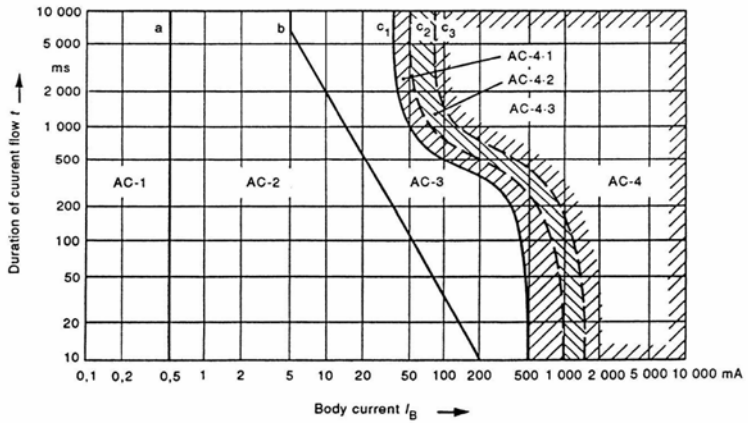
A circuit weighted for let-go – fig 5

加权释放电路——图5

LF AC duration vs. body current

(IEC 60479-1, fig 20)

低频交流持续时间与人体电流的对比



IEEE TC measurement comparison PSES

Startle-reaction is defined by curve a (the 0.5mA line).

曲线a（0.5mA线）定义惊跳反应

Let-go is defined by curve b (which is 5mA under steady state conditions but can go much higher under short time contact.

曲线b（在5mA稳态条件下但是在短时间接触释放更高的电流）定义释放

The c curves identify the region of ventricular fibrillation (VF) which is fatal, if not quickly reversed.

曲线c为心室纤维性颤动的范围，如果不快速的断开，会致命的。

TC frequency factor curves

startle-reaction ckt; let-go ckt

接触电流频率因数曲线

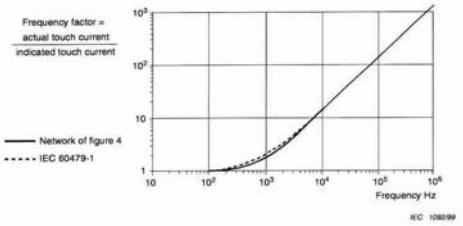


Figure F.2 – Frequency factor for perception or reaction

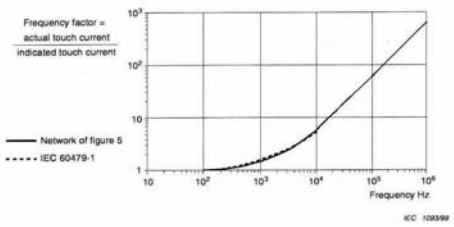


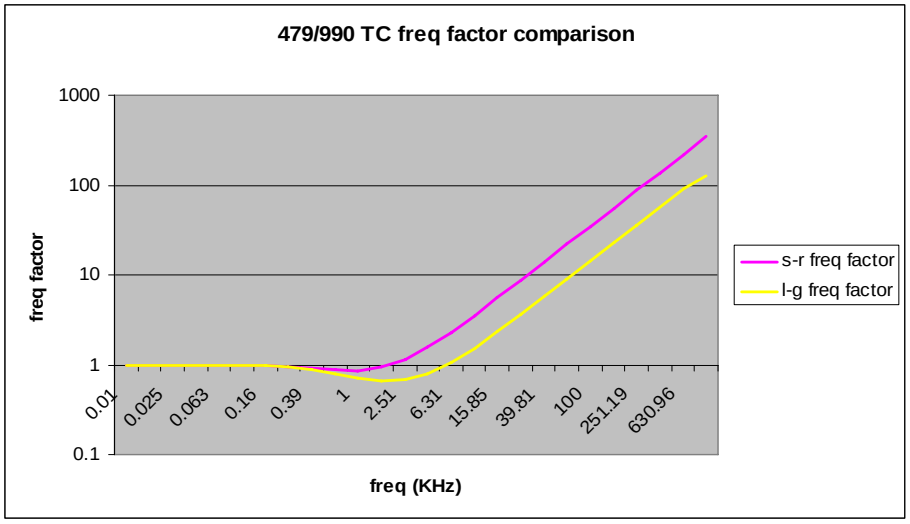
Figure F.3 – Frequency factor for let-go

These curves show the frequency factor for startle-reaction and let-go as well as show the adequacy of the IEC 60990 circuits in adjusting the high frequency components according to this curve.

曲线为惊跳反应和释放的频率因数，根据这个曲线表明IEC 60990电路调整高频率元件

IEC 60479 / IEC 60990

Touch Current frequency factor comparison 比较



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TC measurement comparison

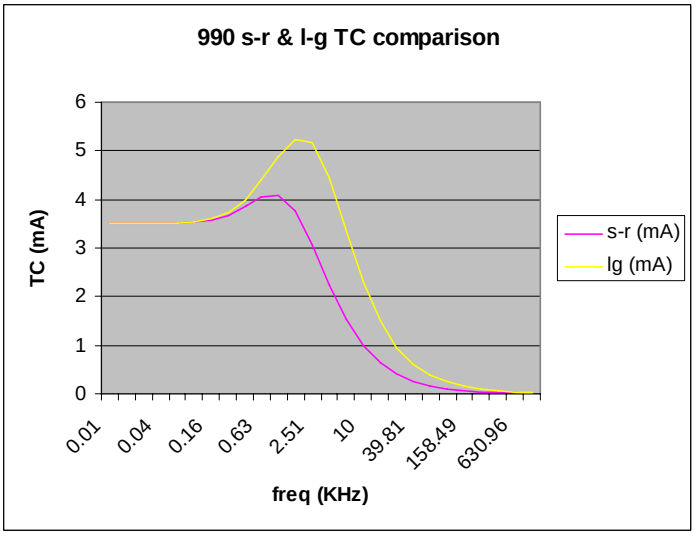
PSES

Here we compare the frequency factor curves for startle-reaction and let-go directly.

这里我们直接比较惊跳反应和释放频率因数曲线

The TC comparison is shown below for the same input conditions.

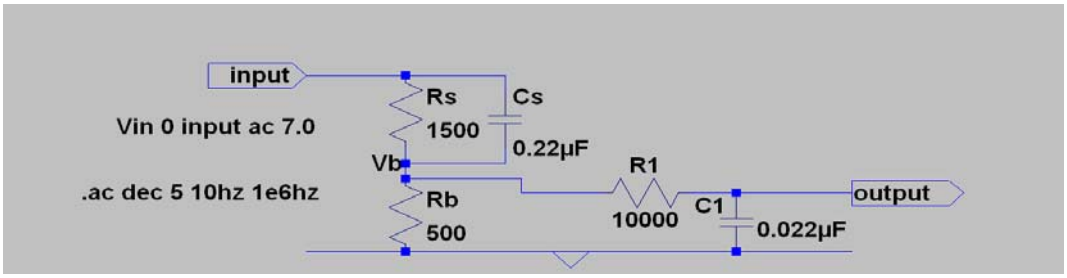
在相同的输入条件下接触电流比较关系

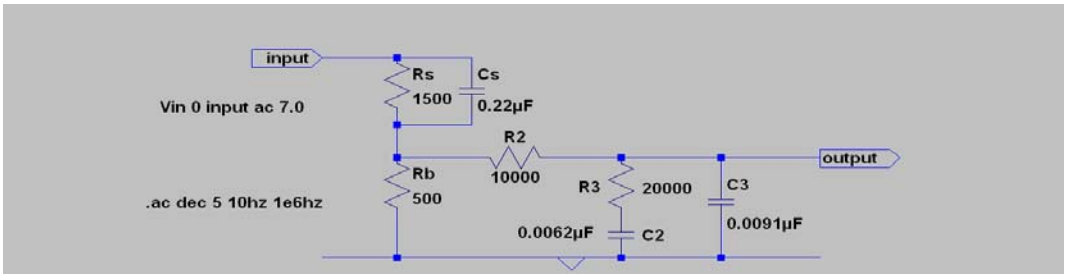


IEC 60990 TC circuits

startle-reaction ckt; let-go ckt

接触电流电路





IEEE

TC measurement comparison

PSES Product Safety Engineering Society

The IEC 60990 circuits meeting the frequency factor curves just described are shown here.

IEC 60990电路满足频率因数曲线描述

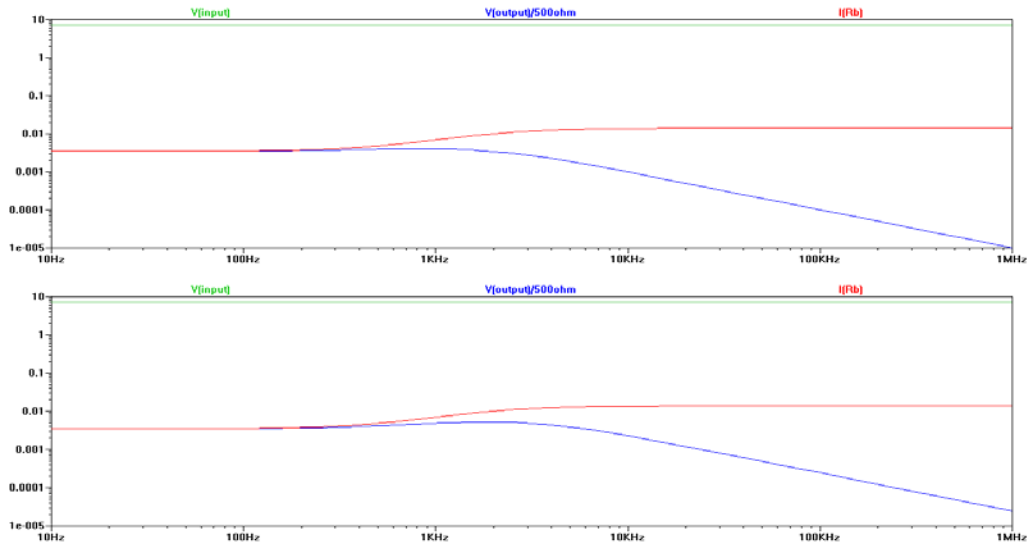
In each circuit the basic body model has a high frequency filter attached to meet the appropriate requirements.

基本的人体模型在每个电路有一个满足适当要求的高频滤波器

IEC 60990 measurement response

startle-reaction ckt; let-go ckt

测量反应



IEEE TC measurement comparison PSES

The performance of each circuit is shown here for the specific case chosen.

选择特殊情况下每个电路的性能

For this discussion, the case of 3.5mA touch current has been selected. This case pushes the startle-reaction situation beyond the 0.5mA expected, but has been commonly used in IEC standards such as IEC 60950 and IEC 61010.

通过讨论，挑选出3.5mA接触电流的情况。这种情况惊跳反应比期望值超过0.5mA，但是通常用在IEC60950和IEC61010标准中

Note that the touch current curve (the V(output)/500ohm - blue curve) is falling. The circuit has been designed to be the inverse of the frequency factor curve so that the same value can be read from the meter and compared to the limit irrespective of the frequency of the TC signal.

注意接触电流曲线（输出电压/500ohm — 蓝色曲线）是下降的。电路的目的在于倒转频率因数曲线，以便从坐标中读出相同的值，与限值相比不考虑接触电流信号的频率。

50 Hz sine wave TC

startle-reaction ckt; let-go ckt

50Hz正弦波接触电流

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	4.94 mA	3.49 mA	1.415
l-g cktTC = I(V(output)/ 500ohm)	4.96 mA	3.50 mA	1.417

IEEE TC measurement comparison PSES

In this case we expect the rms TC to be 3.5mA and the peak value to be sqrt 2 * rms = 5mA. The peak to rms ratio should them be the sqrt 2.

这里我们期望接触电流的有效值为3.5mA，峰值为根号2倍的有效值=5mA。峰值/有效值为根号2

The s-r current should be used for cases where the TC is 2mA or less and the l-g circuit above that. This will ensure that children will be able to let-go of the circuit when touched.

反应电流被用于当接触电流是或低于2mA并释放电流大于2mA时。保证孩子在接触时能够释放电路。

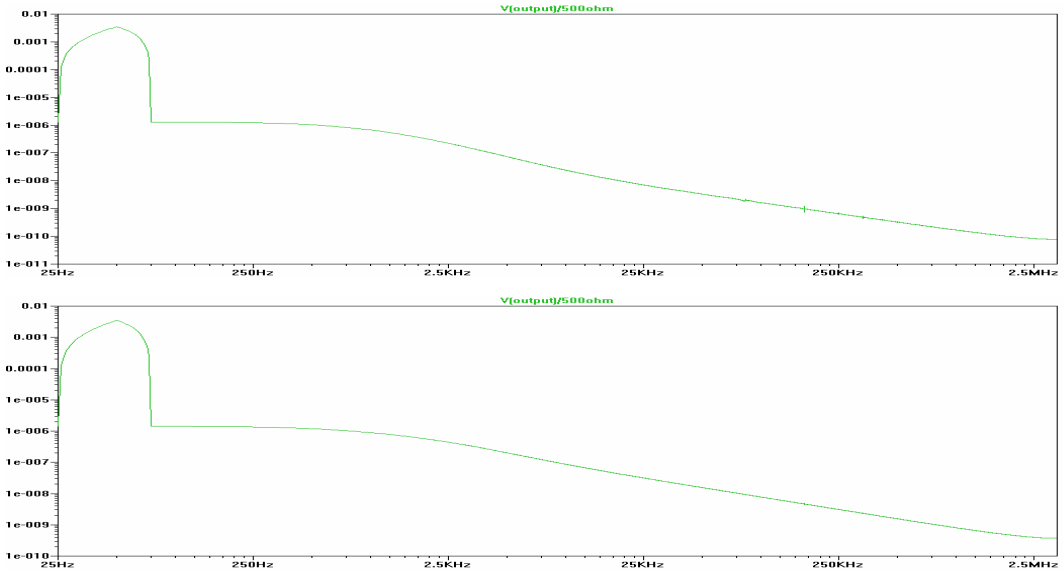
In all of the cases examined here, there will be an emphasis on peak measurement as the body responds to peak values of current for electric shock, not rms values.

在这里的所有检查，主要是强调峰值的测量，当人体反应时是峰值电流产生电击，而不是有效值。

50 Hz sine wave FFT

startle-reaction ckt; let-go ckt

*50Hz*正弦波快速傅里叶变换



IEEE TC measurement comparison PSES

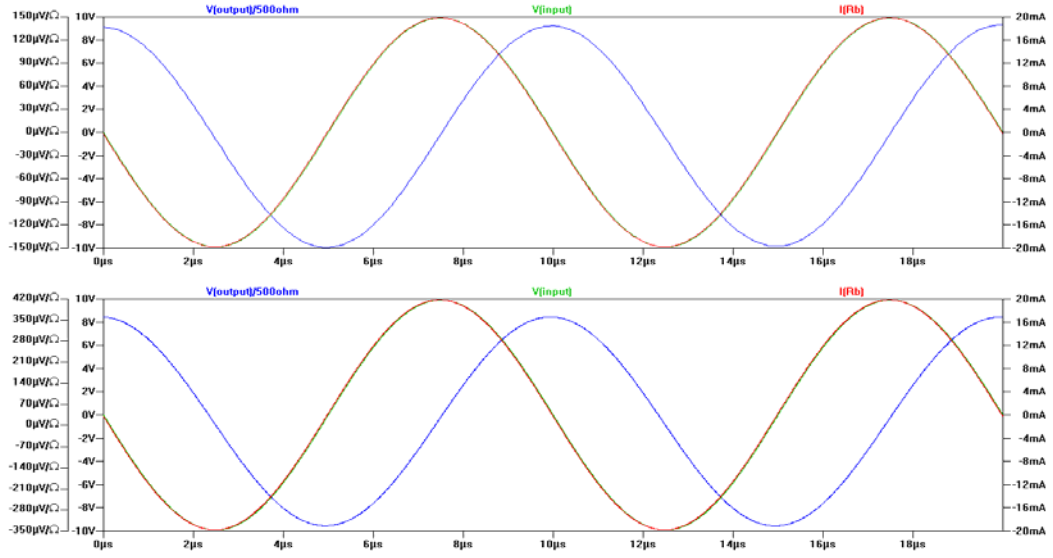
In each case we see the 50 Hz fundamental and no harmonics.

我们看到50Hz基本原理并且没有谐波。

100kHz sin wave response

startle-reaction ckt; let-go ckt

100kHz正弦波反应



TC measurement comparison

This case looks at a 100 kHz sin wave input to each circuit.

看一个100kHz正弦波输入的电路

100kHz sin wave TC
100kHz正弦波接触电流

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	0.143 mA	0.101mA	1.416
l-g cktTC = I(V(output)/ 500ohm)	0.346 mA	0.245 mA	1.412

IEEE TC measurement comparison PSES

The frequency factor circuit reduces the TC value as expected at this frequency.

正如我们预期的一样，频率因数使接触电流减小

Each circuit treats the value in a different way – the TC is higher for the let-go measurement. The increased current starting with the middle frequencies increase the total current.

每个电路处理数值的方法不同——接触电流中的释放电流较高。总电流从中频开始增加。

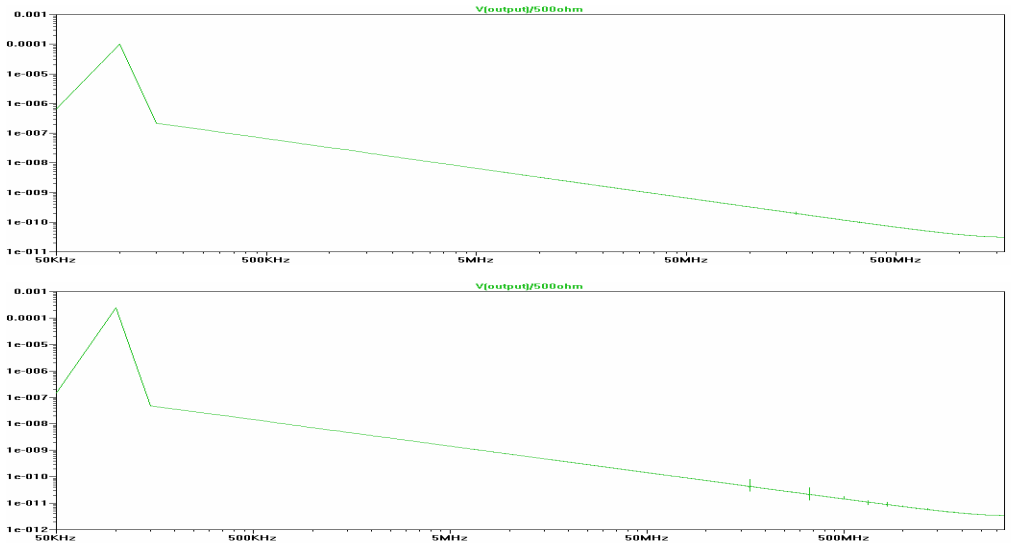
The peak/rms ratio is still sqrt 2.

峰值/有效值比例依然是根号2

100kHz sin wave FFT

startle-reaction ckt; let-go ckt

*100kHz*正弦波快速傅里叶变换



IEEE TC measurement comparison PSES

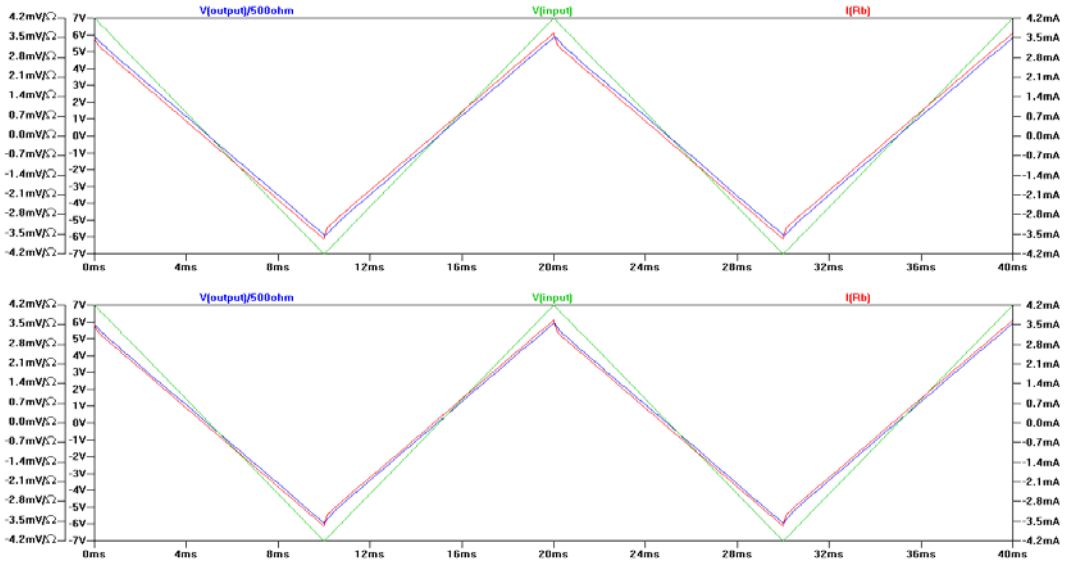
As before, only the fundamental frequency appears in the FFT.

和之前一样，在快速傅里叶变换波形中只有基本频率出现。

Triangular waveform response

20 ms (50Hz) period

三角波反应



TC measurement comparison

The triangular waveform might be considered a ‘stretched out’ sin wave.

三角波可认为是伸展的正弦波。

This type of waveform has been seen in some equipment drawing substantial regulated power for heaters .

这种波形在一些加热器重要规定的电源的设备图中见到

Triangular wave TC
三角波接触电流

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	4.98 mA	2.868 mA	1.736
l-g cktTC = I(V(output)/ 500ohm)	5.05 mA	2.869 mA	1.760

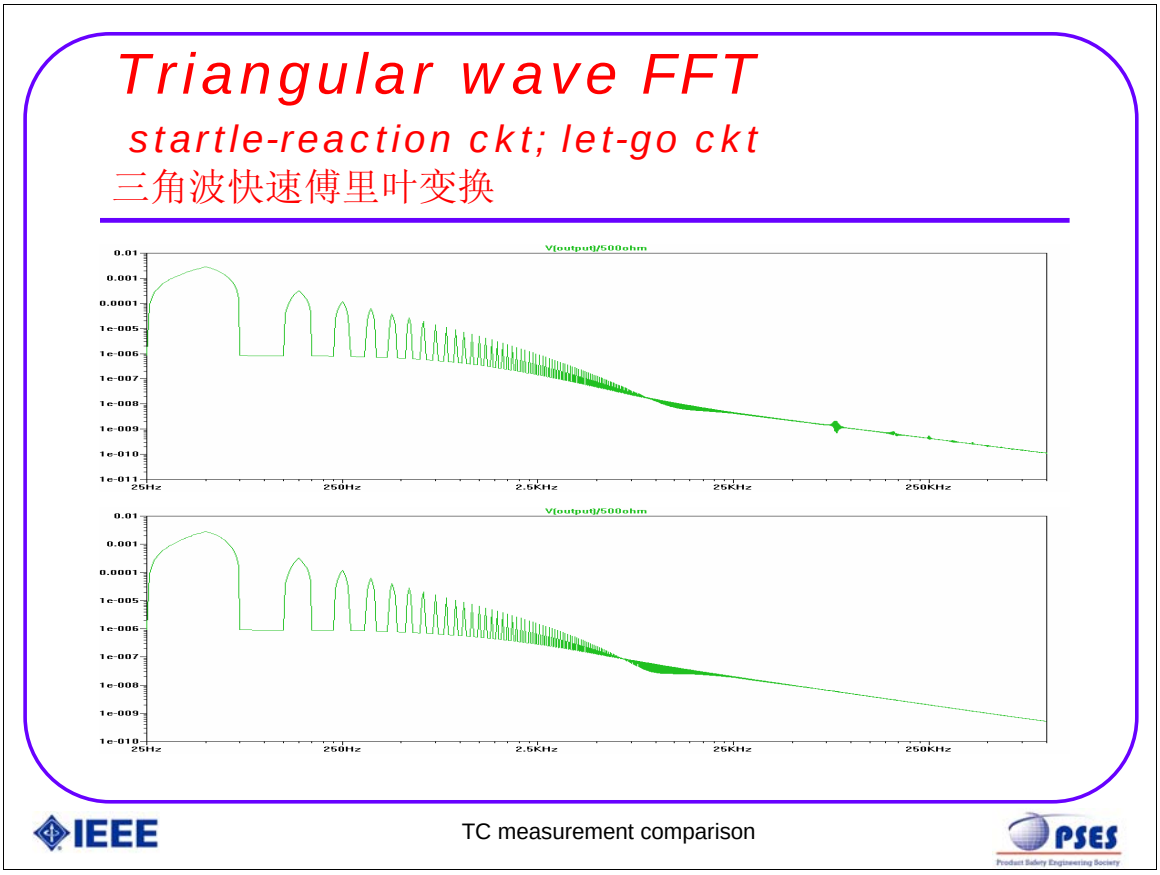
IEEE TC measurement comparison PSES

For this case the rms TC is lower than the 3.5mA that would be allowed while the peak value is higher – about 5mA, one below and one above.

这个表中，接触电流有效值低于3.5mA，峰值大约5mA，一个低一个高是被允许的。

The peak/rms ratio is no longer sqrt 2.

峰值/有效值的比例不再是根号2



Somewhat to our surprise, there are considerable harmonics associated with the triangular waveform.

多少出乎我们意料，可以考虑谐波与三角波有关

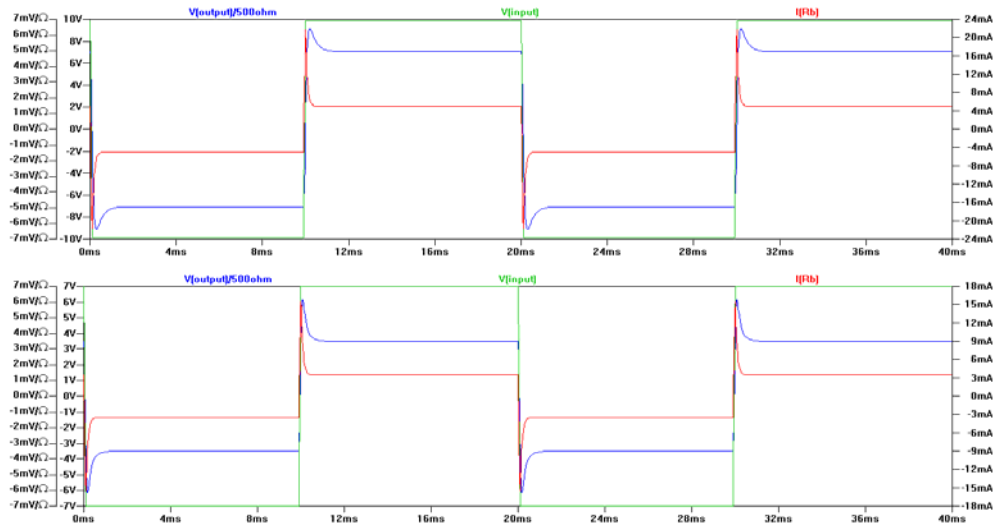
The filter circuit component of the TC circuits acts on the high frequency components of this waveform.

接触电路的滤波电路元件在这个波形中高频率元件运行

20ms (50Hz) Sq Wave response

startle-reaction ckt; let-go ckt

方波反应



The response to a line frequency square wave is shown here.

这个图是线性频率反应方波

The differences in the TC response (blue curve) is easily distinguishable here.

与接触电流反应（蓝色弯曲线）的差别是显而易见的

This square wave has a 1% risetime.

方波有1%的上升时间

20ms (50Hz) Sq Wave TC
方波接触电流

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	6.39 mA	4.991 mA	1.280
l-g cktTC = I(V(output)/ 500ohm)	8.758 mA	5.054 mA	1.733

IEEE TC measurement comparison PSES

There are enough high frequency components here that the circuits treat them differently.

电路中有足够的高频元件处理它们的不同

Although the rms values are about the same, the peak values are quite different.

尽管有效值差不多，但是峰值相差很多

Because of these differences the peak/rms ratios are quite different.

因此峰值/有效值比例也相差很多

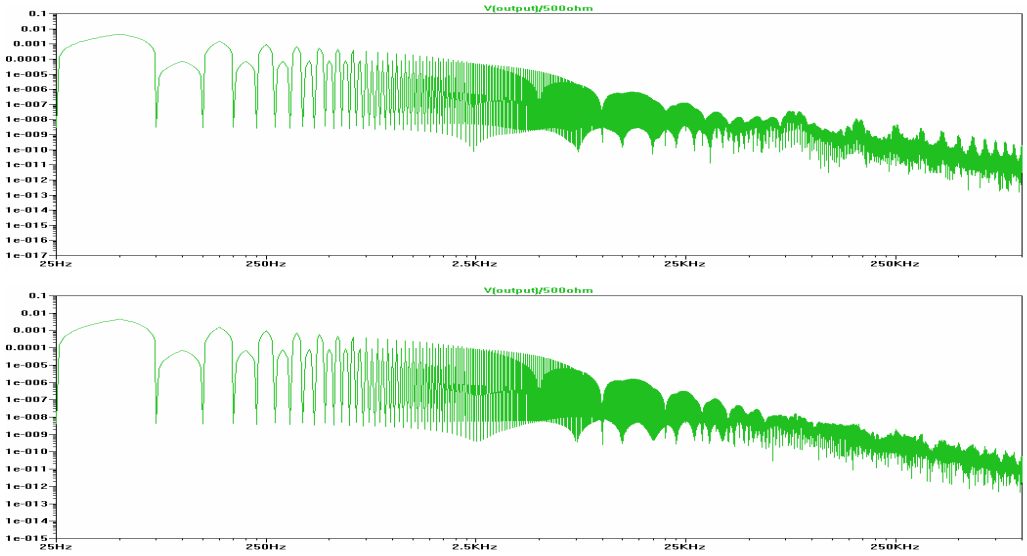
The peak values are the important measurement here.

峰值测量是很重要的。

20ms (50Hz) Sq Wave FFT

startle-reaction ckt; let-go ckt

方波快速傅里叶变换

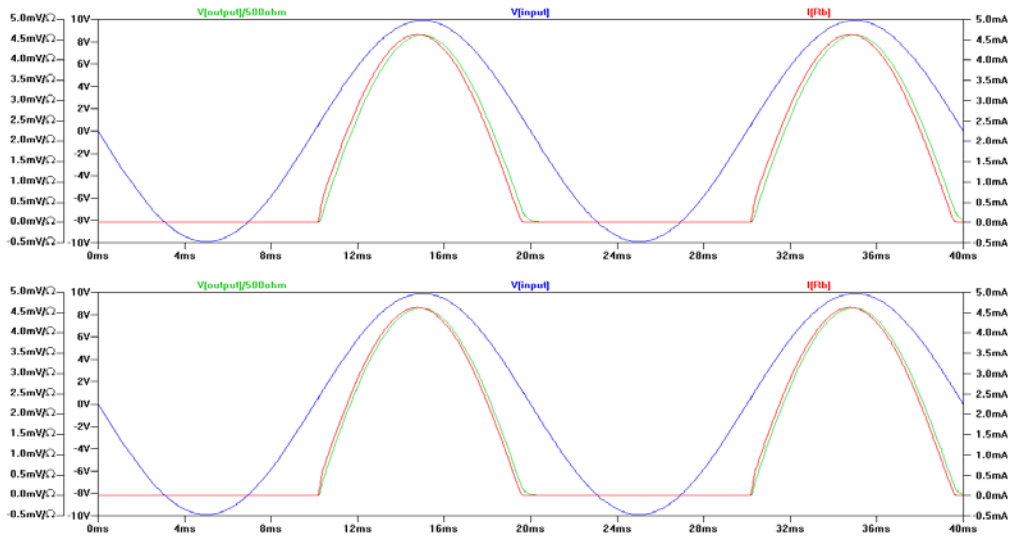


IEEE TC measurement comparison PSES

Some high frequency differences can be seen in comparing these two FFTs of the circuit response to this waveform.

一些高频率的差异可以看这两个电路的快速傅里叶变换的波形

Half-wave rectified line-frequency sin wave response
半波整流线性频率正弦波反应



Rectification of line voltage is an essential part of utilization of electric energy in equipment today.

现在，线性电压的整流在电能的利用是一个重要的部分

Half-wave rectified
line frequency sin wave TC
半波整流线性频率正弦波接触电流

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	4.61 mA	2.264 mA	2.036
l-g cktTC = I(V(output)/ 500ohm)	4.62 mA	2.265 mA	2.038

As we might begin to suspect, the rms values are lower than our sinusoidal base case but the peak values are proportionally higher.

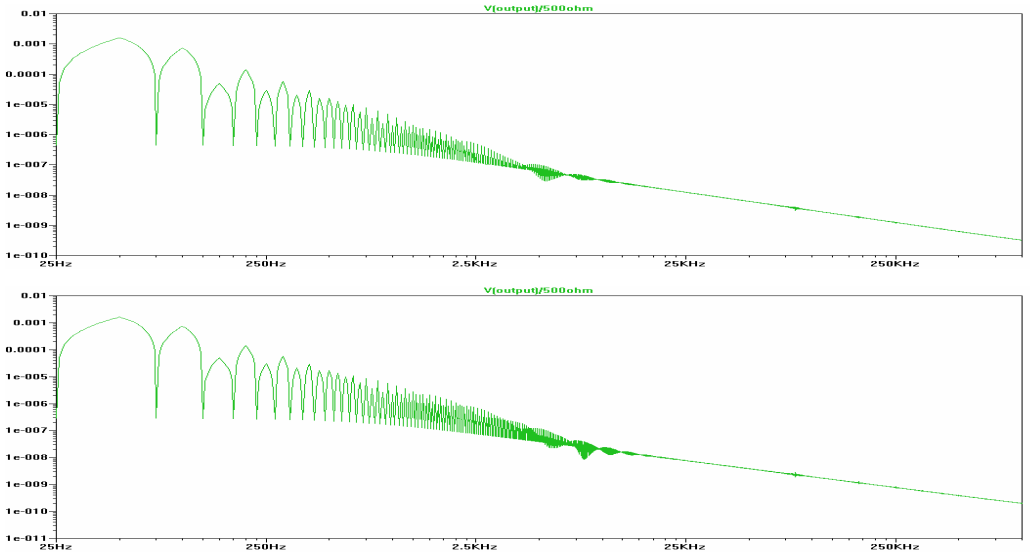
现在我们可以开始怀疑，有效值低于我们基本的非正弦波，但是峰值成比例的高

The peak/rms ratio is over 2.

峰值/有效值比例超过2

Half-wave rectified line-frequency sin wave FFT

半波整流线性频率正弦波快速傅里叶变换

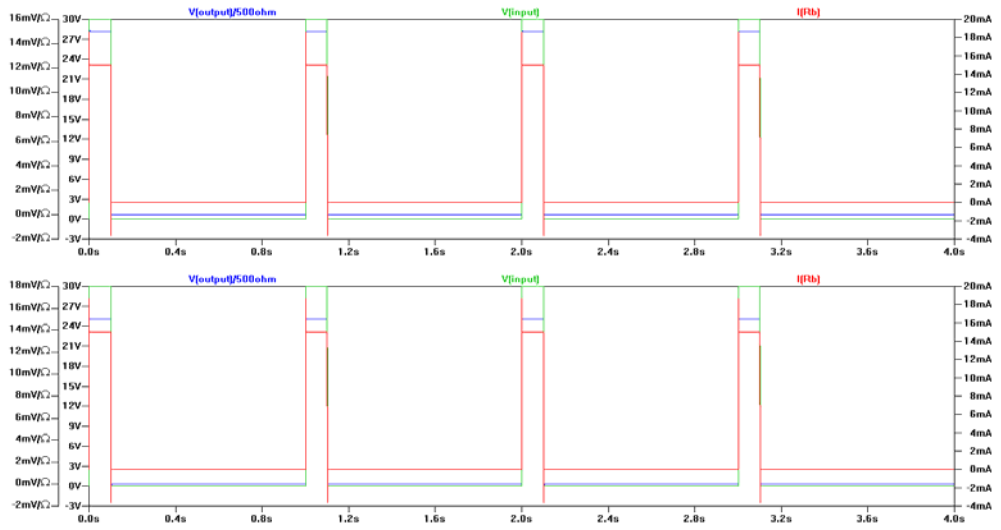


IEEE TC measurement comparison PSES

The high frequency differences appear above 25kHz and up.

高频率的差异出现在25kHz以后并上升

1ms risetime pulse response
*1ms*上升时间脉冲反应



TC measurement comparison

100 ms pulse, 1 sec rep rate (within the heart cycle), 1ms (1%) risetime.

100ms脉冲，1s重复速率（在心搏周期范围内），1ms（1%）上升时间

This calculation was looking for a TC below 14mApk to prevent VF for the particulars of this case.

这个计算找到接触电流在低于14mA峰值时，在这个情况下阻止心室纤维性颤动

1ms risetime pulse TC
*1ms*上升时间脉冲接触电流

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	8.319 mA	4.761 mA	1.747
l-g cktTC = I(V(output)/ 500ohm)	8.917 mA	4.762 mA	1.873

IEEE TC measurement comparison PSES

With this risetime there is only a slight difference in the circuit responses.

在上升时间内电路反应只有很小差异。

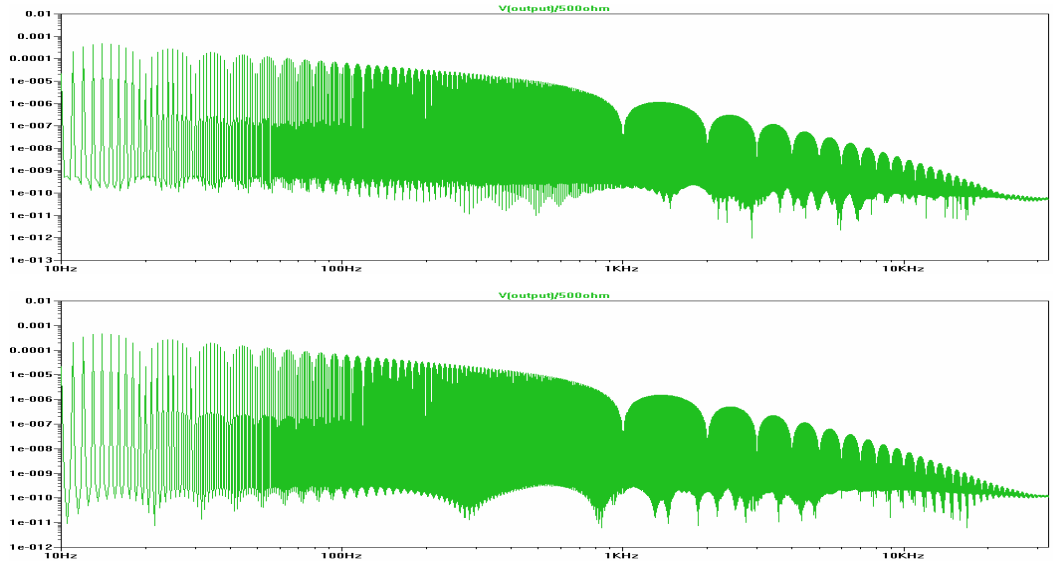
The pk/rms ratio is not sqrt 2, however.

然而，峰值/有效值的比例不是根号2

1ms risetime pulse FFT

startle-reaction ckt; let-go ckt

*1ms*上升时间脉冲快速傅里叶变换



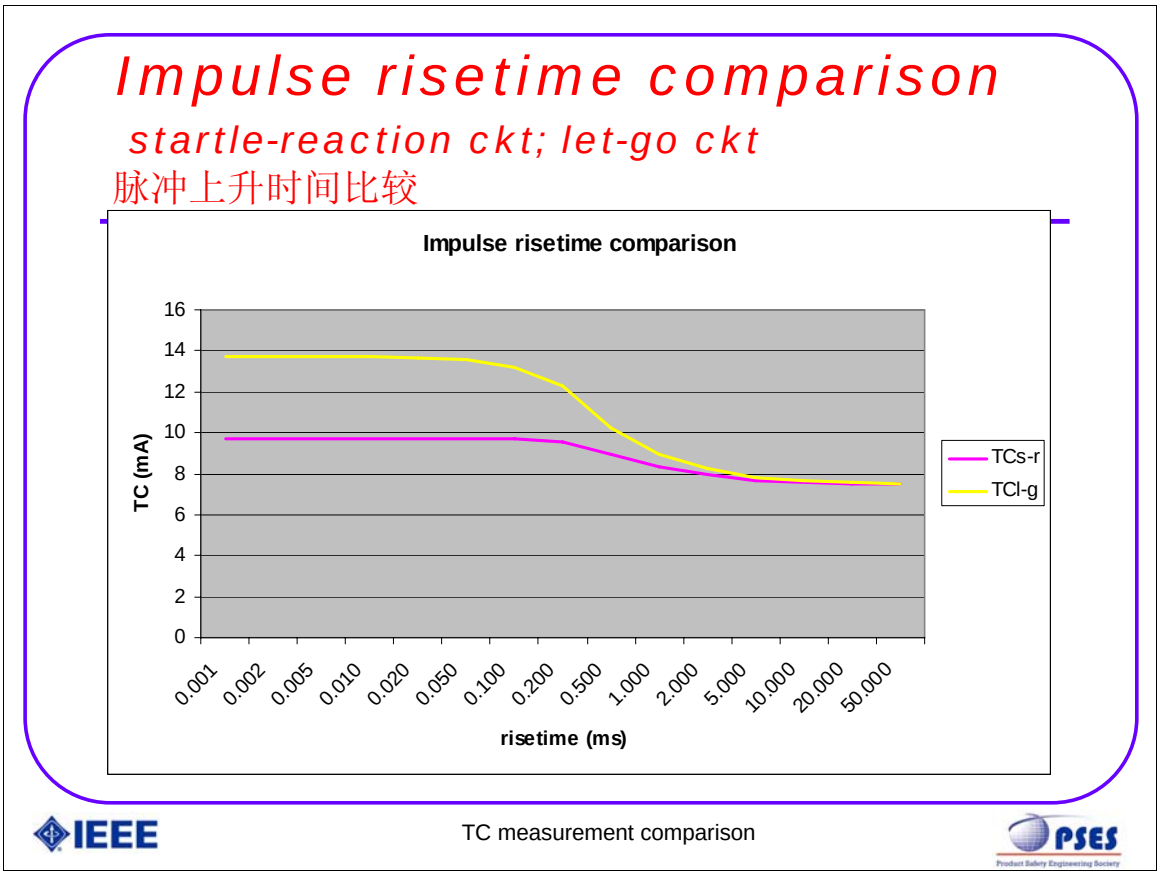
IEEE

TC measurement comparison

PSES Product Safety Engineering Society

The higher frequency components show as slight differences here.

高频率分量显示出轻微的差异



At the slow risetimes the TC is about 7.5 mA in each case.

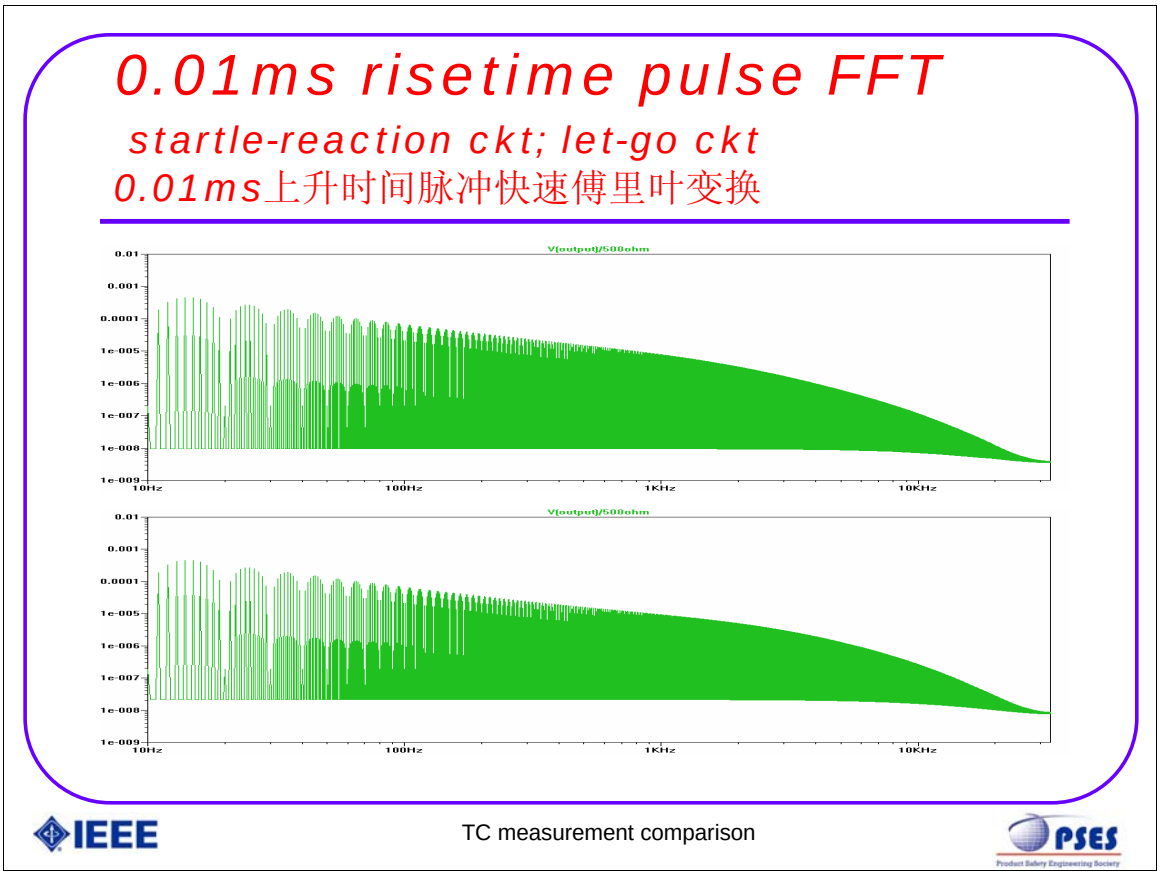
在每一种情况中，接触电流在慢的上升时间时是7.5mA

At the fast risetimes the TC is almost 10 mA for the s-r case and almost 14 mA for the l-g case.

在快速的上升时间时，在s-r情况下是大约10mA，在l-g情况下大约是14mA

The control of risetime is the key to using impulse circuits in applications where TC approaches the limit.

控制上升时间的关键是在接触电流接近限值时，在应用程序中使用脉冲电路。



Although the FFT waveforms seem similar here, the TC magnitude differs as we saw in the last slide.

尽管在这傅里叶变换波形看起来相似，但是接触电流的大小的不同，我们看下一张幻灯片

0.01ms rep pulse TC

startle-reaction ckt; let-go ckt

*0.01ms*重复脉冲接触电流

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	9.732 mA	4.746 mA	2.051
l-g cktTC = I(V(output)/ 500ohm)	13.687 mA	4.749 mA	2.882

IEEE TC measurement comparison PSES

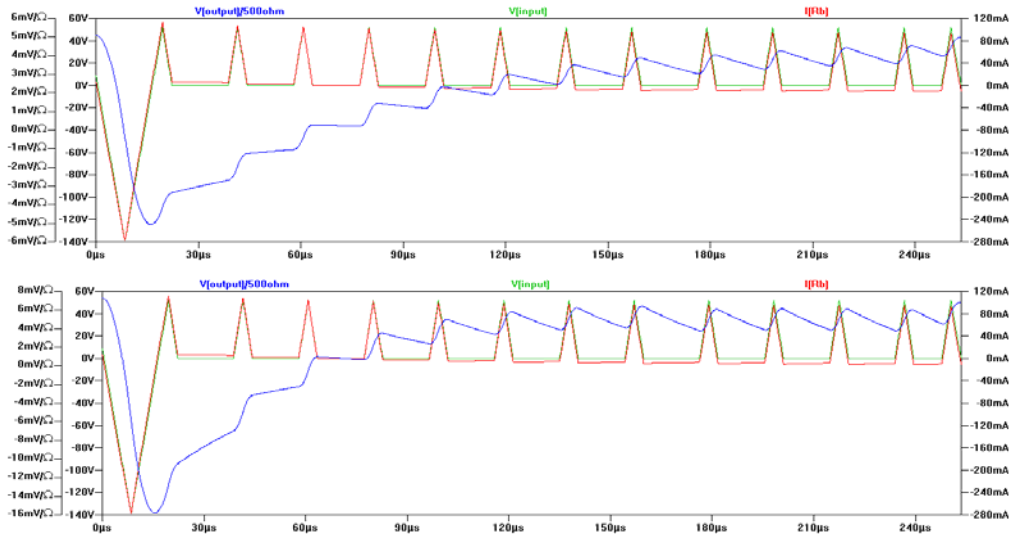
Both the magnitude and the pk/rms ratio are different when filtered by each TC circuit.

当被接触电流电路过滤后，接触电流的大小和峰值/有效值比例是不同的。

LCC circuit

startle-reaction ckt; let-go ckt

限流电路



TC measurement comparison

Limited Current Circuit evaluation

限流电路的评估

IEC 60950 allows access to circuits which will not be an electrical shock hazard.

IEC 60950允许接触到无电击危险的电路

This specific waveform was submitted for analysis because of its characteristics.

由于它的特性，提交特殊的波形供分析

LCC TC comparison

startle-reaction ckt; let-go ckt

限流电路接触电流比较

Current	Peak	RMS	Pk/rms ratio
s-r cktTC = I(V(output)/ 500ohm)	5.070 mA	3.090 mA	1.641
l-g cktTC = I(V(output)/ 500ohm)	11.536 mA	5.645 mA	2.044

IEEE TC measurement comparison PSES

When reviewing the LCC waveform using the s-r circuit it shows the peculiar characteristic of being less than 3.5 mArms but more than 5 mApk.

看LCC电路的s-r波形，表明了它小于3.5mA有效值但大于5mA峰值的特殊特征

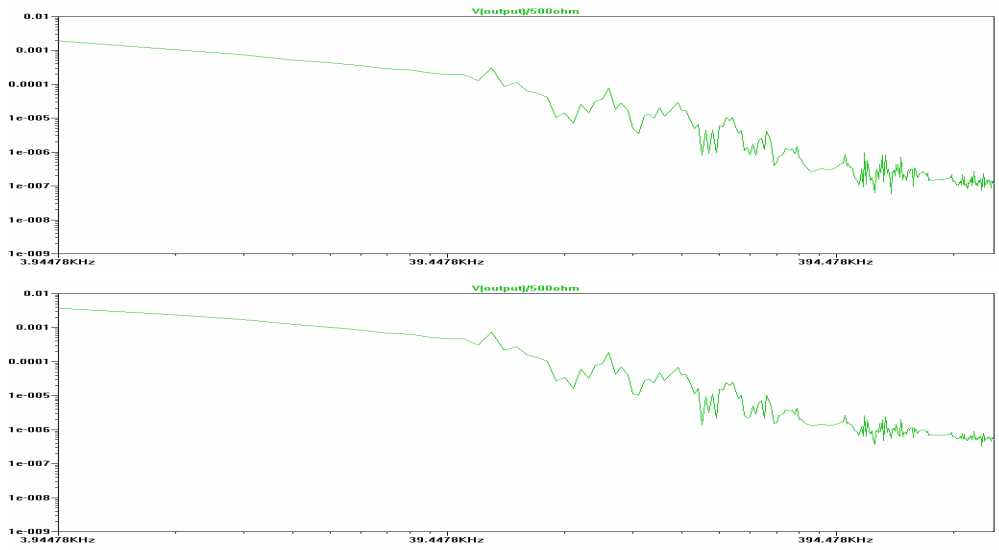
Again, reviewing this LCC waveform using the l-g circuit the values are substantially larger and the pk/rms ratio is also larger.

再看LCC电路的l-g波形值实质上比较大，峰值与有效值的比率也比较大

LLC circuit FFT

startle-reaction ckt; let-go ckt

限流电路快速傅里叶变换



IEEE TC measurement comparison PSES

Comparing these FFT's (which appear quite similar and contain harmonics starting about 40kHz.

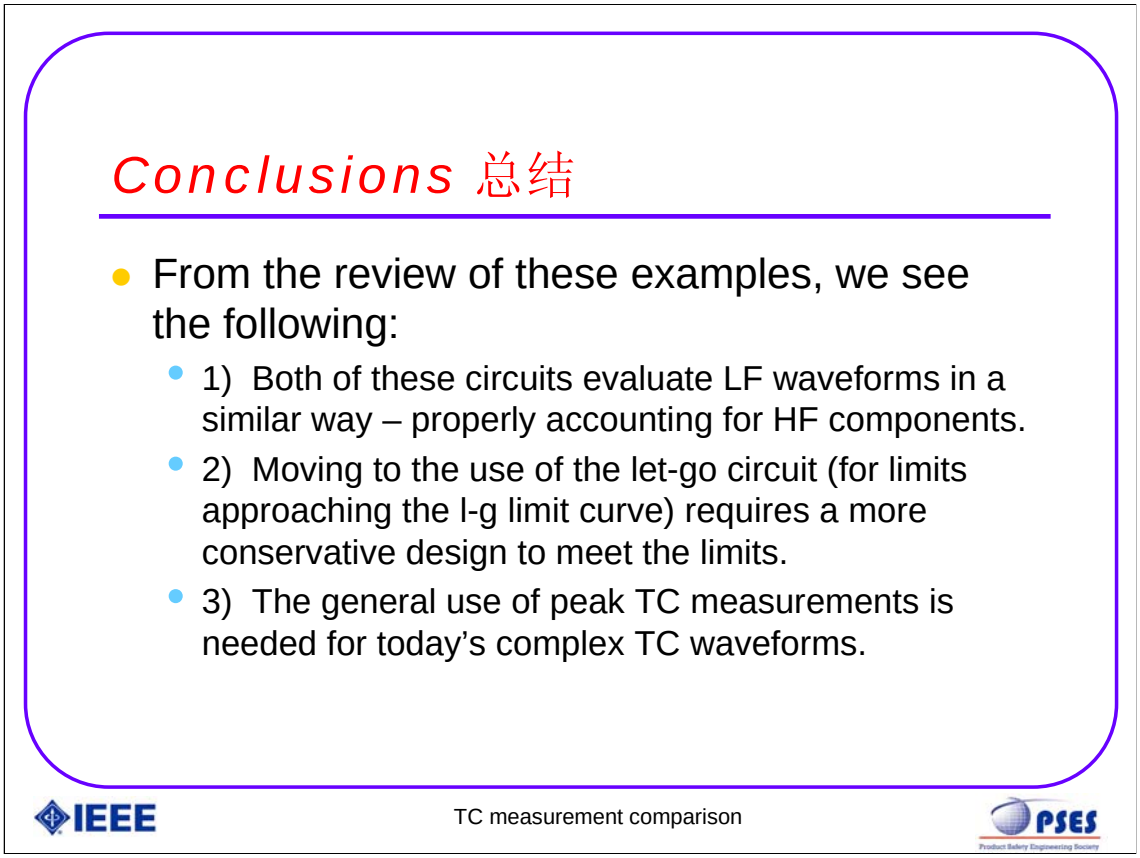
比较快速傅里叶变换，出现很相似并且各次谐波启动大约为40kHz

This complex waveform cannot be evaluated by simply consulting the frequency factor curves.

复杂波形不能用简单频率因子曲线评估

The use of peak measurement is the only way to evaluate this complex waveform.

峰值测量是评估复杂曲线的唯一方法



This paper compares the performance of the IEC 60990 eBurn, startle-reaction and let-go circuits against basic waveforms.

IEC 60990 电灼伤，惊跳反应和释放电路相对的基本波形的比较

This leads to a better understanding as to the action of TC waveforms and encourages the proper evaluation of TC waveforms in equipment.

这样可以比较用以理解关于接触电流波形和鼓励在设备内适当的评估接触电流波形

The waveforms shown here are not yet representative of the TC waveforms for modern equipment using mains switching techniques.

波形在这里不代表接触电流在现代化设备使用的电源开关技术

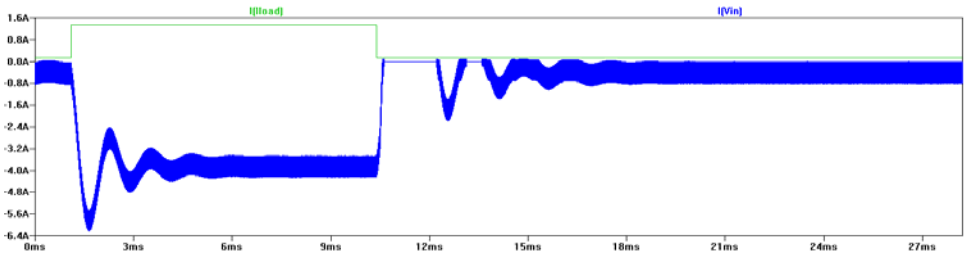
Switching electronics is used in switch mode power supplies and variable speed drives in equipment today. This technology is spreading to many other types of equipment – commercial, industrial and residential.

现在，开关电子技术广泛用于开关电源和变速传动装置。这项技术已经应用到很多类型的设备——商业的，工业的和家用的。

Peak measurements are needed for the s-r and l-g cases; these are specified in standards but not uniformly applied today.

峰值的测量需要s-r和l-g；这些在标准中规定但与现在不适用

Proto DC-DC power supply
I/O currents
直流-直流电源模型 输入/输出电流



- Input and load currents as the supply is switched on then off

IEEE TC measurement comparison PSES

How did we get there and what can we say about real SMPS?

如何得到我们说的真正的电源？

Power supply manufacturers tout the performance of their modules in meeting the needed performance criteria for the applications they support.

电源制造商展示他们的模块性能时，需要相应的性能标准来支持

Note, however, that the input current is never a fixed value, it oscillates over a small range (ooo 1amp or so in this case) to maintain the output regulation needed.

注：输入电流从来就不是一个固定值，它在一个小的范围内波动去维持输出所需要的值

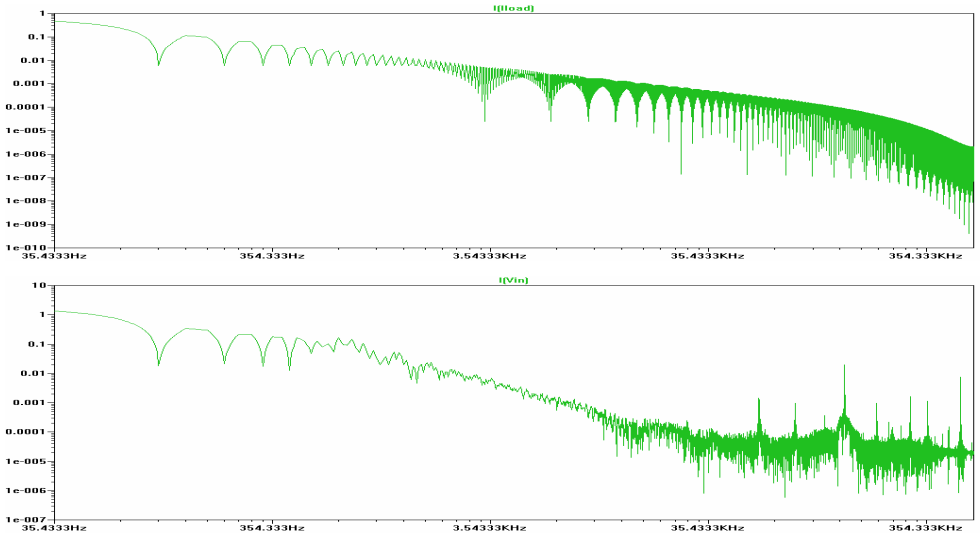
This current oscillation is capacitively coupled to earth and contributes to the TC for the product.

这个电流波动是对地的电容性耦合，增加产品的接触电流

Many products use a multiplicity of these DC-DC converters for the distribution of power in the product; each of these will contribute to the TC for the product in their own way. The measured TC will, of course, sum these sources.

许多产品使用大量的DC-DC转换器用于电力分配，每一个转换器都会增加接触电流。测量接触电流，当然是这些输入源的总和

Proto DC-DC converter I/O FFT's
直流转换器输入/输出快速傅里叶变换

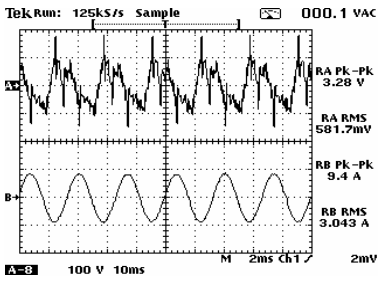


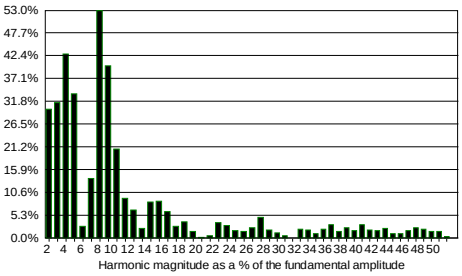
IEEE TC measurement comparison PSES

Note that both the output and the input show a continuous harmonic spectrum for this power supply.

注意，输出和输入在电源内都是连续的谐波谱

Measured Frequency Spectrum for pfcSMPS TC
被测频谱





Voltage:
Current: Ref A
Harmonics: 51
Type: Current Magnitude

IEEE TC measurement comparison PSES

The measured harmonics for a Touch Current waveform are shown here.

这里是接触电流的谐波测量

This oscilloscope analysis shows lots of harmonics near the fundamental as we've seen in many of the non-sinusoidal examples (triangular, square wave, rectified sine wave & pulse). The scope analysis is limited to the first 50 harmonics (2.5 - 3 kHz); the spice analysis includes these first 50 harmonics and then goes to higher frequencies.

示波器分析显示在原点附近有大量的谐波，例如我们看到的许多非正弦波（三角波，方波，整流正弦波和脉冲）。分析范围限值在前50个谐波（2.5-3kHz）;模拟分析包括前50个和之后更高的频率。

This paper clearly shows the need to move to peak measurements for Touch Current in all electronic products.

这个图清楚的显示出在所有的电子产品中需要移动到峰值测量接触电流

This paper also forms a solid basis for further understanding of the effect of system generated waveforms on the TC results for any product which can be more complex than the simple waveforms used as examples here.

这篇论文也为更进一步理解由其他比这里列举的更复杂的系统产生的非单一波形对TC的影响打下了结实的基础

Touch Currents have become the low frequency counterpart to EMC currents – a residual of the design process and not clearly controlled.

接触电流已经成为和EMC电流一样的低频电流——是设计过程未涉及的没有明确控制的因素

Curriculum Vitae, Peter E. Perkins

Mr. Peter E. Perkins, PE has more than 40 years of technical and practical experience. He was, for 17 years, manager in charge of Corporate Product Safety and Regulatory Affairs for an American MNC, a Fortune 500 electronics company. He has also worked in several engineering and managerial capacities within the Display Components Engineering Division of that company.

Mr. Perkins holds a MSEE degree and is a registered Professional Engineer, Electrical and a registered Professional Engineer, Quality in the USA. He is a NARTE certified Product Safety Engineer and also a Certified Product Safety Manager.

Mr. Perkins is a holder of a display patent and the author of numerous papers. He has given numerous talks and training programs for companies all over the world plus the Univ of Wisconsin Extension course 'Getting your CE marking'.

Mr. Perkins has an ongoing involvement in the development of technical safety standards. He currently sits on the following committees:

IEC/TC108(74) - developer of IEC 60950, Safety Standard for IT Equipment; developing the new HBstd (pr IEC 62368) to replace IEC 60950 and IEC 60065. .

IEC/TC108/WG5 - Convenor of this working group that has developed IEC 60990, Methods of Measurement of Touch Current and Protective Conductor Current, a Pilot Safety committee within the IEC.

IEC/TC64/MT4 – developer of IEC 60479, Effects of electric current on the human body …

IEC/TC64/PT61201 – developer of IEC 61201, Touch Voltage threshold values

US/TAG-TC109 - the US Technical Advisory Group developing American input to IEC 60664, Insulation coordination for low voltage equipment

US/TAG-TC64 - the US Technical Advisory Group developing American input to IEC 60479, Effects of electric shock on the human body.

US/TAG-TC66 - the US Technical Advisory Group developing American input to IEC 61010, Safety requirements for electrical equipment for measurement, control and laboratory use.

US/TAG-TC108 - the US Technical Advisory Group developing American input to IEC 60950, Safety of Information Technology Equipment.

Mr. Perkins is currently working as an independent product safety and regulatory consultant for business in addition to offering seminars and training in the product safety and regulatory area.