The relation of isparK ,ThEx-10 and IEC 60079-25

The PTB report ThEx-10 was issued in 1999 as a result of fundamental research work with the intention to give an actual and feasible procedure for evaluation of intrinsically safe circuits where non linear sources take part of.

Nowadays this method is acknowledged and reported by IEC 60079-25 as an annex.

This document is added to the isparK package substantially for the following reasons:

- the data of ThEx-10 (and IEC 60079-25 subsequently) are direct derivatives of isparK
- the differences between using isparK and IEC 60079-25 shall be pointed out
- the diagrams are reported here as an electronic paper; they can easily be printed out whenever needed, be used on computer's desktop and comprises diagrams for L_o = 0.01 mH, while the standard does not
- with this issue, gasgroups IIA and I are included in the same manner

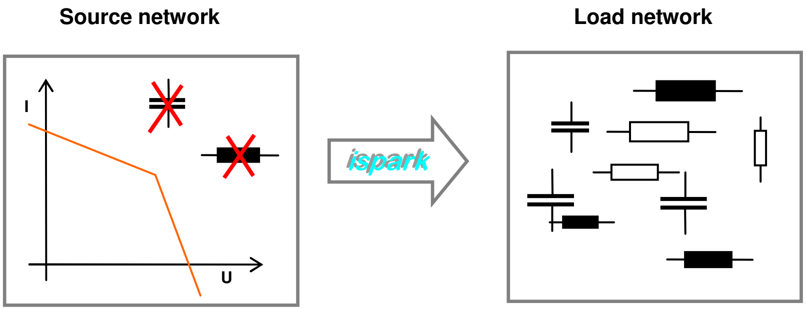
Note: This document is based on a further development of isparK , using advanced sets of parameters introduced with version 7.1 for the first time. So a better matching of known ignition data is achieved, the differences are not too big though.

ispark's principal working

ispark's principal working picks up a source network building the “associated” (active) part of a circuit and draws conclusions about a load network representing the “intrinsically safe” (passive) part.

This implementation natively suits the original intention for detecting and certifying intrinsic safety concerning the source itself based on its “electrical data” and state certain values of maximum permissible external inductances L_o and capacitances C_o as it's necessary for certifying associated apparatus' and certain intrinsically safe apparatus too.

ispark needs to know the effective source characteristic, i.e. interconnection properties and failure assumptions must be taken into account before. Additionally the source characteristic is assumed to be stationary. If there are some inductances and/or capacitances present internally, they have to be neglected with the source characteristic but considered as contributing to L_o resp. C_o.



L_o and C_o represent the simple sum of inductances resp. capacitances independently from their real interconnection.

Why to use ThEx-10 instead of standard's data?

Ignition data reported in standards concerning intrinsically safe apparatus like IEC 60079-11 as tables, diagrams or even simple energy values refer to very simple circuits only:

- the data of the capacitive limit are researched using a very high feeding resistor of 100 kΩ only
- the inductive limits were determined upto 24 V only and there are some hints for the use of even lower voltages in the vicinity of the ohmic boundary
- only circuits using resistive limitation are reported (linear characteristic)

Because of it's physically orientated design, ThEx-10 does not suffer from these restrictions. One may imagine standard's data to be special examples out of which characteristic parameters can be extracted. ThEx-10 represents an over all kind of inter-/extrapolation including a lot of further ignition data, mainly some investigated by PTB. These are for example nonlinear source characteristics like trapezoidal and rectangular.

Furthermore, the interaction of capacitances and inductances present within the same circuit pose a risk formerly not known. Especially in situations where big lumped capacitances and inductances are present simultaneously, it would be hazardous to neglect the possible transformation of capacitively stored energy to an inductively released one.

ThEx-10 solves this problem as well as circuit's non linear properties.

How to work with the diagrams of ThEx-10

Working with the diagrams of ThEx-10 needs to know the effective source characteristic, as stated above, and a target L_o is to be chosen. Result is a certain permissible C_o.

The diagrams are used by drawing in the actual source characteristic (you normally will use a copy print out).

Additionally, lines drawn in parallel with the diagram's axis' are necessary intersecting them at the maximum source voltage resp. current.

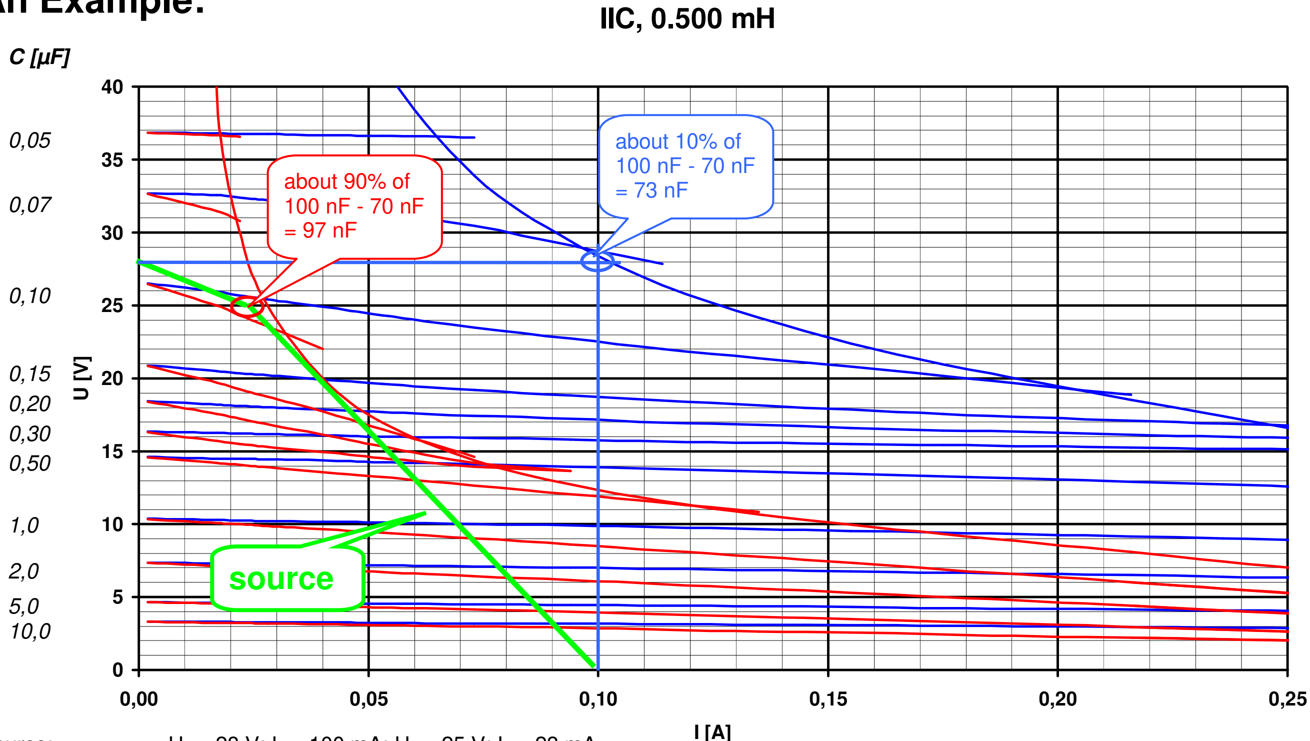
Conditions for confirmed intrinsic safety are:

- A the (original) source characteristic's curve must not exceed the line representing the limit with respect to rectangular sources (red hyperbolic line)
- B the extrapolated point resulting out of maximum voltage and current shall not be beyond the line for linear sources (blue hyperbolic line)

Every diagram, these conditions are fulfilled within, are a basis for determining the L_o associated maximum permissible capacitance C_o.

For this purpose the two different sets of curves for capacitance C_o have to be considered; blue ones to be compared with the extrapolated point mentioned as B above and red ones, not to be exceeded at any point by the curve according to A. Suitable interpolation is allowed.

An Example:



Source: U_o = 28 V; I_o = 100 mA; U_e = 25 V; I_e = 23 mA

Condition A fulfilled, associated C_o according to red curves: ≈ 97 nF

Condition B fulfilled, associated C_o according to blue curves: ≈ 73 nF

Result:

The finally resulting permissible capacitance C_o is the minor one of both (73 nF here).

Note: While this ThEx-10 evaluation results in 0.5 mH and 0.073 µF, ispark will assess this circuit to have a safety factor of 1.28 with opening spark type o-0C only.

Comparing performance of ThEx-10 and *ispark*

The benefit of *ispark* compared to ThEx-10 mainly is not in scope, but in performance, as a consequence of a necessary reduction to a paper related procedure. It's not restricted to special presented inductances but covers the range from nearly zero to 100 mH and no interpolation manually to be performed is necessary. The most essential benefit of *ispark* may be yet, that it's living and will grow with power in future by inclusion of additional properties, which can't be implemented by a paper related procedure.

On the other hand, ThEx-10 doesn't need any computer or software nor imposes a procedure, whose internals are invisible and hardly known by the user.

The most essential difference although, is the property of *ispark*, to maintain the safety factor 1.5 regardless source’s shape, while ThEx-10 may produce results down to a safety factor of about 1.0. Therefore ThEx-10 may be used only with category ib and only for installation purposes.

From a practical point of view *ispark* works significantly faster, allowing to investigate more constellations and coming closer to a possible optimum for example while developing an apparatus.

Spark type's appearance in the diagrams of ThEx-10

As described in isparkt's operating instructions and supplement, a distinction should be made between different spark types. The following figure is intended to achieve some more understanding of spark type properties. Its appearance is like a diagram of ThEx-10 for gasgroup IIC and 0.15 mH and linear source but additionally there are several areas classified according to the locally relevant spark type.

The line for spark type ö-0C-0L segregates the regions where a source itself is intrinsically safe or not when no reactive load at all is present.

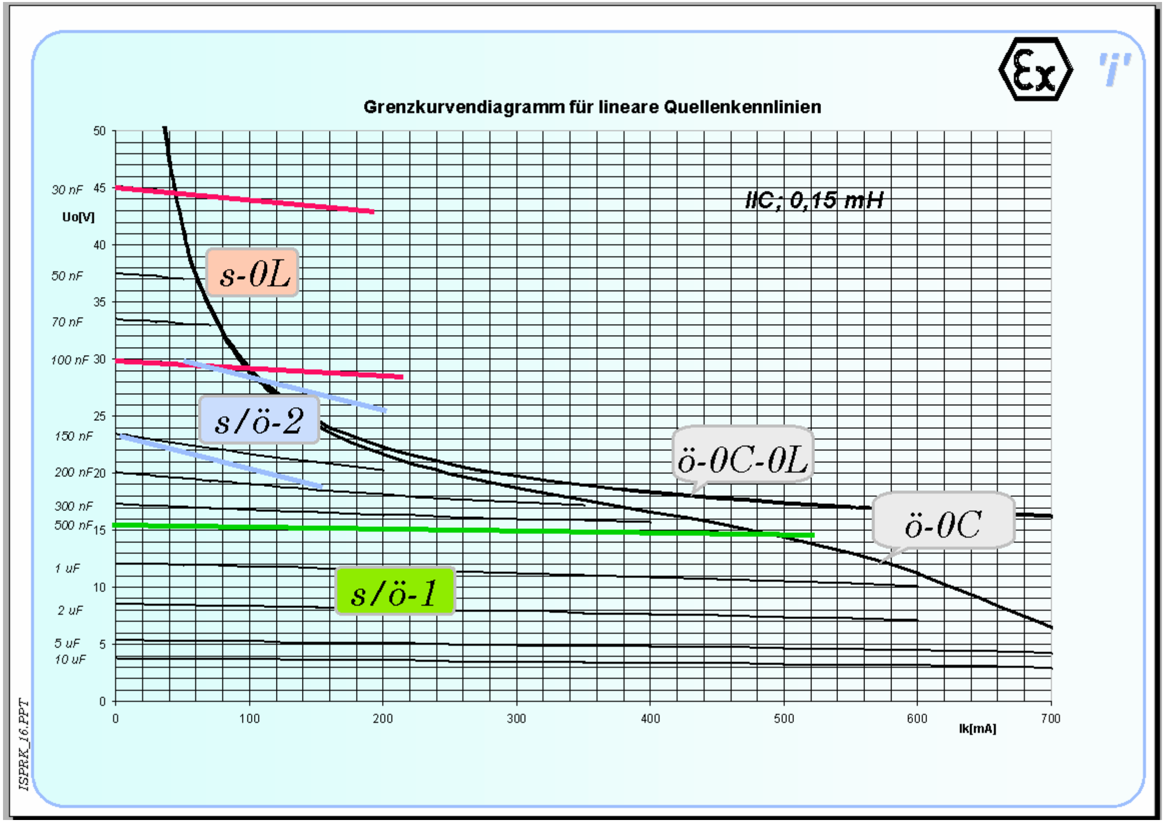
Clearly to be seen is the smooth transition from the line representing spark type ö-0C-0L (no inductance efficient) to that of type ö-0C (including inductance), especially with decreasing current. It's possible to make a distinction between a region, where inductively stored energy significantly contributes to (beneath about 300 mA), and a different one, where simply the sources' available power solely is sufficient for ignition (above 300 mA). With higher inductances this transition will be at lower currents.

For sources of high voltage and low current the spark type s-0L dominates the situation. Because of very short spark durations in this area, the source does not contribute significantly and the curves are flat like the red enhanced colored lines.

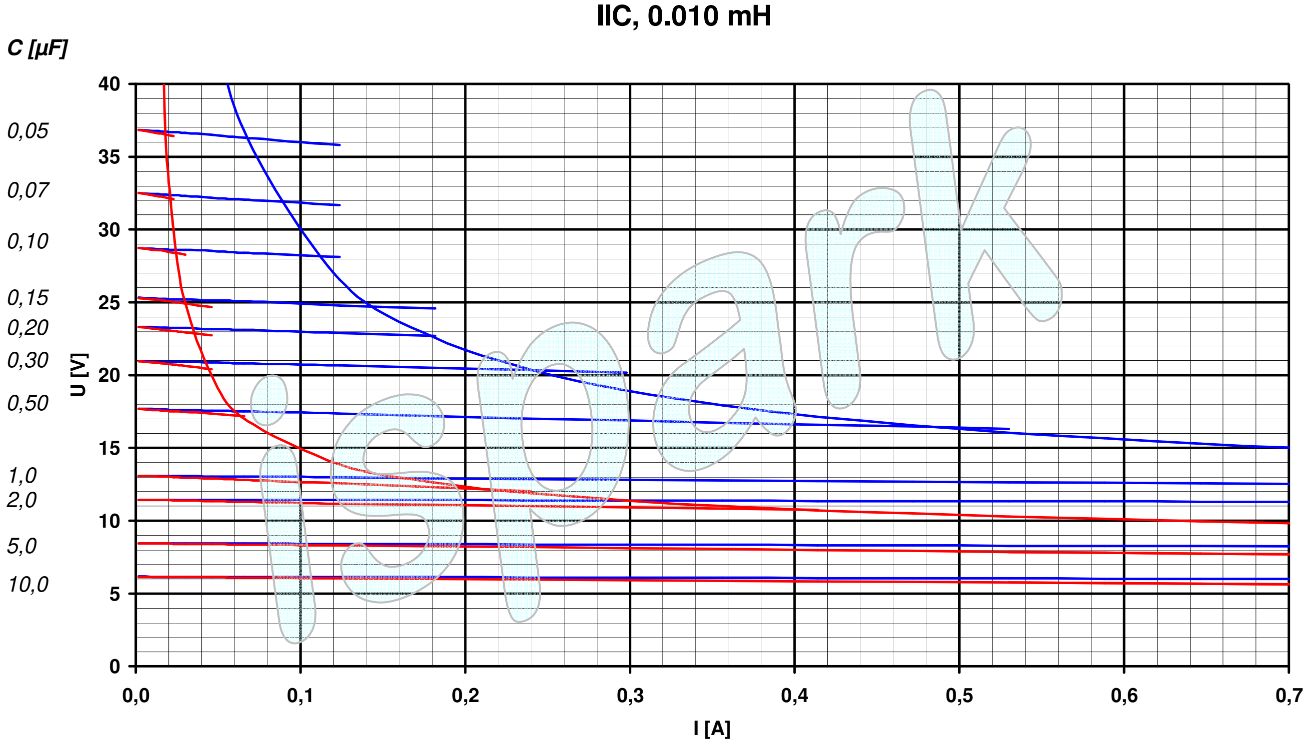
If currents are higher, the most essential spark is of type s/ö-2. Here the sources influence is not negligible at all; the slope is steeper with increasing current (blue lines). Reason is the longer duration of the spark, giving the source enough opportunity to contribute to ignition.

If voltages are relatively small, in principal big capacities are allowed. But in conjunction with inductances they build up a circuit which is able to transform capacitively stored energy to an inductive one as it's typical for sparks of type s/ö-1. In this area the sources' current often is of small influence and the peak current through capacitance and inductance will dominate. The green line therefore is rather flat.

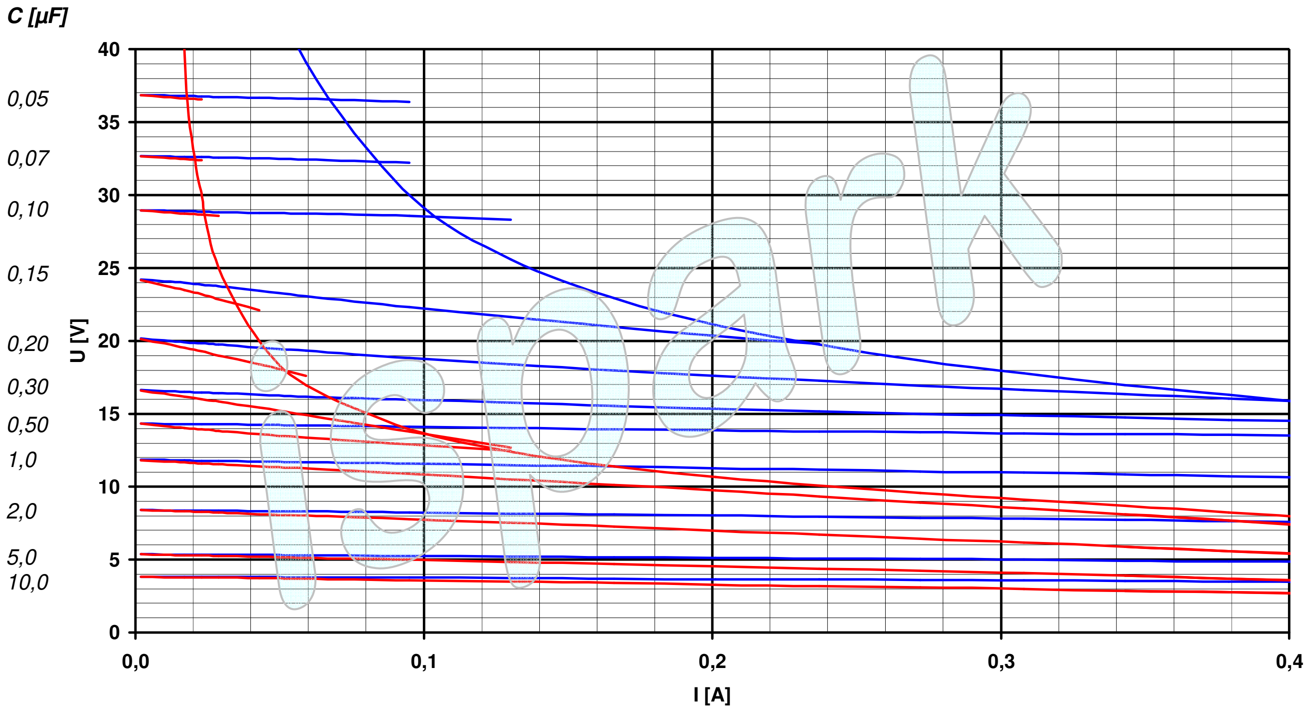
All these properties are more or less visible in all of the diagrams of ThEx-10.

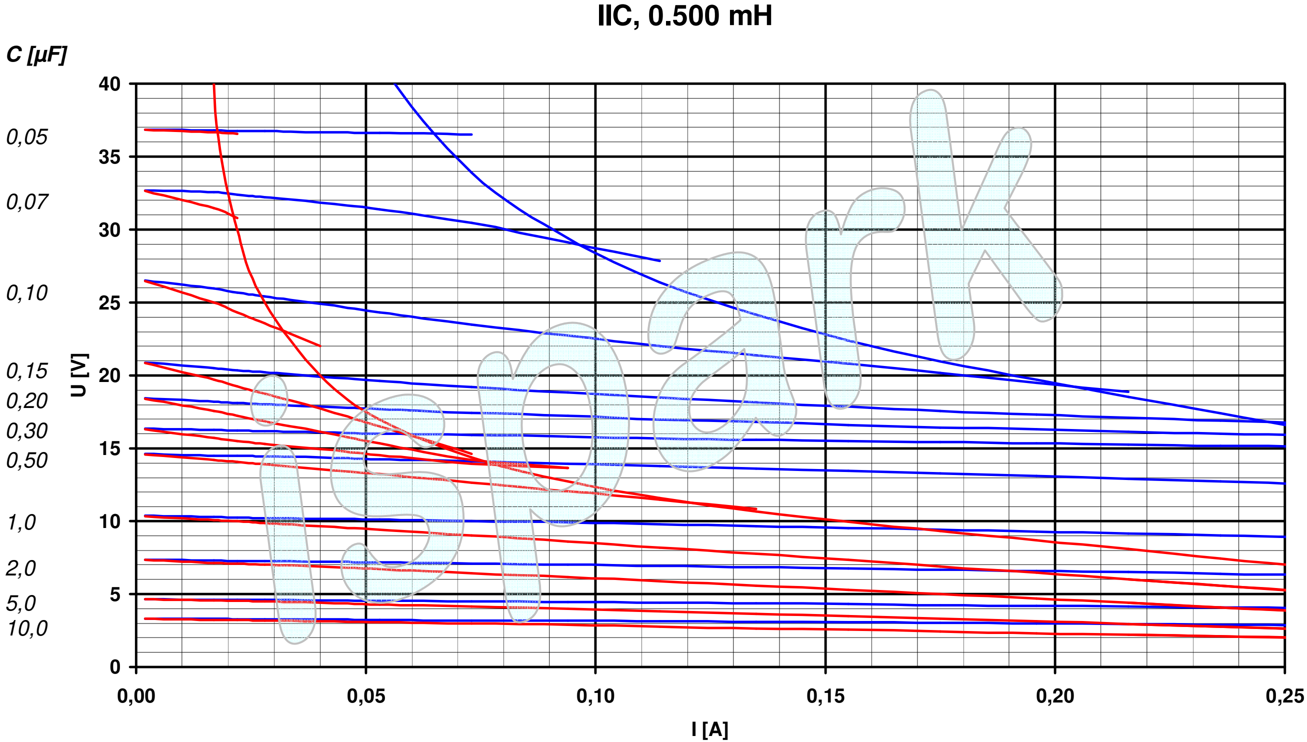

Grenzkurvendiagramm für lineare Quellenkennlinien
IIC; 0,15 mH
Uo[V]
Ik[mA]
30 nF
50 nF
70 nF
100 nF
150 nF
200 nF
300 nF
500 nF
1 uF
2 uF
5 uF
10 uF
0
5
10
15
20
25
30
35
40
45
50
0
100
200
300
400
500
600
700
s-0L
s/ö-2
s/ö-1
ö-0C-0L
ö-0C
ISPRK_16.PPT

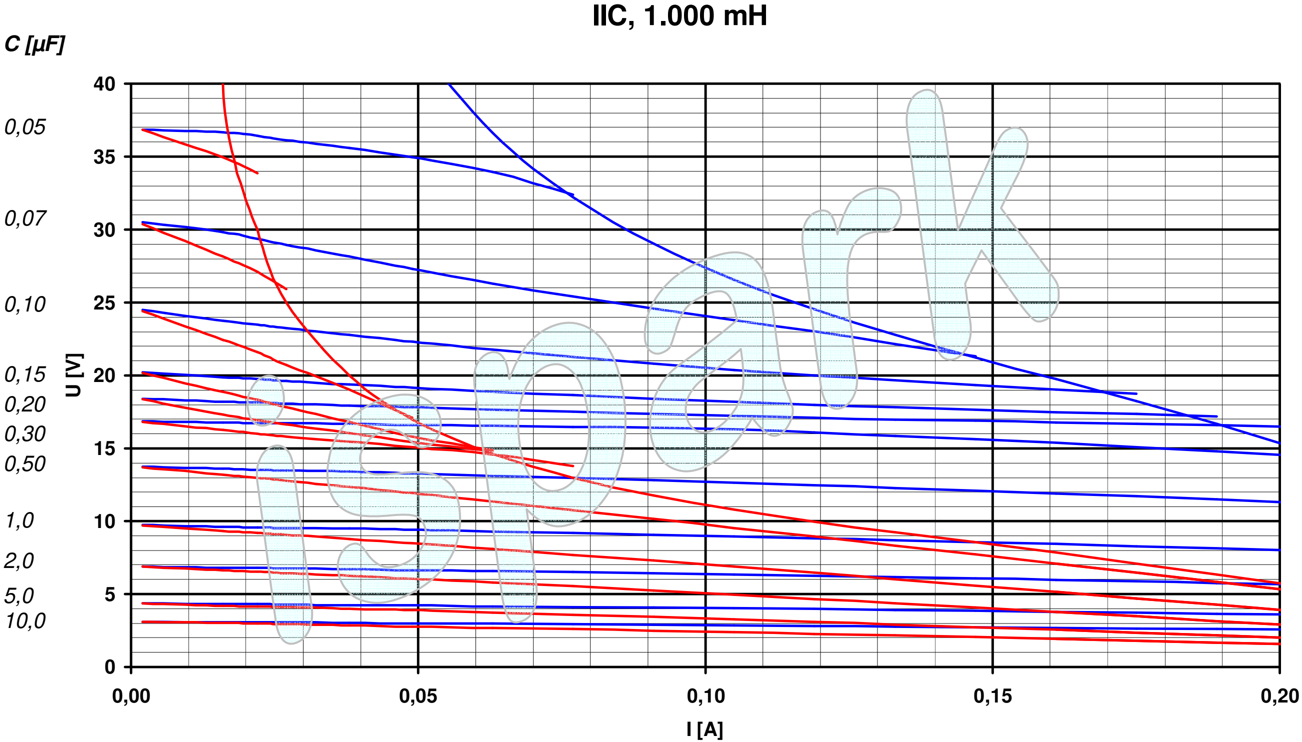
Diagrams

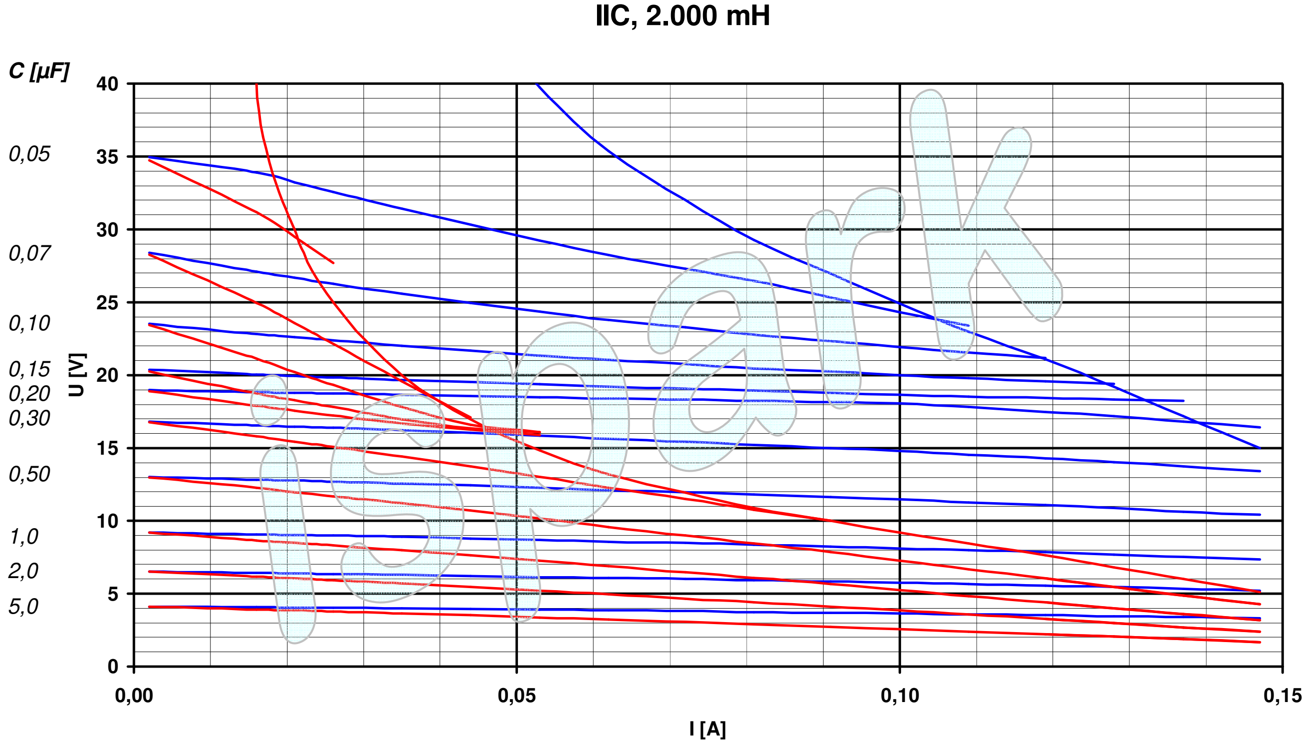

IIC, 0.010 mH
C [µF]
0,05
0,07
0,10
0,15
0,20
0,30
0,50
1,0
2,0
5,0
10,0
40
35
30
25
20
15
10
5
0
U [V]
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
I [A]
ispark

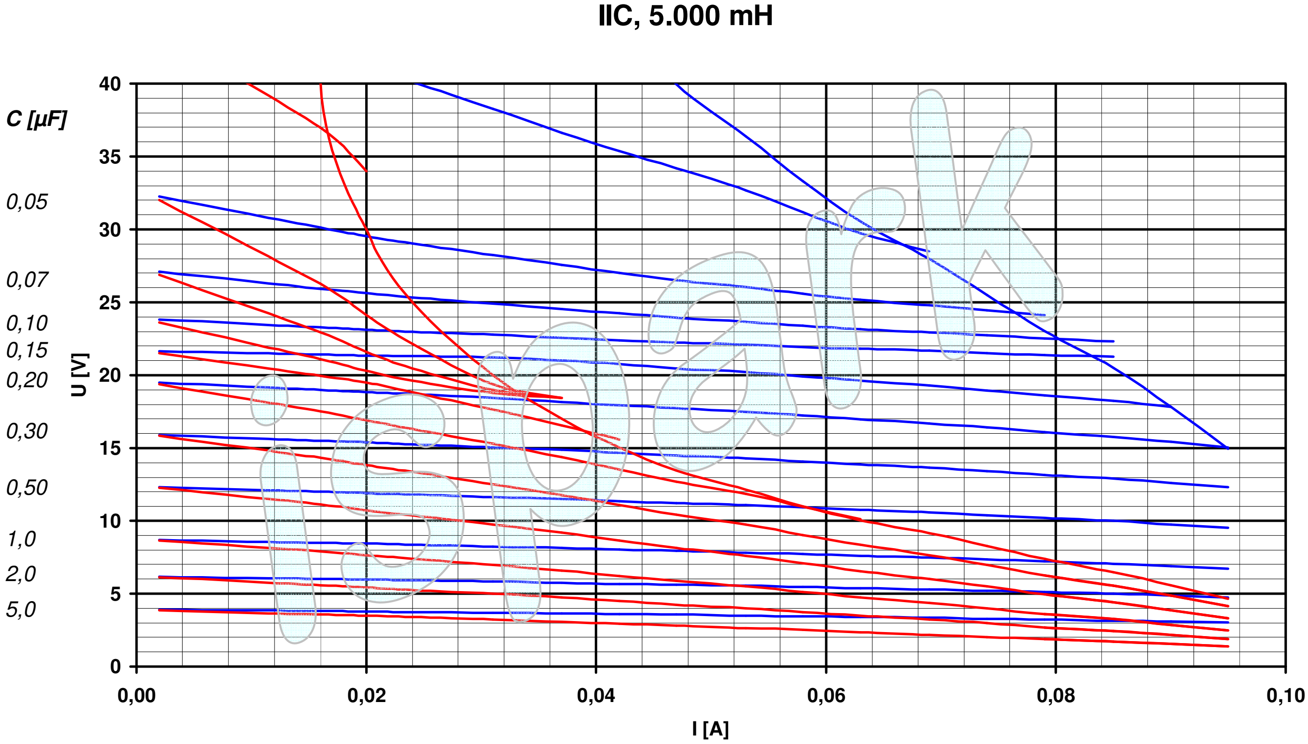
IIC, 0.150 mH

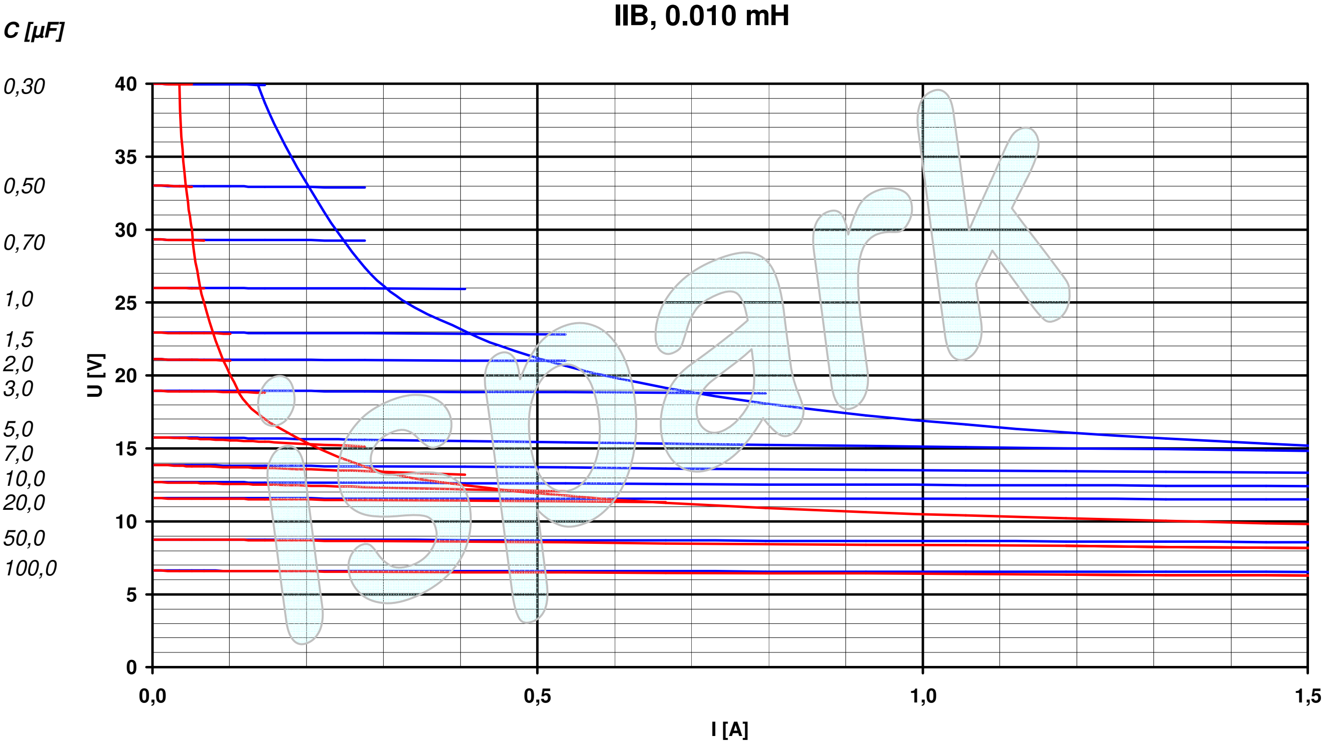

C [µF]
0,05
0,07
0,10
0,15
0,20
0,30
0,50
1,0
2,0
5,0
10,0
40
35
30
25
20
15
10
5
0
U [V]
0,0
0,1
0,2
0,3
0,4
I [A]
ispark

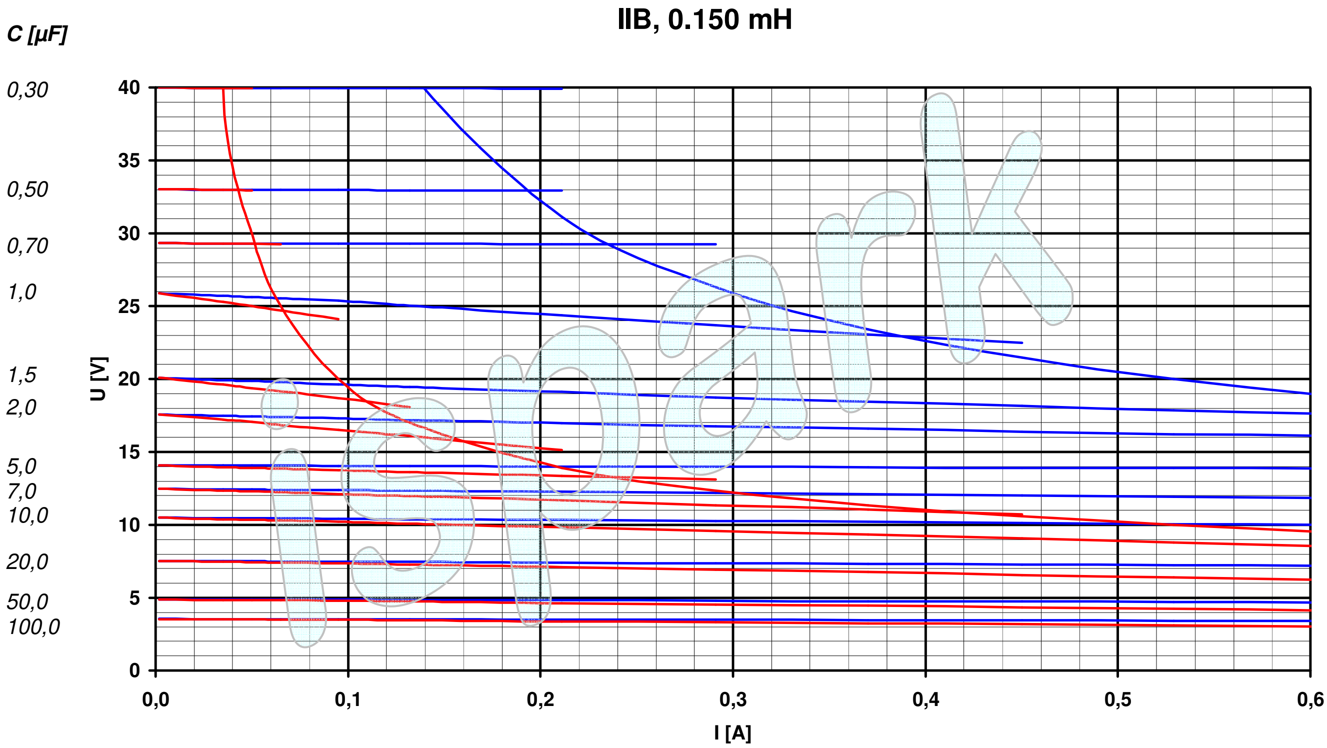

IIC, 0.500 mH
C [µF]
0,05
0,07
0,10
0,15
0,20
0,30
0,50
1,0
2,0
5,0
10,0
U [V]
40
35
30
25
20
15
10
5
0
0,00
0,05
0,10
0,15
0,20
0,25
I [A]
isprk

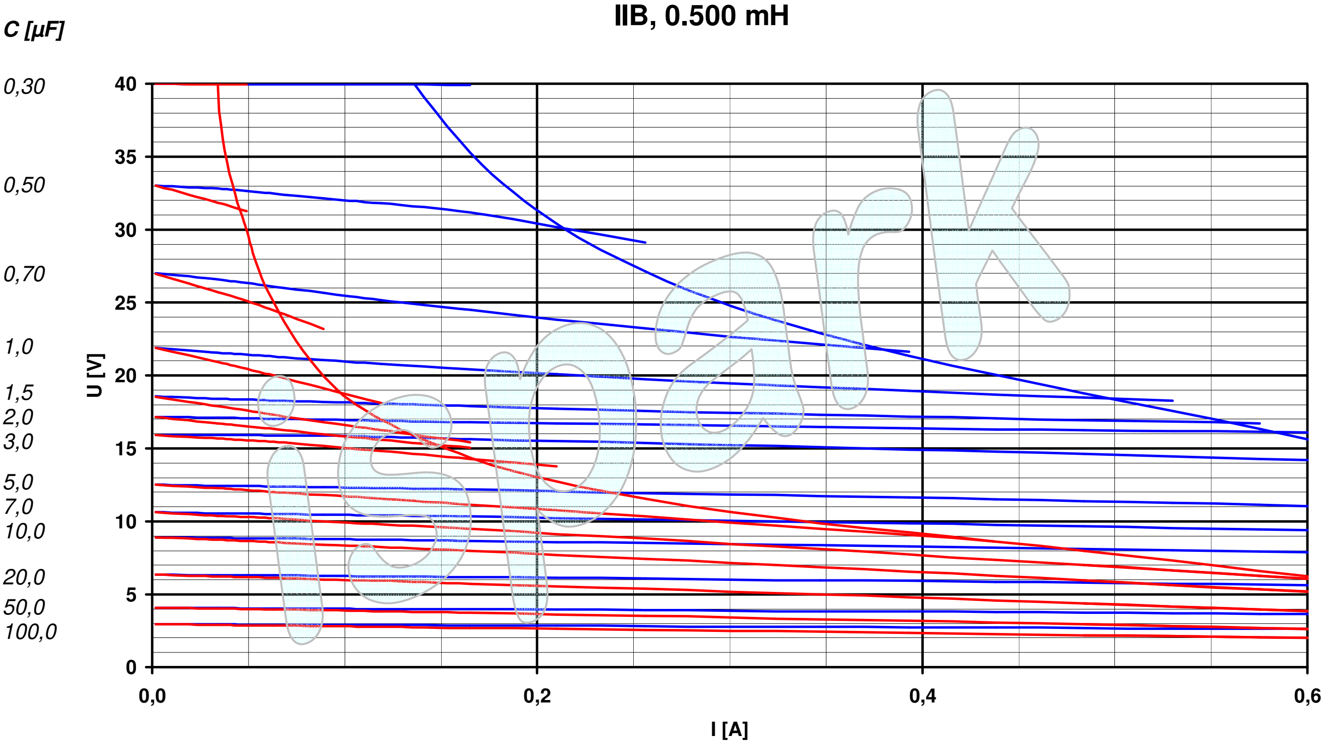

IIC, 1.000 mH
C [µF]
0,05
0,07
0,10
0,15
0,20
0,30
0,50
1,0
2,0
5,0
10,0
U [V]
40
35
30
25
20
15
10
5
0
0,00
0,05
0,10
0,15
0,20
I [A]
ispark


IIC, 2.000 mH
C [µF]
0,05
0,07
0,10
0,15
0,20
0,30
0,50
1,0
2,0
5,0
U [V]
0
5
10
15
20
25
30
35
40
0,00
0,05
0,10
0,15
I [A]
ispark

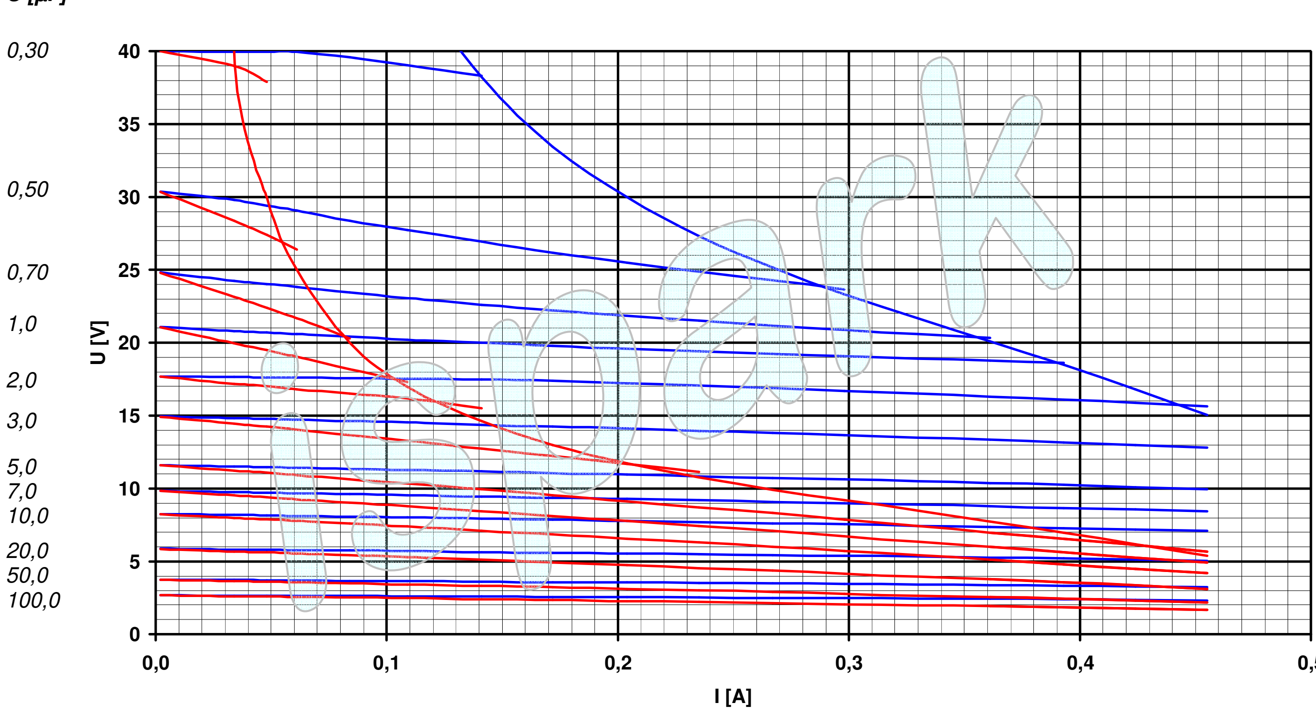

IIC, 5.000 mH
C [µF]
0,05
0,07
0,10
0,15
0,20
0,30
0,50
1,0
2,0
5,0
U [V]
40
35
30
25
20
15
10
5
0
0,00
0,02
0,04
0,06
0,08
0,10
I [A]
ispark

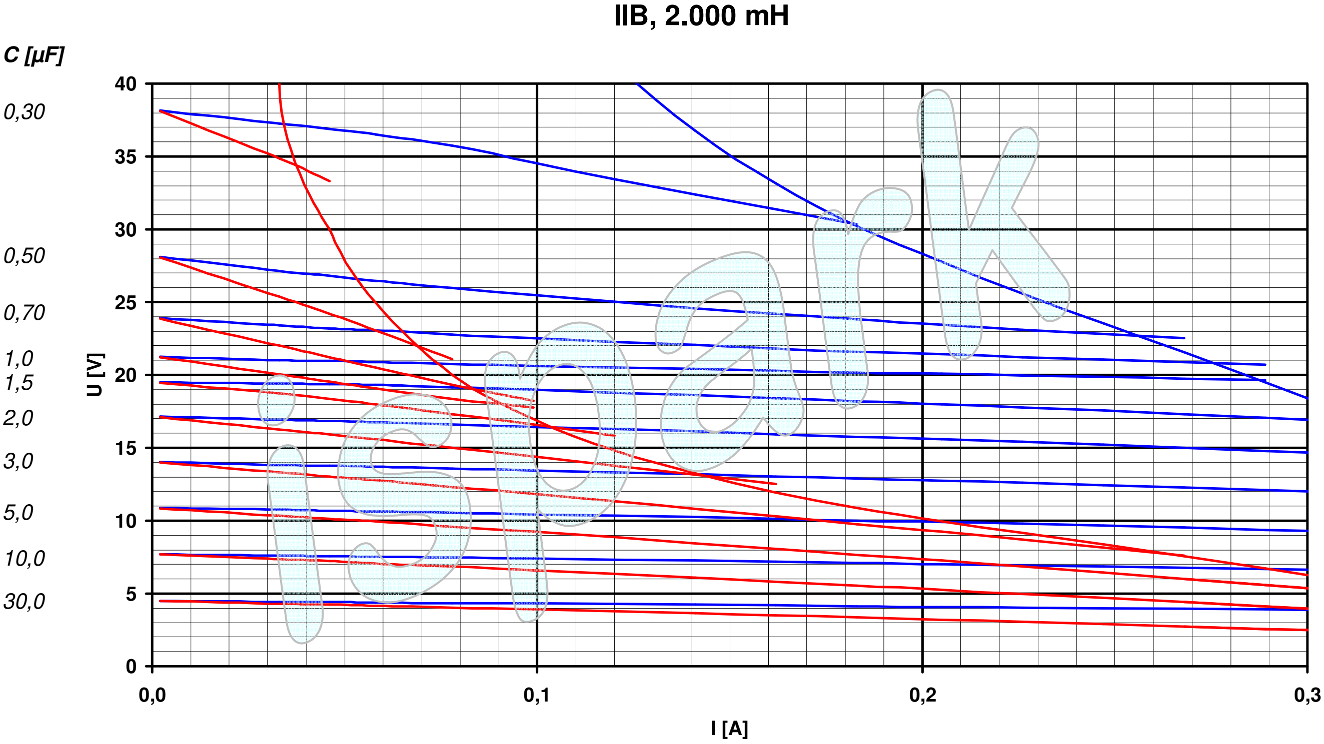

IIB, 0.010 mH
C [µF]
0,30
0,50
0,70
1,0
1,5
2,0
3,0
5,0
7,0
10,0
20,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,5
1,0
1,5
I [A]
ispark


IIB, 0.150 mH
C [µF]
0,30
0,50
0,70
1,0
1,5
2,0
5,0
7,0
10,0
20,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,1
0,2
0,3
0,4
0,5
0,6
I [A]
ispark

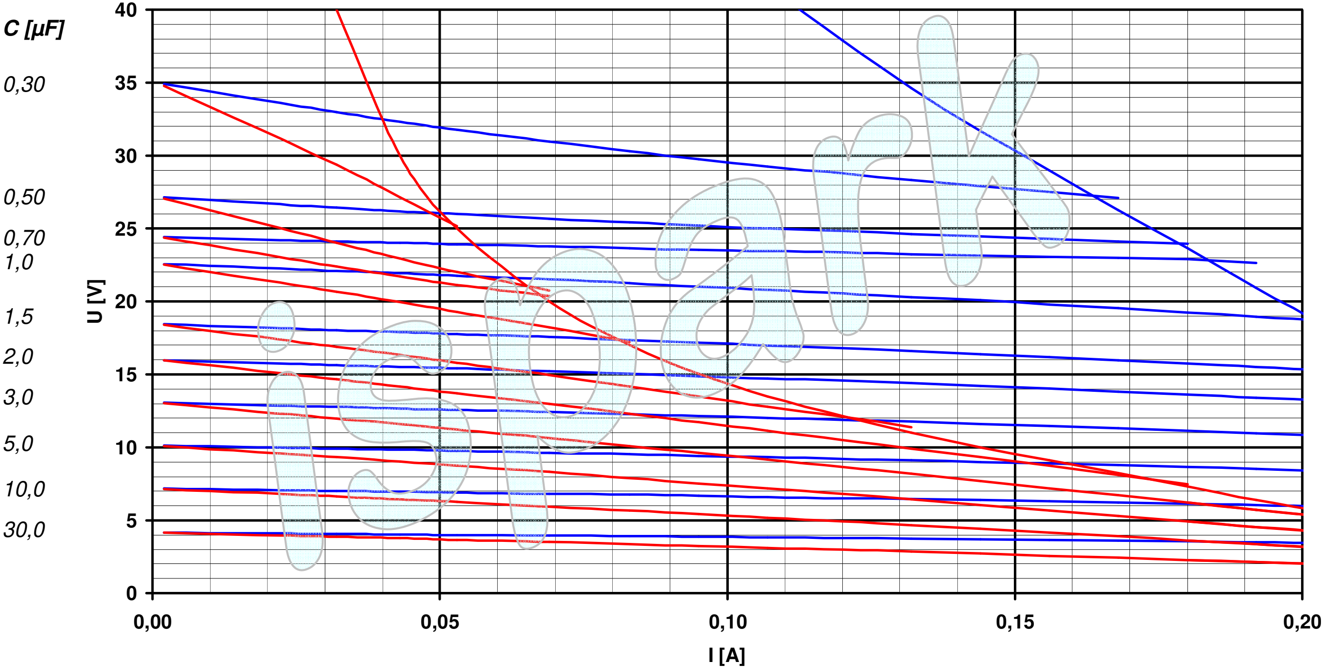

IIB, 0.500 mH
C [µF]
0,30
0,50
0,70
1,0
1,5
2,0
3,0
5,0
7,0
10,0
20,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,2
0,4
0,6
I [A]
ispark

IIB, 1.000 mH

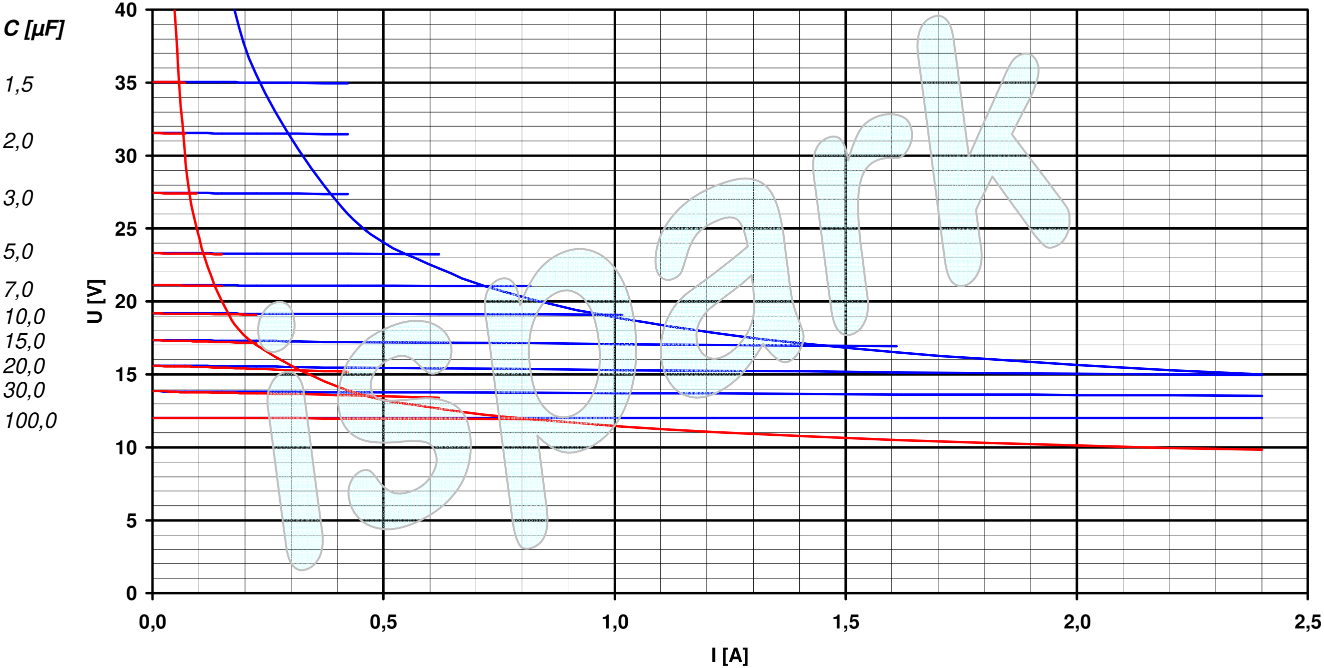

C [µF]
0,30
0,50
0,70
1,0
2,0
3,0
5,0
7,0
10,0
20,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,1
0,2
0,3
0,4
0,5
I [A]
ispark

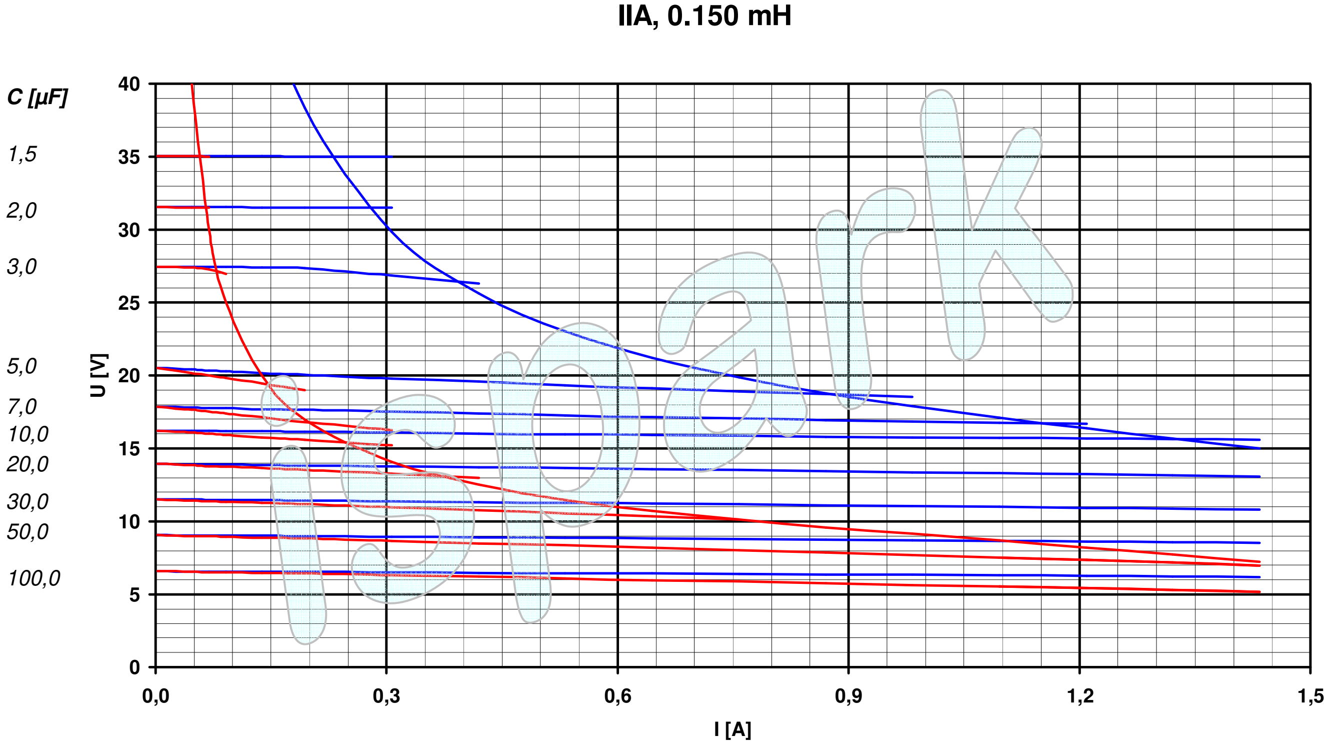

IIB, 2.000 mH
C [µF]
0,30
0,50
0,70
1,0
1,5
2,0
3,0
5,0
10,0
30,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,1
0,2
0,3
I [A]
ispark

IIB, 5.000 mH

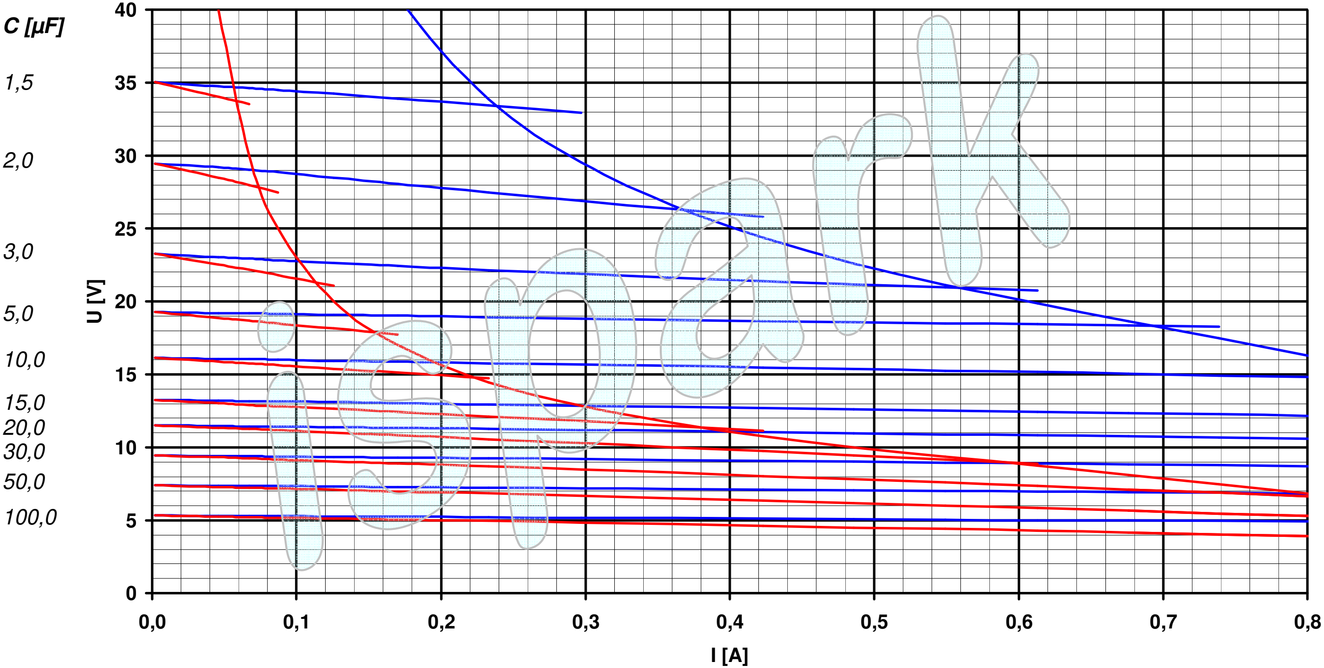

C [µF]
0,30
0,50
0,70
1,0
1,5
2,0
3,0
5,0
10,0
30,0
U [V]
40
35
30
25
20
15
10
5
0
0,00
0,05
0,10
0,15
0,20
I [A]
ispark

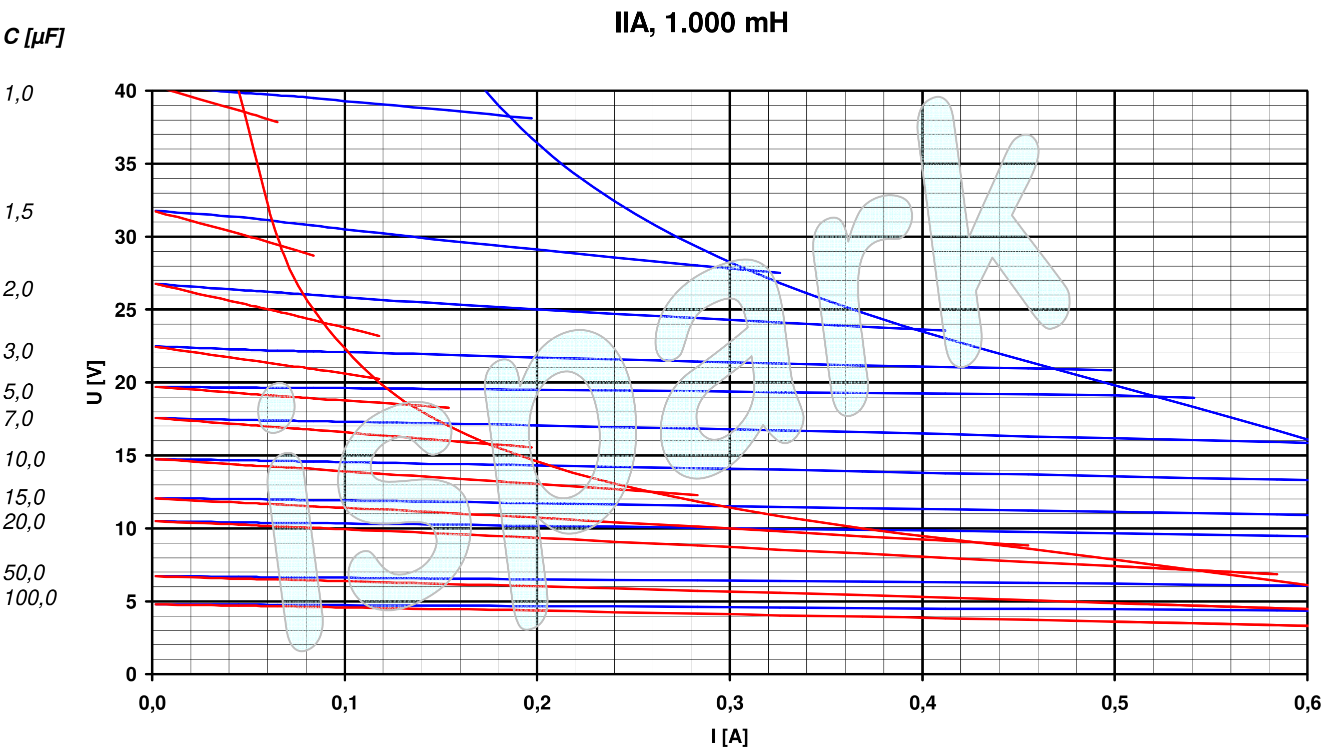
IIA, 0.010 mH

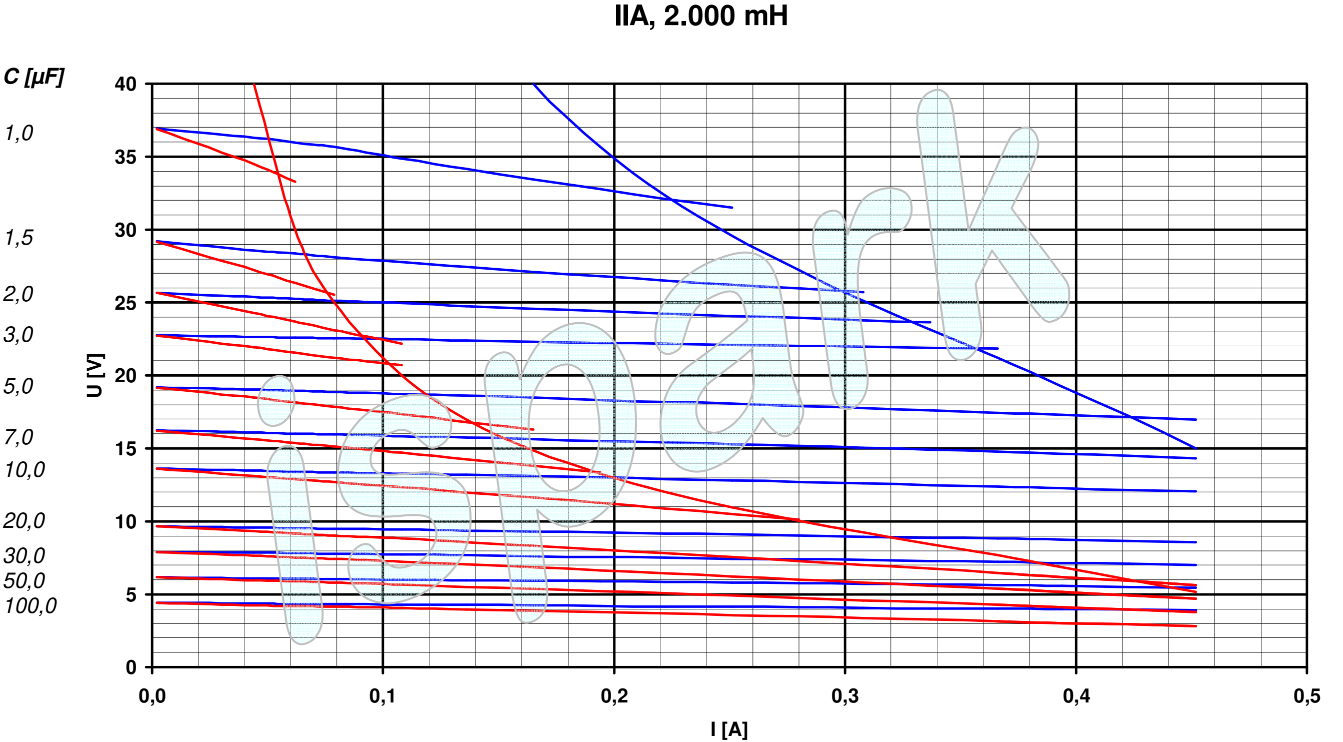

C [µF]
1,5
2,0
3,0
5,0
7,0
10,0
15,0
20,0
30,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,5
1,0
1,5
2,0
2,5
I [A]
ispark


IIA, 0.150 mH
C [µF]
1,5
2,0
3,0
5,0
7,0
10,0
20,0
30,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,3
0,6
0,9
1,2
1,5
I [A]
ispark

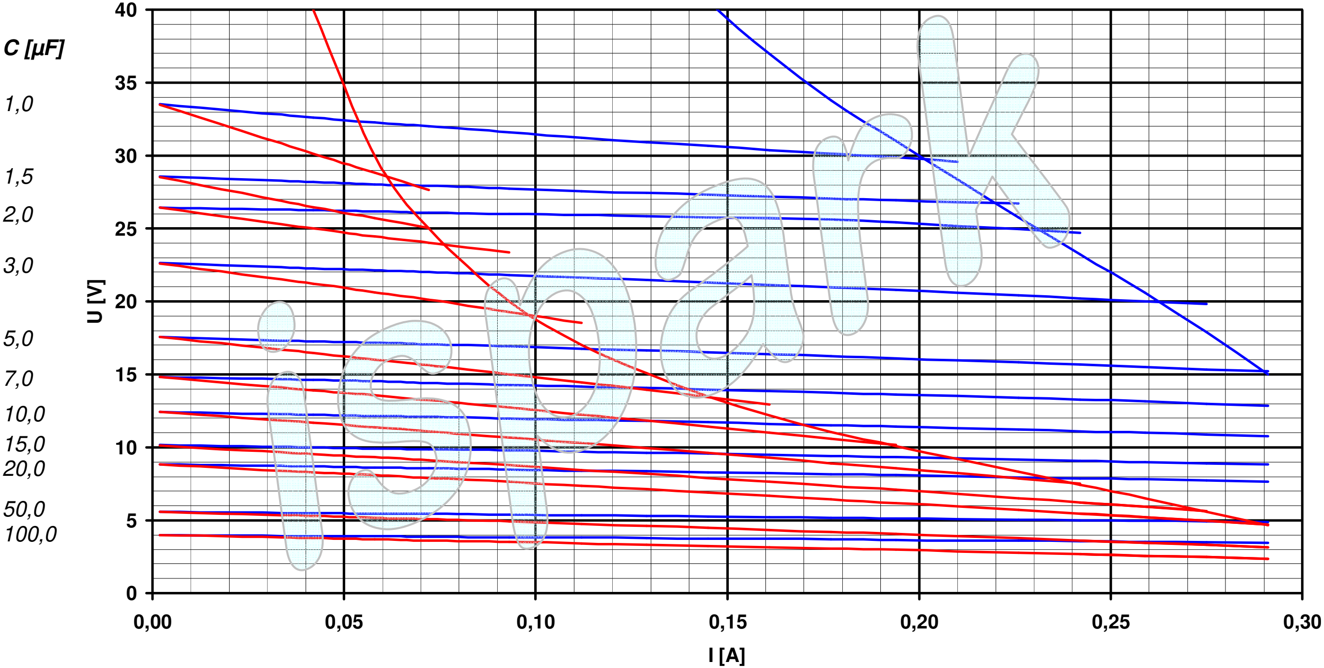
IIA, 0.500 mH

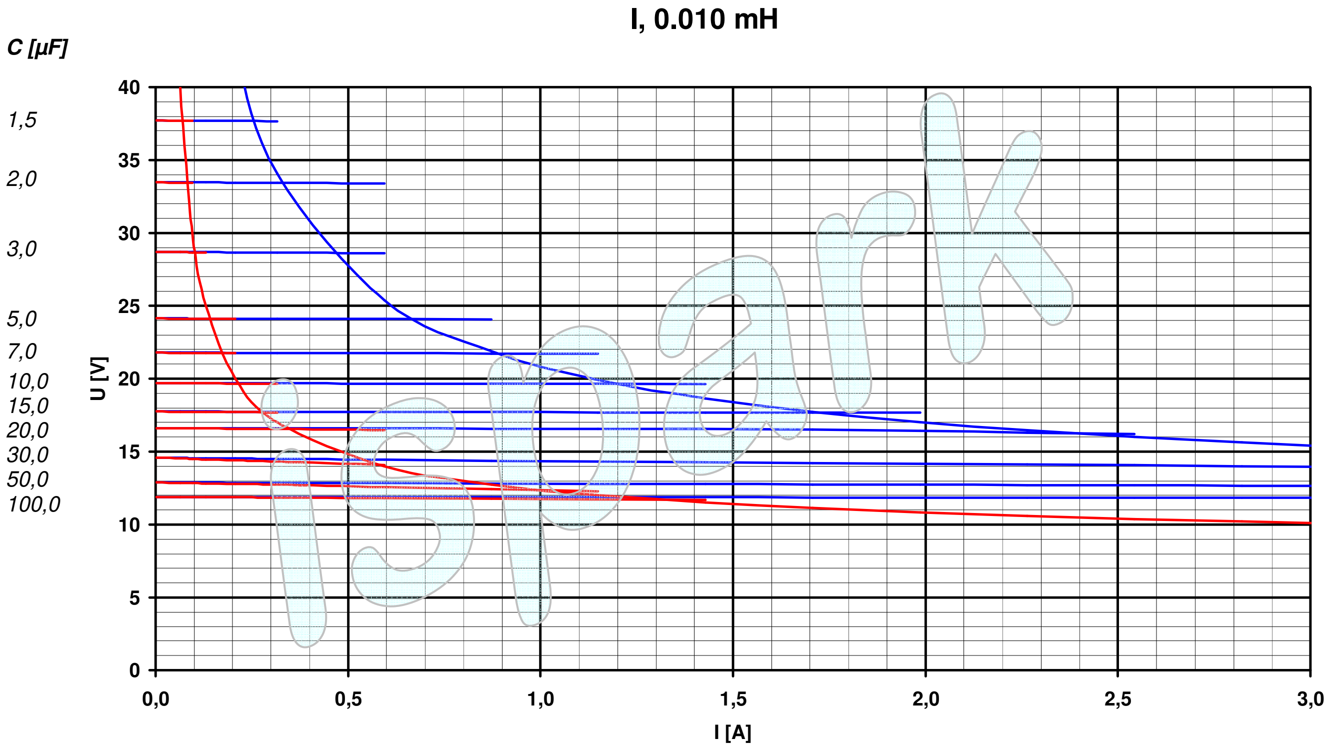

C [µF]
1,5
2,0
3,0
5,0
10,0
15,0
20,0
30,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
I [A]
ispark


IIA, 1.000 mH
C [µF]
1,0
1,5
2,0
3,0
5,0
7,0
10,0
15,0
20,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,1
0,2
0,3
0,4
0,5
0,6
I [A]
ispark

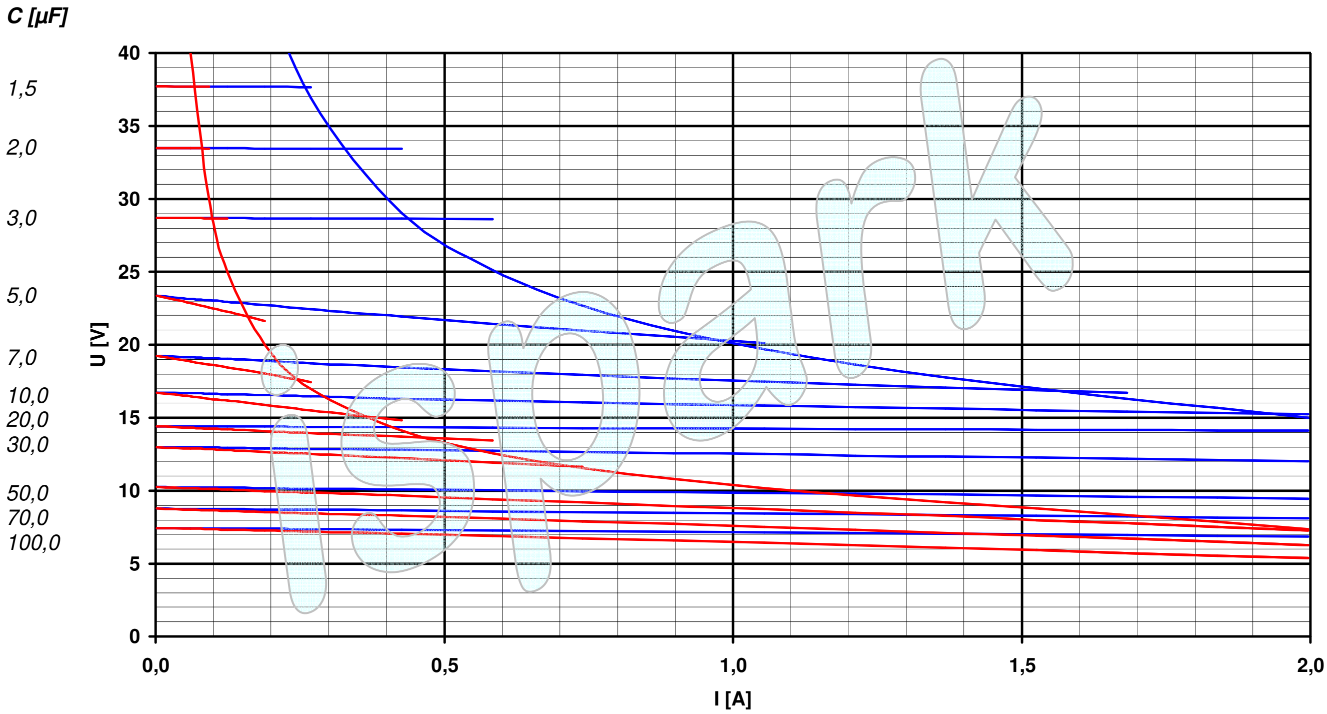

IIA, 2.000 mH
C [µF]
1,0
1,5
2,0
3,0
5,0
7,0
10,0
20,0
30,0
50,0
100,0
U [V]
0
5
10
15
20
25
30
35
40
0,0
0,1
0,2
0,3
0,4
0,5
I [A]
isprk

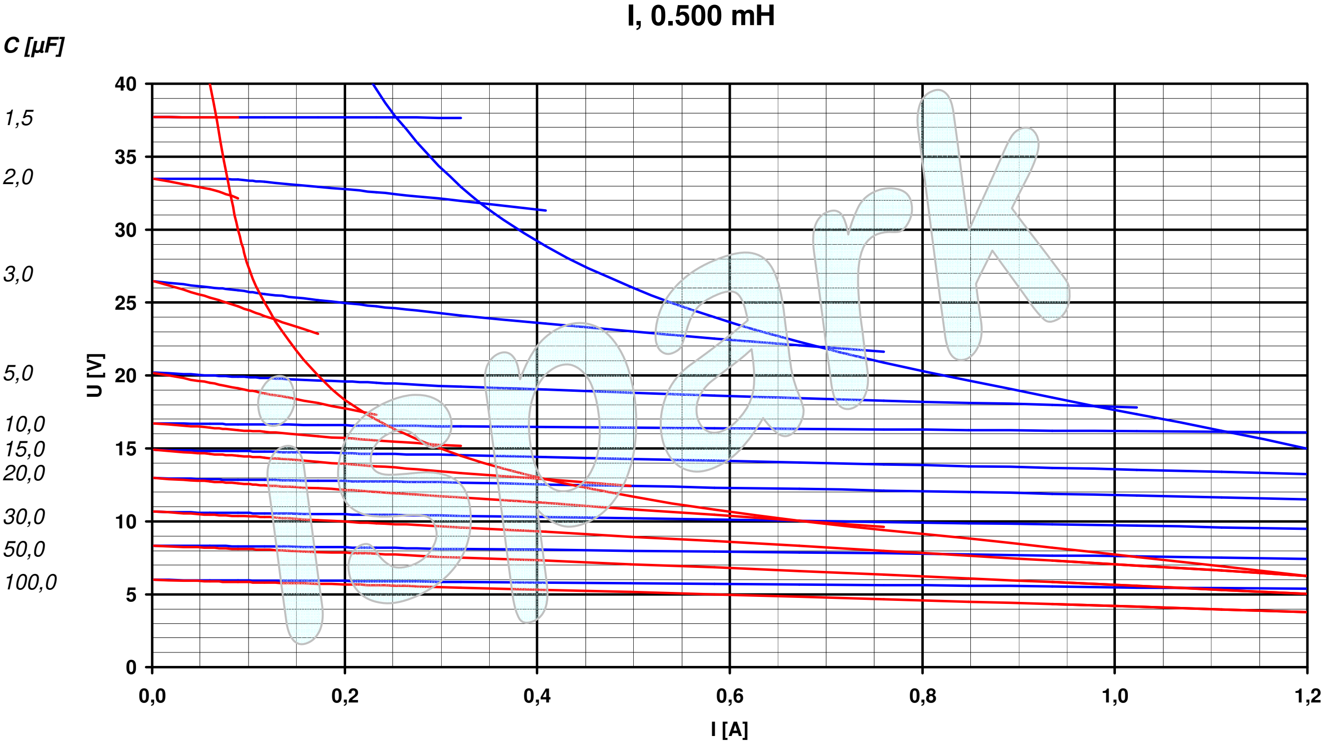
IIA, 5.000 mH


C [µF]
1,0
1,5
2,0
3,0
5,0
7,0
10,0
15,0
20,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,00
0,05
0,10
0,15
0,20
0,25
0,30
I [A]
ispark


I, 0.010 mH
C [µF]
1,5
2,0
3,0
5,0
7,0
10,0
15,0
20,0
30,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
I [A]

I, 0.150 mH


C [µF]
1,5
2,0
3,0
5,0
7,0
10,0
20,0
30,0
50,0
70,0
100,0
U [V]
0
5
10
15
20
25
30
35
40
0,0
0,5
1,0
1,5
2,0
I [A]
ispark


I, 0.500 mH
C [µF]
1,5
2,0
3,0
5,0
10,0
15,0
20,0
30,0
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100,0
U [V]
40
35
30
25
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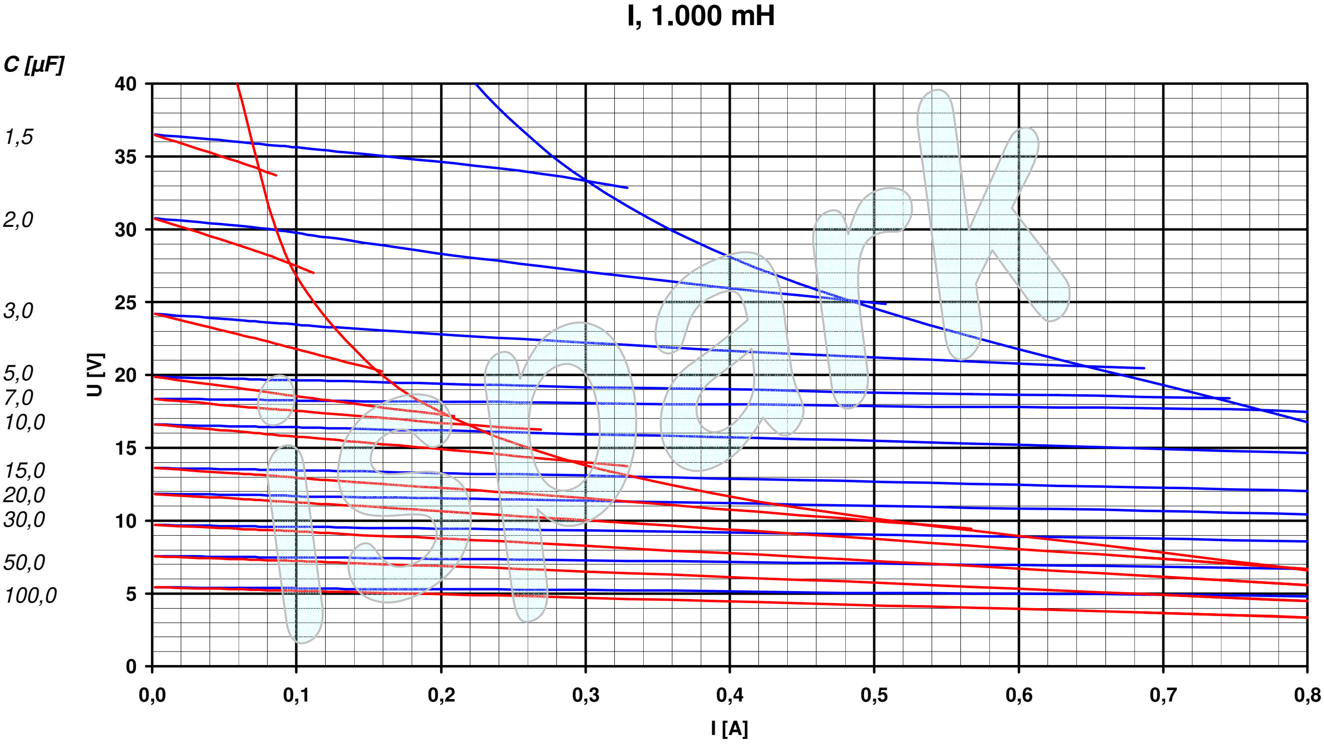
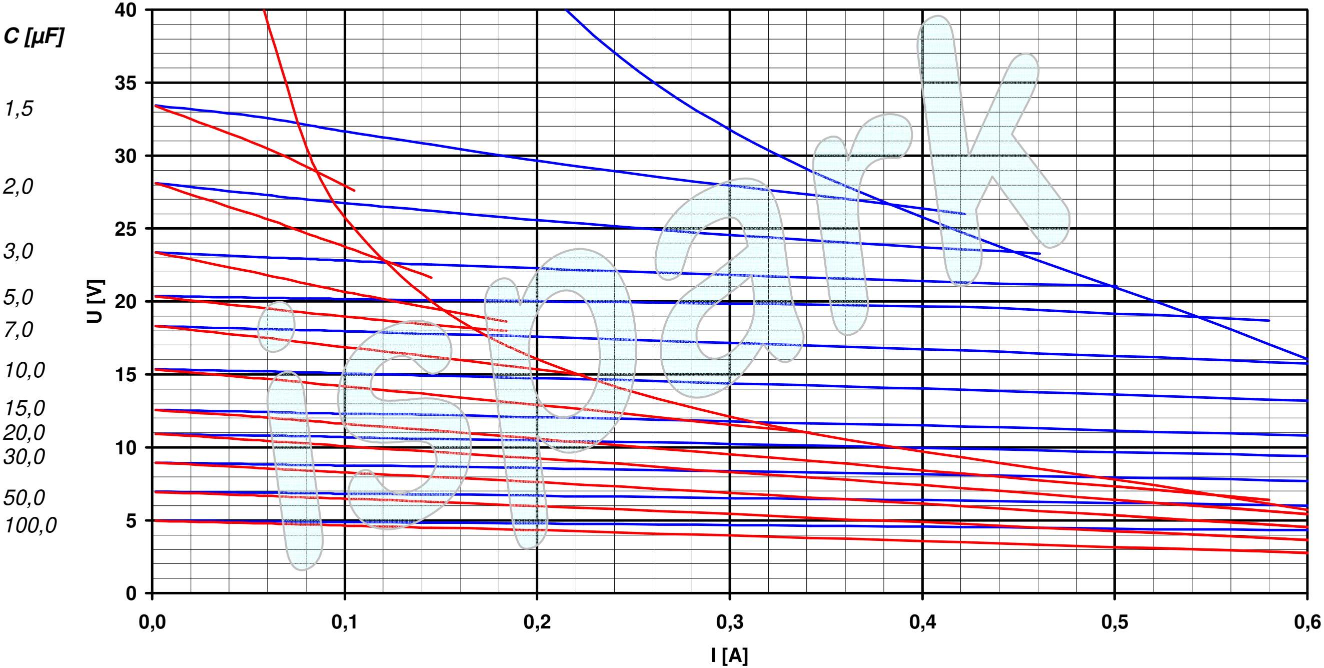
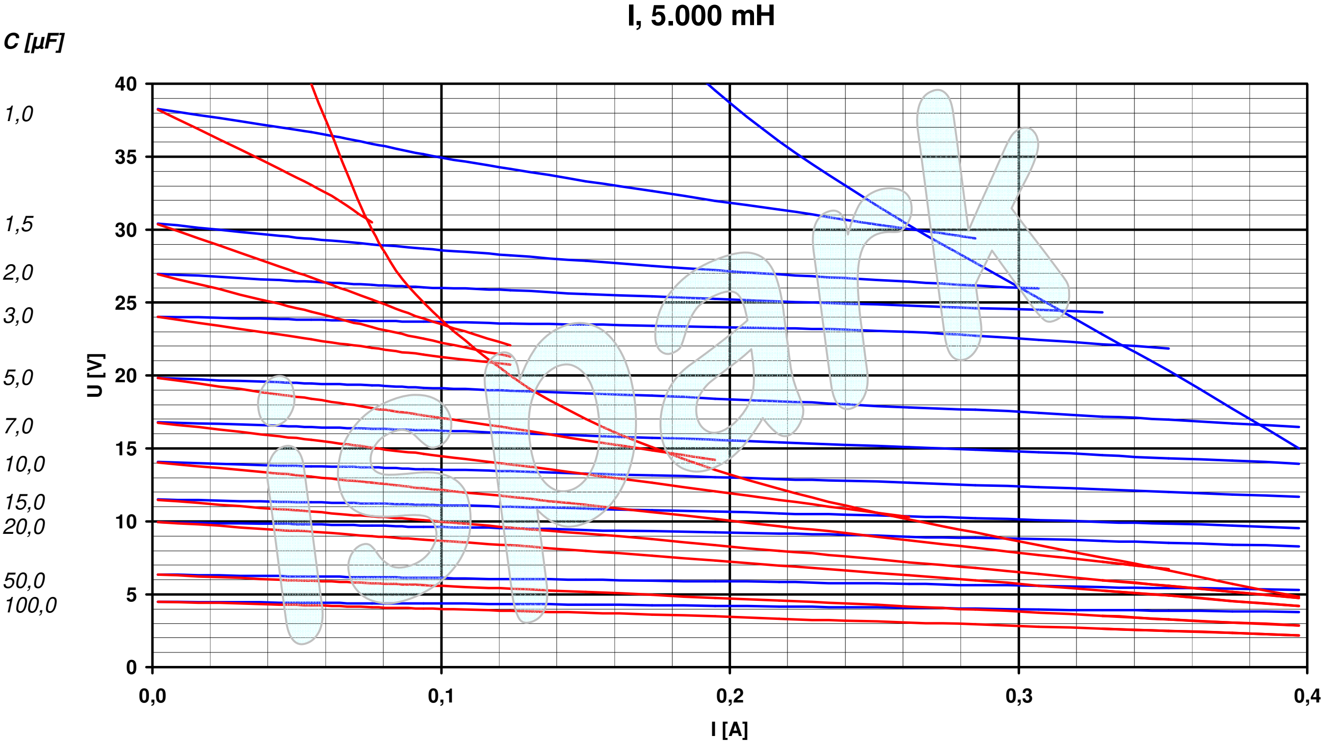
1,2
I [A]
ispark



I, 1.000 mH
C [µF]
1,5
2,0
3,0
5,0
7,0
10,0
15,0
20,0
30,0
50,0
100,0
U [V]
0
5
10
15
20
25
30
35
40
I [A]
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
ispark

I, 2.000 mH


C [µF]
1,5
2,0
3,0
5,0
7,0
10,0
15,0
20,0
30,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,1
0,2
0,3
0,4
0,5
0,6
I [A]
ispark


I, 5.000 mH
C [µF]
1,0
1,5
2,0
3,0
5,0
7,0
10,0
15,0
20,0
50,0
100,0
U [V]
40
35
30
25
20
15
10
5
0
0,0
0,1
0,2
0,3
0,4
I [A]
ispark

Annex isparks with high currents

Preliminary

Sometimes there are questions about the situation with higher short circuit currents (I_o) than the number of 5 A, isparks normally evaluates at maximum like IEC does.

In principal, isparks's mathematical procedures aren't restricted to this number at all. But available experimental data are rare and parasitic properties of the standardized spark test apparatus (STA) can shift into the foreground.

Therefore, developers and testers have to decide whether or not an assessment has to take into account spark test apparatus' internal inductance (which may by upto 3 µH), despite there may be a much smaller value present within the application really.

In the following, simply isparks's calculatory results are presented, users may decide to include STA's inductance or not.

Diagrams' background

Contrary to the original presentation of ThEx-10 above, source's short circuit current I_o is of minor influence on C_o when voltages are low. As a result, it's no real shortcoming to pick up for C_o the value only, which permissible in combination with the absolute maximum L_o as a worst case. Doing so, for each gasgroup only two diagrams are necessary while ThEx-10 needs one for every gasgroup and each inductance.

Please notice, that linear sources are presented here only and target safety factor is 1.5 according to IEC, EPL ib.

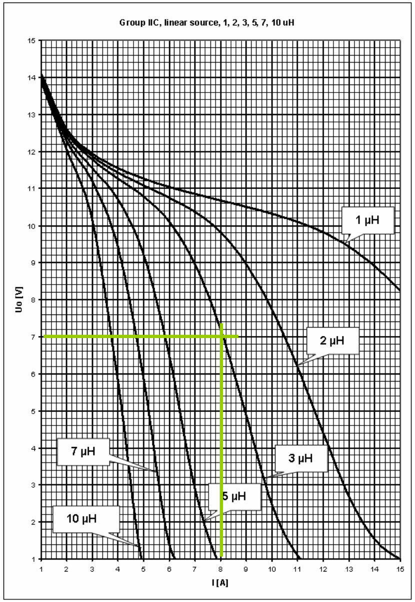
Precautions

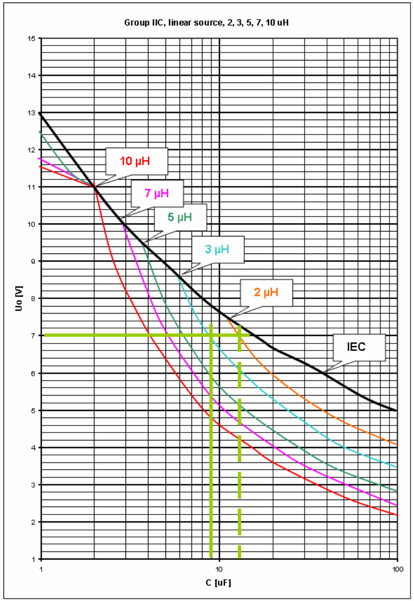
Please be aware, that such high currents will rise further hazards than spark ignition only. Available power is substantial and current density possibly is very high.

Assessment, course of run

The diagrams on the left present the relation of U_o and I_o with a permissible inductance L_o and, keeping in mind U_o and L_o, the diagram on the left leads to an associated permissible C_o (fat black line indicates limits of IEC).

Example:

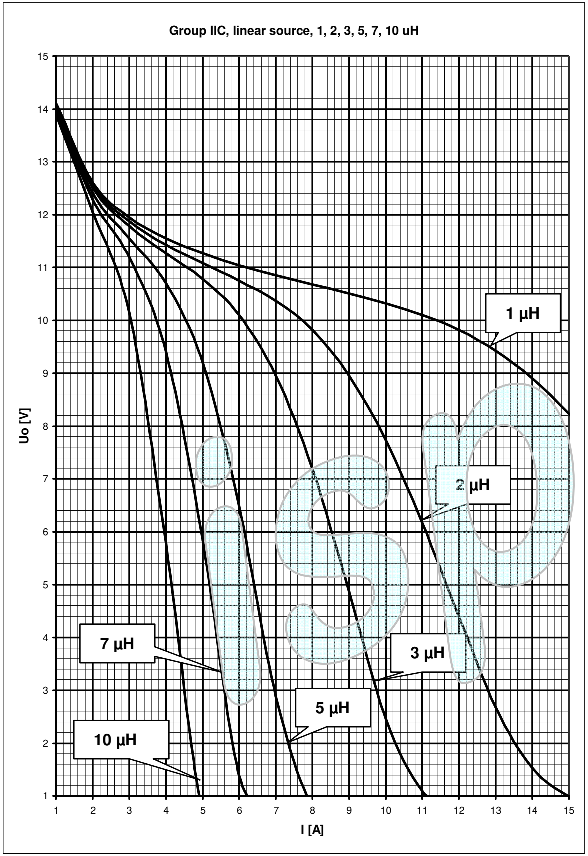


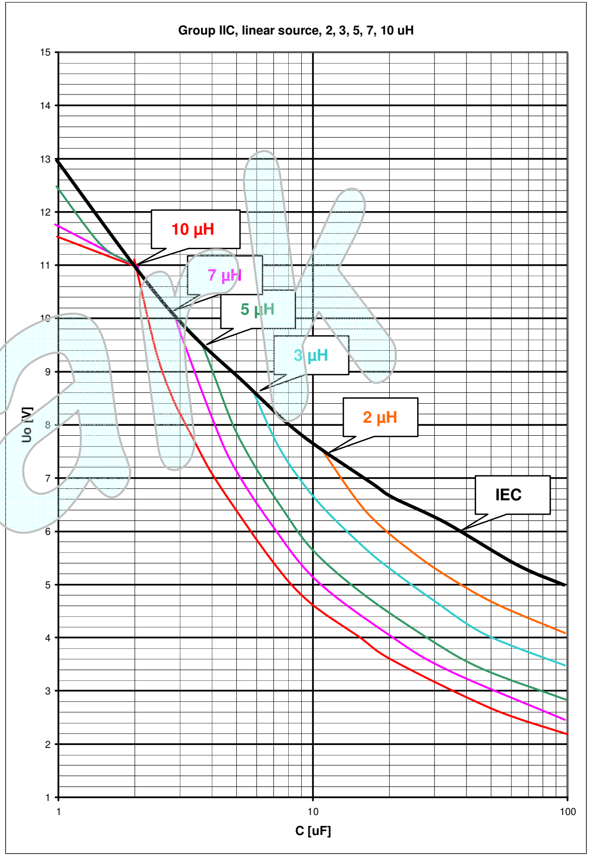


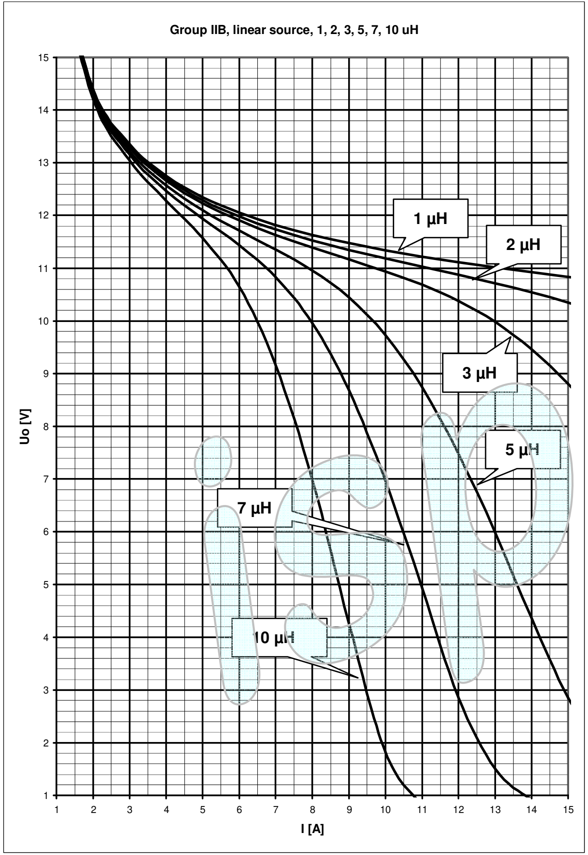
A linear source with U_o = 7 V and I_o = 8 A does allow, according to the diagram on the left, an inductance L_o of 3 µH at maximum.

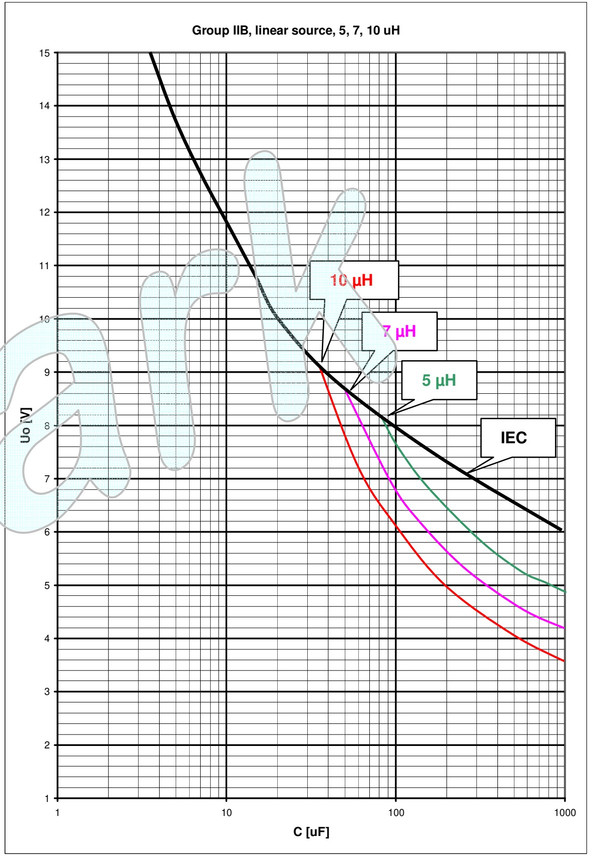
Associated is a C_o of about 9 µF.

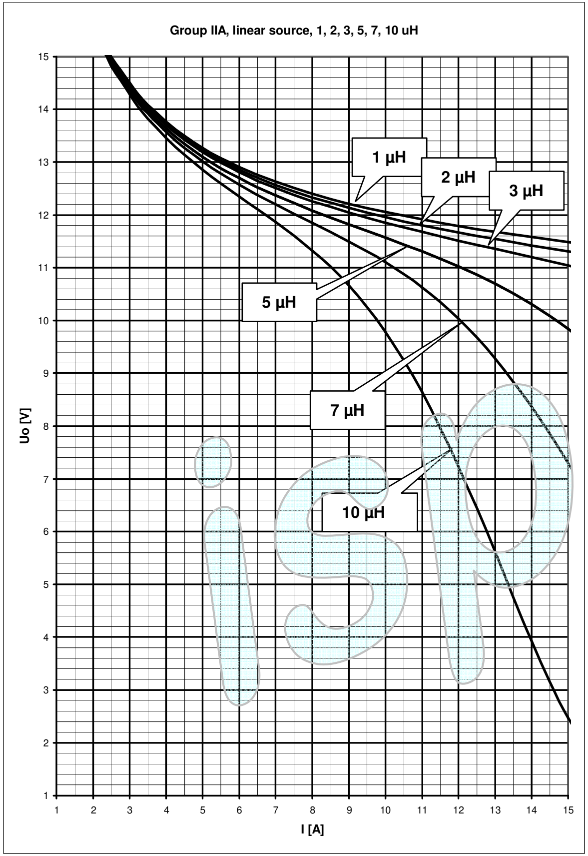
If the L_o limit isn't exhausted fully, but, for example, choosen to be 2 µH only, C_o is limited to about 13 µF (instead of 9 µF as above).

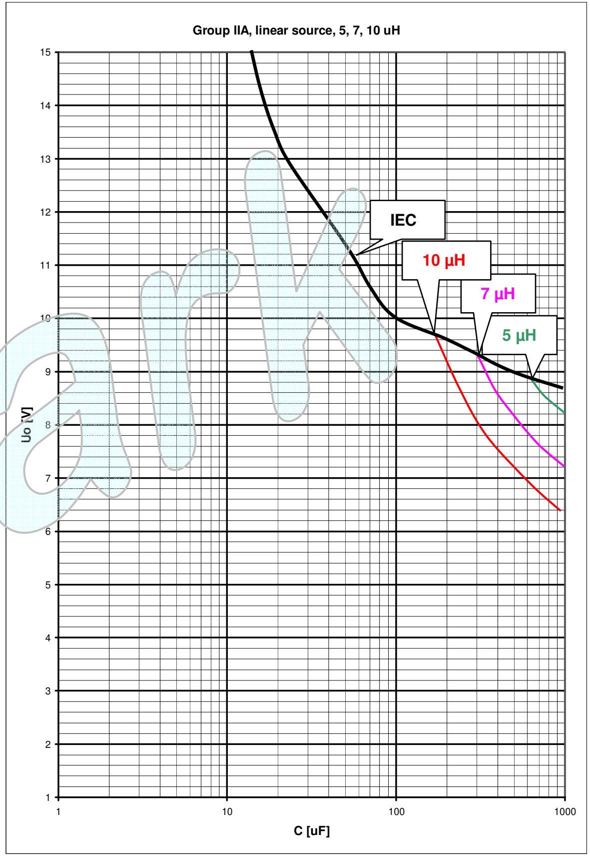

Group IIC, linear source, 1, 2, 3, 5, 7, 10 uH
Uo [V]
I [A]
1 µH
2 µH
3 µH
5 µH
7 µH
10 µH

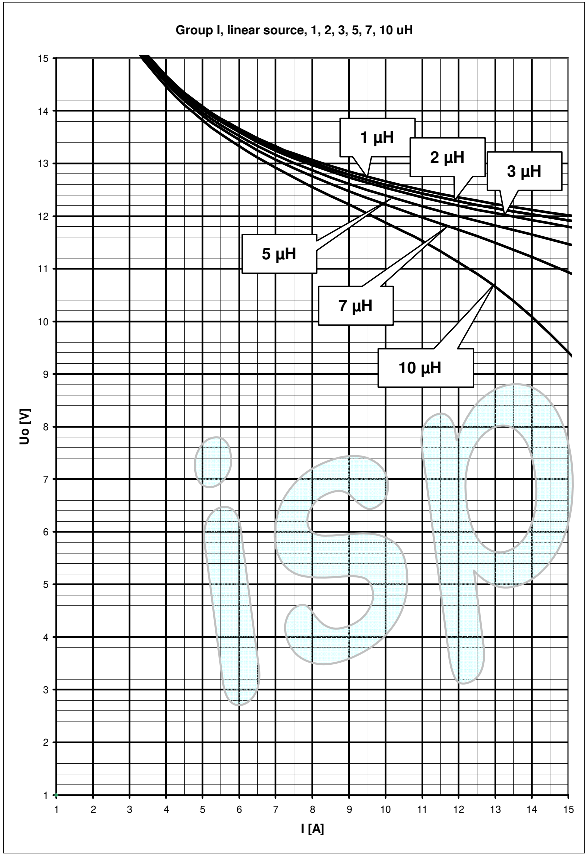

Group IIC, linear source, 2, 3, 5, 7, 10 uH
Uo [V]
C [uF]
10 µH
7 µH
5 µH
3 µH
2 µH
IEC

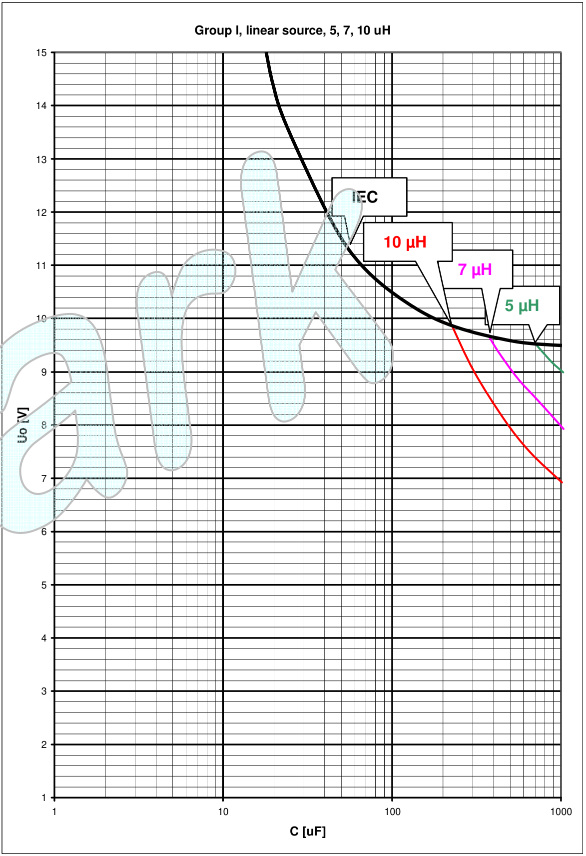

Group IIB, linear source, 1, 2, 3, 5, 7, 10 uH
Uo [V]
I [A]
1 µH
2 µH
3 µH
5 µH
7 µH
10 µH


Group IIB, linear source, 5, 7, 10 uH
Uo [V]
C [uF]
10 µH
7 µH
5 µH
IEC


Group IIA, linear source, 1, 2, 3, 5, 7, 10 uH
1 µH
2 µH
3 µH
5 µH
7 µH
10 µH
Uo [V]
I [A]


Group IIA, linear source, 5, 7, 10 uH
IEC
10 µH
7 µH
5 µH
Uo [V]
C [uF]


Group I, linear source, 1, 2, 3, 5, 7, 10 uH
1 µH
2 µH
3 µH
5 µH
7 µH
10 µH
Uo [V]
I [A]
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


Group I, linear source, 5, 7, 10 uH
IEC
10 µH
7 µH
5 µH
Uo [V]
C [uF]
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1
10
100
1000

Conclusion

Interaction of inductance and capacitance in principal can have an aggravating effect and standard's method to consider both but separately may fail.

Within the data area considered here however, inductances equal or smaller than 3 µH and with gasgroups I, IIA and IIB do not require to lower one's sights below capacitive limits presented in IEC (IEC_{cap}). For voltages above 10 V, this is true also upto 10 µH.

For gasgroup IIC however, an inductance of 2 µH already does degrade permissible capacitances below IEC_{cap} values.