

# *ispark* operating instructions

## Declaration of Warranty

The author Dipl.-Ing. Martin Krämer declares that *ispark* is carefully designed and thoroughly tested and is unaltered in use over several years (2012 resp. 2015) without objections by about 150 competent parties (ExCBs, industrial).

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Mühlenweg 16a  
38543 Hillerse  
Germany

## The Author



Mr. Martin Krämer was born 1950, completed its academic studies at Hannover University getting the grade Dipl.-Ing. of electrical engineering 1979. After some years in design and development of electroacoustical transducers 1989 he joined the Physikalisch-Technische Bundesanstalt (PTB), section explosion protection, type of protection intrinsic safety, as a scientific staff member.

Beneath extensive activities in testing and certifying, there always were research projects covered also (functional safety with explosion protection, RS485is, IEC 60079-11 Annex F and other).

His major interest however always applied to the search for a method of assessing issues of spark ignition with computational means for use in industry and by certification bodies.

In 1995 the basic ideas of the software *ispark* were born and the data basis of RS 485is and IEC 60079-25, Annex C could be created.

*ispark* software for standard end user's needs was completed and introduced to the ex-community on a license basis in 2002.

In 2015 Mr. Krämer retires from PTB but was available for *ispark* matters by mandate until PTB terminates the cooperation in 2021 giving back to him all intellectual and commercial rights of *ispark* software.

## Table of content

- 0 History
- 1 Objective of *ispark*
- 2 System prerequisites for operating
- 3 Installation
- 4. Using *ispark* in a short run
  - 4.1 Foreword
  - 4.2 How to proceed
- 5. Using *ispark* for single source in detail
  - 5.1 Foreword
  - 5.2 Basic items to be declared
  - 5.3 Declaring source quantities
    - 5.3.1 Linear sources
    - 5.3.2 Rectangular sources
    - 5.3.3 Trapezoidal sources
    - 5.3.4 Angular sources
  - 5.4 Intermediate results of *ispark*
  - 5.5 Final results of *ispark*

## 6. Using *ispark* for multiple sources in detail

- 6.1 Foreword
- 6.2 Input requirements
- 6.3 Accumulation
- 6.4 Further treatment
- 6.5 Final results of *ispark*

## 7. Using *ispark* including cables in detail

- 7.1 Foreword
- 7.2 Entry to cable adoption by *ispark*
- 7.3 Cable data
- 7.4 Processing
- 7.5 Results
- 7.6 Interpretations
- 7.7 How to deal with the results of *ispark*

## 8 Additional

- 8.1 Freewheeling
- 8.2 Data limits
- 8.3 Flowchart

## 9 Support

## 10 Known problems and solutions

## 0 History

### What's new with version 6.2?

New: extended final table with cables  $L_{\text{lumped}}$  up to  $L_{\text{pms}}$

Internal: only slight modifications

I/O procs: in- and output procs overhauled

Revision: of operating instructions and supplement

Compatibility: no changes in calculated data should occur



## 1 Objective of *ispark*

*ispark's* objective is to **calculate** maximum permissible  $L_0$  and  $C_0$  with intrinsically safe circuits instead of getting **experimental results** by using the standardized spark test apparatus.

Besides great benefits with respect to reliability and uncertainty of results, the application of *ispark* is more easily to use and works much faster and with superior performance than all other known methods including those using reference data instead of experiments.

Because of it's operational speed *ispark* is able to include failure assumptions according to IEC 60079-11 as well as the effect of combinations of capacitance and inductance without wasting a significant amount of time. Additionally superposition of different sources within the same circuit can be calculated and special properties of cables are picked up now.

## 2 System prerequisites for operating

*ispark* now requires a 32 bit Windows operating system like Win2000 up to Win11 and will run under Win11 64Bit also.

The computer must serve for an USB port.

Actual machines will operate *ispark* requiring only a small amount of resources; only the extensive procedure including cables will take some time even nowadays.

## 3 Installation

*ispark* software doesn't need any installation, all necessary are *ispark* executables accessible via download from <http://ispark-software.com/> suitably placed on your PC and an *ispark* USB key.





## 4 Using *ispark* in a short run

### 4.1 Foreword

This chapter shall describe how to use *ispark* in a strict direct way in form of a simple example. If you only want to evaluate permissible  $C_0$  and  $L_0$  on the base of one known source characteristic it's not necessary to be charged with a lot of background information. If some is desired, please refer to the *ispark* supplement for further information and notice the following more detailed chapters.

### 4.2 How to proceed

Having started *ispark*, at first the associated hardware key is searched and access mode is displayed.

*Note: Text written in red here means an input is expected, green data depict results.*

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

checking dongle access
TestOk                               : 0
The Api Version is                    : 387
The connected Hardlock E-Y-E is       : 5672-Device.
The Hardlock E-Y-E access is          : Local
Connected to the local port address    : 0

press any key
```

When a key is pressed, the introduction screen appears reminding this program's objectives, version information and support addresses.

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

Program for the proof of intrinsically safe circuits according to IEC 60079-11
by calculation based on a thermoelectrical model of the standardized spark
test apparatus

All your comments are very welcome, please contact:

    martin kraemer
    c/o Physikalisch-Technische Bundesanstalt
    Braunschweig und Berlin
    Germany
    38116 Braunschweig
    Bundesallee 100
    tel: (+49) 0531/592-3525
    fax: (+49) 0531/592-3605
    email: martin.kraemer@ptb.de

For news, please visit www.explosionsschutz.ptb.de, "TechnologieTransfer"

call actual DataFile?                (y/n)
```

If you ever have worked with *ispark* within the actual directory, a file named DataFile.txt exists, which comprises the latest calculation results; for better remembering you may present it typing (y)es.

*Note: You must close notepad before proceeding with *ispark*.*

## First step: defining most basic defaults

The next screen is destined for declaration of zone, gasgroup and general properties of the actual source characteristic, which is the first step with *ispark's* course of action.

*Note: The matter freewheeling is in depth explained below. Please do not wonder here.*

With this introduced example, zone 1, the (n)ormal safety factor and gasgroup IIC is chosen, a (s)ingle (l)inear source characteristic with predetermined  $I_o$  and a freewheeling directly at the output connections.

*Note: With data related input, the formerly defined values are predetermined and may be confirmed simply by pressing <enter>; this should ease optimization actions.*

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

first step: defining most basic defaults

zone 0 (0),zone 1 (1) or zone 2 (2)?           zo 1
accept 10% less safety factor? (y/n)         n
gasgroup II(C), II(B), II(A) or (I)?        IIC
(s)ingle or (m)ultiple source?             s
(l)inear, (r)ectangular, (t)rapezoidal or (a)ngular source? l
source defined by (I)o or (R)i?            I
freewheeling with(o)ut or directly in outpu(t) o
```

## Second step: define quantitative data

The second step requires you to determine the electrically active data; for linear sources only two electrical parameters are possible, chosen here to be 28 V and 100 mA (a commonly used standard safety barrier type).

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

second step: define quantitative data

open loop voltage      [V]:      28.000
short circuit current  [mA]:     100.000
```

If the required data are passed to *ispark*, it will do the following:

- Firstly the circuit is examined to be intrinsically safe itself with no reactive load at all; *ispark* then reports 'this source keeps the claimed safety factor'. If this condition isn't met ('this source misses the claimed safety factor'), no further evaluation is possible with this global and quantitative data. In this case you are prompted to (c)ontinue and have to determine lower electrical data or (s)tart to choose a less demanding gasgroup.
- Secondly, a maximum permissible inductance  $L_{pms}$  is determined resulting from spark type o-0C (opening without any capacitance), here to be 0.551 mH.
- The next seven steps calculate allowed capacitances for all different spark types each (please see *ispark's* supplement for relevant spark and connection types) taking account of just this  $L_{pms}$ . One can see from the displayed data, that the most severe spark in this case is of type s/o-2-p with a permissible value of 0.064  $\mu$ F.
- Finally the minimum value of all this capacitances (0.064  $\mu$ F) is determined and reported as  $C_{pms}$ ;  $L_{pms}$  just is repeated.

### Intermediate results based on $L_{pms}$

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

second step: define quantitative data

open loop voltage      [V]:      28.000
short circuit current  [mA]:      100.000

intermediate results based on  $L_{pms}$ :

0 - this source keeps the claimed safety factor
X 0  $L_{pms}$  according to spark type  o-0C   in mH :    0.551

X 0 Cpms according to spark type  s/o-1-s in uF :    0.236
X 0 Cpms according to spark type  s/o-2-s in uF :    0.066
X 0 Cpms according to spark type  s-s     in uF :    0.117
X 0 Cpms according to spark type  s-0L-s  in uF :    0.120

X 0 Cpms according to spark type  s/o-2-p in uF :    0.064
X 0 Cpms according to spark type  s-p     in uF :    0.102
X 0 Cpms according to spark type  s-0L-p  in uF :    0.120

Cpms summ. accord. to spark type  s/o-2-p in uF :    0.064
 $L_{pms}$                                in mH :    0.551

L(l)ist, (e)nd, (c)ontinue, new (s)tart or (i)nclude cable
```

Please keep in mind, that the results presented above are 'intermediate results based on  $L_{pms}$ ' only; you in fact may get a rough overview about ignition properties but the complex mutual influence of inductance and capacitance with spark ignition requires to evaluate the situation against smaller values of the inductance also.

This will be carried out if typing one of the letters L resp. l;

The other options will carry you back to define basic defaults (s), determine different active electrical data (c) or end the program (e) at all.

## All parameters and final results

You should use (!)ist here and a final output of *ispark* is generated. It comprises the pre-determined data and the concluding results of the calculation. The latter are presented as a list of maximum permissible  $C_o$  and  $L_o$  as pairs in a decreasing 5, 2, 1 manner with  $L_o$ .

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

all parameters and final results

zone      : 1
gasgroup: IIC
source    : linear

Uo        [V]= 28.000
Io        [mA]= 100.000
freewheeling: without

Lo[mH]    0.550  -      -      -      -      -      -      -      0.500
Co[uF]    0.064  -      -      -      -      -      -      -      0.066

Lo[mH]    0.200  0.100  0.050  0.020  0.010  0.005  0.002  0.001
Co[uF]    0.083  0.083  0.083  0.083  0.083  0.083  0.083  0.083

interpolate Co?                (y/n)
    
```

Please notice, that *ispark* crops calculated  $C_o$  to IEC reported ones; these are pre-sented not rounded. Calculated ones are rounded to two decimal digits, which is because nobody really can claim more precision with spark ignition. Therefore, with small inductances,  $C_o$  may stay all the same.

*Note: The difference between IEC values and calculated ones mainly results from the standard's procedure, which includes spark's loss voltage while applying the safety factor. For further information, please see *ispark's* supplement.*

Please note, that always  $L_o/C_o$  pairs are delivered as results, for example 0.5 mH and 0.066  $\mu$ F. A circuit then may comprise any combination of effective inductances up to 0.5 mH as well as capacitances up to 0.066  $\mu$ F. But all other pairs are valid also.

If you prefer to use an  $L_o$  not comprised of the given list you may determine a different one and get an interpolated result.

The result with 0.3 mH for example is:

```

Lo[mH]    0.550  -      -      -      -      -      -      -      0.500
Co[uF]    0.064  -      -      -      -      -      -      -      0.066

Lo[mH]    0.200  0.100  0.050  0.020  0.010  0.005  0.002  0.001
Co[uF]    0.083  0.083  0.083  0.083  0.083  0.083  0.083  0.083

interpolate Co?                (y/n)
alternative Lo in mH          :      0.550  0.3
rounded Lo in mH is          :      0.300
interpolated Co in uF is     :      0.080

interpolate Co?                (y/n)
    
```

You may continue with another  $L_o$  to undergo interpolation and if not, you are offered to call the file DataFile via the Windows notepad.

## Datafile

With this example, the file DataFile.txt looks like:

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

zone      : 1
gasgroup: IIC
source   : linear

Uo        [V]= 28.000
Io        [mA]= 100.000
freewheeling: without

Lo[mH]    0.550  -      -      -      -      -      -      -      0.500
Co[uF]    0.064  -      -      -      -      -      -      -      0.066

Lo[mH]    0.200  0.100  0.050  0.020  0.010  0.005  0.002  0.001
Co[uF]    0.083  0.083  0.083  0.083  0.083  0.083  0.083  0.083

actual Lo: 0.300 [mH]; actual Co: 0.080 [uF]
```

Using the common Windows capabilities, the content may copied and pasted to a further document or be saved and archived with a different filename at any convenient location.

*Note: You must close notepad before proceeding with *ispark*.*

And if you want to (e)nd, (c)ontinue or have a new (s)tart as described on the last page:

```
(e)nd, (c)ontinue or new (s)tart
```



## 5. Using *ispark* for single source in detail

### 5.1 Foreword

Instead of using a simple example, as it was in the foregoing chapter, here shall be given more details about applicable options.

### 5.2 Basic items to be declared

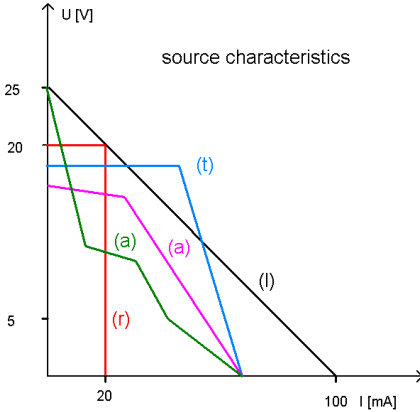
There are some general determinations to be made besides actual electrical data of the source under concern:

zone 0 (0),zone 1 (1) or zone 2 (2)?	zo 1
accept 10% less safety factor?	n
gasgroup II(C), II(B), II(A) or (I)?	IIC
(s)ingle or (m)ultiple source?	s
(l)inear, (r)ectangular, (t)rapezoidal or (a)ngular source?	l
source defined by (I)o or (R)i?	I
freewheeling with(o)ut or directly in outpu(t)	o

- a) the zone of risk decides about the appropriate safety factor, *ispark* uses for calculation: zone 0,1 (,ia' resp. 'ib'): safety factor 1.5; zone 2 (,ic'): safety factor 1.0
- b) in certain cases, a slightly altered safety factor may be suitable:
  - often it's justified to 'rescue' older designs by applying a safety factor 10% less
  - if an experimental review is intended it may be a good idea to choose a 10% increased safety factor
- c) the item gasgroup should not present any question (,c', ,b', ,a' and ,i')
- d) sometimes, mainly with installation procedures, it's necessary to superpose active electrical data: *ispark* can calculate the effective sum of sources itself, please see chapter 7

e) *ispark* offers the possibility to evaluate sources of different shapes as are:

(l)linear as with a simple limiting resistance	using	$U_o, I_o, (R_q)$
(r)ectangular for electronic limiting of voltage and current	using	$U_o, I_o, dU$
(t)rapezoidal when an ,additional' zener is present	using	$U_o, I_o, I_e$
	or	$U_o, I_o, R_q$
(a)ngular, when the source has arbitrary bends (up to 8)	using	$U_o, I_o$
	and	$U_x, I_x$



The figure on the left hand side demonstrates different source shapes and the relevant tokens.

- f) for linear and trapezoidal sources alternatively a  $R_q$  can be predetermined instead of  $I_o$  resp.  $I_e$ ; with the latter source type, the use of  $R_q$  is recommended
- g) for some spark types a freewheeling property is effective; if in doubt, the choice (t) will be on the safe side. For details please see chapter 9.1



### 5.3 Declaring source quantities

Data to be declared are widely dependant on actual source characteristics. Please be aware of a general maximum value of up to 50 V and 5000 mA with *ispark*; for details please see chapter 9.2.

#### 5.3.1 Linear sources

open loop voltage	[V]:	28.000
short circuit current	[mA]:	100.000

With linear sources, only two electrical parameters are possible the same time. While open loop voltage  $U_o$  is obligatory, *ispark* offers the options to assign either  $I_o$  or  $R_q$ .

#### 5.3.2 Rectangular sources

open loop voltage	[V]:	28.000
short circuit current	[mA]:	20.000
deltaU	[V]:	0.500

Concerning rectangular sources,  $U_o$  and  $I_o$  are the most important quantities. The value of  $dU$ , denoting a voltage drop from open loop to engaging current limitation must be stated also. With zener diode limitation, 0.5 V normally is accepted. In doubt you should use this number. If there are special properties of your application, higher values can be named alternatively.

#### 5.3.3 Trapezoidal sources

zener diode voltage	[V]:	20.000
short circuit current	[mA]:	100.000
source resistance	[Ohm]:	280.000

With trapezoidal sources, *ispark* offers the options to assign either  $I_o$  or  $R_q$ . Because a voltage drop of 0.5 V is assumed generally by *ispark* for the transition from open loop to an effective engagement of zener diodes, you should use stating  $R_q$ . Otherwise the calculation of effective  $I_o$  may be somewhat complex; for details please see *ispark's* supplement.

#### 5.3.4 Angular sources

open loop voltage	[V]:	20.000
1 angle voltage	[V]:	14.000
1 angle current	[mA]:	50.000
2 angle voltage	[V]:	10.000
2 angle current	[mA]:	100.000
3 angle voltage	[V]:	7.000
3 angle current	[mA]:	200.000
short circuit current	[mA]:	250.000

Beneath  $U_o$  and  $I_o$ , with angular sources, for each angle a pair of  $U_e/I_e$  is to be stated. Please see, that *ispark* requires a distinct order of falling voltages and increasing currents. There is a minimum difference in consecutive numbers of 0.1 V resp. 1 mA. Maybe you have to construct enveloping data.

*Note: A special case arises if only one angle is chosen; then the freewheeling effect can be denoted to be with(o)ut, by (z)diode or with output(t). Please see chapter 9.1 also. For more than one angle this effect always is set automatically to the worst case (t).*

*A one angle source is denoted with the character 'k' instead of 'a'.*

## 5.4 Intermediate results of *ispark*

Here, as an example, a **trapezoidal source characteristic** is chosen.

Having finished data input, *ispark* starts a first calculation determining an absolute maximum inductance  $L_{pms}$  and an associated overall capacitance  $C_{pms}$ .

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

second step: define quantitative data

zener diode voltage      [V]:      20.000
short circuit current    [mA]:     100.000
source resistance        [Ohm]:    280.000

intermediate results based on Lpms:

0 - this source keeps the claimed safety factor
X 0 Lpms according to spark type  o-0C   in mH :    0.660

X 0 Cpms according to spark type  s/o-1-s in uF :    0.199
X 0 Cpms according to spark type  s/o-2-s in uF :    0.092
X 0 Cpms according to spark type  s-s    in uF :    0.537
X 0 Cpms according to spark type  s-0L-s in uF :    0.559

X 0 Cpms according to spark type  s/o-2-p in uF :    0.100
X 0 Cpms according to spark type  s-p    in uF :    0.910
X 0 Cpms according to spark type  s-0L-p in uF :    0.554

Cpms summ. accord. to spark type  s/o-2-s in uF :    0.092
Lpms                               in mH :    0.660

L(l)ist, (e)nd, (c)ontinue, new (s)tart or (i)nclude cable
    
```

If possible maximum  $L_{pms}$  doesn't suit your needs, further evaluation doesn't make sense; you have to switch over to a less demanding gasgroup or less active electrical parameters.

For the first target, (s)tart is to be chosen, for the latter, (c)ontinue is appropriate.

If  $L_{pms}$  is sufficient for your application, proceeding is actuated by (l)ist.

## 5.5 Final results of *ispark*

As a final result, *ispark* presents the known list form of associated  $L_0/C_0$  pairs in two rows and offers the possibility for interpolate  $C_0$  for an alternative  $L_0$ :

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

all parameters and final results

zone      : 1
gasgroup: IIC
source    : trapezoidal
freewheeling: with output

Uo        [V]= 20.000
Io        [mA]= 100.000
Rq        [Ohm]= 280.000
freewheeling: with output

Lo[mH]    0.660  -    -    -    -    -    -    -    0.500
Co[uF]    0.092  -    -    -    -    -    -    -    0.110

Lo[mH]    0.200  0.100  0.050  0.020  0.010  0.005  0.002  0.001
Co[uF]    0.150  0.190  0.220  0.220  0.220  0.220  0.220  0.220

interpolate Co?                (y/n)

call actual DataFile?          (y/n)
    
```

If you do not want to have some more interpolation, you are prompted to call the file Data-File.txt or not. Calling enables you to save actual data to an arbitrary location and/or use Windows capabilities for copy and paste with further documents.

With this example, the file DataFile.txt looks like:

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

zone      : 1
gasgroup: IIC
source    : trapezoidal

Uo        [V]= 20.000
Io        [mA]= 100.000
Rq        [Ohm]= 280.000
freewheeling: with output

Lo[mH]    0.660  -    -    -    -    -    -    -    0.500
Co[uF]    0.092  -    -    -    -    -    -    -    0.110

Lo[mH]    0.200  0.100  0.050  0.020  0.010  0.005  0.002  0.001
Co[uF]    0.150  0.190  0.220  0.220  0.220  0.220  0.220  0.220
    
```

In case, you did not find a  $L_0/C_0$  pair suitable for your application, there are only the aforementioned possibilities to choose a more harmless gasgroup via (s)tart or weaken the source via (c)ontinue).

```

(e)nd, (c)ontinue or new (s)tart
    
```



## 6. Using *ispark* for multiple sources in detail

### 6.1 Foreword

Installation processes sometimes require considerations with respect to ignition properties of interconnected active electrical sources, in which case the  $L_{\sigma}/C_{\sigma}$  stated by certificates normally are not valid any more.

Beneath its capability to evaluate nearly every electrical source concerning spark ignition, *ispark* now offers the possibility to calculate superpositions of sources itself, thus serving for some more comfort. In the past, the user had to calculate the resulting sum characteristic 'by hand', which can be an annoying task and be prone for mistakes and uncertainties.

*Note: Freewheeling here always is set automatically to output(t).*

### 6.2 Input requirements

*ispark* now offers the possibility, to define up to three sources to be interconnected in serial, parallel or both. With basic predetermination, (m) for multiple sources must have been chosen.

```
how many sources (2) or (3)?           3
include (p)arallel, (s)erial or calculate (b)oth?      b
```

For each single source you are prompted to select from the source characteristics linear, rectangular, trapezoidal and angular and eventually an  $I_0$  or  $R_i$  presetting. With angular, in this case, is meant a source with one single angle.

An example for input:

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

second step: define quantitative data

how many sources (2) or (3)?           3
include (p)arallel, (s)erial or calculate (b)oth?      b

source 1
(l)linear, (r)ectangular, (t)rapezoidal or (a)ngular source? r
open loop voltage      [V]:      9.330
short circuit current  [mA]:     10.000
deltaU                  [V]:      0.500

source 2
(l)linear, (r)ectangular, (t)rapezoidal or (a)ngular source? a
open loop voltage      [V]:      6.000
short circuit current  [mA]:     40.000
angle voltage          [V]:      4.000
angle current          [mA]:     20.000

source 3
(l)linear, (r)ectangular, (t)rapezoidal or (a)ngular source? t
source defined by (I)e or (R)i?      R
zener diode voltage    [V]:     12.000
short circuit current  [mA]:     50.000
source resistance      [Ohm]:    1000.000
```

Although, in principal, with more than two sources an extended choice of mixed parallel/serial connections would be possible, the actual implementation is restricted in the mentioned way. If ever there is an invoice for more variability, an extension may be implemented.

### 6.3 Accumulation

For superposition, *ispark* uses the declared angle points and summarizes them in the respective manner. All parts of the source characteristics taking part of the interconnection, which exceed the first quarter of the I-U diagram are considered not to add (more precisely: do not subtract) any value. If, for example, two linear sources are superposed in this way, other than with the simplified method of IEC 60079-11, one angle is encountered.

For control purposes, the accumulated sum characteristic is reported, stating the voltage of each bend within the first line (starting with summarized open loop voltage) and the associated current within the second (ending with summarized short circuit current).

```
accumulation:

SumU :
Ue [V] 27.330 25.800 16.870 15.740 11.800 10.000 -
Ie [mA] - 9.117 10.000 20.000 38.500 40.000 50.000

SumI :
Ue [V] 12.000 11.500 9.330 8.830 6.000 4.000 -
Ie [mA] - 38.500 40.670 50.287 53.400 75.600 100.000

press any key
```

## 6.4 Further treatment

Further treatment is analogous to the traditional one, at first presenting data arising from an absolute maximum  $L_{pms}$ . Naturally, here all calculations have to be performed twice, one time for parallel (the first line) and another one for serial (second line) interconnection, if (b)oth is preset.

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

SumI :
Ue [V] 12.000 11.500 9.330 8.830 6.000 4.000 -
Ie [mA] - 38.500 40.670 50.287 53.400 75.600 100.000

SumU :
Ue [V] 27.330 25.800 16.870 15.740 11.800 10.000 -
Ie [mA] - 9.117 10.000 20.000 38.500 40.000 50.000

intermediate results based on Lpms

SumI: 0 - this source keeps the claimed safety factor
SumU: 0 - this source keeps the claimed safety factor

SumI: X 0 Lpms according to spark type o-0C in mH : 3.748
SumU: X 0 Lpms according to spark type o-0C in mH : 7.428

SumI: X 0 Cpms according to spark type s/o-1-s in uF : 0.255
SumU: X 0 Cpms according to spark type s/o-1-s in uF : 0.139
SumI: 0 - no calc. necessary with type s/o-2-s Cpms => 1000.000
SumU: X 0 Cpms according to spark type s/o-2-s in uF : 0.045
SumI: 0 - no calc. necessary with type s-s Cpms => 1000.000
SumU: X 0 Cpms according to spark type s-s in uF : 0.142
SumI: 0 - no calc. necessary with type s-0L-s Cpms => 1000.000
SumU: X 0 Cpms according to spark type s-0L-s in uF : 0.137

SumI: 0 - no calc. necessary with type s/o-2-p Cpms => 1000.000
SumU: X 0 Cpms according to spark type s/o-2-p in uF : 0.050
SumI: 0 - no calc. necessary with type s-p Cpms => 1000.000
SumU: X 0 Cpms according to spark type s-p in uF : 0.142
SumI: 0 - no calc. necessary with type s-0L-p Cpms => 1000.000
SumU: X 0 Cpms according to spark type s-0L-p in uF : 0.137

Cpms summ. accord. to spark type s/o-2-s in uF : 0.045
Lpms in mH : 3.748

L(l)ist, (e)nd, (c)ontinue, new (s)tart or (i)nclude cable
    
```

In effect, all further treatment of multiple sources by *ispark* equals the traditional way of evaluating angular sources.

## 6.5 Final results of *ispark*

With an actual (interpolated)  $L_o$  of 1.5 mH, DataFile.txt looks like:

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

zone      : 1
gasgroup: IIC

3 Sources connected in series and parallel

1 rectan.: Uo [V]= 9.330; dU [V]= 0.500;          Io [mA]= 10.000
2 angular: Uo [V]= 6.000; Ue [V]= 4.000; Ie[mA]= 20.000; Io [mA]= 40.000
3 trapez.: Uo [V]=12.000; Rq[Ohm]= 1000.000;      Io [mA]= 50.000

SumU:
Ue [V]  27.330  25.800  16.870  15.740  11.800  10.000  -
Ie[mA]   -      9.117  10.000  20.000  38.500  40.000  50.000

SumI:
Ue [V]  12.000  11.500  9.330  8.830  6.000  4.000  -
Ie[mA]   -     38.500  40.670  50.287  53.400  75.600  100.000

Lo[mH]   3.700  -      -      -      -      -      2.000  1.000  0.500
Co[uF]   0.045  -      -      -      -      -      0.053  0.064  0.077

Lo[mH]   0.200  0.100  0.050  0.020  0.010  0.005  0.002  0.001
Co[uF]   0.087  0.087  0.087  0.087  0.087  0.087  0.087  0.087

actual Lo:  1.500 [mH]; actual Co:  0.057 [uF]

```



## 7. Using *ispark* including cables in detail

### 7.1 Foreword

*ispark* versions below 6.0 were taking into account merely the need for to define Electrical Data as  $L_o$  and  $C_o$  for example to be reported via certificates and were based upon the worst case of combined lumped external inductances and capacitances. This was a first handle and is appended since version 6.1 to pick up the situation of installation evaluation some more precisely by taking distributed reactances into consideration. As a result there is more head space for field circuits gathered without deteriorating safety and on the base of a retraceable method.

### 7.2 Entry to cable adoption by *ispark*

As an example, a linear source of 20 V and 260 mA is predetermined here and the intermediate output is like:

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

second step: define quantitative data

open loop voltage      [V]:      20.000
short circuit current  [mA]:     260.000

intermediate results based on Lpms:

0 - this source keeps the claimed safety factor
X 0 Lpms according to spark type  o-0C   in mH :   0.101

X 0 Cpms according to spark type  s/o-1-s in uF :   0.582
X 0 Cpms according to spark type  s/o-2-s in uF :   0.172
X 0 Cpms according to spark type  s-s    in uF :   0.516
X 0 Cpms according to spark type  s-0L-s in uF :   0.581

X 0 Cpms according to spark type  s/o-2-p in uF :   0.167
X 0 Cpms according to spark type  s-p    in uF :   0.464
X 0 Cpms according to spark type  s-0L-p in uF :   0.577

Cpms summ. accord. to spark type  s/o-2-p in uF :   0.167
Lpms                               in mH :   0.101

L(l)ist, (e)nd, (c)ontinue, new (s)tart or (i)nclude cable
    
```

Note: the final results per (l)ist would be:

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

all parameters and final results

zone      : 1
gasgroup: IIC
source   : linear

Uo        [V]= 20.000
Io        [mA]= 260.000
freewheeling: without

Lo[mH]    0.100  -    -    -    -    -    -    -
Co[uF]    0.170  -    -    -    -    -    -    -

Lo[mH]    -    0.100  0.050  0.020  0.010  0.005  0.002  0.001
Co[uF]    -    0.170  0.220  0.220  0.220  0.220  0.220  0.220

interpolate Co?                (y/n)
    
```

Entry to cable evaluation is somewhat complementary to (l)ist; just type (c)ontinue here and you will get the intermediate results shown before and can choose (i)nclude cable now instead of (l)ist.

*Note: Please see chapter 9.3 for the courses of action implemented.*

### 7.3 Cable data

As cable data, distributed values of inductance, capacitance and resistance, all per kilometer, are required. The following are typical for bus cables and reveal significantly less risk with spark ignition than is to be expected by *ispark's* standard procedures concerning lumped reactances.

```
program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

third step: defining cable parameters

inductance/km      [mH/km]:      0.350
resistance/km     [Ohm/km]:     70.000
capacitance/km    [uF/km]:      0.035
```

*Note: The range of cable data is restricted by *ispark* to a reasonable one; please see chapter 9.2.*

### 7.4 Processing

For information purposes and because they give some insight into general cable properties, the actual values for L'/R' as well as the characteristic cable impedance are calculated and reported.

```
info: L'/R' [uH/Ohm]: 5.000; Sqrt(L'/C') [V/A]: 100.000

now calculating, please wait! *****
```

The hint ,now calculating' is inserted because, compared to the standard procedures of *ispark*, evaluating cables requires about one more order of calculational time.

## 7.5 Results

While the ordinary evaluation of circuits results in a linear list of permissible  $L_0/C_0$  pairs, with cables an additional parameter exists in form of cable length. In principal, a two-dimensional matrix is the output. Please note, that within the following, the idioms

### $L_0$ and $C_0$ determine the sum of lumped reactances

within the circuit. Cable's summarized parameter are some kind of **extra possible reactances**, only introduced by an additional cable, and quantified by a cable length simply.

For most similar design with the introduced linear list of  $L_0$  and  $C_0$  pairs, the data are presented as follows:

0.000	5.000	2.000	1.000	0.500	0.200	0.100	0.050	0.020	0.010
0.000	-	-	-	-	-	0.170	0.220	0.220	0.220
0.010									
0.020									
0.050							0.220		
0.100							0.210		
0.150									
0.200						0.170	0.210		
0.300							0.160	0.200	0.220
0.400							0.160	0.190	0.210
0.500							0.150	0.180	0.200
0.700							0.140	0.160	0.180
1.000							0.130	0.150	0.160
1.500								0.140	0.150
2.000	-	-	-	-	-	0.130	0.140	0.150	0.150

interpolate length and/or Lo? (y/n)

The data arrangement in detail:

- within the first line (in red), lumped inductance ( $L_0$ ) is stated in a falling 5, 2, 1 order from 5 mH down to 0.01 mH. The restricted range is based upon the intention, mainly to cover 'extra' inductances and/or capacitances introduced into the circuit, for example for the purposes of electromagnetic compatibility. But it's broad enough to include  $L_0/C_0$  of simple apparatus too
- the second line (light blue) gives the evaluation results of *ispark* concerning lumped  $C_0$  in  $\mu F$  in the case of no (additional) cable connected. These are exactly the same numbers, reported by standard procedure via (l)ist
- the first column (green) denotes preset cable lengths in kilometers
- all the rest of the table (black) states  $C_0$  in  $\mu F$  (the area framed in light blue depicts the action cropping to IEC quantities)

----- *ispark* operating instructions -----

For demonstration, how to interpret the resulting table, an example shall be given:

	0.000	5.000	2.000	1.000	0.500	0.200	0.100	0.050	0.020	0.010
0.000	-	-	-	-	-	-	0.170	0.220	0.220	0.220
0.010										
0.020										
0.050								0.220		
0.100									0.210	
0.150							0.170	0.210		
0.200										
0.300							0.160	0.200	0.220	
0.400							0.160	0.190	0.210	0.220
0.500							0.150	0.180	0.200	0.200
0.700							0.140	0.160	0.180	0.180
1.000							0.130	0.150	0.160	0.160
1.500								0.140	0.150	0.150
2.000								0.140	0.150	0.150

interpolate for different length and/or Lo? (y/n):

With this example, a sum of lumped inductances  $L_o$  of 0.1 mH is allowed together with a sum of lumped capacitances  $C_o$  of 0.130  $\mu$ F for a maximum length of 2 km of an (additional) cable with  $L' = 0.35$  mH/km,  $C' = 0.035$   $\mu$ F/km and  $R' = 70$   $\Omega$ /km.

All valid data sets consist of three maximum values here instead of two with the procedure (l)ist.

Compared to standard procedures of *ispark*, which for this source allow the pair 0.1 mH and 0.170  $\mu$ F only, a summarized inductive effect of  $2 \cdot 0.35 + 0.1 = 0.8$  mH and a capacitive one of  $2 \cdot 0.035 + 0.130 = 0.200$   $\mu$ F is allowed here, debited to the inclusion of special cable properties.

As with *ispark's* standard procedures a continual interpolation can be invoked (here requiring two parameters,  $L_o$  and length) and a backward step to altered cable properties is possible.

```

interpolate length and/or Lo? (y/n)

new length in km      :      0.160  0.7
rounded length in km is :      0.700
new Lo in mH         :      0.015  0.07
rounded Lo in mH is  :      0.070
interpolated Co in uF is :      0.150

interpolate length and/or Lo? (y/n)

new cable parameter?      (y/n)
    
```

And please treat data as convenient:

```

call actual DataFile?      (y/n)
    
```

Actual DataFile.txt:

```

program ispark, version 6.2, 28.11.2012 ***** copyright @ PTB 2002

zone      : 1
gasgroup: IIC
source   : linear

Uo       [V]= 20.000
Io       [mA]= 260.000
freewheeling: without

inductance/km      [mH/km]: 0.350
resistance/km     [Ohm/km]: 70.000
capacitance/km    [uF/km): 0.035

info: L`/R` [uH/Ohm): 5.000; Sqrt(L`/C`) [V/A): 100.000

0.000  5.000  2.000  1.000  0.500  0.200  0.100  0.050  0.020  0.010
0.000  -      -      -      -      -      0.170  0.220  0.220  0.220
0.010  |      |      |      |      |      |      |      |      |
0.020  |      |      |      |      |      |      |      |      |
0.050  |      |      |      |      |      |      |      |      |
0.100  |      |      |      |      |      |      |      |      |
0.150  |      |      |      |      |      |      |      |      |
0.200  |      |      |      |      |      |      |      |      |
0.300  |      |      |      |      |      |      |      |      |
0.400  |      |      |      |      |      |      |      |      |
0.500  |      |      |      |      |      |      |      |      |
0.700  |      |      |      |      |      |      |      |      |
1.000  |      |      |      |      |      |      |      |      |
1.500  |      |      |      |      |      |      |      |      |
2.000  -      -      -      -      -      0.130  0.140  0.150  0.150

actual length: 0.700 km; actual Lo: 0.070 mH; actual Co: 0.150 uF
    
```

As usual you may now (e)nd the program, have a new (s)tart for different general data or (c)ontinue, when altered electrical source parameters are desired (or necessary).

(e)nd, (c)ontinue or new (s)tart

## 7.6 Interpretations

*Note: For more details, please see *ispark's* supplement.*

The inclusion of cable properties has some principal effects. Therefore, despite *ispark's* operating instructions in a first order should comprise rules for handling the program only, some interpretations seem to be opportune:

Naturally, with installation, one is used to choose a cable as poor as possible of specific reactances  $C'$  and  $L'$ . And of course, cable's resistance  $R'$  must be small enough for the intended application.

With voltage in a midrange,  $L'$  and  $C'$  both are nearly equally engaged in spark ignition; for high currents  $L'$  normally presents the limit, while for higher voltages  $C'$  will be the limiting factor. Because there is no simple rule available, you must try out a best suited cable.

$R'$  is a moderating property of primary order and works for all spark types. Therefore a principal distinction should be made between applications of power supply, where a high cable resistance is counterproductive and such, where safety relevant Electrical Data merely arise from failure assumptions but are not characterizing normal operating conditions, thus leaving cable's resistance of minor interest for functioning.

### **Open loop voltages near to or below 10 V:**

With voltages near to or below 10 V, one normally can experience a weak dependence of reported  $C_0$  with length at all. The overall length restriction mainly is given by opening sparks.

Here a compensating effect of  $C'$  against  $L'$  usually fails because of a great mismatch in quantity between source's impedance  $U_0/I_0$  and the characteristic cable impedance  $\sqrt{L'/C'}$ . Therefore choose a cable with low  $L'$ , eventually regardless a higher  $C'$ .

But cable's specific resistance  $R'$  always compensates some of the inductive effect. If high enough,  $L'$  even can be fully compensated by  $R'$  and cable's length isn't restricted at all.

That's the typical area, where a valid maximum  $L'/R'$  ratio for a cable can be established.

### **Open loop voltages above 10 V and lower than about 30 V:**

Within this area, inductive effects of cables in conjunction with opening sparks are significantly moderated by capacitive ones even without taking into account any  $R'$ . This functions up to nearly full compensation. Therefore choose cable, whose characteristic impedance is near to the feeding resistance of the source. Independently, cable's  $R'$  can reveal a significant additional effect with opening sparks.

Although  $C'$  and  $L'$  may compensate with respect to opening sparks, they mostly collaborate concerning s/o sparks. If the latter are the restricting item, there is no effective chance to balance. The moderating influence of  $R'$  is effective here also, but as it's mainly in concurrency with the characteristic impedance of the assembled  $L$  and  $C$  at the whole, the effect may be weak.

### **Voltages above about 30 V:**

For circuits with even higher voltages, typically some kind of closing spark (s type) is dominating. In this case, a cable damping ( $R'$ ) has a significantly smaller effect only; the relations stay in the order of IEC 60079-11, table A.3.

If possible, choose a cable of low  $C'$ , eventually regardless a higher  $L'$ .

For less demanding gas groups than IIC, the gravity of s type sparks gives way to those of the s/o type. Thus the content of clause „Open loop voltages above 10 V and lower than 30 V“ comes to the fore here.

## 7.7 How to deal with the results of *ispark*

Now *ispark* offers a degree of freedom, up to now normally not covered by stated Electrical Data of certificates, which are dealing with  $L_o$  and  $C_o$  only (and sometimes with  $L'/R'$  ratio).

For installation purposes, things are merely simple. If you have got active sources quantified precisely, you may use *ispark's* results directly and determine whether or not your combination of lumped and distributed reactances is permissible. Tolerances of 5% with cable's  $C'$  and  $L'$  are deemed not to affect validity. The only fact to be considered separately is the temperature dependence of  $R'$ . The lowest working temperature is to be taken into account here.

If manufacturers want to pick up the new situation, they must either define some distinct common cable types, or have to determine discrete spaces for  $C'$  and  $L'$  with a minimum of  $R'$ . In a special case, normally when  $L'$  dominates the situation, defining a maximum  $L'/R'$  ratio may be possible.

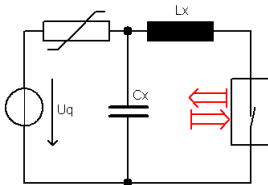




## 8 Additional

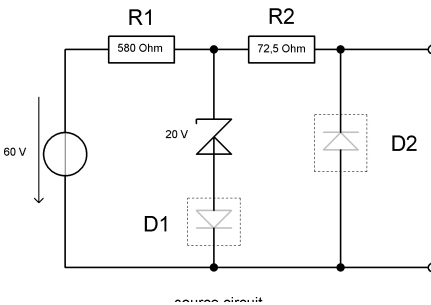
### 8.1 Freewheeling

With respect to source shapes you are sometimes faced to the idiom *freewheeling*. Although some insight is necessary to understand the problem, it shall be clarified here within the operating instructions instead of *ispark's* supplement, because otherwise some mistrust may be left.



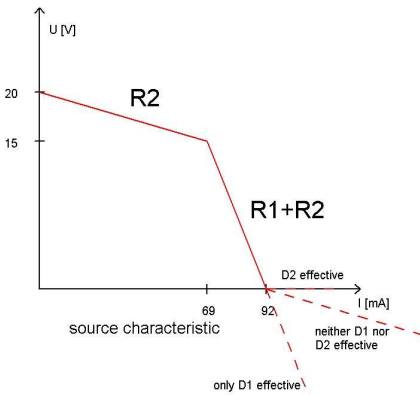
As this is the time span, where spark type s/o gets active, the reverse voltage drop makes a certain difference. This is the effect, named freewheeling here.

*Note: Unfortunately, this effect takes place in a normally not mentioned and denoted area of the U/I diagram. Therefore it may be complicated to determine it on the base of stated Electrical Data within certificates ore other papers.*



For explaining *ispark's* proceeding to some more extent, a distinct circuit is presented here; this is of the angular type (one angle).

Please pay attention to the diodes in a dashed frame; something like this normally isn't used but would create some differences within the forth quarter of the U/I diagram:



Usually -beneath the zener- no one of the drawn diodes is incorporated and freewheeling can be set to (z), according to the curve in the middle.

If there are any doubts, set freewheeling to *output(t)*; this surely represents the worst case and at maximum takes part in the safety factor about 10%.

*Note: ispark automatically "normalizes" freewheeling to a standard value when starting or passing "start". These are:*

#### Presets

<b>source</b>	<b>freewheeling</b>
<i>linear</i>	<i>with(o)ut</i>
<i>rectangular</i>	<i>with output(t)</i>
<i>trapezoidal</i>	<i>with output(t)</i>
<i>angular (one angle)</i>	<i>with (z)ener</i>
<i>multiple source</i>	<i>with output(t)</i>

Closing the spark test apparatus' contacts may produce a high current, even higher than the short circuit current of the source. If so, then the oscillation can switch the voltage at the source's connection even to a negative one.

## 8.2 Data limits

Depending upon the actually chosen source characteristic, *ispark* requires the following input:

parameter	input range	required input vs. source characteristic				
		linear	rectang.	trapez.	angular	
					1 angle	≥ 2 angles
$U_o$	1 ... 50 V	X	X	X	X	X
$I_o$	1 ... 5000 mA	X or ↓	X	X or ↓	X	X
$R_i$	0.1 Ω ... 100 kΩ	X or ↑	-	X or ↑	-	-
dU	0.1 V ... $U_o - 0.1$ V	-	X <sup>1)</sup>	- <sup>3)</sup>	-	-
$U_{e+1}$	$U_e - 0.1$ V	-	-	-	X <sup>4)</sup>	X <sup>4)</sup>
$I_{e+1}$	$I_e + 1$ mA	-	-	X <sup>3)</sup>	X <sup>4)</sup>	X <sup>4)</sup>
freewheeling	-	X <sup>2)</sup>	X <sup>2)</sup>	X <sup>2)</sup>	X <sup>2)</sup>	- <sup>5)</sup>
preset/available	-	o/t	t/o	t/o	z/o,t	t/-

Notes:

- 1) a commonly used value is 0.5 V; this will be accepted without further justification
- 2) normally (without 'additional' blocking diodes), freewheeling is as is stated under 'Presets' above
- 3) *ispark* here automatically uses a value of 0.5 V for the difference between open loop voltage and the voltage at  $I_e$ ; please note, that this dU will alter the effective  $I_e$  to a value above the one calculated simply from zener diode's voltage. Declaring  $R_i$  instead of  $I_e$  may be the alternative easier to use
- 4) *ispark* can't handle exactly horizontal or 'vertically' increasing parts of source characteristics at all; therefore all  $U_e$  and  $I_e$  must be at a minimum distance of 0.1 V respectively 1 mA referring to the neighbored angles
- 5) with angular characteristics with more than one angle *ispark* always assumes freewheeling directly with output; otherwise for each angle an input would be necessary; this seems not to be practical

All mentioned restrictions apply for 'multiple sources' in an equivalent way. Especially the sum restriction of 50 V and 5000 mA may be the most obvious here.

The presetting of cable parameters is restricted by *ispark* to rational ones; for exceeding values please contact me.

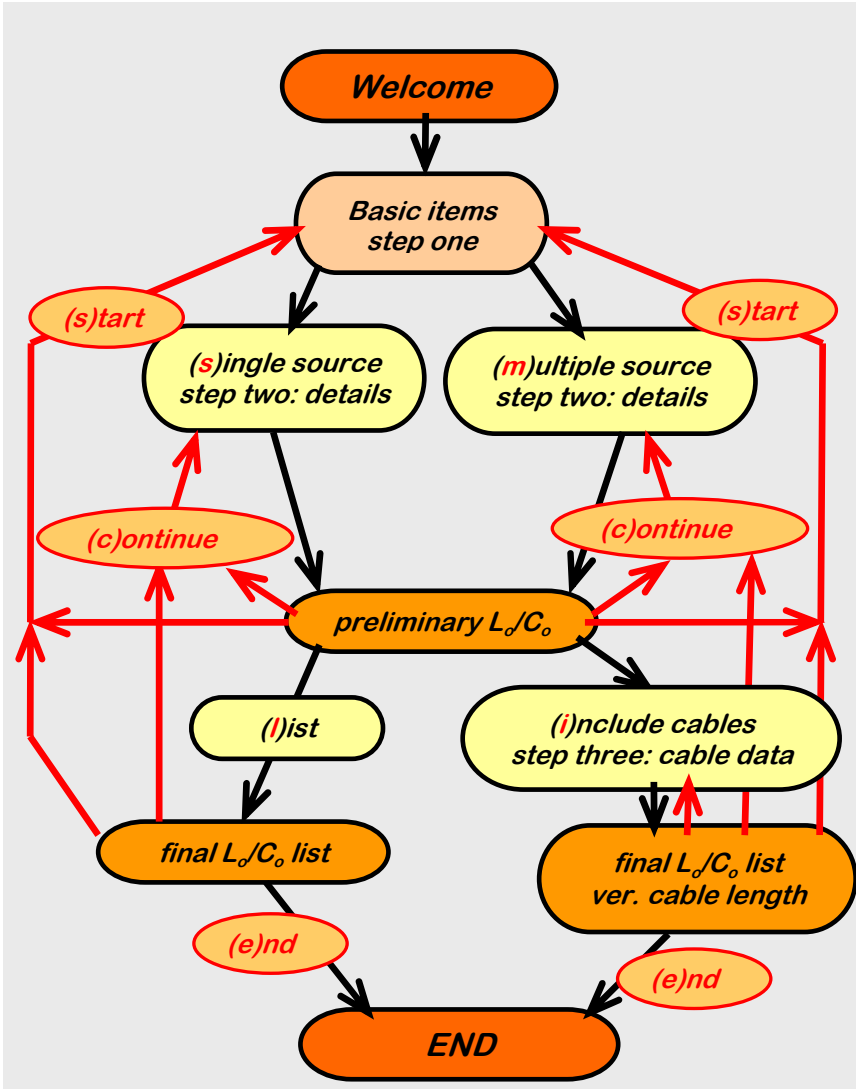
The range of accepted cable parameters is:

0.3	mH/km	≤	L'	≤	1.4	mH/km
0.025	μF/km	≤	C'	≤	0.2	μF/km
10	Ω/km	≤	R'	≤	100	Ω/km

While with  $R'$  the lowest value (at the most unfortunate temperature) has to be stated,  $C'$  and  $L'$  must normally be values with an uncertainty of  $\pm 5\%$  at maximum. The latter is, because especially  $C'$  may have both, a moderating or an aggravating influence on spark ignition.

### 8.3 Flow chart

*ispark* has become a little bit more complex; therefore a flowchart may have sense to ease overview, in what particular place you are situated actually:



Choosing (s)tart always takes you back for to predetermine changed basic items; (c)ontinue allows altered data with the same source characteristics.



## 9 Support

All actual common information about *ispark* always is accessible at:

<http://ispark-software.com/>

Full qualified *ispark* customer support you will get from Dipl.Ing. Martin Krämer via:

**e-mail** : <mailto:ispark@t-online.de?subject=ispark software>

Alternatively by letter:

**Dipl.-Ing. Martin Krämer**  
**Mühlenweg 16a**  
**38543 Hillerse**  
**Germany**

## 10 Known problems and solutions

### 10.1 Virus scan violation

Some virus detection applications nowadays consider the necessary dongle search scan as dubious. There is nothing left than to declare the *ispark* executable as an exception.